IN THE HIGH COURT OF THE REPUBLIC OF SINGAPORE

[2018] SGHC 152

Suit No 610 of 2013

Between

Kalzip Asia Pte Ltd

… *Plaintiff*

And

BFG International Ltd

… *Defendant*

JUDGMENT

[Contract] — [Breach]

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This judgment is subject to final editorial corrections approved by the court and/or redaction pursuant to the publisher's duty in compliance with the law, for publication in LawNet and/or the Singapore Law Reports.

Kalzip Asia Pte Ltd
v
BFG International Ltd

[2018] SGHC 152

High Court — Suit No 610 of 2013
Quentin Loh J
15–17, 22–24, 28–31 March, 1 April, 3–5 October 2016, 21 March 2017; 10 April 2017

29 June 2018 Judgment reserved.

Quentin Loh J:

Introduction

1 Suit No 610 of 2013 ("the Suit") arises from a dispute between a contractor and a sub-contractor over alleged defects in architectural rain screen roof panels (hereafter the "GRP panels") that had been installed on the Marina Bay Sands Integrated Resort Development ("the Development"). The GRP panels were constructed of glass fibre-reinforced skins that enveloped an aluminium honeycomb. The dispute centred first on whether and to what extent the bottom or lower skins (hereafter the "inner skins") of the GRP panels had "delaminated" (*ie*, come apart) from the aluminium honeycomb, and secondly, whether the GRP panels met the fire safety requirements of the contract.

2 One unusual feature of this case is that, unlike the usual construction disputes, there is not a single photograph showing a GRP panel with a

delaminated inner skin. Nor is there any direct evidence, such as a GRP panel with its inner skin delaminated, preserved for viewing. Instead, I have had numerous test reports placed before me to "prove" inner skin delamination had occurred, as well as factual and expert witnesses describing sounds emanating from the GRP panel when it was walked upon, "sponginess" when stepped upon, or coring which produced samples with inner skins of the sample core fully or partially delaminated or fully intact. Based on this evidence, I am asked to conclude, on a balance of probabilities, whether delamination of the inner skins occurred. (As for the core samples, the plaintiff no longer relies on them as evidence of delamination.)

3 Having considered the evidence before me and the parties' submissions, I dismiss the plaintiff's claim. My reasons for so doing and my key findings are set out at [451] below.

Facts

The contract between the parties

4 The plaintiff, Kalzip Asia Pte Ltd ("Kalzip") (previously known as Corus Building Systems Pte Ltd), is a limited private company established under the laws of Singapore. It is a subsidiary of Kalzip Business Unit, which was part of the Distribution and Building Systems Division within the Corus Group, now part of Tata Steel Europe Ltd ("Tata Steel"). It carries on the business of, *inter alia*, manufacturing, processing, importing, exporting and storing aluminium roofing and wall cladding systems.

5 The defendant, BFG International Limited ("BFG"), is a company incorporated in the Kingdom of Bahrain and in the business of manufacturing fibre-reinforced composite products.[1] These products are used for a wide variety

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of purposes, such as aircraft components, airport counters, railcar and aircraft toilet modules, storage tanks and building cladding.[2]

6 On 28 May 2008, Kalzip signed a Trade Contract with Marina Bay Sands Pte Ltd ("MBS"), the owner and developer of the Development. MBS hired Kalzip as a Trade Contractor to provide a roofing system ("the Kalzip Roofing System") for podium roof finishes works for three buildings in the Development, namely, the Meetings, Incentives, Conventions and Exhibitions ("MICE"), the theatre and the casino buildings.[3] These works comprised two curved roofing sections (each primarily comprising a weather-tight aluminium standing-seam roofing system) separated by a vertical clerestory. The upper section of the Kalzip Roofing System was to be overlain by architectural rain screen panels which were to be attached to a support rail system which was in turn fixed to the underlying Kalzip Roofing System.[4] I hereafter refer to the works pertaining to the Kalzip Roofing System as "the Project". The value of Kalzip's contract with MBS was S$28,709,317.[5]

7 Pursuant to a Sub-Contract dated 28 August 2008, Kalzip engaged BFG to supply glass-reinforced plastic-faced aluminium panels at the cost of S$4,927,500 for the Project.[6] GRP panels are a type of fibre-reinforced plastic composite product, which is a product made of a polymer matrix reinforced with fibres. In this case the GRP panels were made of a 20mm-thick aluminium

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1 Agreed Bundle of Documents ("ABD") A, Tab 1 (Statement of Claim (Amendment No 2)) at paras 1–2; Tab 23 (Defendant's Lead Counsel Statement) at pp 4–5.

2 Defendant's Opening Statement at para 3.

3 ABD A, Tab 23 (Defendant's Lead Counsel Statement), p 5.

4 ABD A 5 at paras 6–7.

5 ABD 1L 143 at para 20.

6 ABD A 12 at para 27.

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honeycomb core (19mm cell size) sandwiched and enveloped between two fire-retardant unsaturated polyester resin glass fibre reinforcements, or "skins".[7] The upper skin additionally had a polyester gelcoat.[8] The panels measured about 3m wide and 10–14m long.[9] It is not disputed that the Sub-Contract comprised the following documents:[10]

(a) a Purchase Order dated 28 August 2008, between Kalzip and BFG;[11]

(b) Annexure 1 to the Purchase Order, which incorporated:[12]

(i) a document titled "BFG Comments on Specifications – Appendix 2 – R3 – 29 Aug 08.pdf", containing BFG's comments on the tender specifications for the Sub-Contract;

(ii) a document titled "Podium Roof GRP Deflection Matrix Summary_A_20Jun08.pdf", dated 20 June 2008; and

(iii) a document titled "BFG – Corus – SANDS_Podium roof Price Table_300708.pdf", dated 30 July 2008;

(c) Annexure 2 to the Purchase Order[13]; and

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7 ABD 2B 218 at para 7; Plaintiff's Opening Statement at para 10; Notes of Evidence ("NE") (29 March 2016) at p 129 lines 24–25.

8 ABD 2B 251 at para 93; ABD 2B 363 at para 28.

9 ABD 1C 20 at para 9.

10 ABD A 11 at para 26; Tab 23 (Defendant's Lead Counsel Statement), p 5.

11 ABD 1D 5.

12 ABD 1D 6–8, 27–30.

13 ABD 1D 9–10.

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(d) extracts from the Technical Specification for Podium Roof Finishes WP 3215: MICE Roof, Casino Roof & Theatre Roof, ISSUE_REV C, dated 23 August 2007 ("Specification Revision C")[14].

8 The Sub-Contract specifications which are pertinent to the Suit are: (1) the requirements as to the structural performance of the GRP panels, in terms of the load they would be able to bear and the degree to which they would deflect or bend under specified loads; and (2) requirements as to the fire safety of the GRP panels. I expand on these requirements at [50] and [391] below respectively.

9 The GRP panels were manufactured by BFG in the Philippines in the latter half of 2009.[15] They were manufactured based on information and manufacturing drawings (one drawing per panel) provided by Kalzip.[16] Throughout the manufacturing process, Kalzip's appointed representative, Loxon Philippines Inc ("Loxon"), carried out a quality check on each GRP panel to ensure that it had been manufactured properly, that its dimensions were correct and that it was not delaminated, and thereafter approved it for shipment to Singapore for installation.[17] Kalzip installed the panels from around November 2009 on the casino building roof, followed by the MICE building roof from around January 2010; works on the theatre building roof were scheduled to commence in March 2010.[18]

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14 ABD 1D 13–24.

15 ABD A at Tab 1 (Statement of Claim (Amendment No 2)), para 18.

16 ABD A 35 at para 15.

17 Defendant's Opening Statement at para 5.

18 ABD 1B 16 at paras 31–33.

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Complaints about the panels

10 Sometime around January and February 2010, Kalzip complained that delamination of the GRP panels had been observed during installation on the casino and MICE building roofs. In particular, it was alleged that the inner skins of the GRP panels were coming apart from the aluminium honeycomb core. Surveys were carried out and delamination was allegedly found to be widespread.[19] According to Kalzip, the delamination adversely affected the load-bearing characteristics of the panels, rendering them non-compliant with the Sub-Contract requirements.[20]

11 BFG appeared to accept that delamination had occurred, but took the view that this was because the panels had been misused (*viz*, had been walked on and subjected to excessive loads). Kalzip, on the other hand, took the position that the panels had delaminated due to deficiencies in manufacturing.[21] An internal e-mail within BFG dated 7 March 2010 records that, the night before a meeting with MBS, Kalzip informed BFG that circular samples which had been cored from some GRP panels installed onsite were underweight. BFG protested that the panels had been misused. In response, Kalzip gave BFG "two options". The first was for BFG to "go with [Kalzip] and support them to say to MBS that there is a problem and we will resolve this" in an attempt to "get out of this problem with minimum damage". One of the risks associated with this option was that Kalzip wanted BFG to bear all the liability. The second option was for BFG to "start [an] argument [with Kalzip] about the misuse of panels versus bad manufacturing and go to [a] formal dispute between MBS and BFG where [Kalzip] would not support [BFG]". This would involve BFG officially taking

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19 Plaintiff's Opening Statement at para 22.

20 ABD A, Tab 1 (Statement of Claim (Amendment No 2)), para 19.

21 ABD 10E 6072.1, 6079 and 6526.1.

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the position that the panels, as supplied, met the load bearing requirements in the Sub-Contract.[22]

12 BFG chose the former option. On 9 March 2010, BFG met with Kalzip and "re-iterated BFG's commitment to assisting Kalzip with resolving the upstream issues with MBS and in particular on working together with Kalzip to rectify the alleged defects identified by MBS and/or Kalzip".[23] BFG and Kalzip sought to present a united front to MBS. The parties agreed to adopt the strategy of showing that the panels were strong enough to meet the Sub-Contract load requirements notwithstanding delamination of the lower skin. BFG carried out calculations to show that this was the case. Based on these calculations, BFG took the position that the GRP panels were fit for purpose and met the Sub-Contract requirements without modification even if they were delaminated, and presented this position to MBS on 17 March 2010. Kalzip likewise adopted this position *vis-à-vis* MBS.[24] The less-than-satisfactory test results were explained by pointing out problems with the tests and the other components of the structures supporting the panels, and not the panels themselves.

13 Notwithstanding its position *vis-à-vis* MBS, Kalzip looked to BFG to make good its losses arising from the allegedly delaminated panels. At a meeting with MBS described in BFG's 7 March e-mail, "[Kalzip] used this weak position and put [the] entire responsibility on BFG".[25] On 25 March 2010, Kalzip's solicitors wrote to BFG alleging that the panels were "not manufactured in accordance with the specifications stated in the Purchase

22 ABD 10E 6635.

23 ABD 2B 320 at para 25.

24 Plaintiff's Closing Submissions at para 218; Plaintiff's Reply Submissions at para 17; ABD 1B 49 at paras 121 and 123; ABD 1B 163 at para 37; ABD 2B 321 at para 26; ABD 2G 609–644; ABD 12E 7880–7883.

25 ABD 10E 6635.

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Orders" and that BFG was "clearly in breach" of the Sub-Contract. It reserved its right to recover, from BFG, sums that MBS had withheld from Kalzip under the Trade Contract.[26] BFG replied on 6 April 2010 denying that the panels were defective and alleging that the delamination observed onsite had resulted from misuse and mishandling during and after installation.[27] Kalzip sent another letter dated 25 May 2010 warning BFG that it was "currently facing a **SGD 1 million** to **SGD 33 million** claim, due to the supplied defective panels" [emphasis in original].[28]

14 From March to November 2010, BFG continued to propose rectification solutions to Kalzip, including supplying replacement GRP panels.[29] On 3 August 2010, Kalzip's project director Mr Peter Carter ("Mr Carter") e-mailed BFG's Mr Flook for a quotation for replacement panels and sought confirmation that BFG would "absorb the costs for this work until such time as Kalzip resolves the financial implications of this matter with MBS", following which "[a] solution would also then be worked out between Kalzip and BFG".[30] Mr Flook received a call from Mr Carter, who said that BFG "need to keep the aluminium core, and a percentage of the re manufacturing cost that BFG is prepared to bear. Then if [Kalzip] win[s] the case against MBS then they pay [BFG] back."[31] On 13 November 2010, BFG offered to supply replacement GRP panels at Kalzip's cost.[32] It did not hear back from Kalzip thereafter.

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26 Mr Flook's AEIC at pp 157–158.

27 Mr Flook's AEIC at pp 159–162.

28 ABD 12E 7859.

29 ABD 2B 329–334.

30 ABD 13E 8263.

31 ABD 13E 8265–8266.

32 ABD 2B 334 at para 71; ABD 14E 8901.

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15 Notwithstanding the attempts to convince MBS that the GRP panels would perform satisfactorily even with delaminated inner skins, MBS lost confidence in the panels and took the decision to replace them with aluminium panels.[33] Correspondence from July 2010 shows that MBS held Kalzip responsible for the delamination of the GRP panels and liable to make good any damage, loss or injury suffered by MBS arising therefrom. Kalzip made rectification proposals to MBS, but these were not implemented.[34] Kalzip alleged that at a meeting on 18 November 2010, MBS informed Kalzip that it was not prepared for Kalzip to replace the GRP panels using BFG as the manufacturer as it had lost confidence in BFG.[35] In February 2011, MBS sent another letter to Kalzip expressing disappointment in Kalzip and reserving its right to appoint third party contractors to carry out the rectification work.[36] In March 2011, MBS issued a Construction Manager's Instruction omitting the theatre panels from Kalzip's scope of works. On 15 March 2011, MBS informed Kalzip that it had appointed a third party contractor to remove and replace the GRP panels in the Project.[37] On 28 April 2011, MBS instructed a third party contractor, Craft Facade Pte Ltd ("Craft"), to remove the GRP panels and install replacement aluminium panels.[38] Kalzip claims that it was not involved in the removal of the GRP panels or the instalment of replacement panels.[39] After the panels were removed from the Project, they were stored in the Toll Warehouse in anticipation of their removal.[40] The GRP panels which were meant to be

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33 Statement of Claim (Amendment No 3) at para 23; ABD 1B 68 at para 177.

34 ABD 1B 161–164 at paras 31–39; Plaintiff's Closing Submissions at para 217.

35 ABD 1B 168 at para 51.

36 Mr Mueller's AEIC at p 781.

37 Mr Mueller's AEIC at p 799.

38 ABD A 81; ABD 1B 68 at para 177.

39 ABD A 73 at para 12.

40 ABD 1B 69 at para 179.

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installed on the theatre building were not installed as a result of the problems discovered with the MICE and casino buildings and remained in storage. Some of these panels were subsequently sent for testing though, for reasons which I detail below, the tests did not establish delamination. These panels were disposed of before the commencement of the Suit.

16 Kalzip claims that as a result of the alleged defects, MBS refused to pay Kalzip for the GRP panels already installed. MBS also deducted S$8,685,495.74 from Kalzip's final account for the costs MBS had incurred in connection with the allegedly defective GRP panels (*ie*, for testing the GRP panels and engaging consultants and Craft).[41] Kalzip seeks that sum from BFG in the present proceedings.

The arbitration

17 On 4 July 2011, Kalzip commenced arbitration proceedings against MBS. As will be seen, Kalzip's approach was to first deny liability for the delaminated GRP panels upstream *vis-à-vis* MBS, and to subsequently attempt to visit liability for the same upon BFG downstream. In relation to the GRP panels, Kalzip sought payment from MBS for *inter alia* supplying and installing GRP panels on the MICE and casino buildings; fabricating GRP panels for the theatre building; investigating remedial solutions and further work done in connection with the defective GRP panels; and loss of profit on the work of removal and replacement, which had been awarded to Craft. Kalzip also claimed other sums, including in relation to disputed variations which it had carried out, prolongation costs and the repayment of retention monies; these items were not related to the Kalizp-BFG Sub-Contract.[42] Its total claim against MBS was

41 ABD 1B 42 at para 104; ABD A 20 at para 39; ABD 1B 179 at para 81.

42 ABD A 10 at para 24(f); ABD 1L 148–150.

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S$15,868,904.47, being the difference between the sums it claimed to be entitled to (S$42,368,556.51) and what it had been paid (S$26,499,652.04).[43]

18 Kalzip's position in the arbitration was that it had complied with its contractual obligations, and that MBS bore design responsibility for the GRP panels, which were inherently prone to delaminate. Kalzip's Statement of Claim in the arbitration states that the delamination occurred "as a result of design decisions made by [MBS], which were not [Kalzip's] responsibility", and that MBS wrongly refused to allow Kalzip to replace the defective panels unless Kalzip agreed to vary the contractual terms.[44] Kalzip's Reply and Defence to Counterclaim in the arbitration states that the "basic design of the GRP panels was complete" at the time that MBS issued the Letter of Award to Kalzip, and that the "tendency to delaminate was inherent in the design of the GRP Panels".[45]

19 There were negotiations towards a settlement between MBS and Kalzip in the lead-up to the arbitration hearing. According to Kalzip, MBS remained unwilling to pay any sums to Kalzip for the defective GRP panels, though it indicated that it was willing to compromise on Kalzip's variation claims. Kalzip says that as a matter of principle, MBS refused to compromise on its decision to deduct the sum of S$8,685,495.74 from monies due to Kalzip under the contract (comprising the contract sum paid by MBS to Craft (S$8,121,319.31), the consultancy fees incurred by MBS in connection with the defective GRP panels (S$449,950.75) and testing fees (S$114,225.68)).[46] The arbitration hearing between Kalzip and MBS began on 18 February 2013 and was

43 ABD 1L 199.

44 ABD 1L 147 at paras 27–29.

45 ABD 1L 459, 461–462.

46 ABD 1B 179 at para 81; ABD A 82; NE (15 March 2016) at p 123 lines 12–21.

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scheduled to last five weeks. On 23 February 2013, Kalzip and MBS entered into an in-principle commercial settlement, which they formally executed on 26 February 2013 ("the Settlement Agreement"); MBS agreed to pay Kalzip the sum of S$5.5m, of which S$4m was compensation and S$1.5m was for Kalzip's agreed costs. MBS would also pay the costs of the arbitration proceedings.[47]

20 According to Mr Mueller, the S$4m essentially comprised all of Kalzip's claims apart from those which had to do with the GRP panels.[48] I note, however, that as stated in cl 1.1 of the Settlement Agreement, MBS paid Kalzip S$4m "in full and final settlement of any and all disputes, controversies, claims and counterclaims that each party has against the other". Moreover, cl 8.1 of the Settlement Agreement states, "This Agreement constitutes the entire agreement between the parties in connection with its subject matter and supersedes all prior representations, communications, negotiations and understandings concerning the subject matter of this Agreement."[49] Kalzip's claims against MBS in respect of the allegedly defective GRP panels were therefore part of the claims settled in the Settlement Agreement.

21 On 30 May 2013, Kalzip sent a letter of demand to BFG for the sum of S$13m. BFG claims that it was surprised by the letter of demand, having heard nothing from Kalzip since BFG's offer in November 2010 to supply replacement GRP panels at Kalzip's cost. BFG says it did not hear from Kalzip for close to three years and was left out of the loop regarding Kalzip's arbitration with MBS.[50] One of Kalzip's witnesses confirmed during the trial that Kalzip did not inform BFG about its settlement with MBS prior to signing the

47 ABD A 10 at para 25; ABD 34L 25149; ABD 1B 179 at para 82.

48 ABD 1B 180 at paras 83–84.

49 ABD 34L 25148 and 25151.

50 Defendant's Closing Submissions at para 1041; ABD 2B 335 at paras 72–73.

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Settlement Agreement.[51] There does not seem to be any evidence before me that BFG knew or was otherwise given notice that the panels were being removed from the Project.[52]

22 It does seem strange that after the flurry of accusations and denials of inner skin delamination in the GRP panels from January or February 2010 to November 2010, when BFG did not hear back from Kalzip on its offer to replace GRP panels at Kalzip's cost, BFG appears to have sat tight. Although I note that BFG did not have an office in Singapore, there is no evidence before me as to whether they kept in touch with developments at the site or whether they hoped Kalzip would resolve matters with MBS. Under cross-examination, Mr Premamoorthy, BFG's Vice President who managed the Philippines factory which produced the GRP panels (see [37(b)] below), agreed that from March 2010 through to May 2013, BFG knew that it might face potential liability to Kalzip.[53] It therefore appears that BFG was aware of a potential dispute with Kalzip but perhaps adopted the attitude of letting sleeping dogs lie. Kalzip's strategy, on the other hand, was *inter alia* to deny liability for the delaminated panels in its arbitration with MBS but, whether for tactical or other reasons, without involving BFG. Even though Kalzip was based in Singapore, knew about the panels being removed and replaced and had at the very least a sizeable portion of the panels in its possession, it did not test the panels for delamination or preserve them as evidence. Kalzip ended up settling its claim against MBS and, having obtained what it could from MBS, then turned to BFG in the present Suit to make a claim against BFG for the defective GRP panels and damages caused thereby. Although Kalzip alleges that MBS refused to pay for the GRP

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51 NE (15 March 2016) at p 121 lines 10–17.

52 NE (24 March 2016) at p 31 line 11 – p 34 line 13.

53 NE (24 March 2016) at p 38 line 19 – p 39 line 8.

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panels, I have noted earlier Kalzip's settlement with MBS of its pleaded claims in the arbitration, including the supply and installation of roof finishes and GRP panels to the MICE and casino buildings, the supply of GRP panels and the supply and installation of roof finishes to the theatre building, the cost of investigating remedial solutions and further work done in connection with the defective GRP panels, and loss of profit on removing and replacing the same as a result of that work being awarded to Craft.[54]

23 On 11 July 2013, Kalzip commenced the Suit against BFG. The Suit has been bifurcated and these grounds of decision deal with BFG's liability in the claim only. The quantum of damages would have been dealt with in a subsequent tranche had I allowed the claim.

Parties' cases

24 Kalzip claims that BFG failed to produce GRP panels that met the structural performance requirements and fire safety requirements of the Sub-Contract.[55]

25 As regards the structural performance requirements, Kalzip claims that the GRP panels supplied by BFG suffered extensive inner skin delamination, which meant that they no longer met the deflection requirements in the Sub-Contract. As I have noted earlier, all the GRP panels from the Project were disposed of before the Suit, and testing them for inner skin delamination is no longer an option. No photographs were taken of the underside of the panels *in situ* or during removal as proof of delamination and no panels were sent for laboratory testing or otherwise investigated for inner skin delamination.[56] To

54 ABD 1L 148 at para 31.

55 P's cl subs at para 229.

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prove delamination, Kalzip relies on various site surveys performed in February and March 2010, as well as correspondence from BFG expressly acknowledging delamination.[57] It alleges that the delamination occurred as a result of BFG's failure to:[58]

(a) select or formulate the appropriate constituents of the GRP panels;

(b) properly design the GRP panels to avoid delamination;

(c) undertake or prescribe an appropriate manufacturing or assembly process; and

(d) take all necessary measures to ensure that the GRP panels supplied would comply with the structural performance and fire safety requirements.

26 BFG, on the other hand, denies that the panels ever delaminated. It claims that the reports of delamination in early 2010 were based on crunching sounds which emanated from the panels when walked upon, and that expert evidence shows that such sounds do not necessarily indicate delamination.[59] It further relies on tests carried out in 2015 on GRP panels specially manufactured for that purpose, which were found not to be delaminated. Kalzip submits that these tests are not reliable because they did not involve GRP panels actually supplied to the Project.[60] In the alternative, BFG submits that even if there was delamination, the delamination was attributable to Kalzip's acts, in particular:[61]

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56 ABD 3C 804 at para 2.6.2.

57 Plaintiff's Reply Submissions at paras 217, 273 and 428(d).

58 ABD A 19 at para 35.

59 ABD A 43 at para 30; Defendant's Opening Statement at paras 22 and 23.

60 Plaintiff's Opening Statement at para 28.

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(a) mishandling of the panels by using them as working platforms for installation, failing to store them appropriately onsite, failing to put in place a proper installation process or system, and placing and/or storing heavy materials atop the panels;

(b) defective design of the support rail system, which did not provide adequate support to the GRP panels;

(c) failure to advise BFG about the loads imposed by the handling jigs to be used for the GRP panels;

(d) providing incomplete specifications which failed to: (i) take into account all the installation loads, (ii) provide for movement criteria for the Kalzip Roofing System and the support rails, and (iii) provide for any misalignment of the support rails;

(e) uneven release of the suction cups or uneven loading from misaligned rails, which would have imposed loads other than those specified in the Sub-Contract; and

(f) Kalzip personnel jumping on the GRP panels during the core sampling exercise.

27 BFG further contends that the GRP panels met the structural performance and deflection criteria in the Sub-Contract even if they were delaminated. They also were fit for the purpose for which they were bought, *ie*, to serve as architectural finish panels.[62]

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61 Defendant's Opening Statement at paras 27–32; ABD A 38 at para 17; ABD A 139–143.

62 ABD A 44 para 30; Defendant's Opening Statement at para 39.

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28 The second component of Kalzip's claim is that the GRP panels supplied by BFG failed to meet the fire safety requirements in the Sub-Contract. Sample GRP panels manufactured by BFG passed a suite of fire tests conducted from 2008 to 2010 (before the panels were installed). However, GRP panels which had been installed in the Project and then were subsequently removed for fire testing failed another suite of fire tests in 2011 to 2012. Kalzip relies on the 2011–2012 fire tests as evidence that the GRP panels failed to meet the fire safety requirements while BFG relies on the 2008–2010 fire tests as evidence that they met them. Each party submits that the fire tests relied on by the other party are unreliable.

29 Kalzip also avers that terms were implied into the Sub-Contract that the GRP panels supplied by BFG would:[63]

(a) correspond with the description of the GRP panels in the Sub-Contract, pursuant to s 13(1) of the Sale of Goods Act (Cap 393, 1999 Rev Ed) ("the SGA");

(b) be of satisfactory quality, in that they would meet the standard that a reasonable person would regard as satisfactory, pursuant to s 14(2) read with s 14(2A) of the SGA; and

(c) be reasonably fit for their intended purpose under the Sub-Contract, pursuant to s 14(3) of the SGA.

30 Kalzip submits that, by failing to provide GRP panels which met the structural performance and fire safety requirements of the Sub-Contract, BFG failed to produce a product that met these terms.[64] Although Kalzip originally

63 ABD A 15 at para 31; Plaintiff's Closing Submissions at para 609.

64 Plaintiff's Opening Statement at para 53; ABD A 19 at para 36.

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pleaded terms implied under the Supply of Goods Act (Cap 394, 1999 Rev Ed), it no longer relies on those terms.[65]

31 For breach of the structural performance and fire safety requirements, Kalzip seeks a total of S$14,040,957.64 from BFG, comprising:[66]

(a) reimbursement for MBS' deductions from the contract sum under the Trade Contract with Kalzip (S$8,685,495.74);

(b) the costs of investigating and developing remedial solutions for the defective GRP panels (S$476,969.78);

(c) the costs of implementing safety measures until a remedial solution for the defective GRP panels could be implemented (S$433,880.10);

(d) the costs of storing the GRP panels intended for installation on the theatre building roof from January 2010 to April 2011 while a remedial solution was developed (S$323,842.32);

(e) prolongation costs for a total period of 134 days (S$642,633.00);

(f) costs incurred as a result of MBS' call on the performance bond under the Trade Contract with Kalzip (S$32,649.25);

(g) Kalzip's advisory legal costs prior to the arbitration proceedings against MBS (S$1,328,130.55); and

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65 Plaintiff's Reply Submissions at para 442(b).

66 Plaintiff's Closing Submissions at para 629; Statement of Claim (Amendment No 3) at paras 40–58.

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(h) the costs of the arbitration proceedings against MBS, less the S$1.5m in costs that the arbitral tribunal ordered MBS to pay Kalzip (S$2,117,356.90).

32 Further and/or in the alternative, Kalzip claims S$4,874,319.45 in restitution for the return of monies it paid to BFG under the Sub-Contract on the basis of total failure of consideration. It alleges that BFG completely failed to supply panels which complied with the requirements of the Sub-Contract, were fit for purpose under the Sub-Contract and/or were accepted by MBS for use in the Project.[67]

Issues

33 The issues that fall to be decided are as follows:[68]

(a) What were the structural and loading requirements under the Sub-Contract, and did the GRP panels comply with those requirements? In particular:

(i) Do the structural tests establish that the GRP panels breached the structural and loading requirements of the Sub-Contract?

(ii) Did the GRP panels supplied to the Project exhibit delamination of the inner skin from the honeycomb core? If so, what was the cause of delamination?

(b) Did the GRP panels supplied to the Project meet the fire safety requirements of the Sub-Contract?

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67 Statement of Claim (Amendment No 3) at para 59.

68 Plaintiff's Opening Statement at para 42; Defendant's Opening Statement at para 19.

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(c) Did the GRP panels breach the implied terms set out at [29] above?

34 Kalzip also invites the court to decide on BFG's liability in principle in contract for each of the heads of claim enumerated at [31] above, as well as BFG's liability in restitution.[69] BFG contends that the issue of its liability in restitution should be left to the quantum stage of the trial[70], although its closing submissions canvass its arguments on this issue in full. I will therefore have to decide whether BFG's liability in principle should be determined at this stage, and if so, whether it is liable under the express or implied terms of the Sub-Contract and/or in restitution for the panels supplied.

35 As this is a judgment of some length, I set out a brief table of how I deal with the various issues:

Heading	**Paragraphs**
Issue 1: structural performance requirements	
The requirements	[50]–[63]
The structural tests by BFG and Winwall	[64]–[98]
Whether delaminated panels would have failed the Sub-Contract specifications	[99]–[101]
Issue 2: Whether there was delamination	
Evidence of delamination	[102]–[247]
Factory visits on 3 September 2008 and 23 April 2009	[110]–[121]
Correspondence from BFG and site surveys	[122]–[162]
My analysis of the correspondence and site surveys	[163]–[207]
Prof Nonhoff's inspection onsite in June 2010	[208]–[210]
Deflection underfoot and sagging	[211]–[226]
MBS consultants' opinions	[227]–[231]

69 Plaintiff's Closing Submissions at paras 504 and 590.

70 ABD A 186.

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Fire test panel samples	[232]–[234]
Core sampling	[235]–[239]
Delamination of panels in storage	[240]–[244]
Kalzip's conduct of the arbitration	[245]–[247]
My conclusion on the presence and extent of delamination	[248]–[254]
Issue 3: Causation of delamination	
Burden of proof	[255]–[262]
BFG's explanation of the cause of delamination	
Tests by Loxon	[265]–[269]
Alleged mishandling	[270]–[288]
Defective design of the support rail system	[289]–[292]
Incomplete specifications	[293]
Walking and jumping on the panels	[294]–[312]
Kalzip's explanation of the cause of delamination	
Manufacturing process	[315]–[361]
BFG's lack of experience manufacturing panels of this size and composition	[362]–[365]
Failure to produce the PCS	[366]–[380]
My conclusion on the cause of delamination	[381]–[385]
Issue 4: Implied terms	[386]–[390]
Issue 5: Fire safety requirements	
The requirements	[391]–[401]
The 2008–2010 tests	
The 2008 tests	[402]–[403]
The November 2009 fire tests	[404]–[409]
The June 2010 fire tests	[410]–[412]
The 2011–2012 tests	
The significance of edge-sealing	[414]–[436]
The significance of delamination	[437]–[442]
The significance of exposure or ageing	[443]–[445]
Conclusions on Issue 5	[446]–[448]

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Issue 6: BFG's liability in principle [449]–[450]
Conclusion [451]

Witnesses

36 Kalzip called the following five factual witnesses:[71]

(a) Mr Alan Roy Bridger ("Mr Bridger"), Kalzip's Managing Director for 11 years (1998–2009), then Head of Business Development of Tata Steel (2010 to the present);

(b) Mr Stuart Mackay ("Mr Mackay"), Kalzip's Project Manager for the Project from August 2009 to July 2011, who left Kalzip's employ in June 2015;

(c) Mr Wong Kee Lou ("Mr Wong"), Kalzip's System Design Engineer for the Project from 29 September 2008 to 4 July 2011, who continues to be employed by Kalzip as a Technical Sales Manager;

(d) Dr Jürgen Neuwald ("Dr Neuwald"), the director of Kalzip's holding company, Kalzip Business Unit, from 2003 to 2011; and

(e) Mr Frank Guenter Mueller ("Mr Mueller"), the head of Group Legal and Compliance (Germany) in Tata Steel, who became involved in the Project in June 2010 when he was informed about the alleged delamination.

37 BFG called the following six factual witnesses:[72]

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71 Plaintiff's Closing Submissions at para 16.

72 Defendant's Opening Statement at paras 51–55.

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(a) Mr Suhas Kolhatkar ("Mr Kolhatkar"), the engineer in charge of the design of the GRP panels and the proprietor of Indian firm Composite Designs & Technology ("CD&T"), which enjoys a long-standing working relationship with BFG;

(b) Mr Krishnamoorthy Premamoorthy ("Mr Premamoorthy"), who managed the factory where the GRP panels were produced and has been Vice President of the Philippines branch of BFG since 1997;

(c) Mr Clive Lee Attwood ("Mr Attwood"), who was employed by BFG in 2000 and appointed BFG's Project Manager of the Project from early April 2009 to 30 March 2010;

(d) Mr Kevin Grantly Flook ("Mr Flook"), the Group Business Director of BFG since February 2010;

(e) Mr Sanjay Rade ("Mr Rade"), the design engineer and assistant to Mr Kolhatkar at CD&T; and

(f) Mr Zeeyad Abdul Sattar ("Mr Zeeyad"), appointed as BFG's Quality Assurance Manager for the Project sometime in 2008.

38 Except where I have expressly stated below, I did not find any of the factual witnesses to be particularly evasive or unforthcoming. It is not uncommon for people to form a preliminary view of the facts which, over time, becomes entrenched, leading them to conclusions which may not be entirely accurate or which may not comport entirely with the evidence. The witnesses' views about delamination in this case may have been especially prone to this sort of entrenchment because of the dearth of unambiguous primary evidence. Nevertheless, I did not (except where expressly stated) consider them to be

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dishonest or biased, and accepted that they were for the most part attempting to recollect what had occurred to the best of their ability.

39 Kalzip and BFG each called one structural expert, one GRP expert and one fire expert, as follows:[73]

(a) Structural experts: Mr Stephen Green ("Mr Green") (Kalzip) and Mr Bruce Wymond ("Mr Wymond") (BFG)

(b) GRP experts: Prof Dr -Ing Gottfried Nonhoff ("Prof Nonhoff") (Kalzip) and Mr Uwe Maurieschat ("Mr Maurieschat") (BFG)

(c) Fire experts: Prof James Lygate ("Prof Lygate") (Kalzip) and Dr David Crowder ("Dr Crowder") (BFG)

40 BFG's structural expert was Mr Wymond, the founder and managing director of the Inhabit Group of companies.[74] He had limited experience in the use of GRP as a building material. His previous experiences with GRP had not involved an aluminium honeycomb core, and had not involved the use of GRP in large flat cladding elements.[75] His expertise lay in the mechanical properties and structural issues relating to GRP, whereas Mr Maurieschat's expertise lay in material-related issues concerning GRP.[76]

41 Mr Maurieschat has headed the micro production and application process working group at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM ("Fraunhofer IFAM") since 2008.[77]

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73 Plaintiff's Closing Submissions at para 86.

74 ABD 3C 783 at para 1.

75 ABD 3C 798 at para 9.

76 NE (31 March 2016) at p 58 at lines 15–20.

77 ABD 4C 1154 at para 1.

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However, he did not have any experience working with aluminium honeycomb GRP panels for use in buildings. He had only worked with such panels for building car bodies for the railway industry.[78]

42 Kalzip's structural expert was Mr Green, who holds a degree in mathematical physics from Birmingham University and has spent his entire working life in the window, cladding and curtain walling industry.[79] Mr Green stated that he did not profess to be an expert on any aspect of fibreglass skinned aluminium honeycomb panels, as that was Prof Nonhoff's realm.[80] He had also never worked with a product that combined aluminium with fibreglass-reinforced plastic.[81]

43 Prof Nonhoff has been a Professor Emeritus of structural mechanics, aircraft construction and fibre-reinforced plastics at the University of Applied Sciences Aachen in Germany since 1973.[82]

44 In assessing the reliability of the expert evidence given by the experts before me, I found Mr Wymond's expert evidence more helpful in forming my conclusions in this Suit. His evidence was generally consistent, well-reasoned and usually supported by calculations where appropriate. Mr Green made a few errors in his report (see in particular [54] and [77] below), though he was willing to recognise and admit these errors as well as the limitations of his expertise[83], and came across as an honest witness.

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78 NE (1 April 2016) at p 92 line 19 – p 93 line 4.

79 ABD 1C 125 at para 1.

80 NE (30 March 2016) at p 185 lines 17–20.

81 NE (30 March 2016) at p 193 lines 3–7.

82 ABD 1C 17 at para 1.

83 See, *eg*, NE (1 April 2016) at p 205 lines 5–7 and NE (30 March 2016) at p 62 line 22 – p 63 line 3.

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45 As between Mr Maurieschat and Prof Nonhoff, I found Mr Maurieschat's evidence to be more persuasive. He came across as a forthcoming and neutral witness and was careful about the conclusions which he felt able to draw from his experience and the evidence. While Prof Nonhoff may have had more extensive experience with GRP panels in the past, and was the only one amongst the four experts who had come into contact with the actual panels in this Suit (having been invited onsite in 2010), I had difficulty accepting some aspects of his evidence and placed the least reliance on his evidence. His evidence on the presence and extent of delamination, unlike most experts, was general in nature. He did not mark out and could not identify which panels had "sounds" and which had deformed or deflected underfoot. He did not take a single photograph, besides photographs of samples which he had cored and of a panel which he had pulled apart by hand, to substantiate his observations and conclusions. As to the latter, there were no close-up photographs to substantiate his view. In particular, Prof Nonhoff claimed that he was able to see delamination on GRP panels which were kept in storage by spotting 1mm–2mm deformations on the reflective or shiny surface of the inner skin. I do not accept his evidence on this because, as I explain below, there are other photographs which show that the inner skin had a matted and slightly bumpy texture. This was also apparent from the core sample which was adduced in evidence. Such small deformations of that magnitude would therefore not have been noticeable. Moreover, the panels were packed so closely together in the stillages that it would have been very hard to examine them, save for the two outermost panels (see [244(c)] below). Indeed, when I asked Prof Nonhoff how wide the deformation had spread, he admitted that he could not see very far inside the stillage.[84] I note, moreover, that Prof Nonhoff simply assumed the existence of delamination when he was first invited onsite, and his observations were

[84] NE (30 March 2016) at p 55 lines 8–12.

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perhaps for that reason not well-documented. This may be understandable given that he was invited onsite primarily to aid Kalzip in investigating and formulating remedial measures, rather than to determine whether delamination had in fact occurred. Nevertheless, the scarce primary evidence and lack of documentation with relevant details limited the assistance that I derived from his evidence.

Construction of the panels

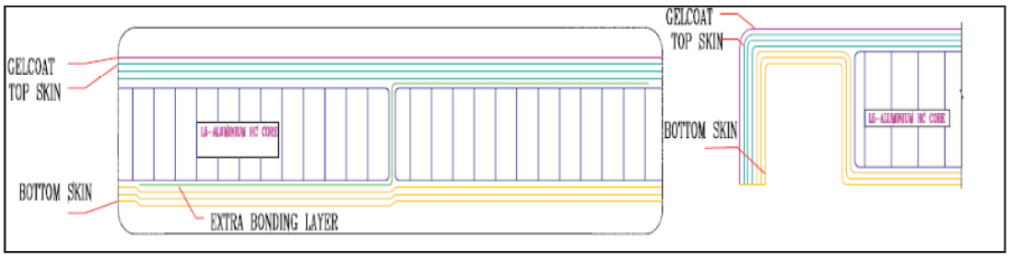
46 It will be appropriate at this stage to briefly explain the composition of the GRP panels. The GRP panels are a type of fibre-reinforced plastic ("FRP") composite product. FRP is composed of a polymer matrix reinforced with fibres. The polymer matrices can be of various resins whilst the fibres used are usually glass or carbon. GRP is a common type of FRP.[85] As indicated above, the GRP panels had a sandwich construction. The top and bottom surfaces of each panel, referred to as the "skins", were fire-retardant and made of glass fibre reinforcements and a polyester resin. The top surface was additionally coated with an off white polyester gelcoat for finish. The two skins sandwiched a layer of aluminium honeycomb with a 19mm cell size.[86] The skins were bonded to the honeycomb with resin. The outer (top) and inner (bottom) skins also extended past the edge of the honeycomb and joined at the ends to form a U-shaped seal or U-channel, thereby forming a complete and seamless envelope around the aluminium honeycomb. This can be seen from the diagram on the right:

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85 ABD 2B 218.

86 ABD 1D 10.

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47 The panels measured about 3m wide and 10–14m long.[87] The honeycomb aluminium came in sheets of 0.5m by 3m, which were laid in the same orientation as the panel (*ie*, with their long sides parallel to the long sides of the panel). At every 500mm juncture along the width of the panel, a strip of chopped strand mat (a "Z-strip") would be laid under one aluminium honeycomb sheet and across the top of the adjacent sheet using the same bonding resin mixture, so as to further strengthen the panel and join the outer and inner skins together. Given that the aluminium honeycomb sheets were 0.5m wide, and the GRP panels were 3m wide, there would have been five Z-strips running through the length of each roof panel. Because the Z-strips were made of the same substance as the inner and outer skins, it fused with them, and the two skins were directly and strongly bonded at the location of each Z-strip. An actual core sample from one of the MICE building panels which had a Z-strip running through it was tendered in evidence. By attempting to pry the inner skin away from the honeycomb, I observed that adhesion between the inner and outer skins and the aluminium honeycomb was much stronger at the location of the Z-strip and that the Z-strip prevented the sample from being pried apart.

48 According to the Sub-Contract, the panels were to be 22mm thick with a manufacturing tolerance of +/- 1mm.[88] BFG pleads that the parties had

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87 ABD 1C 20 at para 9.

88 ABD 1D 6.

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mutually agreed that the thickness of the GRP panel would be changed from 22mm to 24mm.[89] This appears to be based on correspondence between the parties in November 2008 in which BFG informed Kalzip that the panels' minimum thickness was 22mm but their maximum thickness was 24mm, and the drawings showed 24mm as a "space envelope dimension".[90] In any event, whether the panels were 22mm or 24mm thick has no bearing on the issues in dispute.

49 Three types of panels were manufactured for the Project: roof panels, fascia panels and return panels. The roof panels were to be installed horizontally (*ie*, lying atop the roof) while the fascia panels and return panels, which were generally smaller than the roof panels, were to be installed vertically.[91] Kalzip puts the number of manufactured panels at 3,421.[92] According to the site survey plans, there were 350 roof panels on the casino building, 467 roof panels on the MICE building and 296 panels on the theatre building.[93] The process by which they were manufactured is described in detail at [316] below.

Issue 1: structural performance requirements

The requirements

50 The loading requirements of the panels were described in terms of four types of load:

(a) dead load (the panel's own weight);

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89 Defence (Amendment No 2) at para 26.1.

90 ABD 1B 112 at para 52; ABD 2B 250 at para 91.

91 ABD 2B 367–368.

92 NE (23 March 2016) at p 235 line 2.

93 ABD 1I 9 and 11; ABD 7J 1458.

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(b) live load (a temporary load produced during, for example, maintenance by workers, equipment or materials);

(c) maintenance load (similar to a live load, and periodically applied during and as a result of maintenance activities such as cleaning); and

(d) wind load (the forces arising from the impact of the wind).[94]

51 Annexure 2 of the Sub-Contract states:[95]

> 1. The type of panel will be 22 mm thick type A1 as per BFG's document titled "BFG - Corus - SANDS_Podium Roof Price Table_300708.pdf" dtd. 30th July 2008.
>
> 2. Corus [*ie*, Kalzip] will provide continuous supports to GRP panels at every 1500 mm in length direction and at every 800 mm in the width direction of panels as installed. BFG should design the GRP panels based on this support condition and only following loads should be considered in the design of panels.
>
> 1. Dead Load: Self weight of GRP panel
>
> 2. Live Load: Live load of 0.75 kPa or 1.1 kN maintenance load over 150mm diameter.
>
> 3. Wind Load: As per Report -3896 Preliminary wind loads cladding museum dated 15th June07, Maximum Wind Load = +1.25 kPa and -2.0 kPa (suction)
>
> Load cases
>
> LC1: Dead Load + Live Load 0.75kPa
> LC2: Dead Load + Maintenance Load 1.1 kN
> LC3: Dead Load + Wind Load Positive Pressure
> LC4: Dead Load + Wind Load Suction
>
> Any other loads or load combinations or change in support and loading conditions than the above will result in complete redesign of panels.

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94 ABD 1C 139 at para 20.

95 ABD 1D 9.

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52 Specification Revision C reiterated the same loading requirements in respect of the live load and maintenance load, but gave a different wind load requirement:[96]

> 2.1.4 Dead loads
>
> All systems are to support and transfer their own self weight and other associated dead loads to the main building structure. The NSC will be required to identify, design, coordinate and supply all necessary sub-frames and secondary structure.
>
> 2.1.5 Live loads
>
> a. Roofs with access only for cleaning and maintenance :
> b. 0.75kPa or 1.1kN point load over 150mmØ
> c. Canopies with access only for cleaning and maintenance 0.6 kPa
>
> 2.1.6 Wind loads
>
> Refer to CPP Wind Load Report for Podium. Derivation of wind loads for elements not contained in the report to be in accordance with CP3 Chapter V, 1972 (Basic wind speed, V = 33m/s, Terrain category 2). Reference may be made to other international standards to determine localised wind pressure coefficients.
>
> 2.1.7 Maintenance Loads
>
> All trafficable areas including parapet capping's shall make allowance for maintenance loadings. This will include person loadings and indirect loads from abseiling ropes.
>
> Provide for man load on roof and parapet of 1.1kN point load acting on area of 150 mm^2

53 In requiring a "Live Load 0.75kPa", the Sub-Contract required the GRP panels to be capable of bearing a uniformly distributed load of 0.75 kilopascals ("kPa"). This was equivalent to 75kg spread evenly over a surface area of $1m^2$.[97] As for a maintenance load of 1.1 kilonewtons ("kN"), this required the GRP panels to be capable of bearing a point load of 110kg over a circular area 150mm in diameter. The experts agreed that the reference to "150 mm^2" in Specification

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96 ABD 1D 13.

97 NE (30 March 2016) at p 24 lines 19–25.

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Revision C was a mistake, as that would require a maintenance load of 110kg to be borne by an area approximately the size of a postage stamp; the requirement, as correctly stated in Annexure 2, was for that load to be borne by a circular area 150mm in diameter.[98]

54 In terms of wind load, Annexure 2 of the Sub-Contract required the GRP panels to bear a positive wind load resistance of 1.25 kPa (equivalent to a force of 125kg per m^2 of the panel) and a negative wind load (*ie*, suction) of 2 kPa.[99] However, para 2.1.6 of Specification Revision C required the wind load requirements to be calculated from CP3 Chapter V, Part 2, *ie*, the chapter on "Loading", specifically "Wind loads", in the British Standards Institution's Code of Basic Data for the Design of Buildings.[100] Mr Wymond criticises these specifications, on the basis that best building practice requires buildings with a complex form to be wind tunnel tested.[101] Nevertheless, they were contractually agreed. Although Mr Green initially took the view that the negative wind load ought to be 2.25 kPa[102], based on his calculation of wind load requirements in CP3 Chapter V, he conceded during trial that he had made a mistake in the calculation. He had based his calculations on a pressure coefficient table within CP3 Chapter V setting out "Pressure coefficients C_p for canopy roofs with ¼ < h/w < 1 and 1 < L/w < 3", which took account of "the combined effect of the wind on both upper and lower surfaces of the canopy for all wind directions".[103] However, in actual fact, the GRP panels lay atop a Kalzip sheet, such that the

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98 ABD 1C 140 at para 24.2; ABD 4C 1515 at para 4; NE (30 March 2016) at p 22 line 23; NE (29 March 2016) at p 196 lines 10–17.

99 NE (29 March 2016) at p 200 lines 1–8.

100 ABD 1D 137.

101 ABD 4C 1349 at para 98.

102 ABD 1C 140 at para 26 and ABD 1C 159.

103 ABD 1D 162.

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GRP panels only received wind pressure on their top surface and not from wind travelling underneath them. Mr Green was therefore wrong to treat the GRP panels as canopy roofs, and this mistake led him to overstate the design wind load in the original calculations.[104] He was thus content to accept that -2.0 kPa was the correct figure for the design wind load.[105]

55 The parties were in disagreement over what was the "CPP Wind Load Report" referred to in para 2.1.6 of Specification Revision C. Kalzip identifies it as a report issued by Cermak Peterka Petersen ("CPP") on 9 February 2009.[106] However, BFG points out that this report is dated nearly six months after the date of the Purchase Order and cannot have been the report referred to. In any case, this dispute is academic because the parties agree that the wind load requirements were +1.25 kPa and -2.0 kPa.[107] I note also that Mr Green calculated the *positive* wind load under CP3 Chapter V as +1.4 kPa.[108] However, Mr Wymond did not comment on this in his report and I say no more about this given the parties' agreement on the wind load requirements.[109]

56 As for the deflection limits, para 2.2.3 of Specification Revision C stated:[110]

> **2.2.3 Structural Serviceability**
>
> Serviceability deflection limits on cladding elements under working loads shall not exceed:

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104 NE (30 March 2016) at p 210 line 18 – p 212 line 4.

105 NE (31 March 2016) at p 4 lines 4–5.

106 ABD 5D 1410.

107 Plaintiff's Opening Statement at para 12; Plaintiff's Closing Submissions at para 168(c); Defendant's Closing Submissions at para 864.

108 ABD 1C 159.

109 ABD 4C 1349–1351.

110 ABD 1D 14.

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…

b. Any Element of the Roof Finishes

Element	Out of plane*
Live load	L/180 or 15mm whichever is the lesser
Wind load	L/180 or 15mm whichever is the lesser

57 "L" refers to the measurement of the span between supports. Annexure 2 of the Sub-Contract provided that Kalzip would provide "continuous supports to GRP panels at every 1500 mm in length direction and at every 800 mm in the width direction of the panels as installed". As the distance between supports was 1500mm, the maximum allowed deflection would be 8.33mm (1500mm divided by 180).[111]

58 However, this deflection limit was relaxed because Kalzip agreed to purchase panels made to specifications which it knew would have breached the deflection limit of 8.33mm. This appears to have been due to financial considerations. On 21 May 2008, BFG sent Kalzip a price table showing the prices for panels made to various specifications, including:[112]

(a) a 15mm-thick panel with a 500mm-by-400mm support grid (S$140/$m^2$ CIF Singapore; S$131/$m^2$ ex-works BFG Bahrain/Philippines);

(b) a 22mm-thick panel with a 750mm-by-800mm support grid (S$135/$m^2$ CIF Singapore; S$126/$m^2$ ex-works BFG Bahrain/Philippines); and

111 ABD 1C 152 at para 81.

112 ABD 3E 1934.3.

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(c) a 28mm-thick panel with a 1000mm-by-800mm support grid ($185/m^2 CIF Singapore; S$176/m^2 ex-works BFG Bahrain/Philippines).

59 The 22mm-thick panel was thus the cheapest of the three options. BFG subsequently revised its price table to provide for a support spacing of 1500mm by 800mm, which would substantially reduce the cost of the Kalzip support rail structure.[113] On 20 June 2008, BFG e-mailed Kalzip a deflection table stating the deflection limits of GRP panels of different thicknesses and support grid spans.[114] The deflection table, titled "Podium Roof GRP Deflection Matrix Summary_A_20Jun08.pdf" ("the BFG Deflection Table"), was incorporated by Annexure 1 to the Purchase Order.[115] It set out the following deflection limits for 22mm-thick GRP panels with grid spacing across width of 1500mm and length of 800mm:[116]

Loads	**Maximum deflection (mm)**
Dead + Point Load	13.6
Dead + Wind Pressure [*ie*, dead load + wind load pressure of +1.25 kPa]	16.5
Wind Suction - Dead [*ie*, wind load pressure of -2.0 kPa minus dead load]	29.0

60 The BFG Deflection Table expressly stated that a 22mm-thick GRP panel with 1500mm grid spacing across width and 800mm grid spacing across length was "Not Recommended as the wind suction deflection is excessive";

113 Defendant's Closing Submissions at paras 74–76.

114 ABD 2B 238 at paras 59–61 and 64; ABD 4E 2121 and 2125.

115 ABD 1D 6.

116 ABD 1D 29; Defendant's Opening Statement at para 34.

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this was written in red. Another two sets of specifications were annotated with the following remarks in red respectively: "Rejected. Stresses exceed limiting value under wind suction" and "Not recommended as the point load deflection is excessive". In contrast, three other specifications were annotated with "Acceptable limits" in green font and three others with "Could be considered with relaxed Deflection limits" in blue font. Kalzip presented this information to MBS on 26 June 2008 but deleted BFG's column of remarks and instead colour-coded the deflections.[117] Deflections were shaded in green to indicate "less than l/180 & <15mm", yellow to indicate ">l/180 but <15mm", and amber to indicate ">l/180 and >15mm but less than l/50". Mr Bridger explained that removing BFG's remarks and presenting the information using a colour legend was meant to make it "more visual" for MBS.[118] I do not accept this explanation. In my view, this was prone to mislead the reader of that document. The colour-coded table, unlike BFG's remarks column, did not properly convey that the deflections shaded in amber exceeded the deflection limit stated in para 2.2.3 of Specification Revision C. But whatever the case, MBS chose those specifications, and Kalzip therefore contracted to purchase 22mm-thick GRP panels from BFG at S$135/$m^2$ and install them on a 1500mm-by-800mm span grid.[119] There is no question that Kalzip was aware that this configuration would only have a maximum deflection limit of 29mm, and that this relaxed limit was incorporated into the Sub-Contract.

61 The structural experts agreed that the deflection criterion at maximum wind uplift was relaxed either to L/100 or 29mm, but did not know which.[120] As the distance between supports was 1500mm, L/100 = 15mm.[121] If it was the

117 ABD 2B 240 at para 68; ABD 4E 2130.17.

118 NE (15 March 2016) at p 161 lines 16–21.

119 ABD 2B 255 at para 105; ABD 1D 5.

120 ABD 4C 1515 at para 2; NE (30 March 2016) at p 86 lines 6–11.

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lesser of these which applied, then the deflection limit would be 15mm, but if not, then the more generous limit of 29mm would apply.

62 BFG submits that the deflection limit of the GRP panels under a load of -2.0 kPa was 29mm.[122] Kalzip has not taken a position on whether the deflection limit was 29mm or 15mm. The question may be largely academic given the experts' unqualified agreement that delaminated panels would have breached the deflection limits (see [99] below). Mr Green also said at trial that delaminated panels would have breached *even* the relaxed criterion of 29mm[123] and I note that Mr Wymond did not contradict him. However, the question of which was the correct limit does have some relevance to the structural test conducted on 24 September 2010, where the deflections recorded were between 15mm and 29mm (see [96] below). Insofar as the deflection limit carries consequences for the analysis, I prefer BFG's position for the following reasons:

(a) This question concerns the terms of the Sub-Contract. While the experts' views are helpful to me in understanding the technical issues, they cannot be definitive in construing the terms of the contract. In my view, the contractual documents support a relaxed limit of 29mm. Annexure 1 to the Purchase Order expressly incorporates the BFG Deflection Table as "part of this purchase order". It also states unequivocally, "All expected deflections based on the table submitted by BFG using FEA in BFG's mail dated 20th June 2008 under document reference 2 [*ie*, the BFG Deflection Table]."[124] That table clearly states a limit of 29mm at the design negative wind load.

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121 ABD 1C 141 at para 28; NE (30 March 2016) at p 85 lines 14–19; NE (31 March 2016) at p 8 lines 18–25.

122 Defendant's Closing Submissions at para 878.

123 ABD 4C 1515 at para 3(b); NE (30 March 2016) at p 133 lines 13–16.

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(b) Kalzip's account of MBS' choice of the panels also shows that the agreed deflection limit was 29mm. Its closing submissions state:[125]

> 163. Based on BFG's Deflection Table, 22mm thick GRP panels would not satisfy the Specification Revision C deflection criteria of L/180. Kalzip made this clear to MBS in its slides. *Despite this, MBS indicated a strong preference for 22mm thick GRP panels after the Presentation, as these were the lowest cost panels which BFG could supply.*
>
> 164. In light of MBS' preference for GRP panels, Kalzip wrote to MBS on 26 June 2008 to confirm the offer price based on MBS' choice of specification for GRP panels at the Presentation. In its 26 June 2008 letter, Kalzip also made clear to MBS that the maximum deflection of 22mm thick GRP panels was calculated to be 29mm which did not meet the requirement of L/180 in Section 2.2.3 of Specification Revision C.
>
> 165. Despite this, on 3 July 2008, MBS formalised the choice of panels and supplier, i.e. GRP aluminium honeycomb panels of 22mm thickness to be manufactured by BFG …
>
> [emphasis added]

(c) Indeed, Mr Flook's affidavit of evidence-in-chief ("AEIC") confirms that "the panels originally selected by MBS have a 'Span/ 51 limit'" (*ie*, 29mm), whereas Kalzip requested replacement GRP panels in August 2010 with a *different* deflection limit of Span/100 (*ie*, 15mm). This explains Mr Kolhatkar's e-mail to Mr Carter on 4 August 2010, attaching the BFG Deflection Table, which stated that "The panels selected by MBS are having Span / 51 limit."[126] Other e-mails subsequently exchanged between Kalzip and BFG discussed two different prices, one for replacement panels which would be manufactured to comply with the existing deflection limit, and one for

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124 ABD 1D 6.

125 Plaintiff's Closing Submissions at paras 163–165.

126 ABD 2B 330 at para 57 and Mr Flook's AEIC at pp 293–294.

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replacement panels which would conform to a *stricter* limit of L/100 and thus be more expensive.[127]

(d) By contrast, there is no mention of L/100 in the deflection table or, as far as I am aware, any other contractual documents. BFG's reply submissions therefore assert that "Kalzip has not explained how and why the deflection limit ought to be 'L/100' even though this is not stated in the Sub-Contract nor the documents referenced in the Sub-Contract".[128] Counsel for Kalzip had an opportunity to address this in oral submissions over a month later but did not do so.[129]

(e) Kalzip's experts, Mr Green and Prof Nonhoff, testified at trial that if there was a deflection of up to 29mm, the GRP panel would still be within the contract specifications. Mr Wymond also agreed that the panels would have complied with the relaxed deflection criteria if they deflected up to 29mm.[130]

63 I also note that some experts (for example, Prof Nonhoff[131]) were queried about whether other standards would have been more appropriate than Specification Revision C for the Sub-Contract. However, that is irrelevant to the issue at hand: Specification Revision C was chosen by the parties and defines the contractual obligations which the parties undertook to fulfil towards each other.

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127 ABD 13E 8280, 8282–8283, 8383, 8409.

128 Defendant's Reply Submissions at paras 15–16.

129 NE (21 March 2017) at pp 186–187.

130 NE (30 March 2016) at p 85 line 14 – p 86 line 14, p 87 lines 9–16, p 131 lines 10–15.

131 ABD 1C 22 at para 17(c)–(d).

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Whether the structural tests show that the panels breached the structural requirements

64 Various structural tests were performed on the GRP panels in 2008–2010. Some were conducted by BFG and some by Winwall Technology Pte Ltd ("Winwall"). Although Kalzip pleaded reliance on the Winwall tests in its Statement of Claim, it now expressly disavows reliance on those tests as evidence of breach of the structural performance requirements.[132] However, even if Kalzip were to rely on those tests, I do not think they would advance Kalzip's case. For completeness, and because some time was spent on these tests at trial, I set out my views on these tests at [75]–[97] below. This also carries consequences for other parts of the analysis. For example, the tests form part of the basis of Prof Nonhoff's view regarding the delamination[133] as well as the basis of a non-conformance report issued by Aedas on 17 May 2010, which Kalzip does rely on. Moreover, though Kalzip does not rely on these tests "as evidence of breach of the structural performance requirements", the tests may still have relevance in the context of the cause of delamination or quantification of damages.

65 Mr Green and Mr Wymond both agreed that BFG's test methodology was unreliable. Mr Green explained that the samples used by BFG were very small compared to the production panels and the support conditions did not replicate how they were to be supported in practice.[134] The experts' list of agreed points stated:[135]

> Agreed that the BFG testing was rudimentary, that the Winwall testing regime was in accordance with normal industry

132 Plaintiff's Reply Submissions at para 428(e).

133 ABD 1C 29 at para 35.

134 ABD 2C 601 at para 3.76.1.

135 ABD 4C 1515 at para 9.

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> standards, but that boundary conditions were undefined and there was some evidence of rail rotation during testing owing to asymmetric loading on the rail cross-section.

66 However, they disagreed on the weight to be placed on the Winwall tests. While Mr Green accepted that the Winwall tests "were an improvement over the BFG tests", he thought they were unreliable[136] because they "still did not properly replicate the boundary conditions".[137] For example, the support rail failed two tests conducted by Winwall in April and May 2009 due to rotation, because the support rail had been asymmetrically loaded on one side only instead of two sides. In practice, each rail would have supported a pair of panels, which would have balanced out the forces acting on the rail and prevented rotation. Those test results were therefore not representative of how the support rail system functioned in practice.[138] The BFG and Winwall tests therefore could not be reliably adopted as a gauge of whether the GRP panels would have met the deflection limits of the Sub-Contract.[139]

67 Mr Wymond, on the other hand, agreed that the BFG testing was rudimentary but thought that the Winwall testing showed very important information notwithstanding "some evidence of rail rotation during testing owing to asymmetric loading on the rail cross-section".[140] The rotation did not mean that the Winwall test was totally irrelevant, for the following reasons:

(a) First, there were 86 edge panels in the design of the building, and the rails supporting these edge panels would have been subjected to

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136 NE (29 March 2016) at p 202 lines 5–10.

137 ABD 2C 601 at para 3.76.2.

138 NE (29 March 2016) at p 201 lines 6–20; ABD 1C 153 at para 83; ABD 2C 601 at para 3.76.2.

139 NE (31 March 2016) at p 39 lines 5–9.

140 NE (31 March 2016) at p 39 lines 18–21; ABD 4C 1366 at para 9.

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asymmetrical loading.[141] However, drawings of the upper roof of the casino building showed that these edge panels were anchored at their ends, which was not the configuration when the panels were tested.[142]

(b) Secondly, Mr Wymond pointed out that some panels were narrower than others. While most were 3m wide, some were only 0.7m wide.[143] It was therefore possible for a rail to support a full width panel on one side and a much smaller panel on the other side. The load on one side of the rail could be roughly double that on the other side.[144] Mr Green agreed that this seemed logical. However, while he accepted it was possible for the rail to be eccentrically loaded where an edge panel was anchored at the end or where it supported two differently sized panels, it would not be *as* eccentric as it was under the Winwall testing conditions.[145]

(c) Thirdly, asymmetrical loading could also occur for a rail which supported one panel in a high wind load zone adjacent to another panel in a lower wind load zone.[146] Mr Green agreed that this was possible, though he thought that any differential in wind load would be very minor.[147]

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141 NE (30 March 2016) at p 98 line 23 – p 99 line 2 and pp 115–116.

142 ABD 1J 20; NE (30 March 2016) at p 114 lines 1–15.

143 ABD 1J 36 at row 26.

144 NE (30 March 2016) at p 116 lines 1–15.

145 NE (30 March 2016) at p 116 line 21 – p 117 line 1.

146 NE (30 March 2016) at p 103 lines 7–14.

147 NE (30 March 2016) at p 101 lines 12–15 and p 103 line 23 – p 105 line 15.

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68 Notwithstanding that he considered the Winwall tests to be of some value, Mr Wymond acknowledged that they did not test the performance of the GRP panels in isolation. He stated:[148]

> Performance testing at Winwall involved testing *the complete roof system* Kalzip, rails and cladding, plus associated fixing brackets. *There was no clear demarcation between the GRP-HC panel performance and the performance of the complete roof system.* Hence any conclusions made in relation to this testing could not be verified. Videos provided in relation to the testing highlight areas where system issues had a major influence on panel testing. [emphasis added]

69 This reduces the utility of the Winwall tests, because BFG's contractual responsibility was limited to ensuring that the *panels* met the Sub-Contract requirements provided they had "continuous supports … at every 1500mm in length direction and at every 800 mm in the width direction of panels as installed". BFG was not responsible for designing or installing the supporting structure. The Sub-Contract stated that the "assessment of capacity of the entire support structure" was "out of BFG's scope" and it did not have to "ensure the safety & adequacy of supports in terms of reactions from the Cladding".[149] In fact, Mr Wymond took the view that the panels deflected excessively in the Winwall tests only because of rail deflection and rotation, rather than because of any deficiency in the panels themselves. For example, he noted that bracket disengagement was a problem in the test on 14 and 15 July 2009.[150] I now turn to the individual tests.

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148 ABD 3C 803 at para 2.5.4.

149 ABD 1D 9; see also NE (22 March 2016) at p 74 lines 9–11.

150 ABD 4C 1352 at paras 104–105 (*cf* ABD 1C 142–143 at para 35).

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29 September 2008 (BFG)

70 BFG refers to two static load tests that it carried out on 29 September and 24 November 2008.[151]

71 On 29 September, two load conditions were simulated on a 1m-by-3m panel. It was made to bear first an imposed load of 1.25 kPa (corresponding to the wind load requirement, see [54] above). That load was then removed and the panel made to bear a "man load" of 1.1 kN in the form of a person weighing more than 100kg standing on the panel at pre-determined locations and walking on it.[152] The panel did not show any cracks or delamination following these tests. Nobody from Kalzip or MBS was present at this test.[153] Because of the lack of third-party certification, this test was repeated on 24 November 2008 (see [73] below).[154]

72 In Mr Green's view, this test was of "questionable" accuracy because a measuring point was shown in the geometric centre of the panel, which was no longer accessible once the sandbags used to impose the 1.25 kPa load were in place. Moreover, the photographs appeared to show a support at the mid span of the panel and the deflections were clearly visible. In any event, panel performance did not appear to be satisfactory because deflections of 8mm were recorded under a load of 220kg; the limit of L/180 in the case of a 1m metre panel would be 5.55mm.[155] (Mr Green's expert report states that the panel deflected up to 9mm under a load of 220kg.[156] However, the test results show a

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151 Defendant's Closing Submissions at paras 541–544; Defendant's Reply Submissions at para 93.

152 ABD 5E 2972 and 2976–2977.

153 ABD 1B 139 at para 117.

154 NE (28 March 2016) at p 183 line 24 – p 184 line 2.

155 ABD 1C 160 at para 4.

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deflection of 8mm at this load and a deflection of 9mm at a full load of 386kg.[157]) Moreover, given that both experts criticised BFG's testing methodology (see [65] above), I place little weight on these test results.

24 November 2008 (BFG)

73 The test on 29 September 2008 was repeated on 24 November 2008 so that it could be certified by a third party, TUV Middle East.[158] This time round, the "man load" was imposed by having a person stand on the panel and increasing his weight to 112kg by having him hold small sand bags. He then walked on the panel and deflections were recorded.[159] No cracking sounds were heard during or after testing and the panel remained intact.[160]

74 However, the test on 24 November 2008 was also unreliable because deflections were recorded around the quarter-points of the panel, instead of at the mid span, where deflection would probably have been greater.[161] Mr Green and Mr Wymond both agreed that tests by BFG on 29 September and 24 November 2008 were inconclusive.[162]

14 and 15 July 2009 (Winwall)

75 On 14 and 15 July, Winwall performed a structural test comprising (1) a cycle pressure structural test; (2) a structural test at serviceability limit state; and (3) a pull out test of the aluminium clip.[163] The test panel passed the first

156 ABD 1C 160 at para 4.3.

157 ABD 5E 2975.

158 ABD 2G 503.

159 ABD 10E 6458 and 6465.

160 ABD 2G 508 and 513.

161 ABD 1C 160–161 at paras 2–4.

162 ABD 2C 593 at para 3.32.

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two tests but the screws fixing the seam clip to the aluminium rail detached at -3 kPa.[164] However, Mr Wymond pointed out that this failure was due to disengagement of the supporting brackets (*ie*, a component provided by Kalzip) rather than failure of the GRP panel itself.[165]

76 Kalzip's witnesses, Mr Wong (who attended the test) and Mr Bridger, understood that the GRP panel had passed these tests.[166] Mr Green originally took the view that the panel had deflected excessively during the tests on 14 and 15 July 2009. Under a negative wind pressure of 2.25 kPa, the panel's deflections ranged from 15.21mm to 51.63mm. Mr Green had prepared his first expert report on the basis that the deflection limit was 15mm rather than 29mm[167] (see [61] above); if this was correct, it would mean that the test panel exceeded the deflection limit at every measurement location. Under a positive wind pressure of 1.25 kPa, the panel deflected as much as 25.89mm, which would have exceeded a deflection limit of 15mm but not of 29mm.[168]

77 It turned out that Mr Green's analysis of the 14 and 15 July 2009 test results were not only based on the wrong deflection limit (15mm), but also a misinterpretation of the test results. He originally asserted that the panel deflections recorded ranged from 15.21mm to 51.63mm. These figures represented the deflections recorded on two particular displacement transducers on the test specimen, as recorded in a table in the test report titled "A.2-3 Structural Test at Serviceability State (Negative Pressure)".[169] However, Mr

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163 ABD 2G 564; ABD 1B 147 at para 140.

164 ABD 2G 570; ABD 3G 807.

165 ABD 4C 1352 at paras 104–105.

166 ABD 1B 85 at para 43; ABD 1B 147 at para 140.

167 NE (30 March 2016) at p 131 lines 2–15.

168 ABD 1C 161.

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Green conceded during trial that he ought instead to have taken the figures in Table 5.2, "Structural Test at Serviceability Limit State", which calculated the deflection of the GRP panel based on mid-span displacement minus the average of the corresponding two end values.[170] This table recorded the deflections at a maximum negative wind load of -2.25 kPa as ranging from -5.68mm to -12.87mm, which were within the deflection limit. The maximum deflection recorded at +1.25 kPa was 8.31mm. This led Mr Green to revise his opinion and conclude that the panel had in fact passed the test. Mr Green acknowledged that he had made a mistake and that his analysis of the underlying test data was very poor.[171] I also note that Mr Green initially took the view that the maximum wind suction under the Sub-Contract was -2.25 kPa, but during trial conceded that it was -2.20 kPa (see [54] above). In Mr Wymond's view, a study of the deflections recorded by individual transducers showed that "the GRP-HC panel was stiff" and deflected in a similar way predicted by the finite element analysis.[172] I therefore do not accept the tests on 14 and 15 July 2009 as evidence that the GRP panels supplied by BFG failed the structural performance requirements under the Sub-Contract.

29 and 30 April 2010 (Winwall)

78 Winwall conducted a cycle pressure structural test and a structural performance test on 29 and 30 April 2010 respectively.[173] An e-mail from Arup Façade Engineering ("Arup") records that "[c]rackling noise[s]" were heard and became louder as the pressure was increased, until bangs were heard "when the

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169 ABD 2G 578 (also 2PCB 805).

170 ABD 2G 569 (also 2PCB 796).

171 NE (31 March 2016) at p 30 line 24 – p 31 line 16; p 31 lines 19–25.

172 ABD 3C 850 at para 200.

173 3PCB 935.

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pressure was reaching towards ~2000/2250 Pa" and a couple of areas towards the central area and towards one side of the panel "lifted up". At this point the test was stopped.[174] As a result, the panels did not even undergo the more stringent proof load test at the ultimate limit state.[175]

79 According to Arup, failure occurred during the design load negative pressure test. However, this was premised on the assumption that the design load negative pressure was -2.25 kPa,[176] whereas I have explained at [54] above that the wind load requirement was actually -2.0 kPa. Although the panel failed at "~2000/2250 Pa", according to Mr Wong, after applying an area reduction factor, the equivalent of 2.25 kPa suction was a test load of 2.067 kPa. This meant that the test panel did in fact withstand the design suction load, since the test failure occurred only at a test load of 2.20 kPa.[177]

80 Moreover, the failure appears to be attributable to failure of the supporting components. Mr Rade's report of the test records that at a load of 2.2 kPa, "the aluminium support structure failed at one of the side[s]" and that the "flanges of the aluminum rail, where z-cleats were engaged, were buckled excessively under suction". This "resulted [in] the delamination of the ferrule from panel" and in "excessive deflection in GRP panel". The report states that because the sliding Z-clips disengaged, the entire load became concentrated on the location of the fixed Z-clips, causing the ferrule to debond at that location; "[i]n short, the test mock of support structure failed to provide the structural support to GRP panels".[178] A set of photographs taken of the April 2010 tests

174 3PCB 875.

175 ABD 1C 27 at para 30.

176 ABD 2G 648.

177 ABD 2B 344–345.

178 3PCB 935 and 939.

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showed aluminium rail failure due to bending, sub-rail connection failure, rotation of the Z-clips and significant deflection of the panels.[179] Mr Wong agreed on the basis of these photographs that the support rails had rotated during the test.[180] This is corroborated by an e-mail sent by Mr Carter on 3 May 2010, which stated, "Report on the nature of failure - it is presumed that the structural failure occurred due to excessive rigidity being introduced into the test rig build up".[181] I therefore accept BFG's submission[182] that the tests carried out on 29 and 30 April 2010 do not prove that the GRP panels failed to satisfy the structural loading and/or deflection requirements of the Sub-Contract.

14 May 2010 (Winwall)

81 On 14 May 2010, Winwall performed a test on a panel measuring 3.53m by 11.7m, originally destined for the theatre building roof. This involved using air pressure to simulate wind loading on the panel. The panel performed satisfactorily in the cyclic pressure and positive pressure tests, but the rail and Z-clips along one side of the panel disengaged due to the support rail undergoing excessive rotation during the negative pressure test at a negative pressure of -2.067 kPa.[183] At that point, panel deflections had already exceeded 15mm. The test report issued by Winwall states in relation to the negative pressure test, "Excessive displacement along entire length of GRP panel, about 500 mm from one side of GRP panel was noted during application of negative pressure. Excessive deflection caused the panel to rupture at -2067 Pa. Test stopped."[184]

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179 ABD 12E 7742–7754.

180 NE (16 March 2016) at p 127 lines 17–20.

181 ABD 12E 7739.

182 Defendant's Closing Submissions at para 925.

183 ABD 2G 707.3; ABD 3C 854 at para 221.

184 ABD 2G 714.

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82 Mr Wymond considered that the GRP panel failed the test not because it was inherently inadequate but because of design faults in the aluminium support system.[185] In support of this he referred to screenshots taken from videos of the 14 May 2010 test.[186] Mr Wymond thought these screenshots showed that the angle between the horizontal flange and the vertical wall of the support rail had widened after load testing.[187] If he was right, this would be evidence of rail bending and deformation. Mr Green, on the other hand, thought that the rail had merely rotated without bending or deforming.[188] I agree with Mr Wymond; a close study of the two screenshots shows that the angle between the vertical wall of the rail and the horizontal flange had widened.

83 BFG rightly points out that the pressure at which the panel ruptured, -2.067 kPa, exceeded the design wind load of -2 kPa. At -2.067 kPa, the highest deflection was recorded as 28.68mm, which was still below the deflection limit of 29mm.[189] (Although BFG reads this deflection as 28.88mm, the test report appears to state 28.68mm, but this is inconsequential for present purposes.[190]) Moreover, a report prepared by BFG on the 14 May 2010 test explains that after applying a reduction factor, 2067 Pa was equivalent to 2.25 kPa of suction.[191]

84 BFG attributed the failure of the April and May 2010 tests to the other test components rather than the GRP panels themselves. Its report states:[192]

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185 ABD 4C 1352 at para 105.

186 ABD 3C 857.

187 NE (31 March 2016) at p 46 line 22 – p 47 line 8.

188 NE (31 March 2016) at p 46 lines 5–18.

189 ABD 2G 714; NE (16 March 2016) at p 119 lines 5–18.

190 Defendant's Closing Submissions at para 934; ABD 2G 714.

191 ABD 2G 707.2; Defendant's Closing Submissions at para 926.

192 ABD 2G 707.3.

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> 2. Under full designed suction load, it is evident from the video that the support rail structure underwent excessive rotation, which results in insufficient holding of the panels. Hence the rail structure needs further securing to prevent its deflection and rotation.
>
> 3. From the video of the suction test, it is evident that as a result of the support rail rotation and deflections of panels, the panels are seen to start getting disengaged from the rail supports as the load reached maximum design load, z-cleats started moving laterally mainly due to rotation in the rail support structure. Hence the panels having rotated support resulted into lateral movement of panel under the full design suction loads. In our opinion, this movement of panel needs to be restricted by having fully rigid rail structure that does not undergo any rotation. In fact, in reality except at the front and rear end of each bay, at rest of the rail supports, each rail structure supports two adjacent panels, that may bring stability to the rail structure against rotation. However, this condition was not simulated in the actual load test. This resulted into excessive rotation in the support rail structure. Hence we suggest to incorporate these aspects by completely simulating the actual support structure and to have more rigid rail fixation for the next test.

85 The same explanation was repeated in an e-mail from Mr Flook to Mr Carter on 17 May 2010; he said that it was "evident from the video" of the 14 May 2010 test that the movement of the panels had to be restricted by having a fully rigid rail structure. Mr Flook also pointed out that the rail structure in the test was unevenly loaded, and that even loading might bring stability to the rail structure in practice.[193]

86 Kalzip appeared to accept that the test failed because the Kalzip *support rail* had rotated, not because the GRP panels were structurally inadequate. This is evident from a GRP status report sent by Mr Carter to MBS on 4 June 2010:[194]

> To date two structural tests have been conducted, unfortunately both with less than satisfactory results with the panel failing at pressures somewhat less than those targeted.

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193 ABD 2B 325.

194 ABD 12E 7880–7881.

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> It is believed that in both instances the failures resulted from deficiencies with the test configuration and not with the panel.
>
> During the first test the panel support rail was observed to rotate and consequently overstressed the connecting ferrule. It should be noted that rail rotation cannot occur in the as built condition.
>
> In the second test due to the rig configuration a fixed point was unable to be installed. Under negative loading this situation allowed the panel edge to move laterally, increasing vertical deflection and subsequently overstressing the panel edge seam. Again this situation cannot occur in the as built condition.
>
> It should be noted that up until the point of failure both test samples performed in line with expectations derived from calculation.

87 In BFG's submission, Mr Carter's e-mail related to the April and May 2010 tests and showed that the failures occurred because the support rail system designed for the test did not really reflect actual site conditions.[195] There was no problem with the GRP panels themselves. Although Mr Wong disagreed with Mr Carter's e-mail, he accepted that the test set-up was not identical to the site condition. He disagreed primarily because he felt that the test set-up, although not identical to the site condition, had been approved by Arup and was the best that could be done.[196] Be that as it may, the question is whether the test – however it was conducted – is evidence that the GRP panels breached the structural requirements of the Sub-Contract. Having considered the evidence, I find that it did not.

17 June 2010 (Winwall)

88 Winwall conducted another test on 17 June 2010 on another uninstalled theatre panel. It was subjected to a cycle pressure structural test, a structural test at serviceability limit state (to +1.25 kPa and -1.15 kPa) and an ultimate load

195 NE (16 March 2016) at p 129 lines 6–13.

196 NE (16 March 2016) at p 130 line 24 – p 131 line 11.

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test (to +1.875 kPa and -1.725 kPa).[197] At a negative pressure of -1.15 kPa, large deformation was recorded in the centre of the panel which exceeded the maximum measuring capacity of the linear transducers. The largest recorded figure was 36.72mm at a positive pressure of 1.25 kPa.[198] It appears that Transducers 15 and 19 malfunctioned,[199] but even disregarding the deflection of 36.72mm recorded by Transducer 19, the next highest deflection would be 34.11mm (recorded by Transducer 10). The panel withstood the positive pressure of 1.875 kPa for 10 seconds without any rupture or visible failure of any component. However, it ruptured after being subjected to a negative pressure of 1.725 kPa for eight seconds, at which point a screw also became detached and an aluminium support bracket began to bend.[200]

89 After the negative pressure test, photographs were taken showing a screw detached from a bracket, a bent bracket, and a portion of the GRP panel which had ruptured.[201] These were, again, components of the support system provided by Kalzip. Mr Rade, who witnessed this test, recalled that there were no signs of any structural failure of the test panel, although the fixation screw between one of the fixed brackets and aluminium rail had snapped out.[202] Mr Wymond noted that, as with previous tests, "the mock-up failed at the junction between the Z Clips and the rails with a screw coming out, rail flange bending and the prying of a z clip out of the GRP-HC panel".[203] I therefore agree with

197 ABD 2G 727.1; ABD 3G 728.

198 ABD 3G 734; NE (31 March 2016) at p 34 lines 10–14.

199 ABD 2B 279 at row 3; ABD 2G 727.5; ABD 2B 349 at para 21.5.

200 ABD 3G 735.

201 ABD 3G 735 and 749.

202 ABD 2B 348 at para 21.3.

203 ABD 3C 859 at para 224.

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BFG that this test does not prove that the GRP panels failed to comply with the structural loading and/or deflection requirements of the Sub-Contract.[204]

8 September 2010 (Winwall)

90 Winwall was commissioned by BFG to conduct a pressure test on 8 September 2010, which involved using air pressure to simulate wind loading on a large panel measuring 2.98m by 10.27m originally meant to be installed on the theatre building roof.[205] The panel was subjected to a cycle pressure structural test and to a structural test with loads of up to +1.25 kPa and -2.25 kPa. In order to test the performance of the panels in isolation, and avoid failure of the support structure, the test panels were mounted on a rigid steel support structure.[206] The panel performed satisfactorily under a positive pressure of 1.25 kPa. However, at -2.25 kPa (which was equivalent to a load of -2.475 kPa given the area of the test chamber), the specimen withstood the load for one minute but the bolts fixing the aluminium fixed clips to the GRP panel detached at two locations.[207]

91 Mr Green and Prof Nonhoff emphasised that the panel "had additional fixings and a different method of support and resulted in the pulling out of the cast in ferrules to which the Z clip is fixed".[208] Similarly, Prof Nonhoff said that the panel had "additional external fixings", and agreed with Arup's analysis that the test therefore did not give any indication as to whether the panels would withstand the design wind pressures without remedial measures.[209]

204 Defendant's Closing Submissions at para 944.

205 ABD 3G 749.1.

206 ABD 2B 274 at para 165; ABD 2B 326 at para 43; ABD 3C 859 at para 227.

207 ABD 3G 756.

208 ABD 2C 600 at para 3.72.

209 ABD 1C 29 at para 32.

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92 Mr Green pointed out that under a negative pressure of 2.25 kPa, structural failure occurred "in the form of detachment of the aluminium fixing clips".[210] BFG takes this to mean that it was the aluminium clip supplied by Kalzip that failed, and not the GRP panel.[211] It was also Mr Wymond's view that the test failed because no measures had been taken to prevent the Z-clips from rotating and causing the ferrules to bend.[212] (In any event, the maximum suction under the Sub-Contract was -2.0 kPa, not -2.25 kPa: see [54] above.)

93 However, Mr Green also observed that deflections were measured as high as 36.99mm at a negative pressure of 2.25 kPa, and he considered the high residual deformations recorded within the test results as evidence of failure.[213] BFG disputes that the deflections were this high. It hypothesises that Mr Green adopted this figure from a table in the test report stating the deflection recorded by one particular transducer (Transducer 1), whereas the deflection ought to have been calculated based on the mid-span displacement minus the average of the corresponding two end values (which, in the case of Transducer 1, was 4.94mm only).[214] Unfortunately this was not put to Mr Green during the trial. Nevertheless, this appears to be the exact same error which Mr Green acknowledged he had made in relation to the tests on 14 and 15 July (see [77] above) and the Winwall test report is clear that the deflection limits were not exceeded. I therefore do not accept Mr Green's evidence that the 8 September 2010 test showed that the GRP panels deflected excessively, much less that they deflected excessively *at design load*. I find that this test also does

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210 ABD 1C 162.

211 Defendant's Closing Submissions at para 975.

212 ABD 3C 859–860.

213 ABD 1C 162; ABD 2C 600 at para 3.72.

214 Defendant's Closing Submissions at paras 976–977; ABD 3G 756 and 763.

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not show that the GRP panels breached the structural requirements of the Sub-Contract.

24 September 2010 (Winwall)

94 Winwall performed another test on 24 September 2010, which involved using air pressure to simulate wind loading on a large panel measuring 2.98m by 11.5m.[215] The panel was subjected to a structural test at serviceability limit state and an ultimate load test. The latter involved applying negative step pressures to the test panel, the greatest being a pressure of 3.25 kPa for one minute.[216] Under positive wind load pressures up to 1.25 kPa, the maximum deflection recorded was 17.97mm. Under negative wind load pressures of up to 2.25 kPa, the maximum deflection recorded was 21.75mm (recorded at a wind load of -1.15 kPa).[217] At a negative pressure of 3 kPa, the panel started to rupture and made cracking noises. (According to Mr Wong, this meant that the panel failed at -3 kPa.[218]) It was observed that the panel bulged upwards, several aluminium clips along the middle railing detached, a portion of the aluminium railing bent at the middle of the specimen, and the aluminium railing at the sides of the specimen tilted.[219]

95 Prof Nonhoff thought that this test showed that there was a problem with the manufacturing of the GRP panels, because the panel ruptured and bulged upwards during the ultimate load test.[220] However, the pressure of -3 kPa far exceeded the design pressure under the Sub-Contract. The panel's performance

215 ABD 3G 784.

216 NE (16 March 2016) at p 152 line 19 – p 153 line 1.

217 ABD 3G 790–791.

218 NE (16 March 2016) at p 155 lines 9–22.

219 ABD 3G 792.

220 ABD 1C 29 at para 33.

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at that pressure is not indicative of its compliance with the structural requirements of the Sub-Contract. Moreover, as Mr Wymond observed, the Winwall test report highlighted a failure of the rails and clips and it is not known whether the rails and clips caused the panel failure or *vice versa*.[221] I accept Mr Wymond's view. In this respect I find Prof Nonhoff's views rather partial.

96 Mr Green considered that the deflections recorded showed the structural inadequacy of the GRP panels. However, as with his comments on the 14 and 15 July 2009 tests, Mr Green had based this analysis on a deflection limit of 15mm. He thus considered that the largest recorded deflections – 17.97mm and 21.75mm at pressures of +1.25 kPa and -1.15 kPa respectively – exceeded the "maximum allowable deflection limit of 15mm".[222] These were, however, well within a relaxed limit of 29mm (see [62] above).

97 BFG submits that the test specimen was not representative of an actual GRP panel because holes were cored along the sides of the test panel, filled with resin and cured prior to the test.[223] Mr Wong agreed that the test panel was therefore different from the panels installed on site.[224] However, as Mr Wong pointed out, the holes were cored so that screws could be put in to fix the panels to the support rail. This was done on Mr Carter's instructions to improve the support conditions, so that the test results would be improved.[225] BFG did not adduce any evidence or explanation why the presence of the holes would have impaired panel performance. In any event, the deflections were, in my view, within the deflection limit of 29mm.

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221 ABD 3C 860 at para 229.

222 ABD 1C 162; ABD 1C 144 at para 37.2.

223 ABD 3G 787 at para 3; Defendant's Closing Submissions at para 946.

224 NE (16 March 2016) at p 133 lines 6–9, p 146 lines 7–15.

225 NE (16 March 2016) at p 142 line 22 – p 144 line 25, p 146 line 23 – p 147 line 4.

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98 Given my finding that the Winwall tests do not show that the panels failed to meet the structural performance requirements in the Sub-Contract, and bearing in mind that Kalzip does not rely on them to establish its case (see [64] above), I turn to the question of delamination. Unless Kalzip is able to prove that the panels delaminated due to defective manufacturing, it will have failed to establish that BFG breached the terms of the Sub-Contract.

Whether delaminated panels would have failed the Sub-Contract specifications

99 Importantly, the experts agreed that "[i]f the panels had delaminated they would not have satisfied the deflection criteria". Mr Green clarified at trial that delaminated panels would have breached *even* the relaxed criterion of 29mm.[226] This was shown by a set of tests commissioned by Mr Wymond and Mr Maurieschat and conducted by Kaskal Façade Testing Centre ("Kaskal") and Fraunhofer IFAM on 17 and 18 August and 14 September 2015 ("the 2015 Tests"). I elaborate on these tests in greater detail at [183] below. In Mr Green's view, the tests from August 2015 showed that delaminated panels deflected more than non-delaminated panels; the panels with "floating" inner skins failed the deflection criteria under negative pressure.[227] With the inner skin detached, the test panel deflected up to 59.26mm, strongly suggesting that if the panels had delaminated in 2009 or 2010, they would not have met the deflection criteria set out in Specification Revision C.[228] Kalzip therefore takes the position that delaminated GRP panels would not have satisfied the deflection criteria of the Sub-Contract, and that the question of BFG's compliance with the requirements

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226 ABD 4C 1515 at para 3(b); NE (30 March 2016) at p 133 lines 13–16.

227 ABD 1C 144 at para 38.1; ABD 2C 597 at para 3.54.

228 ABD 2C 588 at para 3.6.

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of the Sub-Contract can be determined by investigating whether the GRP panels had in fact delaminated.[229]

100 BFG takes a contrary view to that of the experts. It submits that "the structural experts' opinion that the deflection criteria would not be satisfied [if delamination occurred] is not in fact tested and/or supported by any test results – it is based on an entirely theoretical assumption that can never occur on site".[230] Although the panels with "floating" inner skins may have failed the deflection criteria under the Sub-Contract, the actual GRP panels installed for the Project would not have *completely* delaminated due to the presence of Z-strips at 500mm intervals.[231] Moreover, no tests were conducted on actual delaminated panels from the Project to see how much they deflected.[232] I also note that some of BFG's witnesses referred to documents which suggested that even delaminated panels would have met the Sub-Contract Requirements. For example, Mr Kolhatkar referred to a document titled "MBS_Analysis of Delaminated panel_11march10" which allegedly demonstrated that panels with a "floating bottom skin" nevertheless had sufficient residual strength to resist stresses specified in the Sub-Contract,[233] as well as to a report by BFG dated 23 March 2010 which suggested that a delaminated panel would deflect only up to 16.14 or 15mm.[234] However, these documents were not put to the expert

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229 Plaintiff's Closing Submissions at para 232; Plaintiff's Reply Submissions at para 428(c).

230 Defendant's Closing Submissions at para 863; Defendant's Reply Submissions at para 79.

231 Defendant's Closing Submissions at paras 985 and 1004.

232 Defendant's Reply Submissions at para 80.

233 ABD 2B 270 at para 150.

234 Plaintiff's Closing Submissions at paras 218–219; ABD 2B 279 at row 1; ABD 2G 609; ABD M 252–265.

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witnesses or referred to in BFG's closing submissions, leading me to conclude that they did not play any significant role in BFG's case.

101 I accept the experts' evidence that delaminated panels would not have met the Sub-Contract requirements, for the following reasons:

(a) *Both* Mr Wymond and Mr Green agreed that delaminated panels would have failed the deflection criteria under the Sub-Contract. They both also confirmed this view at trial.[235] Significantly, their agreement on this point was not confined to a panel that had delaminated *fully*, even though they were both aware that the 2015 Tests had been conducted on totally delaminated panels (and in fact Mr Wymond directed and attended the tests on 17 and 18 August 2015).[236] There was no reason for me to disagree with their expert opinion. If BFG had reasons for disagreeing with the experts' conclusion, it ought to have probed and tested their evidence on this issue at trial, but did not do so.

(b) During the 2015 Tests, the test panels with delaminated inner skins deflected up to 59.26mm. This was very much higher than the contractual deflection limit of 29mm. Even if BFG is right that the GRP panels installed onsite would not have delaminated *totally*, and would therefore have deflected less, the deflection in the 2015 Tests was so excessive that I have little difficulty accepting the experts' view that delaminated panels would likely have failed the deflection limit of 29mm.

(c) BFG refers to the opinion expressed by Kalzip's wind-loading expert in the arbitration, Dr-Ing Rolf-Dieter Lieb, that "even in a

235 ABD 4C 1515 at para 3(b); NE (30 March 2016) at p 133 lines 13–16, p 134 line 16.

236 ABD 3C 955.

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delaminated state, the majority of the panels could meet the actual wind loads. There were only a small number of GRP panels in highly loaded areas which could not meet the wind loads".[237] However, even in Dr Lieb's opinion, *some* panels would (if delaminated) have been unable to bear the actual wind loads. Furthermore, these "actual wind loads" do not appear to have been the wind loads specified by the Sub-Contract – they were "significantly lower than those that applied to the closed building envelope (as had been specified in Revision C)".[238] In any event, since Dr Lieb is not a witness in the Suit and was not present to explain or defend his view, I do not take his opinion into account.

Issue 2: Whether there was delamination

Evidence of delamination

102 It follows that I must determine the issue of whether delamination occurred onsite. As I have already noted above, unfortunately, the panels which were actually installed in the Project were removed and had been discarded by the time of the hearing. There is no primary evidence of what condition the panels were in at the time they were removed.[239] As noted earlier, there are also no photographs showing a panel with a delaminated skin. Although the panels were removed, no tests were conducted on them nor were they preserved to show that they had delaminated. None of the panels that had yet to be installed on the theatre roof were retained for the purpose of proving that there was inner skin delamination in this Suit, even though Kalzip sent some of these for testing by Winwall and could have preserved others or at least photographed those panels they claimed had suffered delamination.

237 Defendant's Closing Submissions at para 1005.

238 ABD 28L 20487.

239 NE (1 April 2016) at p 13 line 14 – p 14 line 5.

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103 Kalzip's case is that "extensive delamination of the GRP panels was observed".[240] It relies on the following evidence in support of its contention that the panels had delaminated:[241]

(a) internal communications within BFG from January to March 2010, showing its acknowledgement and acceptance that the GRP panels produced for the Project had delaminated;

(b) the evidence given by BFG's witnesses of fact at trial, reinforcing that BFG accepted that the GRP panels produced for the Project had delaminated;

(c) site surveys carried out jointly by Kalzip, BFG and MBS between February and March 2010, which allegedly identified and located delaminated panels onsite;

(d) evidence that MBS' consultants, Aedas Pte Ltd ("Aedas") and Arup, concluded that the GRP panels on the casino and MICE building roofs had delaminated; and

(e) BFG's provision to Kalzip of a draft proposed remedial solution on 21 January 2011, which was also consistent with its acknowledgement of the existence of delaminated GRP panels onsite.

104 First, I deal with BFG's preliminary point that Kalzip has only pleaded reliance on four site surveys in support of its case on delamination.[242] These were surveys that Kalzip commissioned and carried out to identify delaminated

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240 Statement of Claim (Amendment No 3) at para 19.

241 Plaintiff's Reply Submissions at paras 217, 273 and 428(d).

242 Defendant's Closing Submissions at paras 408, 418 and 890; Defendant's Reply Submissions at para 25; ABD A 16 at para 33(a).

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GRP panels on site. The four survey diagrams – two of the casino roof, dated 6 and 25 February 2010, and two of the MICE roof, dated 2 and 8 March 2010 – were essentially site plans of the panels installed on each building, annotated in yellow to show areas which had allegedly delaminated.[243]

105 The fact that Kalzip only pleaded reliance on four site surveys does not, on the facts and circumstances of this case, preclude reliance on other evidence to establish its case. Order 18 r 7 of the Rules of Court (Cap 322, R 5, 2014 Rev Ed) only requires the parties to plead "a statement in a summary form of the material facts on which the party pleading relies for his claim or defence … but not the evidence by which those facts are to be proved". As stated in *Singapore Civil Procedure 2017* vol 1 (Foo Chee Hock JC gen ed) (Sweet & Maxwell, 2017) at para 18/7/10:

> Every pleading must contain only a statement of the material facts on which the party pleading relies, and not the evidence by which they are to be proved …
>
> All facts which tend to prove the fact in issue will be relevant at the trial, but they are not "material facts" for pleading purposes. Lord Denman C.J. in *Williams v Wilcox* (1838) 8 A. & E. 314 at 331 stated that "It is an elementary rule in pleading that, when a statement of facts is relied on, it is enough to allege it simply without setting out the subordinate facts which are the means of proving it, or the evidence sustaining the allegation". This was followed in *Jusoh v. Ng Ah Sooi & Anor.* [1963] 1 M.L.J. 92 where Suffian J. cautioned, "Not all facts which tend to prove a fact in issue and which are therefore relevant at the trial are 'material facts' for pleading purposes".

106 Material facts refer to "all the facts which constitute a cause of action or defence so that [the party] will be in a position to offer evidence of them at trial". Where an action is brought for breach of contract, the material facts will include the existence of the contract, its nature (whether it was oral or verbal or by deed, express or implied), the terms alleged to have been breached, the nature

243 ABD 1I 9–12.

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of the breach and the loss and damage sustained as a result of the breach (Jeffrey Pinsler, *Singapore Court Practice 2017* vol 2 (LexisNexis, 2017) at pp 696 and 698).

107 Kalzip *has* pleaded the alleged facts crucial to its claim, including that the panels exhibited delamination of the lower face sheet from the honeycomb core of the GRP panels, and that this delamination impaired the panels' load-bearing behaviour, rendering them non-compliant with the loading and structural performance requirements of the Sub-Contract.[244] Kalzip did not need to plead the correspondence between the parties and the various observations of its witnesses during site inspections, since these merely constituted the evidence supporting its allegation of delamination.

108 Having said that, I should point out that, especially in building and construction cases of this nature, which involve detailed facts and technical issues, it would be good practice to plead with greater specificity so as not to take the other side by surprise. As the discovery progressed here, I note that BFG did *not* ask Kalzip if it was going to rely on anything other than the surveys to prove delamination of the inner skins. That would have been the correct course to take if BFG had wanted Kalzip to nail its colours to the mast. However, in this case, given the evidence put forward by both sides, no prejudice was caused as each party knew what it had to meet.

109 On the facts and circumstances of this case, I may therefore have regard to all the evidence relied upon by Kalzip. The evidence, taken together, paints a coherent picture of the state of affairs between the parties in 2009 and 2010. They agreed that the GRP panels had delaminated. This was borne out by correspondence within BFG internally, between BFG and Kalzip, and reports

244 Statement of Claim (Amendment No 3) at paras 33(a) and 33(b).

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from MBS' consultants Arup and Aedas. However, BFG's case is that this consensus was based on an *erroneous* assumption that certain noises which the panels emitted when walked upon were indicative of delamination. In the next two subsections I explain how the issue of delamination arose and set out the site surveys and correspondence which Kalzip relies on as evidence of the same.

Factory visits on 3 September 2008 and 23 April 2009

110 I first address two factory visits which were conducted on 3 September 2008 and 23 April 2009. I note that Kalzip is clearly not relying on the events of either visit as proof of delamination,[245] and will here explain why it is in my view unable to do so.

111 First, there was an inspection of BFG's factory on 3 September 2008. According to Mr Bridger, who was not present, defects involving delamination of the GRP panels became evident during the inspection and the panels were subjected to a "'live load' (foot traffic) test".[246] A report produced by Arup and Aedas records that when Mr Jan Oebeles walked along the panel, a "cracking" sound was heard by all present. The conclusion of the test was that:[247]

> "Cracking" sound was heard during the Live Load test. Subsequent inspection and test of the 300mm x 300mm samples suggested that the sound came from the aluminium honeycomb core delaminating from the inner GRP layer. The aluminium honeycomb was still attached to the outer GRP layer. The aluminium honeycomb appears to be better adhered to the external GRP layer.

112 This test spawned concerned e-mails from Mr Carter (Kalzip's project director), who informed BFG's Mr Kolhatkar that there was "extensive panel

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245 Plaintiff's Reply Submissions at paras 271–273.

246 ABD 1B 137 at para 110.

247 ABD 5E 2938, 2946.

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deformation and delamination of the 22mm panel" apparently due to "insufficient resin cover across the honeycomb", and from Kalzip's Mr Michael Moloney ("Mr Moloney"), who added that the 22mm-thick panel "cracks & moans (loadly) [*sic*] when you walk on it, giving evidence to the de-lamination of the resin from honeycomb".[248] The "moans" was clearly an exaggeration as no one else described such a sound.

113 I accept Mr Kolhatkar's explanation on this point. He explained that the samples used for this test had been provided primarily for visual purposes and for fitout and joinery testing, rather than for live load testing. They had not been made using the intended reinforcements and resin, as these items had not yet been ordered, and had not undergone a vacuum bagging process due to lack of time.[249] Moreover, the test had involved *manually tearing apart the sample*, "as a result [of which] the inner GRP layer delaminated from the aluminium honeycomb with the honeycomb still attached to the outer GRP layer". This, in Mr Kolhatkar's view, was the wrong way to test for delamination as an actual panel would not have to undergo that type of force.[250] He disagreed that a properly bonded panel would be able to withstand such a tear test and therefore did not consider this test as evidence of delamination of the GRP panels.[251]

114 I note that Mr Premamoorthy gave evidence in his AEIC that he would "typically carry out tap testing *as well as try to physically pull apart the skins of open edge sample panels to determine if there is adequate adhesion*".[252] In his view, it should not be possible to pull the skin apart from the aluminium

248 ABD 5E 2850 and 2851.

249 ABD 2B 242 at paras 71–72; ABD 5E 2849.

250 ABD 5E 2950; NE (28 March 2016) at p 163 line 22 – p 164 line 4.

251 NE (29 March 2016) at p 5 lines 7–11; NE (28 March 2016) at p 204 lines 17–23.

252 ABD 2B 365 at para 34.

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honeycomb by hand if there was proper adhesion between them.[253] However, Mr Premamoorthy made that remark in the context of his discussion of the process development phase, *ie*, the phase of trying to develop a process for the manufacture of the GRP panels. He did not say that it was a scientific method of determining whether a panel had delaminated; it was, rather, a means of testing the strength of the adhesion between the skins and the honeycomb core. Mr Kolhatkar explained that a tear test would result in delamination if "the force exerted exceeds the resin strength of the honeycomb of any core with the skin laminates". If one were to try pulling the skins apart by hand, different people would exert different forces. The more appropriate test would be to apply a load to the panels and measure the pull-out strength by reference to the stresses induced. Mr Kolhatkar disagreed with counsel's suggestion that "where you have a properly laminated, properly bonded panel, you should be able to retain the bonding when you do such a tear test".[254] Indeed, the expert evidence supported Mr Kolhatkar's statement that a tear test was not necessarily indicative of a delamination problem. Prof Nonhoff's and Mr Wymond's expert opinion was that it was possible to peel the inner skin off a panel by hand (see [244(d)] below). Prof Nonhoff and Mr Maurieschat also agreed that the bonding at the edges of an intact GRP panel would have made the panel stronger at those edges, and therefore harder to pull apart.[255]

115 Leaving the 3 September 2008 inspection to one side, Mr Kolhatkar claimed that he observed a problem of debonding during other trials on the GRP panels around September 2008.[256] That he considered delamination to be a problem is evident from his e-mail to the process engineer from BFG's

253 NE (23 March 2016) at p 57 lines 9–12.

254 NE (29 March 2016) at p 5 lines 7–11; p 7 lines 2–9; p 8 line 3 – p 9 line 7.

255 NE (1 April 2016) at p 28 lines 9–25; p 32 lines 10–17.

256 NE (28 March 2016) at p 170 lines 16–22, p 172 lines 18–25.

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headquarters in Bahrain, Mr Ananthanarayanan Venkateswaran (referred to in the proceedings as "Mr Anand") on 26 September 2008, titled "Podium Roof ALHC Bondi[n]g problem":[257]

> The problem of delimitation of the Aluminium core, I have discussed with Robert of Crown Alliance …
>
> Robert had a suggestion that at BFG he thinks the panels are demoulded before the laminate reached its full bond strength. So it may need longer cure time before demoulding. …

116 "Delimitation" appears to have been a typographical error; it should have been "delamination". Mr Kolhatkar also agreed during cross-examination that he was "seriously concerned about … the back skin delamination problem".[258] However, this correspondence occurred during the process development phase of the project, when the process of manufacturing the panels was still being finalised.

117 The next event which Kalzip refers to in its closing submissions is a factory visit on 23 April 2009.[259] Representatives of MBS, Aedas, Arup, Moshe Safdie Architectural ("MSA") and BFG attended an inspection at the BFG production facility in the Philippines. During the visit, Mr Carter stood on one of the sample fascia panels to test its structural strength. According to Mr Bridger, who does not appear to have attended the inspection, the panel "exhibited excessive deflection characteristics with audible cracking and it was apparent that the lower face sheet was delaminating" when Mr Carter stood on it.[260] Mr Attwood and Mr Premamoorthy, who attended the inspection, both gave evidence that Mr Carter not only stood but *jumped* on the panel. I pause to note

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257 ABD 5E 2924.

258 NE (28 March 2016) at p 210 lines 21–25.

259 Plaintiff's Closing Submissions at para 178.

260 ABD 1B 144 at para 133.

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that under cross-examination, it was put to Mr Premamoorthy by counsel for Kalzip that it could not be true that Mr Carter jumped on the panel because if that had happened he would have put it in writing, and Mr Premamoorthy agreed.[261] However, that answer was, in my assessment, a result of my intervention as I tried to clarify for him what a "put" question meant. Prior to that, he was quite adamant that Mr Carter had jumped on the panel. During the visit, BFG was requested to cut samples from a large panel to be taken away and this was done.[262] Arup produced a report labelled "BFG Philippines GRP Panel Inspection (TC3215) - No. 2" dated May 2009 ("the May 2009 report"). Under the section titled "Honeycomb Construction", the report stated:[263]

> It was noted that there was no specific adhesive between the honeycomb and the layers of glass fibre. However the outer face was pushed into the wet resin but the inner skin relied upon the resin from the application of that skin dripping down the honeycombs.
>
> A number of samples were requested but only one was supplied and *during the cutting of the panel the inner skin began to delaminate from the honeycomb.*
>
> This raised a major concern that there was inadequate bond between the skin and the honeycomb which could result in debonding in service. …
>
> [emphasis added]

118 As with the 3 September 2008 inspection, Kalzip expressly eschews reliance on the 23 April 2009 factory inspection as proof of delamination.[264] In my view it does so rightly, because the observations of delamination do not appear to be reliable. First, Mr Attwood gave evidence that he and others from BFG had objected to cutting the samples from a panel because such samples

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261 NE (23 March 2016) at p 70 lines 2–5.

262 ABD 2B 292 at para 24; ABD 2B 416 at para 124.

263 ABD 1I 127.

264 Plaintiff's Reply Submissions at paras 271–273.

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would definitely have been damaged by the very process of cutting, but did so anyway on MBS' insistence.[265] Kalzip makes the point that Mr Attwood made this objection as a non-expert and was not technically trained to make the observation that jumping would damage the panel.[266] However, this criticism rings hollow given that Kalzip itself mentions Mr Attwood's 30-odd years of experience in the composites industry in relying on his assessment that delamination had occurred.[267] The objection was reiterated in an e-mail sent by Mr Kolhatkar to Mr Moloney on 27 April 2009, in which he stated, "On a properly cured panel in regular production cycle, there is no delamination of back layer … What you have seen was unproperly cut piece not from a regular production panel. … [T]he actual production panels have a direct connection between top and bottom layers with a layer of glass every 500 mm."[268] This is also supported by expert evidence from Mr Wymond, who states that the "peel resistance of aluminium honeycomb is very low due to a very small contact area being subjected to a highly concentrated load", and so peeling a cut sample is not a realistic test of delamination.[269] The reference to a "direct connection" every 500mm was a reference to the Z-strips. I have explained, at [47] above, that the Z-strips bonded the inner and outer skins directly and helped to fortify the panels against delamination.

119 Secondly, Mr Attwood also gave evidence that, during the inspection, he objected to Mr Carter standing and jumping on the panel on the basis that the GRP panels had been designed only to withstand the loads specified in the Sub-

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265 ABD 2B 292 at para 24; NE (24 March 2016) at pp 231–232.

266 NE (24 March 2016) at p 234 lines 5–11, p 235 lines 7–12, p 236 lines 7–10; Plaintiff's Closing Submissions at para 369(c).

267 Plaintiff's Closing Submissions at para 256.

268 ABD 8E 4742.

269 ABD 3C 815 at para 67.

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Contract.[270] Mr Attwood's criticisms are echoed by Mr Premamoorthy. He explained that the test panel had been prepared merely for visual inspection and was placed on a random material handling frame. The panel was not supported with a proper support frame and the span of the support was approximately 4–5m, compared with the panel's span of 0.5m. Nor was the frame affixed to the panel. As a fascia panel, it was meant to be installed in a vertical position onsite and would not have been walked upon (although Mr Premamoorthy did not say that fascia panels were manufactured differently or to different specifications than the roof panels, which were to be installed horizontally).[271] I also find that jumping on the panel would have imposed a load in excess of the Sub-Contract requirements (see [306] below).

120 On the other hand, Kalzip refers to an e-mail from Mr Kolhatkar to Mr Anand on 10 May 2009 as evidence that BFG acknowledged that it faced a problem of delamination at that point in time.[272] The e-mail stated, "At this stage the inter layer debonding is a serious concern, *so is the client concern for back side ALHC to back skin debonding*."[273] [emphasis added] However, Mr Kolhatkar explained during cross-examination that the first matter (inter laminar delamination, or delamination *within* one of the skins), which is not in issue here, concerned him, but the second issue (delamination of the inner skin or back skin) was a "client concern which [he] conveyed back to Anand" and not something which seriously concerned him personally.[274] I accept his account, which is supported by another e-mail which he sent to Mr Carter on 8 July 2009, copying BFG's Mr Attwood and Kalzip's Mr Robert Talbot. In this e-mail Mr

270 ABD 2B 292 at para 24.

271 ABD 2B 416 at para 124.

272 Plaintiff's Closing Submissions at para 189.

273 ABD 8E 4888.

274 NE (28 March 2016) at p 211 lines 2–6, p 215 lines 2–4.

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Kolhatkar attempted to assuage concerns of delamination arising from the May 2009 report.[275] He stated:[276]

> The back skin delamination is has not been a problem on the moulded panels. This was observed only when the panel was cut through the thickness and the [aluminium honeycomb] to FRP bond was openedup [*sic*]. BFG has already incorporated the Z joggle strips adjacent to the Ferrule lines as well as at every 0.5 m across width of the panel to make a direct connection between top and bottom skins. … We once again re-iterate that the panel needs to be looked at as a product as a whole and not cut into small pieces, as the GRP composite is not a uniform material like an aluminium or [steel] sheet. The ingredients will [behave] differently when handled individually and when used as a composite product.

121 During cross-examination, Mr Kolhatkar explained that these cut panels were not representative of actual GRP panels because they lacked the U-channel edge detail which intact GRP panels would have had, and they had been subjected to cutting tools that could have induced vibrations in the panel, causing the inner skin to separate.[277] Moreover, the panels had not delaminated when they were cut; they only delaminated when they were pried apart. He therefore did not consider the tests on 3 September 2008 or 23 April 2009 as evidence of delamination of the GRP panels.[278] I therefore find that Kalzip was correct to abandon reliance on the factory visits on 3 September 2008 and 23 April 2009. However, these two factory visits caused Mr Carter, who appears to have a strong and assertive personality, to form the view that "cracking" noises in the panels evidenced delamination of the inner skins. He subsequently told BFG, as recorded in an e-mail from Mr Kolhatkar to Dr Samer on 8

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275 NE (28 March 2016) at p 200 lines 16–20, p 201 lines 9–19.

276 ABD 9E 5270.

277 NE (28 March 2016) at p 202 lines 2–19.

278 NE (28 March 2016) at p 204 lines 17–23.

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February 2010, that what started off as a "metallic crinkling noise" in the panels would "eventually [result] in a de-bonding".[279]

Correspondence from BFG and site surveys

122 Putting the two factory inspections to one side, Kalzip relies on subsequent site surveys and correspondence from BFG in 2009 and 2010 to show that BFG came to accept that there was delamination and it was a problem. While I set these out in some detail below, I should first caveat this section by saying that the correspondence can only show so much. The question in this suit, in view of BFG's claim that it mistakenly confused the noises coming from the panels with delamination, is not merely whether BFG *thought* there was delamination, but whether it was *right* to think so or mistaken at the time in thinking so. The experts themselves disagreed on important questions such as whether the noises produced by the panels were evidence that they had delaminated, and whether inner skin delamination on localised areas could be visually observed. If some of the experts could have erred on these questions, then BFG, which had not manufactured panels of this type in such large sizes before, could have similarly made an erroneous assumption. BFG's assertion that it was mistaken that the panels were defective therefore has to be carefully evaluated.

123 On 26 May 2009, during the process development phase and before the panels began to be manufactured[280], Mr Rade e-mailed Mr Attwood saying:[281]

> Panel failure is not expected under -2kPa static load. We have major concern about the practical problem of bonding between aluminum [*sic*] core and FRP skin. Therefore, *if* there is any

279 ABD 10E 6264.

280 ABD 2B 364 at para 32.

281 ABD 8E 5000.

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> debonding takes place even at the local area under static load test, it will propagate further during cyclic load test and may result in failure under cyclic test. ... [emphasis added]

124 Counsel for Kalzip referred to this e-mail as evidence that delamination of the lower skin was a recognised problem at this stage. However, Mr Kolhatkar interpreted this e-mail as a caution that delamination *would be* a problem if the panel were subjected to loads (*ie*, the cylic loading test) which were not specified in the specifications previously given to BFG.[282] This e-mail was generated before GRP panel production began.

125 The next e-mail, dated 7 December 2009, was written after panels had begun to be installed on site. Mr Attwood e-mailed Mr Kolhatkar, Mr Premamoorthy and others. The e-mail subject was "delamination of panels on site" and the body contained the following text:[283]

> [Kalzip] are aware of this on site last week of the 40 or so panels installed there a 3 with big areas of delamination they didnt leave here with it and I cant believe that it happened in transit so it must be during the vacume [*sic*] lifting or install.

Mr Attwood agreed during cross-examination that he was not reporting complaints or allegations by Kalzip, but giving his own observations of what had occurred onsite.[284] However, there was no examination of Mr Attwood on what exactly he had observed onsite to come to this view.

126 Sometime in early January 2010, when Mr Mackay was carrying out a morning inspection of the GRP panels on the casino building with MBS' Project Manager of Facades Mr Jan Oebeles, Mr Mackay heard a cracking sound while traversing some of the panels. He notified Mr Carter of this after the inspection.

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282 NE (29 March 2016) at p 21; p 26; p 31 lines 21–22; p 33 line 4 – p 34 line 6.

283 ABD 9E 5843.

284 NE (28 March 2016) at p 5 lines 18–22.

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The two of them then went onto the casino building roof and again noticed various panels producing a cracking noise underfoot.[285] Mr Mackay described this incident during trial as follows:[286]

> Q. You describe the noises as being "cracking noises" again?
>
> A. Yes. It's like a very deep crunching -- crunching sound. It's -- when we were walking on the panels, it would be fairly solid, and we'd come to a spot where it would be a deep crunch and very spongy.
>
> Q. So, Mr Mackay, are you suggesting that a cracking noise is the same as a crunching noise?
>
> A. It's what I heard and what I saw, it is like a deep crunching, crunching noise itself, and the actual -- when you put your foot on the actual panel in the area, it would actually -- it actually went down as well. It wasn't like on the rest of the panels, where it was fairly solid itself.

127 On 11 January 2010, Mr Attwood e-mailed Mr Kolhatkar, Mr Premamoorthy and Mr Zeeyad amongst others. The e-mail was titled "Delaminated Panels On site" and stated:[287]

> As I advised before there are around 6 places where delamination has taken place between *front top face* and aluminium honeycomb. … [W]e n[e]ed to put in place a procedure for rectifying this on site.
>
> …
>
> My only thoughts are to drill holes in front face over area and inject resin/filler mixture into the void then repair gelcoat any thought on this please advise
>
> …
>
> [emphasis added]

128 When this e-mail was brought to Mr Attwood's attention during cross-examination, his answer was that he had simply used the word "delamination"

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285 ABD 1B 21 at paras 46–47.

286 NE (22 March 2016) at p 49 lines 6–19.

287 ABD 10E 6010.

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because it was "common parlance at the time on site for what was perceived to be happening with [the] panels" and that he was, at the time, unsure of what was in fact wrong with the panels.[288] The six areas had been identified based on the presence of crunching sounds.[289] I have noted above at [111], [112] and [121] that at the factory visit on 3 September 2008, Kalzip and MBS' consultants who were present formed the view that the "cracking" sound was indicative of delamination of the inner skin. It should also be noted that the e-mail above appears to describe delamination of the *outer skin* ("between front top face and aluminium honeycomb"), whereas Kalzip's claim is for delamination of the *inner skin*.[290]

129 On 18 January 2010, Mr Attwood emailed Mr Premamoorthy, Mr Kolhatkar, Mr Zeeyad and others. The subject of the e-mail was "Damaged crates and panels @ Toll Singapore". It included the following:[291]

> Delamination repairs Please update me on progress in factory of developing a viable process this is becoming a big issue. … [A]t present I would estimate 6 -7 places where this has occurred largest around 700mm Diameter

130 In another e-mail about an hour later, Mr Attwood stated that the debonding issue "appears to be on the top surface but there [is] no way of saying 100% that this is the case with out [*sic*] cutting".[292] When Mr Anand replied to ask how many panels were affected, Mr Attwood replied six panels.[293]

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288 NE (28 March 2016) at p 9 lines 4–12.

289 ABD 2B 299 at para 42.

290 Statement of Claim (Amendment No 3) at para 33(a).

291 ABD 10E 6044.

292 ABD 10E 6068.

293 ABD 10E 6068.

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131 Again on 18 January 2010, Mr Attwood wrote to Mr Mackay (copying Mr Carter and Mr Kolhatkar) that:[294]

> BFG strongly recommend that all panels on site suffering from delamination are Identified [*sic*] and protected with plastic and plywood on top in order to halt the ongoing damage being cause[d] by foot traffic in those are[a]s in particular the end areas nearest the vertical walls.
>
> Particular attention should be paid to avoid point loading during the installation of the edge trim panels, plywood should be used in these areas during this install as significant force is being used to force the edge trim panel curved top edge into the roof panels which are in most cases flatter.

132 Mr Carter replied on the same day, stating, "Following receipt of the plastic and plywood (Have you considered structural foam), [Kalzip] will arrange for this to be installed."[295] Notably, Mr Carter did not deny that the panels were being walked on, or that the walking had damaged the panels. Rather, he simply assured Mr Attwood that Kalzip would arrange for plywood to be installed. This suggests that Mr Carter – who was described by other witnesses as aggressive, and who comes across in the correspondence as assertive and not easily persuaded to change his mind – accepted the possibility of damage to the panels as a result of foot traffic.

133 On 20 January 2010, Mr Attwood e-mailed Mr Carter, Mr Kolhatkar, Mr Premamoorthy, Mr Zeeyad and others, stating:[296]

> We have been informally informed by … Kalzip about the delamination of some panels after installation. BFG has informally carried out the inspection of the panels and identified 6 panels out of total panels installed at site till 15/01/2010. BFG reports as follows:

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294 ABD 10E 6045.

295 ABD 10E 6045.

296 ABD 10E 6072.1.

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> It is observed that the delamination is present in 6 panels at the peripheral area, in patches of approximately 0.5 x 0.5 m. It is observed that during the installation activity at site the panels are being used as walkways and many persons are walking on the panels. This is an unusual working condition for the panels, as the panels are designed for occasional 1 man walking on the panels with a load spreader like a 2.4 x 1.3 m sheet of 25 mm plywood placed on the top of panels. … [T]he delamination has occurred due to unusual loading outside the designed loads …

134 As noted above, this probably referred to the same six panels at [127]–[128] above, which were described as experiencing outer skin and not inner skin delamination. Mr Attwood agreed that this e-mail showed that he and BFG had concluded, after a site inspection by BFG (probably done by Mr Attwood and Mr Anand or Mr Rade), that six panels had delaminated.[297] Mr Attwood agreed that BFG reached that conclusion independently of Kalzip and on the advice of Mr Attwood and a product expert (whom Mr Attwood thought would have been either Mr Anand or Mr Rade).[298]I have also noted that in his 18 January 2010 e-mail (see [130] above), Mr Attwood did say that debonding "appears" on the top surface and that the only way to say this *was* the case was by "cutting" into the panel.

135 On 21 January 2010, Mr Kolhatkar e-mailed Mr Carter regarding the delamination. He wrote:[299]

> … [T]he several site visits by our Project Manager and Product expert we have observed the use of panels in a manner that exceeds the limits of the load specification in the manner in which the maintenance load of 1.1 kN is applied on the panels. … If the panels are properly handled and used within the design limits, there are no possibility of any *further cases* of panel delaminations foreseen. …

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297 NE (28 March 2016) at p 17 line 13 – p 18 line 9; p 19.

298 NE (28 March 2016) at p 21 lines 14–22.

299 ABD 10E 6079.

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> We have finalised the proposed draft methodology for the 6 panels which have shown delamination of small patches. …
>
> [emphasis added]

136 This "draft methodology" involved drilling an 11mm-diameter hole into an area of the panel experiencing delamination and funnelling resin into the honeycomb, which would then drip through the honeycomb and fill the delaminated gap.[300] Mr Kolhatkar did not accept during cross-examination that this repair methodology was evidence that delamination had in fact occurred; it was, rather, a response to a "perceived problem" which had been reported back to him by his BFG team onsite.

137 On 26 January 2010, Mr Attwood and others went on another site visit. At a progress meeting that day, which Mr Carter attended, the minutes of meeting noted: "MBS advised that beside panel 13 on Casino leaf 13, 2 more panels are found damaged …".[301] I note that this only refers to "damaged" and not "delaminated" panels.

138 On 27 January 2010, Mr Attwood emailed Mr Premamoorthy, Mr Kolhatkar, Mr Zeeyad and others. The e-mail subject was "MICE furher [*sic*] delaminated panels" and it stated, "After walk through yesterday there are in total 20no delaminated panels on Mice random throughout the panel area and this is after just being installed. [T]here is talk that these panels will be condemned".[302] During trial, Mr Attwood explained that he had referred to "delaminated panels" as panels exhibiting a crunching sound when walked upon. As he was not a technical expert, he had assumed that these sounds were evidence of delamination.[303] These were panels which had just been installed,

300 ABD 10E 6082.

301 Mr Mackay's AEIC at p 389.

302 ABD 10E 6107.

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which meant that any delamination which had occurred by that point was not attributable to foot traffic.[304]

139 On 27 January 2010, Mr Attwood again emailed Mr Premamoorthy, Mr Kolhatkar, Mr Zeeyad and others stating: "Out [of] 70 odd panels (Shipments 1 and 2) installed so far on MICE 20 have delamination which is in areas limited to less than 1 [square metre] at a time. … So far in whole of casino there are a further 8 panels." Mr Attwood stated that the MICE panels were not delaminated when they left the factory and considered it unlikely that they had delaminated during travel or from being stepped on after installation. He theorised that the way in which they were lifted or handled was over-stressing parts of the panel which were less strongly bonded, thus causing the delamination.[305] During cross-examination, Mr Attwood denied that BFG had independently arrived at the conclusions stated in the e-mail[306], even though he had earlier agreed that BFG had independently arrived at the conclusion stated in his e-mail of 20 January 2010 (see [134] above). Notably, the e-mail shows that BFG was undecided about the cause of the reported delamination and took the view that the panels had left the factory intact and without delamination.

140 On 29 January 2010, Mr Kolhatkar e-mailed Dr Samer Al Jishi (the managing director of BFG) ("Dr Samer") with an "update on the site issues with MBS panels". He stated:[307]

> [I]t is reported that there is delaimination [*sic*] of some panels at site as installed. Each panel has been inspected and

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303 ABD 2B 301 at paras 48–49.

304 NE (28 March 2016) at p 22 lines 15–21.

305 ABD 10E 6109.

306 NE (28 March 2016) at p 27 lines 9–15.

307 ABD 10E 6127.

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> approved as fit before dispatch from plant by [Loxon]. The panels as randomly checked before installation also show no defects. So this puts forward following possibilities:
>
> 1. The Vacuum jig used for lifting panels to installation position is putting suction force beyond originally advised by [Kalzip] causing delaimination [*sic*] of upper skin
>
> 2. The panels, once installed, being used as walkable surface by site personnel is putting excessive deformations, causing the bottom skin to delamiate. [*sic*]
>
> 3. The panels once installed, with expansion and contraction of air in the ALHC is giving excessive force on the skins. As the edges of ALHC are less than 1mm thick, and we are depending upon the resin raised on the faces of Honeycomb cell walls for bonding, there may be excess air pressure within cells causing debonding.
>
> *4. There may not be actual delaimination [sic] but the sound of ALHC during walking may be giving an impression of a debond.*
>
> [Mr Premamoorthy] was in Singapore when initial problem was reported. *However at site, [Kalzip] could not show him an actual incidence of the debonding.* Now that there is a report of about 20% panels showing areas of under 1m2 per panel [delaminated], [Mr Anand] and [Mr Rade] will inspect the panels on Sunday and try to get to the decision as to which of the above possibilities exist or if there is a situation beyond these. …
>
> [emphasis added]

141 I note that this e-mail captured what had been "reported" to Mr Kolhatkar. In other words, Mr Kolhatkar was not giving Dr Samer his own view of what had occurred onsite, but merely relating what he had been told. Mr Kolhatkar also suggested various hypotheses: for example, that the panels had deformed as a result of being subjected to excessive loads, and that there was in fact no delamination but only the impression of delamination as a result of the sounds being made by the panels when walked on. Importantly, he told Dr Samer that Kalzip was unable to show Mr Premamoorthy an actual instance of delamination when he was onsite.

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142 On 30 January 2010, Mr Kolhatkar e-mailed Mr Premamoorthy and Mr Attwood and wrote, "It is apparent that CASINO panels do have real delamination. On MICE Panels there is ALHC sound."[308] When asked in cross-examination why he did not reply to this e-mail to correct Mr Kolhatkar, Mr Attwood responded that he had not had time to send an e-mail.[309] This was of course untrue as he had replied that very day, attaching a Quicktime video of the sounds heard when the MICE panels were walked on, which he described as "pretty wide spread in the areas being walked on" and "much less so on the areas that aren't".[310]

143 Also on 30 January 2010, Mr Attwood e-mailed Mr Kolhatkar, Mr Premamoorthy and Mr Anand. The subject of this e-mail was "panel that is spongy on casino" and the text of the e-mail stated, "this is on bay 10, there are others [despite] us telling them to cove[r] with ply it is not panel has sunk it is as most of the delamination is in the area where there is roped access".[311] Mr Attwood explained that the subject of his e-mail referred to the sensation of the panel deflecting downwards as he stepped on it.[312] According to Mr Attwood, this was the only panel he saw which exhibited such sagging.[313] During cross-examination, Mr Kolhatkar accepted that the photograph attached to the e-mail showed that the panel was sagging.[314]

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308 ABD 10E 6128.

309 NE (28 March 2016) at p 46 lines 6–8.

310 ABD 10E 6128.

311 ABD 10E 6130.

312 NE (28 March 2016) at p 33.

313 ABD 2B 302 at para 52.

314 NE (29 March 2016) at p 74 line 24 – p 75 line 5.

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144 On 31 January 2010, Mr Attwood sent an e-mail to other persons from BFG saying, "can we please check that we are not producing panels that have crunchy aluminium in them as has been seen on site in Singapore".[315]

145 On 1 February 2010, a team attended an inspection of the MICE and casino buildings. In his AEIC, Mr Rade stated that he attended this inspection along with a number of Kalzip personnel, including Mr Carter and Mr Charles Leong ("Mr Leong"), and a few other workmen. He recalled that Mr Attwood and Mr Anand also attended. Mr Rade's purpose in attending the inspection was to inspect the panels and identify if there were any structural defects (including, potentially, delamination) associated with a metallic crunching sound that had been heard emanating from the panels.[316] During that survey, Kalzip workmen walked and/or jumped on the panels looking for crunching sounds. They appeared to associate the crunching sounds with delamination. Mr Carter also instructed a team of about eight to ten people to stand in a line across the entire width of a selected panel and walk up and down the panel at the same time to detect crunching sounds. Mr Rade recollected that some of the people jumped on the panels.[317] He considered this method of attempting to detect delamination to be "completely incorrect" because the alleged delamination had occurred between the aluminium honeycomb and the inner skin, and would therefore have to be detected from below, not above.[318] The correct method, in his view, would be to remove the panel and inspect the inner skin.[319] Mr Rade stated at trial (though this was not in his affidavit) that he had raised this objection to Mr Carter and Mr Kolhatkar but to no avail.[320] Indeed, Mr Kolhatkar had expressed

315 ABD 10E 6132.

316 ABD 2B 339 at para 7; NE (24 March 2016) at pp 136–139.

317 ABD 2B 339 at para 8.

318 ABD 2B 339 at para 8; NE (24 March 2016) at pp 140–142.

319 NE (24 March 2016) at p 144 lines 9–10.

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his view that metallic noises were not necessarily indicative of delamination in his e-mails to Dr Samer and Mr Carter on 29 January and 2 February 2010 (see [140] above and [147] below).

146 Following the 1 February 2010 inspection, Mr Attwood e-mailed Mr Kolhatkar, Mr Premamoorthy and others. The subject of the e-mail was "1st Feb report on site visit and debrief discussions on MBS panel defects". The e-mail stated that there were two distinctly different types of problems onsite:[321]

> Casino
>
> These are due to initial high [point] loads resulting in delamination of the bottom face in small areas that have been enlarged by foot traffic, heavy load forces due to installation of panels.
>
> Mice
>
> These are recently installed panels there is no delamination but the aluminium is noisy there is no debonding but there are areas in which the problem seems to be extreme – very noisy aluminium scruntching [*sic*] sound

Mr Attwood agreed, on the basis of this e-mail, that he was in fact reporting delamination on the casino panels.[322] When asked why he did not object to this e-mail since he did not think that the crunching sound could be equivocated with delamination, Mr Rade said that he simply deferred to Mr Attwood's observations since Mr Attwood was onsite for a much longer period and had inspected more of the roof.[323] Whatever the case, Mr Rade seems to have accepted delamination as a problem soon after (see [150] below).

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320 NE (24 March 2016) at p 142 lines 22–25, p 143 line 16.

321 ABD 10E 6155.

322 NE (28 March 2016) at p 48 lines 13–18.

323 NE (24 March 2016) at pp 152–153.

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147 On 2 February 2010, Mr Kolhatkar e-mailed Mr Carter to inform him of the preliminary observations of BFG's inspection and assessment team onsite. These were as follows:[324]

> 1. CASINO: *The panels near the Edge Trim show some delamination.* We have interviewed the site personnel and have been informed that there have been direct jumping from upper level to lower level panels as part of the site activity. Also there is have been several incidences of use of panels as site access walkways and storage place for scaffolding panels etc. Also a very heavy usage of panels in that area is also noted. This clearly exceeds the maintenance load which is an occasional load expected with extremely low frequency. Hence clearly the panels have exceeded the design loads repeatedly. Our inspection team has carried out a test repair of one such damaged panel. The method of repair has been finalised. Once [Kalzip] is able to provide the work visa to BFG technicians, *the damaged panels (About 20)* on CASINO shall be attended to with help from [Kalzip] in the interest of the project without bringing any contractual angles to this activity.
>
> 2. MICE: The panels do not show any delamination signs. The metallic noise coming out of ALuminium Core has been studied. We shall get back to the plant and check the noise on the panels at plant and shall advice if any action is required. *Mere noise of the core is normal phenomenon observed in ALuminium cored composite cladding panels and in itself is not a defect in the panels.*
>
> [emphasis added]

148 On 3 February 2010, a site investigation was conducted by Mr Carter, Mr Attwood, Mr Anand and Mr Rade. Their joint report, attached to Mr Kolhatkar's e-mail to Dr Samer dated 8 February 2010, largely repeated the observations regarding the casino panels, but new delamination was observed on some of the MICE panels:[325]

> 2. MICE: Few panels show delamination signs. Such damaged areas will be repaired on similar lines … However, rest of the places, the metallic noise coming out of Aluminum Core has been studied. It is evident from the walk through had at site

[324] ABD 10E 6163.

[325] ABD 10E 6263.

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> that there is a potential difference (metallic crinkling noise) between the initial set of panels supplied for Casino and some panels supplied for MICE. … The initial set of panels does not display the metallic crinkling noise. It has been explained to [Kalzip] by BFG site inspection team that the mere noise of the core is normal phenomenon observed in Aluminum cored composite cladding panels and is itself is not a defect …
>
> 3. …
>
> a. … Peter Carter also states that from [their] experience at site the panels start with the metallic crinkling noise which eventually results in a de-bonding.

149 On 6 February 2010, a partial survey of the casino building roof was carried out.[326] This is the first of the four site surveys pleaded by Kalzip (see [104] above). According to Mr Mackay's AEIC, the survey was undertaken by Mr Leong on Mr Carter's instructions. The survey showed that 9% of the roof area "exhibited signs of sagging and emitted crackling sounds when walked upon".[327] I pause to note that, while Mr Mackay maintained that the site surveys were based on *both* the cracking sounds *and* sagging or deflection underfoot, other witnesses claimed that the site surveys were based wholly on the sounds produced, and it is not clear which (if any) site surveys Mr Mackay attended (see [172]–[174] below). I therefore do not accept his interpretation of the site surveys as evidence of panels which emitted cracking sounds and deflected underfoot. None of Kalzip's witnesses in this suit was able to say for sure that they had attended this site survey (see [174] below). Mr Attwood, however, gave the following evidence in his AEIC:[328]

> During the period from February to March 2010, Ananth and I were present on-site when some of these surveys were conducted and from my recollection, in conducting these surveys, Carter had instructed a team of approximately 10 people to stand in a line across the entire width of a selected

326 ABD 1I 9.

327 ABD 1B 33 at para 78.

328 ABD 2B 303 at para 55.

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> panel. These people would then traverse up and down the panel at the same time. Carter had a pen and a piece of paper with him, and could be seen marking on areas in which a crunching sound had been heard when a panel was traversed upon. Carter appeared to have taken the crunching sounds to be indicative of the presence of delamination. This did not seem right to Ananth and I, but as this is not an area of my expertise, I will leave it to BFG's composites expert to opine on Kalzip's method of surveying the alleged delamination.

I note that this method is similar to Mr Rade's recollection of what was done during the 1 February 2010 site inspection (see [145] above). I return to this site survey at [171] below.

150 On 8 February 2010, following a site inspection by a team of technical experts engaged by BFG, Mr Rade reported the findings of the inspection to Mr Kolhatkar, Mr Attwood and others by e-mail. He wrote:[329]

> At site for MICE roof panels, as the problem observed is two fold:
>
> 1) Panels with patches of delamination and
>
> 2) Panels where delamination is not evident but the metallic cracking sound. The extent of this problem is higher than delamination problem.
>
> The delamination certainly needs to be attended on similar way what we already demonstrated on one of the CASINO panel. However, for metallic sound only case, we can think of testing the panel before taking up any repair as *the cause of the problem is still unknown*. …
>
> [emphasis added]

151 This e-mail appeared to be inconsistent with Mr Rade's evidence at trial that he had not personally observed any delamination as a result of the 1 February 2010 inspection (see [145] above). However, Mr Rade explained that Mr Attwood had by then already reported delamination, and BFG was in the process of devising a repair procedure. Mr Rade therefore apparently

329 ABD 10E 6220.

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accepted Mr Attwood's position that there was delamination, although he also pointed out in paragraph 2 that the "metallic cracking sound" did not necessarily indicate delamination.[330]

152 On 11 February 2010, Mr Kolhatkar e-mailed Mr Attwood, copying Mr Anand, Mr Rade and others. His e-mail stated:[331]

> 1. As per Peter, the problem on CASINO and MICE are the same. As per BFG CASINO have delamination [whereas] MICE has sound of ALHC as the issue. I have proposed that BFG conducts a sandbag load test on a 5m x 3m patch of a MICE Panel which BFG feels has sound but no delamination. …
>
> …
>
> 2. CASINO repair: BFG Will attend to delamination repairs with 2 TEchnicians from BFG and local contractor.

153 Mr Attwood agreed on the basis of this e-mail and others that BFG personnel consistently recognised that delamination had occurred to the GRP panels on the casino building.[332]

154 The second of the four site surveys pleaded by Kalzip was conducted on 25 February 2010.[333] According to Mr Mackay's AEIC, Mr Leong carried out this survey.[334] Mr Attwood testified that he had attended and that Mr Rade and Mr Anand were also present.[335] According to Mr Mackay, the survey shows that 14% of the casino building roof surface area "exhibited signs of sagging and emitted crackling sounds when walked upon". This appears to be his general understanding of the survey process as he does not profess to have attended this

330 NE (24 March 2016) at p 153 line 19 – p 154 line 5.

331 ABD 10E 6283.

332 NE (28 March 2016) at p 61 lines 8–14.

333 ABD 10E 6332, ABD 1I 10.

334 ABD 1B 34 at para 84.

335 NE (28 March 2016) at p 63 lines 3–11.

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particular survey.[336] After this survey, Mr Attwood e-mailed Mr Kolhatkar and others from BFG attaching the marked-up site diagram. He wrote: "attached is the pic of survey completed yesterday on Casino orange areas show dela[m]inated panels 56 areas on 46 panels".[337]

155 Mr Attwood agreed that if he felt any hesitation about the conclusion that the survey showed delamination on 56 areas on 46 panels, he would have made that clear in his e-mail report. However, he also said he had by this time "begun to believe that the panels were delaminated" but "had not seen any evidence to that [effect]".[338] He maintained that he had not seen any delamination during the site surveys.[339] I pause to note that there is no evidence at all during these surveys that anyone inspected the inner skins of any of these panels emitting sounds to confirm that there was inner skin delamination or that a panel was taken off and examined or tested to confirm the same.

156 There was another site inspection on or around 26 February 2010, although it did not result in a site diagram marked up in yellow unlike the other four site surveys. Mr Mackay and other representatives from MBS and BFG inspected the casino and MICE building roofs. Mr Mackay recalls that everyone who attended "observed that there were significant numbers of delaminated panels by walking on the panels to identify deep crunching noises".[340] The assumption that deep crunching noises mean delamination is evident from this.

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336 ABD 1B 34 at para 84.

337 ABD 10E 6332.

338 NE (28 March 2016) at p 67 lines 12–16.

339 NE (24 March 2016) at p 223 lines 14–16, p 224 lines 16–17.

340 ABD 1B 35 at para 86.

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157 There was another site inspection on 2 March 2010[341], as well as a core sampling exercise (which I expand on at [235] below). Mr Flook recalled attending the inspection and said that Mr Carter had walked and jumped on some panels to show that they were emitting crunching sounds, but Mr Flook himself "found it very difficult to hear any alleged crunching sounds".[342] Mr Attwood and Mr Flook also attended the core sampling exercise along with Mr Anand and possibly Mr Rade.[343] Mr Mackay also recalled attending the core sampling exercise,[344] during which he heard "cracking sounds" coming from the GRP panels on the MICE building roof and "[d]eep cracking noises" from the casino building roof[345]. According to Mr Mackay, the survey showed that almost all the installed GRP panels on the MICE building roof "exhibited signs of sagging and emitted crackling sounds when walked upon".[346] This is clearly an exaggeration, because the site survey only shows about 113 panels marked in yellow. I note that not all the panels had been installed by this point, but even counting only those bays which had been fully installed and which had panels marked in yellow, only about half or just over half of the panels were marked as delaminated.

158 On 8 March 2010, Mr Leong conducted the fourth of the site surveys, on the MICE building roof. Mr Flook attended this survey and recounted that it was carried out in the same manner as the survey on 2 March 2010, *ie*, based on the crunching sounds heard when the panels were walked and jumped upon.[347]

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341 ABD 1I 11.

342 ABD 2B 318 at paras 18 and 19.

343 NE (28 March 2016) at p 79 lines 8–17; ABD 2B 318 at para 20.

344 ABD 1B 43 at para 107.

345 ABD 1B 44 at paras 109 and 111.

346 ABD 1B 42 at para 102.

347 ABD 2B 319 at para 21; NE (24 March 2016) at p 196 line 14 – p 197 line 1.

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All the GRP panels had been installed by that point. The survey,[348] in Mr Mackay's words, showed that nearly all the panels "exhibited signs of sagging and emitted cracking sounds when walked upon".[349] Again, this was an exaggeration: just under half of the panels on the site survey (220 of about 467) were marked in yellow.

159 On 11 March 2010, Mr Premamoorthy e-mailed Dr Samer apparently attributing the delamination to the resin used and the choice of material. He stated: "My opinion is that the aluminum honeycomb and k133 Resin that we used. Aluminum will not bond well with GRP … In addition to that, whenever we use K133 Resin, we always ended up with problems."[350] Dr Samer replied that same day, saying, "This incosistency [*sic*] cannot happen from a process problem and is more indicative of a manufacturing defect. Come on Moorthy, the delaminated skins are very dry …"[351]

160 Dr Neuwald also stated at trial (although this was not in his affidavit) that he had personally observed delamination during his site visits in June 2010. He was in the company of Prof Nonhoff on some of these occasions.[352] When asked how he identified delamination, Dr Neuwald responded that "[y]ou can witness [delamination] by a number of aspects", including that the panel was no longer stiff but softer or spongy and/or was emitting crunching sounds.[353] Unfortunately, he did not say which (if any) of these phenomena he *in fact* observed in June 2010 or how widespread these phenomena were, or identify

348 ABD 1I 12.

349 ABD 1B 48 at para 117.

350 ABD 11E 6888.

351 ABD 11E 6887.

352 NE (16 March 2016) at p 172 line 24 – p 173 line 17; ABD 2C 567 at para 5.

353 NE (17 March 2016) at p 20 lines 9–14, p 22 lines 3–9.

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which panels, in his view, had delaminated inner skins. I also note that Dr Neuwald's evidence corroborates Prof Nonhoff's account (see [208] below).

161 Kalzip's expert, Mr Green, relied on these internal e-mails from BFG as evidence of delamination, as he had never seen the GRP panels or walked on them.[354] When asked what his view would be if he were told to disregard those e-mails, Mr Green said he would still hold his opinion that there was delamination on the basis of what he had "subsequently heard from the evidence of other people, including expert evidence from Professor Nonhoff".[355]

162 It may seem odd that there is no record of any delamination being visually observed. However, this does not necessarily mean that none occurred. The evidence suggested that the delamination would not be obvious to the naked eye. Prof Nonhoff said that the surface of the inner skin would be "a little bit shining" (which I understood to mean slightly reflective), which would make it easier to notice distortions and "loose areas", allowing delamination to be seen very easily. [356] However, he appeared to recognise the need for "special training" in order to be able to determine if a panel had delaminated by examining it visually.[357] Mr Maurieschat went even further, disagreeing that delamination could be seen in the way that Prof Nonhoff suggested. He took the view that any delamination would be localised due to the presence of Z-strips every 500mm and would therefore not be of such large dimensions. Moreover, because of the stiffness of the inner skin, one would not see a "bubble" as a result of delamination. Delamination in a "little area" would not be visible. If, however the entire panel were to delaminate, then its surface would probably be

354 NE (30 March 2016) at p 188 lines 6–18; ABD 2C 586 at para 2.4.1.

355 NE (30 March 2016) at p 190 lines 8–15.

356 NE (1 April 2016) at p 202 lines 3–16.

357 NE (1 April 2016) at p 8 lines 19–20.

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noticeably curved.[358] I accept this evidence of Mr Maurieschat. Mr Wymond likewise thought that delamination would not have occurred over spans exceeding 500mm and that it was "unlikely" that somebody would be able to see delamination from the back of a panel.[359] While the surface was somewhat reflective, it was also broken up by Z-strips and joint lines from lapping layers, and was not smooth.[360] The absence of any visual identification is therefore not necessarily conclusive as to whether delamination had or had not occurred.

My analysis of the correspondence and site surveys

(1) Whether BFG's position was that delamination had occurred

163 Kalzip relies heavily on BFG's internal correspondence to support its case that delamination had occurred, whereas BFG submits that it did not in fact hold such a view but merely went along with *Kalzip*'s assertion that delamination had occurred.

164 First, Mr Attwood said that he had used the word "delamination" extensively in his communications with BFG because it was "very hard to disagree with [Kalzip] at that time, being very forceful, that delamination had occurred on the panels", and that by "delamination" he had meant to denote the noises that were coming from the panels.[361] Mr Attwood also insisted that he had used the word "delamination" because he had no evidence that it was *not* delamination, and he made certain judgments that he came to believe were wrong. With the benefit of hindsight, he realised that he did not know what was

358 NE (30 March 2016) at p 120 line 24 – p 121 line 4; NE (1 April 2016) at p 202 line 18 – p 203 line 23.

359 ABD 3C 803 at para 2.5.5, 3C 812 at para 49; NE (30 March 2016) at p 119 lines 16–20.

360 NE (30 March 2016) at p 57 line 16 – p 58 line 3.

361 NE (24 March 2016) at p 226 lines 14–21.

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going on onsite.[362] He stated that he lacked the technical depth to deal with issues relating to delamination.[363] However, he did not qualify any of his e-mails or observations of delamination with the caveat that he lacked technical expertise, nor did anyone his team ever suggest that he was out of his depth.[364] He also repudiated any suggestion that he had been intimidated into saying that delamination had occurred when it had not.[365] Having considered the totality of his evidence and his demeanour under cross-examination, I accept that Mr Attwood based his assertions of delamination on the sounds emanating from the panels and on the prevailing view driven by Kalzip, and the forceful Mr Carter, who formed and strongly held the view that the sounds he heard meant that inner skin delamination had occurred. I consider the expert evidence on these sounds at [196]–[204] below.

165 Mr Kolhatkar likewise sought to distance himself from his own assertions of delamination. He testified at trial that his earlier e-mails to Mr Carter (see [135], [140] and [147] above), which appeared to acknowledge that delamination was a problem, did not in fact represent BFG's views. In his words, BFG was under "tremendous pressure" because Mr Carter "had a very aggressive personality", and so had to attend to Kalzip's complaints of delamination and formulate a remedial proposal while carrying out its own investigations to verify the reports of delamination. While BFG's own investigations were underway in January and February 2010, Mr Kolhatkar did not express any doubt that delamination had occurred because his e-mails were "written in the spirit of a supplier/client relationship" with Kalzip. It was only around the start of March 2010, after BFG's investigations were completed, that

362 NE (28 March 2016) at p 12 line 15 – p 13 line 1.

363 NE (28 March 2016) at p 28 line 25 – p 29 line 4.

364 NE (28 March 2016) at p 27 line 16 – p 28 line 15.

365 NE (24 March 2016) at p 226 line 22 – p 227 line 13.

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Mr Kolhatkar allegedly told Mr Carter that the only way to verify if delamination had occurred was to physically inspect the bottoms of the panels.[366] Mr Kolhatkar also referred to a meeting with Mr Flook, at which they agreed to assume that delamination had occurred so that BFG could work with Kalzip to resolve the problem.[367]

166 Mr Kolhatkar's account rings a little hollow for four reasons.

(a) First, if BFG was still unsure whether delamination had occurred in January and February 2010, it would have mentioned its doubts to Kalzip rather than accept that this was so. As Mr Kolhatkar himself said, "If the allegations were correct, there would have been serious commercial implications for BFG." Moreover, he claimed that his communications to Kalzip on technical matters were "open, candid and truthful".[368]

(b) Secondly, Mr Kolhatkar himself agreed under cross-examination that this account was contradicted by the contents of his e-mail of 21 January 2010 to Mr Carter (at [135] above). He accepted that that e-mail was based on the assessment, judgment and report of an investigation team which he had despatched onsite, comprising persons who were in Mr Kolhatkar's view amply qualified to investigate whether (and to what extent) delamination had occurred.[369] They included Mr Anand and Mr Rade, whom Mr Kolhatkar described as product experts.[370] He agreed that the reports of delamination from his team did not simply

366 NE (29 March 2016) at p 58 line 12 – p 60 line 8, p 61 lines 1–9.

367 NE (29 March 2016) at p 109 lines 3–13.

368 NE (29 March 2016) at p 72 lines 13–15, p 73 lines 6–8.

369 NE (29 March 2016) at p 62 lines 1–8; p 60 lines 9–17; p 40 line 24 – p 41 line 5.

370 NE (29 March 2016) at p 51, lines 5–7.

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convey *Kalzip*'s allegations of delamination, but were reports of what the team assessed and judged for itself.[371]

(c) Thirdly, Mr Kolhatkar informed Dr Samer by way of an e-mail on 8 February 2010 that BFG's site inspection and remedy trials discovered delamination on 60 GRP panels on the casino building *in addition to* the sound of crumbling aluminium honeycomb inside the GRP panels on the MICE building.[372] Mr Kolhatkar had carefully distinguished between delamination and mere metallic noises in his e-mail to Dr Samer on 8 February 2010, which must mean that he recognised them as two legitimate and distinct concerns. This distinction also appears in Mr Kolhatkar's previous e-mails on 29 and 30 January and 2 February 2010 (see [140], [142] and [147] above). Mr Kolhatkar testified that by 2 February 2010 he had concluded that "it was a mistake to equate these noises that were being heard on the panels [during the site surveys] with the panels having delaminated".[373] Moreover, even if it were true that Mr Kolhatkar felt intimidated by Mr Carter, this could not explain why he felt the need to maintain the pretence that delamination had occurred to Dr Samer. Mr Kolhatkar agreed that his e-mails to Dr Samer would not have been subject to any such pressure.[374]

(d) Fourthly, even after his alleged meeting with Mr Carter around the start of March 2010, Mr Kolhatkar sent further correspondence which appeared to accept that delamination had occurred. For example, on 3 March 2017, Mr Kolhatkar e-mailed Mr Carter regarding "the

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371 NE (29 March 2016) at p 37 lines 14–23.

372 ABD 10E 6259; NE (29 March 2016) at p 96 lines 12–25.

373 NE (29 March 2016) at p 89 line 21 – p 90 line 2, p 102 lines 18–22.

374 NE (29 March 2016) at p 109 line 23 – p 110 line 2.

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delamination problem noticed on the panels installed at CASINO and MICE sites".[375] Similarly, on 7 March 2010, Mr Kolhatkar e-mailed Dr Samer and others from BFG. He wrote:[376]

> Unfortunately our panels at site have real problems of low weight and delamination of back skins. …
>
> …
>
> So the actual technical problem is that there are some panels that have not been manufactured upto [*sic*] the required level of quality.

Mr Kolhatkar agreed that by his last sentence he was referring to the manufacturing process that took place in BFG Philippines.[377]

167 It does not make sense for Mr Kolhatkar to have reported delamination to Dr Samer on the basis of his team's report (see [166(c)] above), which he understood was based wholly on the noise heard from the panels, if he did not accept that this noise was indicative of delamination. Mr Kolhatkar ultimately conceded that, contrary to his initial position, "it [was] clear that BFG understood and accepted that there [were] delaminated panels on both the casino and the MICE buildings" based on "assessments and judgments reached by BFG's site team".[378]

168 I therefore find that BFG did come to the view in around January and February 2010 that delamination had occurred in some of the panels on the casino and MICE buildings. This can be seen in the language used in BFG's internal correspondence. However, this is subject to my comments on those e-mails which do express a residual doubt. Mr Attwood's e-mail of 1 February

375 ABD 10E 6486.

376 ABD 10E 6635.

377 NE (29 March 2016) at p 117 lines 17–19.

378 NE (29 March 2016) at p 117 line 24 – p 118 line 6, p 123 lines 13–24.

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2010 (see [146] above) shows that he concluded that some casino panels had delaminated while the MICE panels had no delamination but were emitting noises when walked on. The members of BFG's site team also inspected the site and arrived at the conclusion that delamination was a problem on the casino building and, to a lesser extent, the MICE building. This was reported to Mr Kolhatkar, who in turn reported to Dr Samer on 8 February that "[f]ew panels" on the MICE building showed signs of delamination while the casino building panels near the edge trim "show[ed] some delamination", but which he attributed to the workers onsite jumping on the panels between bays (see [147] and [148] above). On the same day, Mr Rade reported to Mr Attwood that the MICE building suffered *both* from "[p]anels with patches of delamination" *and* "[p]anels where delamination is not evident but [there was] the metallic cracking sound" (see [150] above). This was a view that BFG arrived at based on its own site inspection. I therefore do not think that BFG was merely going along with Kalzip's impression that delamination had occurred.

169 Notwithstanding the foregoing, I do find that manufacturing these panels with aluminium honeycomb, and in such large sizes, was something new to BFG. There were understandable doubts on BFG's part and some lack of confidence in their product when vigorously attacked by Kalzip; this gave rise to internal finger-pointing within BFG. As I have pointed out above at [122]–[162], these e-mails, read fairly, also show that BFG was not *completely* certain that delamination due to defective manufacturing had occurred. I have noted above that no panel emitting crunching or crinkling noises was taken off its fixings for inspection to confirm that delamination had occurred. Even Mr Attwood can be seen to be changing his views of the cause of delamination. They swung from mishandling by Kalzip to crumbling or failure of the aluminium honeycomb, a hypothesis which no one pursued at trial. I also note

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that these e-mails covered only a short span of time, a time when matters suddenly boiled over and came to a head in January to early March 2010.

170 Even accepting that BFG's own personnel accepted that delamination had occurred, the question in this suit is whether they were correct to do so. For the same reason, the fact that BFG submitted a remedial proposal to Kalzip can only take Kalzip so far. I also conclude that the correspondence is not determinative of Kalzip's case for the following reasons:

(a) First, the significance of the sounds emanating from the panels when walked upon is an important issue. It was these sounds which led Mr Carter, Mr Attwood and Mr Mackay to form the view that the panels had delaminated, thus leading to much of the correspondence described above (see [126], [138], [144], [145], [156]–[158] above and [180] below). Mr Kolhatkar likewise received reports of delamination from his team which he understood to be based in turn on the noise that was reported to come from the panels onsite.[379] However, he maintained at trial that "the noise observed in the aluminium honeycomb while walking on the panels is due to the Metal FRP Interface and does not represent any panel failure".[380] This requires a closer consideration of the sounds allegedly made by the GRP panels, which I return to at [177] below.

(b) Secondly, Kalzip claims that the delamination was "extensive" based on the four site surveys described above. However, these appear to have been recorded on the premise that the sounds emitted by the panels were evidence of delamination.

379 NE (29 March 2016) at p 62 lines 18–23, p 72 lines 22–24, p 101 line 22 – p 102 line 3; also ABD 2B 430 at para 9 and [141] above.

380 ABD 2B 272 at para 157; ABD 2B 278 at para 175.

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(c) Thirdly, BFG lacked experience manufacturing panels of this type of such a large size (see [362]–[364] below), and may therefore have been mistaken in concluding that delamination had occurred. I have already made this point at [122] above.

(d) Fourthly, even if BFG accepted that some panels had delaminated, that would only constitute a breach of contract on BFG's part if the delamination occurred because the panels were defective in the first place. As will be seen, BFG alleges that any delamination which occurred is attributable to the panels having been misused onsite.

(2) The site surveys

171 Kalzip makes much of the fact that the surveys were conducted jointly in the presence of representatives from both MBS and BFG, none of whom raised issues with the methodology adopted or challenged the allegation of delamination.[381] However, I do not accept the site surveys themselves as evidence of delamination, for the following reasons.

172 First, it is not totally clear whether these surveys recorded areas which emitted a particular sound (as Mr Kolhatkar[382] and Mr Flook[383] claimed), or which both "exhibited signs of sagging and emitted cracking sounds when walked upon" (as Mr Mackay claimed). The surveys themselves do not contain any legend stating the significance of the yellow annotations. Mr Mackay agreed that it was impossible to tell from the surveys which panels may have exhibited signs of sagging.[384] Insofar as the surveys were based on crinkling or

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381 Plaintiff's Reply Submissions at para 231.

382 NE (29 March 2016) at p 89 lines 1–7.

383 ABD 2B 318 at para 19; NE (24 March 2016) at p 188 lines 7–18 and p 196 line 14 – p 197 line 4.

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crunching sounds, I accept Mr Wymond's and Mr Maurieschat's evidence that the crinkling sounds alone were not evidence of delamination (see [205] below).

173 Secondly, there is much that is not clear about the surveys. For one, it is not clear who attended which surveys. According to Kalzip's Further and Better Particulars in the arbitration, the attendees were as follows:[385]

(a) 6 and 25 February 2010: Mr Carter (Kalzip), Mr Leong (Kalzip), Mr Peter Morgan (Aedas), Mr Jan Oebeles (BFG) and Mr Peter Dooley (BFG)

(b) 2 and 8 March 2010: Mr Lenny Hill (Kalzip), Mr Leong (Kalzip), Mr Ted Mahoney (BFG), Mr Peter Morgan (Aedas)

174 None of these persons were called to testify in the present suit. Instead, Kalzip's witnesses in the present suit claimed to have attended the site surveys (though, significantly, none of them claimed to be responsible for actually annotating the surveys). For example, Mr Attwood said that he participated in "some" of the surveys but could not recall if he was present at the surveys on 2 and 8 March 2010.[386] Mr Mackay recalled attending "at least one or two surveys" but could not remember the actual dates and said that Mr Leong was "more in charge of doing the surveys itself". He was willing to accept that he "may not have been on [the 6 February 2010] survey".[387] BFG submits that "there is no evidence at all" to show that Mr Mackay attended any of the four site surveys and the court should therefore give little weight to his evidence about the surveys.[388]

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384 NE (22 March 2016) at p 112 lines 10–13.

385 ABD 1L 363–365.

386 ABD 2B 303 at para 55 and 304 at para 60; NE (24 March 2016) at p 223 lines 14–16.

387 NE (22 March 2016) at p 95 line 14 – p 97 line 25.

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175 Thirdly, it is not true that BFG raised no objections to Kalzip's methodology of assessing delamination. As I have noted, Mr Kolhatkar sent an e-mail on 2 February 2010 to Mr Carter explaining that the metallic noises emanating from the panels on the MICE building roof were a "normal phenomenon" and that the panels themselves did not show signs of delamination (see [147] above). This explanation was included in the report jointly compiled by Mr Attwood, Mr Anand and Mr Rade[389] (see [148] above). Besides this written evidence, Mr Rade testified that he had raised an objection to Mr Carter about jumping on the panels to test for delamination (see [145] above).

176 More importantly, as Kalzip itself says, BFG's internal communications, the four site surveys and the evidence given by its key witnesses at trial at best establish that "*BFG accepted* that the GRP panels produced for the Project had delaminated" [emphasis added].[390] While BFG did occasionally raise concerns about the methodology used to identify delamination, the correspondence between the parties and within BFG internally establish that BFG accepted that delamination had occurred. However, whether the panels *in fact* delaminated is a different issue. Mr Carter, who related the sounds of "crunching" to the phenomenon of delamination, was described by Kalzip as "lack[ing] the necessary expertise in GRP, a highly specialized composite material".[391] I therefore turn to the sounds which were described.

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388 Defendant's Closing Submissions at para 426.

389 NE (28 March 2016) at p 51 line 24 – p 52 line 5.

390 P reply submissions at para 3(c)(ii).

391 Defendant's Reply Submissions at para 33.

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(3) Cracking, crackling, crunching and crinkling sounds

177 The noises made by the panels when walked or stepped on were variously described as "cracking", "crackling", "crunching" and "crinkling" by different persons. They are described in much of the correspondence as "metallic" sounds. The variety and subjectivity of these descriptions make it difficult to identify exactly what sounds were heard, and what they could have been caused by. Mr Mackay's evidence exemplifies these difficulties. He used the first three terms in the following ways:

(a) Mr Mackay allegedly heard "cracking" sounds when walking on the panels in January 2010, as well as during site inspections on 26 February 2010 and 2 March 2010 (see [126] and [157] above). Mr Mackay seemed to equivocate this to deep "crunching" sounds, and associated this sound with sponginess of the panel (see [126] above).

(b) Three of the four site survey diagrams, which were shaded to show delamination, allegedly captured panel sagging and "crackling" sounds (see [149], [154] and [157] above). In his AEIC, however, Mr Mackay stated that a "crackling" sound was indicative of crushed honeycomb or resin-coated honeycomb and could be contrasted with "crunching" sounds (see [220] below). The fourth site survey, on 8 March 2010, is described in terms of "cracking" sounds (see [158] above) but Mr Mackay stated during cross-examination that this was probably a typographical error and was meant to be "crackling".[392]

178 During cross-examination, Mr Mackay distinguished these sounds as follows:[393]

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[392] NE (22 March 20160 at p 106 lines 22–25.

[393] NE (22 March 2016) at p 56 line 14 – p 57 line 24, p 110 lines 2–8.

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> Q. … Are you now suggesting to the court that the term "cracking noise" is interchangeable with "crunching noise" and that it is also interchangeable with "crackling noise"?
>
> A. It's -- there's basically two that I could hear up on the roof, and it was just a light crackling, and then there was like a deep -- kind of a crunching sound itself.
>
> Q. So when there's a light crackling sound, it is different from what you described to be a deep crunching sound, correct?
>
> A. Yes, that's correct.
>
> Q. So, two different things.
>
> A. Yes.
>
> Q. Would you agree with me that the crackling sound should not concern anyone?
>
> A. When we walked on the roof and just heard the light crackling, it was still -- the panel was still quite intact, was still fairly solid, so it --
>
> Q. I take it you agree with me.
>
> A. Yes.
>
> Q. Thank you. Are you suggesting then that the cracking noise is interchangeable with crunching noise, or the crackling noise is interchangeable with the crunching noise? Which is which?
>
> A. Basically, the crackling noise is a light crackling sound, which the panel seemed to be okay to walk on. You would hear that noise, but the crunching sound was a different -- well, a different sound, and plus a different issue, where if you walked on the area where it was a deep crunching, your actually -- your foot on the panel would just go down itself, like deflate, compared to the actual crackling sound.
>
> …
>
> A. … it is two completely different -- different items with the crackling and also with crunching. The crackling was -- the panel would still be fairly straight, so to speak, but the crunching, it actually -- it would actually drop down the panel, deflect, and obviously the sound itself was completely different.

179 Mr Mackay therefore agreed that the "crackling sounds" allegedly recorded in the four site surveys could not be relied upon to suggest delamination. However, he then said that there were also deeper crunching

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sounds, but he could not remember at which (if any) of the four site surveys he had attended that he heard these crunching sounds, or the ratio of crackling to crunching sounds heard.[394]

180 I place no weight on Mr Mackay's evidence on the significance of the various sounds. He was a factual witness, not an expert witness, and was prepared on that basis to withdraw his opinion that crunching sounds indicated structural failure.[395] Moreover, his view that the sounds emitted by the panels were indicative of delamination appears to have been based on Mr Carter's assertions. According to Mr Mackay, Mr Carter told him that the noise emitted was the same as sounds which he had heard during factory inspections in 2008 and 2009, when they were indicative of inner skin delamination.[396] But Mr Mackay was not present at those inspections and could not vouch for the accuracy or veracity of Mr Carter's view:[397]

> Q. What you say … is that Carter told you he was concerned, correct?
>
> A. Yes, correct, yeah.
>
> Q. And Carter told you he was concerned because Carter is associating the noise on that day, January 2010, with the noise from factory inspections in September 2008 and April 2009, correct?
>
> A. Yes, he did mention it.
>
> Q. But you were not present at the factory inspections of 3 September 2008 or 23 April 2009, correct?
>
> A. Yes, correct, no.
>
> Q. So you would not be able to validate any opinion that the noise in January 2010 was the noise that was the same as the historical sound that was heard?

394 NE (22 March 2016) at p 107 line 1 – p 108 line 9.

395 NE (22 March 2016) at p 110 lines 17–25.

396 ABD 1B 21 at para 46.

397 NE (22 March 2016) at p 50 line 18 – p 52 line 5.

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> A. Yes, that's correct.
>
> Q. And you wouldn't know if Mr Carter walked on the panels in September 2008 or 23 April 2009 at a factory, correct?
>
> A. He mentioned it was the same, same noise as his factory visit.
>
> Q. But would you know whether Mr Carter walked on panels during those factory visits in September 2008 and April 2009?
>
> A. I don't -- no, I could not remember, no, him saying he was walking on the panels.
>
> Q. In short, Mr Mackay, you have no knowledge of the circumstances of what was observed at the factory inspections that Mr Peter Carter told you of, correct?
>
> A. Correct, yes.
>
> Q. Would you agree with me that it is entirely possible that the conditions on the roof in January 2010 would be different from the conditions in the factory, correct?
>
> A. Yes, correct.

181 Mr Carter himself was not a witness in the Suit. His conclusion that noise was indicative of delamination was wrong, because the samples which delaminated during the two factory visits were not representative of the actual GRP panels. They differed in one or more of the following ways: (a) they were smaller than an actual GRP panel, were not edge-sealed and may not have had Z-strips; (b) they had not been made using the intended reinforcements and resin; and (c) they had not undergone vacuum-bagging. I have explained in detail at [110]–[121] above why the factory inspections of 3 September 2008 and 23 April 2009 did not in fact show evidence of delamination. Mr Mackay also conceded that it was "pure conjecture or speculation" to conclude that the lower face of a panel which produced those sounds had delaminated, because it was impossible to actually see the inner skin while walking on the panels.[398] Mr Mackay's evidence suggests at best that he did in fact hear the sounds which he

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398 NE (22 March 2016) at p 53 lines 12–17.

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described. I should add that, unlike Mr Mackay, Mr Attwood and Mr Rade did not distinguish between two types of sounds; they described what they heard (and what was heard on the panels during the site surveys) only in terms of "crunching" sounds.

182 I now turn to the expert evidence on the significance of these sounds. The experts relied heavily on the 2015 Tests in forming their conclusions about the significance of the sounds. I first describe these tests and their results before turning to the experts' opinions.

(A) THE 2015 TESTS

183 As none of the original GRP panels which were actually installed in the Project were preserved, Mr Wymond commissioned BFG to manufacture and test additional panels for the purpose of the 2015 Tests. A series of sample panels was made, supposedly in the same way that the GRP panels had been manufactured. Each sample panel measured approximately 6m long and 3m wide with inserts and clips at 800mm spacing on each side and staggered at 400mm centres along the centre of the panel.[399] Nine panels were tested: seven that were standard, and two that were manufactured so as to have "floating" inner skins – *ie*, inner skins that were totally delaminated. The seven standard panels were tested in the following way, and with the following results:[400]

> (a) First, a point load test was carried out by imposing a statically-applied load of 1.1 kN on the panels. No local damage was caused to the panels. A tap test was carried out on the underside of the panel after the test and no delamination was recorded.

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399 ABD 3C 840 at para 139.

400 ABD 3C 955, 956 and 959.

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(b) Secondly, a positive pressure test was carried out by first pre-loading the panel and then loading it to 0.75 kPa. The deflection readings were consistent with the calculations. A tap test was carried out on the underside of the panel after the test and no delamination was recorded.

(c) Thirdly, a negative pressure test was carried out by first pre-loading the panel and then loading it to -2.0 kPa. The deflection readings were consistent with the calculations. A tap test was carried out on the underside of the panel after the test and no delamination was recorded.

(d) Fourthly, a cyclic maintenance loading test was carried out. This involved five men (weighing between 69kg and 110kg) taking turns to walk across one half of a 6m by 3m panel in a zigzag pattern, each man walking 20 cycles, making a total of 100 cycles.[401] According to the test report, the noise of aluminium honeycomb crinkling was present and consistent throughout and there was no difference in noise from variations in a person's weight or with the number of cycles.[402] A tap test was carried out on the underside of the panel after the test and no delamination was recorded.

(e) The panels were then subjected to a repeat positive pressure test and repeat negative pressure test as at (b) and (c) above. The panels did not deflect much more than they had prior to undergoing the cyclic maintenance loading test. The two halves of the panel (only one of which was walked on during the cyclic maintenance loading test) had approximately equal deflections.

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401 ABD 3C 845; NE (31 March 2016) at p 76 line 23 – p 79 line 3.

402 ABD 3C 959.

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184 The two panels with "floating" inner skins were subjected first to a positive pressure test (0.75 kPa), then to a negative pressure test (-2.0 kPa), then to walking. The deflection readings were consistent with calculations (*ie*, not excessive).

185 Following these tests at Kaskal on 17 and 18 August 2015, smaller segments were cut from both the standard and delaminated panels which had been tested and sent to Fraunhofer IFAM for further tests.[403] Mr Maurieschat also obtained cut samples from some panels which had originally been produced for installation in the Project, but which were never installed because they exhibited defects, for example scratches in the gel coat.[404] These panels had therefore been left in the Philippines. BFG personnel selected some of these for testing[405], cut 11 samples from three panels selected at random[406], and sent the cut samples to Mr Maurieschat. The only evidence that these cut samples had come from the panels manufactured for the Project was that each was labelled with a code from "OL-1" to "OL-11".[407] The following tests were then conducted at Fraunhofer IFAM on 14 September 2015:

(a) Noise tests: specimens which had not been charged with any load before were mounted in a sample and subjected to a compression load exerted through a dolly. The compression load was gradually increased until the first crinkling sound was heard, at which point the load was recorded. These tests showed that the panels manufactured exactly as per the documented materials and manufacturing processes began

403 ABD 4C 1215–1217.

404 NE (31 March 2016) at p 131 lines 2–9.

405 NE (31 March 2016) at p 132 lines 15–16.

406 NE (31 March 2016) at p 133 line 24 – p 134 line 1; ABD 3C 1095.

407 NE (31 March 2016) at p 134 line 18 – 135 line 17.

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producing crinkling sounds at about 20–40kg of force. The test panels did not exhibit any delamination and were then subjected to direct pull-out tests (also referred to as tensile tests) to test their structural adequacy.[408]

(b) Direct pull-out tests, also referred to as tensile tests: 20cm-by-20cm samples were cut out of each panel sample and cored with a diameter of 117mm. Only the inner skin of the sample was cored; the aluminium honeycomb was not torn or subjected to significant pressure.[409] The inner layers of the test samples were bonded with a dolly and then subjected to a pull-out test by a testing machine with a 20 kN load cell. The results showed that there was sufficient adhesion between the aluminium honeycomb and the inner skin even though the specimens had begun making crinkling noises.[410]

186 Kalzip and its experts raise various arguments to cast doubt on the reliability and persuasiveness of the 2015 Tests. I examine these in turn and explain why I am not persuaded by them.

(I) PROVENANCE AND SUITABILITY OF THE SAMPLES

187 First, Kalzip attempts to discredit the 2015 Tests by casting doubt on the provenance and suitability of the samples allegedly derived from panels produced in 2010.[411] Mr Wymond did not personally investigate the provenance of these panels and appears to have simply accepted on the faith of photographs showing the tag markings of the panels set into the panels by resin that they

408 ABD 3C 843 at para 7.5.2; ABD 4C 1221 at para 185.

409 ABD 3C 842 at para 149.

410 ABD 4C 1221 at para 185.

411 Plaintiff's Closing Submissions at para 114; Plaintiff's Reply Submissions at para 259.

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were indeed panels from the original production run.[412] BFG witnesses did not mention any of these original panel samples. Mr Wymond could not comment on the suitability of the panels for testing from a material perspective, and agreed that there "may have been an issue" if, for example, the panels had been "stored in a way that had caused corrosion or some sort of deterioration" or if the panels were "subject to a cyclone in the Philippines".[413]

188 I am not persuaded by Kalzip's submission. Mr Maurieschat, who received the samples from BFG, confirmed that he had visited BFG's Philippines facility before the preparation of the samples and personally saw those panels onsite labelled with their production dates. He also received a report from Mr Rade as proof that the samples which were sent to him were extracted from the original panels for the Project.[414] As for the suitability of the panels, Mr Wymond's concern was that the original panels may have deteriorated with time depending on the conditions of their storage. There would be no reason to expect them to have performed *better* in the 2015 Tests than they would have in 2010.

(II) DIFFERENCES BETWEEN THE 2015 TEST SAMPLES AND THE GRP PANELS

189 Mr Green and Mr Wymond agreed that if the GRP panels supplied to the Project were identical to the test panels used in 2015, they would have met the Sub-Contract requirements. Prof Nonhoff likewise accepted that Mr Maurieschat's pull-out test[415], assuming the results were accurate, showed that the samples achieved a good bond between the aluminium honeycomb and the

412 NE (31 March 2016) at p 93 lines 7–20, pp 95–96.

413 NE (31 March 2016) at p 88 lines 12–14, p 89 lines 5–15.

414 NE (31 March 2016) at p 126 lines 10–14, p 127 lines 9–16 and 20–24.

415 ABD 4C 1259.

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inner skin, and that if the GRP panels had shared these characteristics, they would not have delaminated.[416] However, whereas Mr Wymond took the view that the panels were made to the same specification and had the same composition,[417] Mr Green thought that the panels tested in the 2015 Tests were not representative of the panels supplied to the Project.[418]

190 Mr Maurieschat and Mr Premamoorthy gave evidence that the same quality control and manufacturing documents were used in 2009–2010 and in 2015[419], and that the 2015 Test panels had been through an identical manufacturing process as that used in 2009–2010 (described in detail at [316] below)[420], save for minor deviations which were unlikely to have any impact on the performance of the panels to the specifications.[421] At trial, however, Mr Maurieschat and Mr Premamoorthy agreed that there were three differences between the manufacturing process in 2009–2010 and that used in 2015, in relation to how the inner skin was manufactured after the aluminium honeycomb and upper skin were subjected to vacuum-bagging:

(a) In 2009–2010, after the vacuum-bagging process, the three layers of matter which would comprise the inner skin of the GRP panel were introduced to the mould one at a time. In 2015, however, the three layers were introduced to the mould together.[422]

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416 NE (1 April 2016) at p 67 line 13 – p 71 line 20.

417 NE (29 March 2016) at p 213 lines 10–13; NE (30 March 2016) at p 18 lines 7–12.

418 ABD 2C 589 at para 3.11.

419 ABD 4C 1202 at para 151.

420 ABD 2B 423 at para 142; NE (30 March 2016) at p 18, lines 14–22.

421 ABD 4C 1201 at paras 147–148; ABD 4C 1193 at para 129.

422 NE (23 March 2016) at p 147 lines 16–20; NE (1 April 2016) at p 136 lines 2–8.

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(b) In 2009–2010, resin was applied to the first layer of chopped strand mat ("CSM") 225 (a process known as "pre-wetting") before it was introduced to the mould. In 2015, the three layers were dry when they were introduced to the mould.[423]

(c) In 2009–2010, the layers were laid flat on the aluminium honeycomb in the mould. In 2015, the layers were folded.[424] I note there was some disagreement over how exactly they were folded. According to Mr Maurieschat, the three layers were folded down the middle and resin applied to them as folded; they were then unfolded and more resin applied; they were then folded again in the other direction and resin applied; and finally they were unfolded and resin applied again. According to Mr Premamoorthy, resin was applied as each of the three layers were folded one at a time.[425] Regardless of this difference, the fact remains that they were folded, whereas the layers in 2009 were not. (I note that Mr Premamoorthy subsequently said that there *was* folding in 2009[426], but this was not described in his AEIC and appears to have been an afterthought.)

191 Mr Maurieschat considered that these differences were not important or material; they were simply alternative ways of introducing the CSM to the mould.[427] Nor did the other experts testify that these differences would have led to differences in performance between the GRP panels produced in 2009–2010 and the test panels produced in 2015. I therefore do not find that these

423 NE (23 March 2016) at p 147 lines 8–14; NE (1 April 2016) at p 137 lines 2–10.

424 NE (23 March 2016) at p 147 lines 21–25; NE (1 April 2016) at p 139 lines 10–18.

425 NE (23 March 2016) at p 145 lines 4–20.

426 NE (23 March 2016) at p 149 line 25 – p 150 line 5, p 151 lines 14–18.

427 NE (1 April 2016) at p 140 lines 17–25, p 144 line 18 – p 145 line 1.

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differences in manufacturing process invalidate the conclusions of the 2015 Tests.

192 Kalzip seeks to discredit Mr Maurieschat's view that the differences between the two manufacturing processes were unimportant and immaterial, on the basis that his knowledge of the 2009–2010 manufacturing process was limited. In particular, Mr Maurieschat only conducted a desktop review of the 2009–2010 manufacturing process and only saw one process control sheet ("PCS") – a document recording critical parts of the manufacturing process for the panel – from the 2009–2010 production run even though there ought to have been one PCS per panel for 3,421 panels.[428] The one PCS which Mr Maurieschat obtained was for panel 16 of bay 7 of the MICE building roof, which was indicated on the site survey dated 8 March 2010 as non-delaminated.[429] Indeed, Mr Maurieschat conceded that he ought to have asked for more PCS.[430] However, I do not agree that this invalidates Mr Maurieschat's opinion. Mr Maurieschat personally audited the 2015 manufacturing process, and Mr Premamoorthy helped to develop the 2009–2010 manufacturing process.[431] Together they were able to provide a reliable comparison of the two processes. Absent any positive evidence that the manufacturing processes as described by Mr Premamoorthy and Mr Maurieschat were inaccurate or not adhered to, I see no reason to doubt their descriptions thereof. There is nothing to contradict Mr Maurieschat's opinion that the differences would not have been material to performance.

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428 NE (1 April 2016) at p 153 lines 16–20, p 154 lines 20–23, p 157 lines 9–11; NE (23 March 2016) at p 235 line 2; Plaintiff's Closing Submissions at paras 108 and 358(b); Plaintiff's Reply Submissions at para 351.

429 ABD N 338; NE (3 October 2016) at p 39.

430 NE (1 April 2016) at p 174 lines 11–19, p 177 lines 8–17.

431 ABD 4C 1162–1200; NE (1 April 2016) at p 93 line 25 – p 94 line 3; Plaintiff's Closing Submissions at para 358(b).

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193 I therefore do not think that the 2015 Tests are unreliable simply because of differences in the manufacturing process between 2009–2010 and 2015. Even if this criticism were valid, it would not apply to the tensile tests conducted by Fraunhofer IFAM on panels which had been manufactured in 2010. Moreover, a shear test conducted by Fraunhofer IFAM showed that the minimum strength of the 2010 panels was greater than that of the new panels, thus suggesting that the 2015 test panels were not deliberately made stronger for the purpose of testing.[432]

(III) METHODOLOGY OF THE 2015 TESTS

194 When asked about the 2015 Tests performed by Mr Maurieschat, Prof Nonhoff said he thought that most of these were done "properly and right", but that the "boundary conditions" for some tests were "not right".[433] The noise test specimens differed from the GRP panels in a few ways:

(a) In the noise test, the force from the dolly was applied to a sample measuring 200cm by 200cm, which was much smaller than an actual panel.

(b) The noise test sample lay on a square frame, whereas the GRP panels would have lain on three rails, and stepping in between two rails could have produced a different effect from stepping on a part of the panel lying directly over a rail.[434]

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432 ABD 4C 1335 at para 47.

433 NE (1 April 2016) at p 57 lines 20–25.

434 NE (1 April 2016) at p 60 line 17–24; p 62 lines 11–23; p 66 lines 11–13; p 66 line 15 – p 67 line 4.

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(c) The noise test samples had exposed edges, unlike the GRP panels.[435] In Prof Nonhoff's view, the samples "exhibited crinkling noises because the edges of the panel were free".[436]

195 Mr Maurieschat's response to these points was that it did not actually matter whether the GRP panels would also have emitted sounds under these conditions; the noise test was undertaken *purely* for the purpose of verifying whether the emission of such noises was necessarily proof of delamination.[437] I accept his explanation. There is no apparent reason, and Prof Nonhoff did not offer any, why the difference in boundary conditions should disturb Mr Maurieschat's conclusions about the *correlation* between the noises emitted and the presence of delamination.

(B) BFG'S EXPERTS' VIEWS ON THE SOUNDS

196 Mr Wymond's expert view was that the sounds could not necessarily be correlated with deformation of the honeycomb. The 2015 Tests showed that crinkling did not necessarily show any structural inadequacy:

(a) The cyclic maintenance loading test during the 2015 Tests showed that the crinkling or crunching sound did not indicate delamination or structural inadequacy. Even though a crinkling sound was present over many cycles of walking, the panels which produced these sounds were not delaminated at the end of the test.[438]

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435 NE (1 April 2016) at p 194 lines 17–22.

436 NE (30 March 2016) at p 7 lines 21–24.

437 NE (1 April 2016) at p 61 lines 5–9; p 65 lines 8–17.

438 ABD 3C 845.

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(b) The tests conducted at Fraunhofer IFAM showed that noise occurred as a result of applying pressure directly to the GRP panels, but no delamination occurred and there was no change to the structural performance of the test specimens.[439] Indeed, during the noise test, samples which emitted crinkling sounds in the range of 475N to 647N were nevertheless able to carry loads of between 1100N and 2078N.[440]

197 Mr Maurieschat also relied on the 2015 Tests for his conclusion that there was no evidence of delamination in the panels which Prof Nonhoff claimed to have observed.[441] These tests showed that the panels began producing crinkling sounds at about 20–40kg of force, leading Mr Maurieschat to conclude that someone walking on the panels would be enough to cause them to generate crinkling noises.[442] However, these same panels were not delaminated and the direct pull-out tensile tests showed that they were able to withstand specified loads even though they had produced crinkling noises.[443]

198 If that is the case, what caused the GRP panels to make the sounds which were heard? I reiterate that at least two different sounds were heard by Mr Mackay: a lighter crinkling sound and what Mr Mackay described as a "deep crunching sound". Mr Maurieschat opined that the noises were simply a characteristic of the panels – specifically, a result of extra resin pooling at the junctions of the upper skin (*ie*, the lower layer of fibreglass in the mould) and the aluminium honeycomb. When forces were applied to the panel (for example, people walking on it), the resin would start chipping off with a *cracking* noise

439 ABD 3C 843 at paras 153 and 154; ABD 3C 846 at para 175.

440 ABD 3C 844 at para 161.

441 ABD 4C 1492 at para 43.

442 ABD 4C 1221 at para 184.

443 ABD 4C 1210 at paras 169–170.

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and there would also be a *crinkling* noise as a result of the basic aluminium honeycomb foil spring action. The two of these noises together might be described as cracking and/or crinkling noises. The noise of the resin chipping off would stop after the panels had been walked on several times, whereas the crinkling noise of the deformation of the aluminium honeycomb foils would continue. This suggested that the crinkling noises heard during the 2015 Tests were not due to delamination, since they would have stopped after the panels delaminated if that were the case.[444]

199 Mr Wymond took the same view. He observed that, during the walking test, the panels did not initially produce a crunching sound but began producing a consistent crunching sound after a few cycles of walking. This was "consistent with the upper skin initially providing a load spreading platform through excess resin in the honeycomb, but once the excess resin was cracked the panels made a regular and consistent crinkling sound with each step". This sound was not an indicator of delamination but was due to deformation of the honeycomb.[445] At trial Mr Wymond stated (and Mr Maurieschat agreed):[446]

> On the delaminated panel, when you walk on it, you do hear a different sound, *it's a crunching sound*, but I don't necessarily believe you can correlate the deformation of the honeycomb foil with the crunching noise. I think the crinkling noise is caused by the deformation of the honeycomb. I think the crunching noise is coming from the resin.

200 Kalzip relies on this statement in support of the proposition that "a delaminated panel would produce a 'crunching' sound if one was to walk on it".[447] But that is not how I understand Mr Wymond's evidence. The

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444 ABD 4C 1210 at paras 169–170; NE (30 March 2016) at p 70 line 20 – p 71 line 7.

445 ABD 3C 814 at para 67; ABD 3C 844 at para 166; ABD 3C 845 at para 174; NE (30 March 2016) at p 63 lines 8–19.

446 NE (30 March 2016) at p 67 lines 15–23.

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phenomenon that he and Mr Maurieschat were referring to was when *excess* resin that had flowed over the honeycomb cracked.[448] Mr Maurieschat explained this in the following terms:[449]

> This is a non-structural brittle fillet of cast resin without any reinforcements to strengthen it. When movements are applied to the panel, these fillets start chipping off with a crack like noise. As the walking continues more filets [*sic*] would chip off. In addition, the basic aluminium honeycomb foil spring action crinkling noise would also be mixed with the fillet noise. Hence we can see the noise sometimes described as cracking noise and sometimes crinkling noise as it would be a combination of these noises. The fillet noise would stop after several walks and the crinkling noise of the aluminium honey-comb foils would continue. If this noise was due to delamination, after delamination the noise should have stopped. A laminate, once delaminated cannot delaminate again. However as the crinkling noise is due to the aluminium foil deformation and not any delamination, the crinkling noise is observed to continue with repeated walking on the panels. The panels passing the load test, after having noise with walk, also confirms that the noise does not mean delamination. These are my observations from the experience of sandwich laminate constructions and observations during the investigation tests commissioned by me in Bangkok Kaskal and Germany Fraunhofer IFAM laboratories.

201 BFG's experts therefore took the position that the sounds emitted by the panels were not indicative of delamination. I pause here to note that though BFG's experts attributed the sounds to deformation of the honeycomb, Kalzip has not alleged any contractual breach on BFG's part in relation to such deformation.

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447 Plaintiff's Closing Submissions at para 260; Plaintiff's Reply Submissions at para 254(a)(ii).

448 ABD 3C 845 at para 174.

449 ABD 4C 1215 at para 171.

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(C) KALZIP'S EXPERTS' VIEWS ON THE SOUNDS

202 Prof Nonhoff thought that the crunching noises that he had heard were "symptomatic of structural failure" and "indicative of" delamination.[450] He disagreed that crinkling or crunching noises were characteristic of GRP panels. Prof Nonhoff attested to having walked across a lot of panels with a honeycomb construction in his career, and never having heard any crinkling sounds,[451] though he thought it "perfectly normal" to hear a light crinkling sound when stepping around the edges of a cored hole.[452] By contrast, an intact panel would only produce crunching noises "if one of the face layers is delaminated or the honeycomb is crushed locally".[453] In his view, "[i]f a panel with a sandwich construction is properly manufactured then practically no sound should be audible".[454] He stated:[455]

> I would not, in my experience, expect a laminated GRP panel to make crunching noises when walked on. During my inspection of the assembled roof in June 2010, I observed movement of the panels, which also made crunching noises, and it is quite clear therefore whether a panel had delaminated or not. The deflection levels of panels that had delaminated were significantly greater than those that had not delaminated.

203 Prof Nonhoff disagreed that the crunching or crinkling sounds arose from excess resin at the junction of the upper skin and the aluminium honeycomb, because he had not observed any such excess resin in the panels he inspected in 2010. The noises arose *only* because of delamination.[456] Against

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450 NE (30 March 2016) at p 5 lines 14–15; ABD 1C 38 at para 72.

451 NE (30 March 2016) at p 64 line 25 – p 65 line 3.

452 NE (30 March 2016) at p 7 lines 8–14.

453 NE (30 March 2016) at p 7 lines 15–18.

454 ABD 2C 574 at para 21.

455 ABD 1C 38 at para 72.

456 ABD 2C 574 at para 22.

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this, however, I note that Mr Maurieschat's expert report contained close-up photographs of the upper skin, which he had annotated with the following comments: "Dropped down resin onto the backside of the outer skin" and "Cracks in the surface of the dropped down resin".[457] Although Mr Maurieschat made this point at trial with reference to these very photographs, Prof Nonhoff did not contradict Mr Maurieschat or express any disagreement.[458]

204 Mr Green stated that he knew "for a fact" that mere noise of the core was not a normal phenomenon observed in aluminium-cored composite cladding panels, because he had dealt with such panels and had walked on them without hearing any noise.[459] However, Mr Green's assertion lost much of its force when he conceded that he had never walked on a fibreglass panel with an aluminium honeycomb core, as he had not encountered one prior to this case. He had only had experience with an aluminium-*faced* honeycomb panel.[460] Mr Green stated that he did not profess to be an expert on any aspect of fibreglass skinned aluminium honeycomb panels, as that was Prof Nonhoff's realm.[461] He had also never worked with a product that combined aluminium with fibreglass reinforced plastic.[462]

(4) Sounds were not indicative of delamination

205 Having considered the expert evidence, I have formed the view that the sounds heard from the panels (and which formed the basis for the four site surveys), whether described as crunching, crinkling or cracking noises, were not

457 ABD 4C 1212–1214.

458 NE (30 March 2016) at p 71 lines 4–9.

459 NE (30 March 2016) at p 192 lines 17–21.

460 NE (30 March 2016) at p 62 line 22 – p 63 line 3.

461 NE (30 March 2016) at p 185 lines 17–20.

462 NE (30 March 2016) at p 193 lines 3–7.

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indicative of delamination. The idea that the crunching noises were indicative of delamination appears to have lodged itself firmly in the mind of Mr Carter at the time of the factory inspections on 3 September 2008 and 23 April 2009. Mr Carter was a forceful figure and was adamant that the noises emitted by the GRP panels were proof of delamination.[463] This is borne out by his e-mail to Mr Kolhatkar in early March 2010, in which he referred to a video that Mr Kolhatkar had sent; Mr Carter considered that "the existing delamination is *clearly evident from the audio* in this video" [emphasis added].[464] He then propagated this idea to Mr Mackay (see [180] above) and used it to test for the presence of delamination onsite.[465] But surprisingly, none of the panels which produced sounds were taken off their fixings to confirm that they had in fact delaminated. This was the case even after MBS made the decision to engage another contractor to replace all the GRP panels with aluminium panels. Mr Mackay, as noted at [181] above, conceded as much in cross-examination and agreed that it was "conjecture or speculation" to say that the inner skin had delaminated based on the sounds heard when walking on the panels "because it was impossible to view the lower face or bottom skin".[466] The experts could not agree whether the sounds were evidence of delamination. I find that the 2015 Tests constitute objective and convincing evidence that the presence of such sounds does not indicate delamination. This is corroborated by Kalzip's core sampling video from 2 March 2010, which showed that crinkling sounds were made by cored panels even if the core samples were not delaminated. Insofar as the BFG correspondence was based on those sounds, I do not find them to be proof of delamination.

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463 NE (24 March 2016) at p 142 line 24, p 226 line 18; NE (29 March 2016) at p 59 line 19, p 106 lines 13–21; ABD 10e 6411.

464 ABD 10E 6526.31.

465 ABD 2B 318 at para 19; ABD 2B 422 at para 137.

466 NE (22 March 2016) at p 49 line 4 – p 56 line 9.

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206 The earlier correspondence from BFG appears to have proceeded on the assumption that the sounds were evidence of delamination. Mr Attwood's e-mail on 7 December 2009 was based on Kalzip's report of delamination, probably based in turn on the sounds that had been heard, and his e-mails on 11, 18 and 27 January 2010 were likewise based on those sounds. Importantly, however, there were various internal e-mails from end January to February 2010 which distinguished between the problem of delamination and the mere emission of metallic or "ALHC" (aluminium honeycomb) sounds (see [140], [146], [147], [148], [150], [152] and [166(c)] above). Indeed, Mr Kolhatkar testified that by 2 February 2010 he had concluded that "it was a mistake to equate these noises that were being heard on the panels [during the site surveys] with the panels having delaminated".[467] Unfortunately those e-mails do not say what other signs (besides the noises, which were a different problem) led the team to deduce delamination, or how widespread these were. Mr Kolhatkar was unable to explain why he had reported delamination if he did not think that the noises were proof of this, though he also mentioned that "there are six panels on which they had done the local drilling".[468] Mr Attwood's e-mail at [146] mentions "drilling into panel front [face] and examining the aluminium honeycomb". What sort of drilling this was and what the examination of the aluminium honeycomb showed were not explored at trial with either Mr Attwood or Mr Kolhatkar. Indeed, Kalzip did not give much attention to these e-mails, preferring to focus on the noises as evidence of delamination. However, as I explain below, there were other phenomena besides the noises – for example the fact that some panels deflected underfoot – that appear to have led BFG to conclude that delamination had occurred (see [225]–[226] below).

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467 NE (29 March 2016) at p 89 line 21 – p 90 line 2, p 102 lines 18–22.

468 NE (29 March 2016) at p 102 lines 13–14; see generally p 101 line 22 – p 105 line 4.

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207 That concludes, for the present, my analysis of the correspondence from BFG and the four site surveys. I now move on to other evidence of delamination.

Prof Nonhoff's inspection onsite in June 2010

208 Around 20–21 June 2010[469], Prof Nonhoff visited the Project and inspected both the MICE and casino building roofs. He walked the length of the MICE building roof and inspected "a large number of panels", and conducted a more limited inspection on the casino building roof.[470] On both roofs, Prof Nonhoff noticed that a lot of the panels made loud crunching noises; he states that his investigation established that these sounds were a result of delamination:[471]

(a) Prof Nonhoff knelt on the panels to identify the cause of the noise, and it was clear to him that the noises were coming from the panels themselves and not from the connections to the Kalzip roof.

(b) At two different positions where he heard loud noises and observed deformation, the inspection team cored circular samples from the panels.[472] These panels showed complete delamination of the inner skin and delamination around the perimeter of the core hole, thus establishing that the crunching noises were indicative of delamination.[473] A photograph of a cored sample shows that the inner GRP face of the cored sample had delaminated from the aluminium honeycomb core.[474]

469 NE (31 March 2016) at p 211 lines 14–25.

470 NE (30 March 2016) at p 5 lines 1–12.

471 ABD 2C 566–569 at paras 6–9.

472 ABD 2C 575 at para 23(a); NE (30 March 2016) at p 5, lines 16–23.

473 NE (30 March 2016) at p 5, lines 14–15.

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> Another photograph of the perimeter of the cored hole in a panel *in situ* shows that the inner face had delaminated sufficiently from the honeycomb core for a €1 coin (approximately 2mm thick) to be wedged between them.[475]

209 Prof Nonhoff also "saw deformations of large areas when [he] and the other people stepped on the panels".[476] It was clear to him that the weight of the individuals walking on the panels was causing "significant deformation". In his view, this was only possible because the panels were not made correctly; if the panels had been made correctly, they could be walked on without any problem.[477]

210 I note that Prof Nonhoff has an advantage over the other experts in that he managed to visit the panels onsite in 2010. However, his evidence does not satisfy me that widespread delamination occurred on a balance of probabilities, for the following reasons:

> (a) Prof Nonhoff thought that the four site surveys were "consistent" with the delamination he had observed.[478] In his view, the "load-bearing ability of the GRP panels was clearly impaired by the delamination of the inner face".[479] However, Prof Nonhoff accepted at trial that he was not present onsite in February and March 2010, and could not correlate whatever sounds Kalzip personnel had heard in those months to the

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474 ABD 2C 569–570 at paras 12–13.

475 ABD 2C 568 and 569 at paras 8 and 10.

476 NE (30 March 2016) at p 5 lines 11–13.

477 ABD 2C 567 at para 6.

478 ABD 1C 38 at para 73.

479 ABD 1C 26 at para 27; ABD 1C 29 at para 35.

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sounds that he personally heard in June 2010. While the noises heard by the Kalzip personnel had been described to him, and he had formed "an idea" of what they were, he admitted that noises could be interpreted differently by different people.[480]

(b) There is no documentation of Prof Nonhoff's inspection; he agreed during cross-examination that his inspections in 2010 were so poorly documented that it was impossible to know what he had actually seen or heard.[481] I do not expect this of an expert giving expert evidence before me. As an illustration, Aedas' report of 22 January 2010 (see [227] below) carefully documented the problems reported onsite, with photographic evidence and comments, as well as identified the panels and components in question. In contrast to Prof Nonhoff's assertions that panels which produced crunching sounds had delaminated, the 2015 Tests provide objective evidence that such sounds do *not* show delamination.

(c) The only evidence from Prof Nonhoff's inspection is the two photographs he adduced of the cored samples. However, there is no video of the coring, so it is impossible to tell if the coring was performed properly or not. [482] BFG submits that the coring process would have exerted vibration forces *causing* the delamination. [483] While Prof Nonhoff stated that he was present during core sampling and observed that the circular samples were cored carefully with reduced cutting speed, [484] Mr Wymond considered that delamination could occur as a

480 NE (1 April 2016) at p 5 line 14 – p 6 line 1, p 7 lines 4–6 and 20–24.

481 NE (1 April 2016) at p 9 lines 9–16.

482 NE (31 March 2016) at p 212 lines 16–22.

483 Defendant's Closing Submissions at para 509.

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result of other variables in the coring process *even if* the coring was done properly.[485] Moreover, the coring was only carried out at two areas,[486] whereas Kalzip alleges that widespread delamination occurred across the hundreds of panels installed.

(d) Prof Nonhoff acknowledged that in June 2010 and while preparing his first expert report, he had *assumed* that there was delamination of the inner skin (as opposed to *concluding* that this was the case from his own survey of the evidence). It was only in his rebuttal report that he referred to evidence of delamination.[487] He also agreed that he had "not discharged [his] expert obligations to properly analyse the nature and extent of the alleged delamination",[488] and that delamination occurred only in very localised and limited areas of the Project roofs.[489]

(e) Prof Nonhoff's view that the GRP panels "clearly did not meet the requirements of Specification Revision C" was based on the structural tests which I have discussed above and Mr Green's analysis of those tests.[490] For the reasons I have stated, these tests were not reliable evidence of delamination, because they appear to have failed for other reasons (see [75]–[97] above).[491]

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484 ABD 2C 569 at para 9.

485 NE (31 March 2016) at p 102 lines 5–8; p 104 lines 12–18.

486 NE (30 March 2016) at p 5 lines 16–19.

487 NE (31 March 2016) at p 202 lines 2–10; p 203 line 23 – p 204 line 8.

488 NE (1 April 2016) at p 4 lines 18–24.

489 NE (1 April 2016) at p 10 line 18 – p 11 line 2.

490 ABD 1C 26 at para 27; ABD 1C 29 at para 35; ABD 1C 37 at para 62.

491 ABD 1C 29 at para 35.

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Deflection underfoot and sagging

211 Besides the noises emitted by the panels, another phenomenon observed by Mr Mackay and Prof Nonhoff was that there were areas of the panels which felt "spongy" underfoot and/or deformed when walked upon (see [126] and [208] above). Mr Mackay correlated this to the crunching sounds:[492]

> It's -- basically, your Honour, it's -- when I walked on the panels, when you come to an area, you'd -- like the deep crunching sound, you would actually -- your foot or your feet will just sag into the panel itself, like, it just gave into the panel and deflected a lot, compared to walking on the typical panel with -- just, say, with either crackling or no crackling involved. So it was like a very spongy and deep-sounding crunching noise as well.

212 While Mr Rade denied that the panels would become "spongy" when delaminated, he did say that delaminated panels would "deform more" when walked upon[493] and that your feet would "sink in more".[494] However, he did not observe any such deformation during the site inspection on 1 February 2010[495], nor did Mr Premamoorthy when he walked on the panels in January 2010.[496]

213 BFG submits that what Mr Mackay described as "sponginess" when walking on the panels was simply the natural bounciness they possessed given the deflection limits to which they had been designed.[497] I do not agree as that was not what Mr Mackay meant. Mr Mackay was clear that when he was walking across the roof, he would come to "a *spot* where it would be a deep

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492 NE (22 March 2016) at p 168 line 17 – p 169 line 1.

493 NE (24 March 2016) at p 149 lines 2–5, 11–23.

494 NE (24 March 2016) at p 163 lines 1–11.

495 ABD 2B 339 at para 9; NE (24 March 2016) at p 148 lines 19–24.

496 NE (24 March 2016) at p 59 lines 5–7.

497 Defendant's Closing Submissions at para 455.

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crunch and very spongy" [emphasis added] and that it "wasn't like on the rest of the panels, where it was fairly solid" (see [126] above).

214 Mr Green was unable to comment on whether "spongy" was an appropriate term in this case, having never seen the GRP panels, walked on them or performed tests on them.[498] Mr Wymond said that "sponginess" was not an engineering term that he would normally ascribe to the performance of a material; it was more appropriate to talk about how much a panel was deflecting underfoot.[499] The experts agreed that a panel designed to experience greater deflections would naturally feel less firm to someone walking on it; but the rate at which it recovered from that downwards deflection would be a function of elasticity and other characteristics of the panel.[500] As Mr Kolhatkar said, it was part of the "natural characteristics" of a panel for it to deflect and return to its original shape when walked on,[501] within the deflection limits to which it was designed.

215 Kalzip's position was that a properly manufactured panel should be firm and should not deflect when walked upon.[502] The experts appeared to be in agreement that deflection underfoot was abnormal:

(a) Mr Green said that if a panel deflected underfoot, resulting in a depression, that would suggest that there was something wrong with it, though he could not say whether it would be due to crushing of the

498 NE (30 March 2016) at p 126 lines 19–25.

499 NE (30 March 2016) at p 127 lines 14–20.

500 NE (30 March 2016) at p 129 line 17 – p 130 line 3.

501 NE (29 March 2016) at p 75 lines 19–21, p 124 lines 20–22.

502 NE (29 March 2016) at p 124 line 23 – p 125 line 2.

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honeycomb or delamination. He would not expect a panel to behave like that ordinarily.[503]

(b) Prof Nonhoff agreed that deflection underfoot was abnormal. A panel whose lower layer had delaminated from the honeycomb would be "softer" and deform more underfoot because the shear forces could not be transferred. If the foot was lifted from the panel, it would come back to its original position but not as quickly as an intact panel.[504] However, he did not think this would occur as a result of the honeycomb giving way. In that situation, one would not feel any deformation because the upper skin would be hard and thick enough to support one's weight.[505]

(c) Mr Wymond agreed with Prof Nonhoff because the 2015 Tests showed that a delaminated panel deflected more than a non-delaminated panel when stepped on.[506]

(d) Mr Rade – who, though strictly speaking a factual witness, was a structural design engineer and had been working with composite designs and technology for many years[507] – also said that if one stood over a delaminated area of a GRP panel, one would expect to see the panel sag or deform. Apart from sagging, it would not be possible to visually observe delamination from the top of the panels and Mr Rade saw none.[508]

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503 NE (30 March 2016) at p 72 lines 10–18.

504 NE (30 March 2016) at p 74 lines 1–9.

505 NE (30 March 2016) at p 72 line 20 – p 73 line 4.

506 NE (30 March 2016) at p 76 lines 4–7.

507 NE (24 March 2016) at p 135 lines 10–19.

508 NE (24 March 2016) at p 149 lines 6–10, p 152 lines 17–22.

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216 I note that Mr Maurieschat said that he would expect "some spongy feeling beneath your feet" while walking on a GRP panel which had nothing to do with delamination of the bottom layer or deformation of the honeycombs. BFG relies on this to say that the phenomenon of deflection underfoot does not indicate delamination.[509] However, I do not think that is what Mr Maurieschat meant. He said:[510]

> MR MAURIESCHAT: (In English) May I agree to many of what Mr Wymond says but also as an additional explanation, of course, the behaviour or the feeling during walking on that GRP panel is completely different to walking on a concrete roof or whatever and, therefore, you maybe have some spongy feeling beneath your feet but at least it does not have anything to do with delamination of the inner layer or deforming of the honeycombs.
>
> COURT: Yes. I think the witnesses were saying this: when I walk, I get one feeling. No-one is saying it is like walking on a concrete floor. There may be a bit of give, but suddenly one foot can sink down, spongy; it sinks.
>
> MR MAURIESCHAT: (In English) Nothing I ever seen on the panels which we investigated on the test in 2015.
>
> COURT: Have you ever come across in your experience?
>
> MR MAURIESCHAT: (In English) No.

217 As I understood him, Mr Maurieschat meant to say that a GRP panel would ordinarily feel less firm than a concrete roof. However, he was quite clear that he had not personally experienced one GRP panel sinking or deflecting underfoot in a particularly pronounced way. This corroborated the other experts' views that a panel which did so would be abnormal.

218 However, the evidence of panels deflecting underfoot does not persuade me that widespread delamination occurred. First, only Mr Mackay and Prof Nonhoff positively attested to having experienced such deflection underfoot.

509 Defendant's Closing Submissions at paras 451–452.

510 NE (30 March 2016) at p 77 lines 1–20.

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Mr Rade and Mr Premamoorthy denied having experienced this. Moreover, Mr Mackay's description of the deflections appears to have been exaggerated. His descriptions of a foot "sag[ging] into the panel itself" and "[giving] into the panel" and of panels being "very spongy" at a particular "spot" gave the impression of a foot, importantly not both feet, suddenly sinking deeply into a small area. This was incongruous with the composition and characteristics of a GRP panel. As I explain at [244(c)] below, a delaminated skin would not bulge out from the panel because of the stiffness of the skin. The fibreglass skins were not soft and flexible; they were hard and fairly rigid. Indeed Prof Nonhoff made the point that, if the honeycomb core were to give way, the upper skin would break rather than bend if loaded excessively, because of its stiffness (see also [215(b)] above).[511] The experts also agreed that any delamination which occurred would have been localised due to the presence of Z-strips (see [162] and [210(d)] above and [250] below). I therefore find it difficult to imagine that stepping on an area suffering from inner skin delamination could have caused that small area around one foot to dramatically deflect downwards. The stiffness of both the inner and outer skins, and the reinforcement provided by the Z-strips, would have limited the deflection underfoot. At most, if someone stepped on a panel which had widespread delamination, the entire panel would have curved downwards more noticeably. This was shown in the video of the core sampling exercise on 2 March 2010, during which Mr Carter jumped on the mock-up panel and the panel deflected downwards across its entire surface slightly. The core sampling team also walked and pressed down with the balls of their feet over the panels to detect cracking or crinkling sounds, and yet the video does not show any panels suddenly or dramatically dipping or sinking under their weight, though I could hear crinkling noises from the panels. There is not a

511 NE (30 March 2016) at p 72 line 20 – p 73 line 4.

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single photograph of a panel deflecting substantially underfoot at a particular spot while being stepped or walked on.

219 Furthermore, none of the panels which allegedly deflected underfoot were removed and examined or tested, so there is no way of knowing *how much* they deflected; how much of this deflection was natural for a panel designed to the deflection limits specified in the Sub-Contract and how much was unnatural; and whether other factors (besides delamination) could have contributed to this phenomenon.

220 There also appears to have been another, different phenomenon – namely, an *enduring* deformation of the panels. Mr Attwood's e-mail of 30 January 2010, for example, mentioned "sponginess" in the subject but attached the *one* photograph of a panel that appeared to be slightly depressed although there was nothing atop it (see [143] above). Mr Mackay also alluded to this possibility in his AEIC:[512]

> If this was merely a case of crushed honeycomb or resin-coated honeycomb, the panels, when stepped upon, would have emitted a simple crackling sound. This was not the case here. Instead, they emitted a deep crunching sound, which pointed to the failure of the structural integrity of the panel as a whole. Another telling indication was the fact that the spot on the GRP panels, which had been walked upon during all the site inspections, *deflected downwards in a permanent manner, and did not re-level upwards again.*
>
> [emphasis added]

221 Mr Mackay also referred to this at trial:[513]

> [I]t's quite difficult to actually see the sagging because of the panels with the same contrast of white, but you'd notice it if there was any rain, there would be a pooling of water or

512 ABD 1B 34 at para 83.

513 NE (22 March 2016) at p 169 lines 14–25.

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> construction -- I would just say dirt or the environment would be stuck around that area, where it's been kind of, like, sagging itself. So once the water would, say, evaporate from the rain, you'd still see like a -- the -- the typical construction dust or dirt around that area. It's just, kind of, like a dry pool.

However, I note once more that no photographs were taken of these "dry pools".[514]

222 Prof Nonhoff also testified that it was possible for a panel to sag if the lower layer was delaminated, as shown in the photograph referred to at [143] above.[515]

223 I do not accept the sagging as evidence of delamination. There was no documentary evidence to back up the allegation of sagging, except for that one isolated photograph provided by Mr Attwood. The only other person who claimed to have experienced it was Mr Mackay. However, I did not find his evidence to be credible on this point. Mr Mackay gave the impression that a fairly small area of the panel (a "spot", in his words; see [220]–[221] above) would exhibit sagging. As noted above this could have been photographed to show the same, but no photographs were taken. For the reasons I have stated at [218] above, I do not accept that the GRP panels would behave in such a way. Moreover, the sagging was not measured, so there is no way of knowing the severity of the problem. (I note that Mr Kolhatkar thought that the photograph showed a deflection of about 1mm or 2mm, which was "pretty normal variation" and "pretty normal for a panel in the course of its installation and its service"[516], though it is obvious from the photograph that the sagging depicted would have far exceeded 2mm.)

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514 NE (22 March 2016) at p 170 lines 5–7.

515 NE (30 March 2016) at p 74 line 23 – p 75 line 12.

516 NE (29 March 2016) at p 77 lines 7–18.

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224 It was also not clear that the sagging depicted in that photograph was definitely caused by delamination. In the 2015 Tests, a fully-delaminated panel recovered to its original position fully after the load was taken off it, and Mr Wymond did not observe any deformation.[517] Mr Wymond pertinently suggested that deformations on the surface of the panel could be due to a failure of the clips to align or engage properly.[518] This is supported by photographs from Aedas' report from the 3 September 2008 and 23 April 2009 factory visits, which shows that a panel can curve downwards at its ends if it is propped up in the middle.[519] If the clips had not been aligned properly, then the non-aligned part of the panel may have protruded, creating the impression of a depression in the adjacent areas. Moreover, even if that one panel shown in the photograph was indeed sagging as a result of delamination, I would be inclined to attribute this to mishandling. The photograph taken by Mr Attwood shows that the panel was adjacent to a vertical panel, which increases the likelihood of it having been jumped on. Two ropes are clearly visible at the forefront of the photograph, which the workers would have used to traverse the panel. (I discuss the effect that walking and jumping on the panels could have had on the panels in greater detail at [298]–[312] below.)

225 Importantly, Mr Kolhatkar acknowledged at trial that BFG's representatives had reported evidence of sagging, sponginess and deflection underfoot (he did not distinguish between these three terms).[520] The following excerpt from his re-examination is particularly illuminating:[521]

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517 NE (30 March 2016) at p 76 lines 8–14.

518 NE (30 March 2016) at p 76 lines 15–24.

519 ABD 1I 100 and 133.

520 NE (29 March 2016) at p 124 line 5 – p 125 line 13.

521 NE (29 March 2016) at p 186 line 7 – p 187 line 14.

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> Q. … [I]n agreeing to Mr Pillay's suggestion that there were delaminated panels at the casino and the MICE, what was the extent of delamination that you had in your mind?
>
> A. In the entire course of investigations that went at site, there was no access to the bottom skin visualisation. Hence, my words of perceived delamination related to whether the bottom skin was physically separated from the panels or not. When I agreed to the statement that there were some delaminations in the casino and MICE panels, I had made a statement that those two delaminations were observed for reasons other than -- or rather, the observations other than the noise coming in the panels or the bottom skin separating from the panels. There were records of sagging or sponging as referenced by Clive and those were the references by which these delaminations in 50 or 60 panels were identified as possible defect of delamination in the panels, but it did not refer to the physical observation of bottom skin being separated from the panels, or the noise coming. So other than these two criteria, these 50 or 60 panels were identified as delaminated based on signs other than bottom skin physically being seen or a noise being heard.

226 This, in my view, explains why Mr Kolhatkar maintained that delamination had occurred *notwithstanding* his view that the noises produced by the panels were not evidence of delamination (see [206] above). The reports of delamination from the BFG team onsite were based on phenomena other than the noises, particularly the panels "sponging" or deflecting underfoot. I therefore accept that some panels did deflect underfoot, although for the reasons stated at [218] above, I do not accept that this was as widespread as Mr Mackay suggested. I consider the extent of the delamination in greater detail at [248]–[254] below.

MBS consultants' opinions

227 Kalzip also refers to evidence from MBS' consultants, Arup and Aedas. The first of these is a non-conformance report ("NCR") produced by Aedas dated 22 January 2010 following inspections on 8 and 20 January 2010. Annotations on the photographs within the report stated that delaminated GRP

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panels had been observed during the walk-up, including on leaves 10 and 13.[522] One of the bullet points under "Design & Technical" stated: "The issue regarding the damaged delaminated GRP panels (currently leaves 10 and 13) needs urgent response from [Kalzip] / BFG."[523] A photograph of the stepped roof area is annotated with the sentence, "During the walk up the roof damaged delaminated GRP panels observed in highlighted area."[524] Three other photographs record that there were damaged, delaminated GRP panels on leaf 10 as well as leaf 13.[525]

228 Secondly, there was a letter from Arup to Aedas on 19 May 2010, titled "Summary of status on the GRP cladding". Under "Investigation of Delamination", the letter stated:[526]

> In February / March 2010 extensive delamination of the GRP was detected. An investigation by [Kalzip] in March confirmed that the inner skin of the composite was delaminating. This investigation also suggested that there was a high degree of variability in the achieved thickness of the upper skin.
>
> …
>
> The extent of the delamination was mapped in March 2010 and it was found that panels for the theatre in storage were also delaminated.

229 Kalzip submits that "[t]he opinion of these third party building professionals must be given weight".[527] However, BFG points out that it has never been submitted by Kalzip, nor does the evidence suggest, that MBS' consultants carried out independent checks of the podium roofs.[528] Significantly,

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522 ABD N 98–100, 109.

523 ABD N 112 (also ABD 10E 6101).

524 ABD N 98.

525 ABD N 99, 100 and 109.

526 ABD 12E 7820.

527 Plaintiff's Closing Submissions at para 243.

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no representatives from Arup or Aedas gave evidence in the Suit, and there is no way for me to know what their assertions in the correspondence were based on. If they were based on the report of BFG's and Kalzip's witnesses, or if they likewise simply inferred delamination from the sounds emitted by the panel, they do not strengthen Kalzip's case that delamination occurred. I note that representatives of Arup and Aedas were also present at the factory visits with Mr Carter (see [111] and [117] above). Although the report produced by Aedas on 22 January 2010 records that the inspection was attended by Mr Wong and Mr Mackay[529], who were witnesses in the Suit, they did not discuss this in their AEICs nor were they questioned about it during trial. I am unable to see any signs of delamination from the photographs included in the report, and the consultants would not have been able to view the panels from below to conclude whether delamination in fact occurred. Moreover, the bulk of the report focuses on Kalzip's non-conformances concerning the installation of the panels and their supporting structures, for example the lack of fasteners in the upper panel brackets; the removal of brackets from some panels; missing components; misalignment of parts; and other aspects of the installed roof which differed from the design intent and shop drawings. The reports of delamination receive comparatively little attention (four of 28 photographed defects) and appear to be confined to a few panels.

230 As for the letter dated 19 May 2010, this appears to have based the allegation of "extensive delamination" on Kalzip's own investigation in March 2010. This may refer to the core sampling exercise which Kalzip undertook on 2 March 2010, which gave rise to concerns about variations in panel weight, but Kalzip expressly disavows reliance on that exercise as evidence of delamination

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528 Defendant's Reply Submissions at para 65.

529 ABD N 97.

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(see [235]–[236] below). The same letter observes that "[a]lthough there have been several meetings a clear report on the cause and impact of the delamination has not been provided by [Kalzip]".

231 I note that Aedas also issued NCRs on 1 March 2010[530] and 5 March 2010[531] which referred to delaminated GRP roof panels. However, the latter NCR was expressly based on the 25 February site survey (see [154] above), which in turn was based on crunching sounds. In fact Mr Peter Morgan from Aedas, who was the "originator" of the NCRs, had attended that survey. There was no evidence as to how the findings in the NCR on 1 March 2010 were arrived at though it also referred to "site investigations / inspections of the MICE GRP panels carried out on 24-02-10 and 25-02-10". Aedas also produced an NCR on 17 May 2010 stating that "the theatre panels [could not] be considered suitable for installation" in the light of the tests conducted on 14 May 2010 (see [81] above).[532] However, given the problems I earlier identified with the Winwall tests and the site surveys (see [81]–[87] and [171]–[176] above), I do not accept Aedas' NCR as evidence that the panels were non-compliant with the Sub-Contract structural requirements or that they delaminated. Moreover, all three NCRs were signed off by Mr Peter Morgan, who was not a witness in the proceedings and did not give evidence.

Fire test panel samples

232 I agree with BFG[533] that the fire test samples suggest that any delamination which occurred was not widespread. This was a point made by Mr

530 Mr Mackay's AEIC at p 470.

531 Mr Mackay's AEIC at p 536.

532 Mr Mackay's AEIC at p 772.

533 NE (21 March 2017) at p 133 line 2 – p 134 line 5.

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Wymond in his expert report. According to Kalzip's four site surveys, it would appear that a large proportion of panels had delaminated. If this were so, one would expect to see a similar proportion of delaminated panels from the samples that were cut up for fire testing. However, out of the many cut samples used for fire testing – 249 samples according to Mr Wymond, 350[534] or 390[535] according to BFG – not one was reported to be delaminated.[536]

233 Mr Wymond subsequently deleted this section of his report because it appeared to him from the rebuttal report of Dr Crowder, BFG's fire expert, that many of the panels he referred to were reported to have delamination.[537] The relevant portion of Dr Crowder's rebuttal report states:[538]

> The samples provided for [fire] testing were delaminated. It has not yet been established by the other experts whether delamination had occurred in the installed panels prior to their removal. However, regardless of this debate, the samples which were removed from the building do not appear to have been delaminated, whereas samples delivered to two of the three laboratories are noted as being delaminated.

234 As it turns out, however, Mr Wymond's original point was in fact correct. As will be seen below, the fire experts came to the firm conclusion that the samples removed from the installed panels for fire tests were not delaminated *at the time of their removal from the site*. Delamination was only observed prior to testing, suggesting that the samples had delaminated sometime between removal from the site and testing (see [437]–[438] below). Unfortunately, this was not brought to Mr Wymond's attention. I accept, on the basis of the fire experts' evidence, that the fire test samples were not

534 NE (21 March 2017) at p 133 line 9.

535 Defendant's Closing Submissions at paras 323–325.

536 ABD 4C 1333 at para 40.

537 NE (31 March 2016) at p 66 lines 6–13, p 68 line 11 – p 69 line 8.

538 ABD 4C 1281 at para 43.2.

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delaminated at the time of their removal from the site. This was supported by a well-documented report prepared by one Mr Kettle in the arbitration, which contained photographic evidence of the fire test samples being prepared for transportation to the testing houses.[539] In my view, this contradicts Kalzip's allegation of widespread delamination.

Core sampling

235 During trial, Kalzip played a video showing core sampling of panels on 2 March 2010 ("the 2 March video").[540] The video showed samples being cored from the visual mock-up (a scaled representation of the podium roof finishes to demonstrate the quality of the GRP panels[541]), the MICE building upper roof section and the casino building upper roof. The video captures the following:

(a) Two samples were cored from panels 2 and 3 of the visual mock-up. These showed no delamination, although Mr Carter could be heard saying that the core sample from panel 3 might have been "a little lighter" than panel 2. Mr Carter then jumped on the panels from which they were cored and remarked that these panels bore no sign of delamination or change in structural integrity.

(b) One sample was cored from leaf 16, panel 5 of the MICE building roof. The inner skin of the sample was totally delaminated; the upper skin was not delaminated. The perimeter of the cored hole emitted crinkling sounds when stepped on.

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539 ABD 30L 21852–21936.

540 ABD M 130.

541 ABD 1B 43 at para 107.

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(c) One sample was cored from leaf 15, panel 9 of the MICE building roof. The panel had not delaminated and showed good resin saturation, but weighed 10.84kg/m^2 against the mock-up panel's weight of 14.76kg/m^2. The perimeter of the cored hole showed no delamination propagation.

(d) Three samples were cored from leaf 13, panel 13 of the casino building roof. The inner skin of one sample was totally delaminated. The inner skin of another was partly delaminated. The inner skin of the third sample was almost totally delaminated; it delaminated completely upon some prying by Mr Carter.

(e) One sample was cored from leaf 12, panel 7 of the casino building. It showed no delamination.

236 I note that Kalzip expressly disavows reliance on this video as evidence of delamination.[542] For completeness, I explain in this section why I would not, in any event, have considered it as evidence of delamination.

237 First, the very act of coring the panels could have induced the delamination. Kalzip's expert, Mr Green, acknowledged that improper coring could possibly initiate delamination.[543] He played a video in court which showed that it was possible for a good panel to delaminate if it was cored using a drill with a blunt whole saw, because the drill would have to be pressed so hard against the panel that it might cause the panel to distort and delaminate.[544] Mr Wymond explained that the core sampling exercise in this case involved coring

542 Plaintiff's Reply Submissions at para 270.

543 NE (30 March 2016) at p 78 line 25 – p 79 line 6, p 172 lines 21–24.

544 NE (29 March 2016) at p 204 line 21 – p 206 line 14.

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the panel at an angle, thereby inducing uneven loads to the inner skin, which could have resulted in a peeling failure of the core sample. Any pressure applied to the inner skin could "force it to separate from the honeycomb".[545] Mr Wymond pointed out from the video that, although the circular sample itself had totally delaminated, the perimeter of the cored hole in the panel showed no visible delamination, suggesting that the delamination occurred as a result of the coring exercise itself[546] and also that it was possible for delamination to occur as a result of improper coring while leaving the perimeter of the hole intact[547], for example if the central core is subject to torsions that do not occur to the outside of it[548]. Indeed, tests carried out by BFG at Kaskal on 16 February 2016 showed that a core sample could delaminate due to stresses induced through the coring operations, and that this did not equate to panel delamination.[549] Core sampling during the 2015 Tests also resulted in one core sample losing adhesion.[550]

238 Mr Maurieschat agreed with this analysis. In his view, core sampling using a hole saw induced excessive vibrations in the hollow honeycomb cells. The vibrations induced debonding between the honeycomb core and the inner skin.[551] A video of the coring exercise performed at Kaskal in February 2016 showed debonding occurring in the cells which had been broken by the saw.[552]

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545 ABD 3C 833 at para 123.

546 ABD 3C 833; ABD 4C 1325–1328; NE (30 March 2016) at p 175 line 22 – p 176 line 7.

547 NE (31 March 2016) at p 101 lines 12–14.

548 NE (31 March 2016) at p 121 lines 12–21.

549 ABD 4C 1329–1330.

550 ABD 3C 844 at para 163.

551 ABD 4C 1485 at para 15.

552 ABD 4C 1487.

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239 Indeed, Mr Rade and Mr Flook – who both attended the core sampling exercise – took the view that Kalzip's method of cutting would have damaged the panels and was an incorrect way of ascertaining delamination.[553] Mr Flook "could feel a lot of vibrations in the panel and could see that excessive force was being applied by the operatives to force the cutter through the panel", and that even after the cutter had passed through the aluminium honeycomb core, "force was again required to cut through the back face of the panel, demonstrating that the back face was indeed bonded to the aluminium core". Mr Rade observed that "excessive force was being applied to force a cutter through the panels".[554] I therefore do not consider the core sampling exercise as evidence that the panels had delaminated.

Delamination of the panels in storage

240 Kalzip states that the panels manufactured for installation on the theatre building, which were stored in its warehouse, also delaminated. It further argues that this shows that delamination must have occurred before installation.[555] I set out the evidence regarding the delamination of the panels in storage before explaining why I do not accept this as evidence of widespread delamination.

241 First, the letter from Arup to Aedas dated 19 May 2010 (see [228] above) also stated that "[t]he extent of delamination was mapped in March 2010 and it was found that panels for the theatre in storage were also delaminated".

242 Secondly, on 7 June 2010, Aedas and Arup conducted an inspection of the uninstalled theatre building panels stored in the Toll Warehouse. Arup e-

553 ABD 2B 340.

554 ABD 2B 319 at para 20; ABD 2B 340 at para 10.

555 Plaintiff's Closing Submissions at para 253; Plaintiff's Reply Submissions at paras 285–289.

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mailed MBS representatives on 7 June 2010 attaching photographs from an inspection at the warehouse which allegedly showed a delaminated theatre panel (leaf 11, panel 14) in storage.[556] Mr Wong also attended this inspection and deposed that "[t]he tested panels exhibited signs of delamination", but unfortunately did not state what "signs" these were and was not cross-examined about this.[557] (I note that he refers to this as the "7 June 2010 structural test" in his AEIC, but clarifies at para 47 that this was an "inspection" at the warehouse. This should not be confused with the 17 June 2010 *structural test* at [88] above.) Though Mr Wong's AEIC refers to delaminated *panels*, the e-mail from Arup only refers to *one* delaminated panel, namely, leaf 11 panel 14 of the theatre building.

243 Thirdly, Prof Nonhoff gave evidence that he observed delamination in panels stored vertically in stillages in the storage facility in Singapore in June 2010. He came to this conclusion based on a number of visual tests and lifting the panels, which showed a buckling deformation of the inner face clearly indicating that delamination had occurred. He claimed to have seen deformations of 1mm–2mm out of the vertical plate (by which he probably meant "plane").[558] His report included a photograph of an uninstalled panel, the bottom layer of which had completely delaminated when pulled by hand. Prof Nonhoff considered this to be evidence of delamination in that if the panel had been manufactured properly, it would have been impossible to delaminate it by hand.[559]

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556 ABD 12E 7884.

557 ABD 1B 86 at para 47.

558 ABD N 83 at para 5; NE (30 March 2016) at p 55 lines 2–5.

559 ABD 2C 570–571 at paras 14–15; NE (30 March 2016) at p 6 lines 2–8.

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244 I do not accept the foregoing as evidence that the GRP panels in storage suffered widespread delamination for the following reasons:

(a) Arup's letter to Aedas dated 19 May 2010 expressed reliance on Kalzip's own investigation in March 2010 (see [228]–[229] above). However, at that time, the view within Kalzip was that the sounds emitted by the panels were indicative of delamination. (Mr Wong would also likely have subscribed to this view.) I agree with Mr Wymond that any so-called delamination discovered in the panels could have been presumed by Kalzip on the basis of crunching or crinkling sounds, which did not necessarily signify delamination.[560] Since no representatives from Arup and Aedas gave evidence in these proceedings, it was impossible to know the basis of the letter, which could not be probed in cross-examination.

(b) Aedas' and Arup's inspection on 7 June 2010 also suffers from the same problem. In fact, the photographs of the panel appear to show people walking on the panel and marking out specific areas with tape, suggesting that the observation of "delamination" may have been based on sounds produced by the panel when walked on. Moreover, BFG submits that the photographs attached to Arup's email on 7 June 2010 do not show any inner skin delamination,[561] and I am indeed unable to identify any by sight. There are no photographs showing the delamination or of onsite personnel testing for delamination via other methods (for example, tap testing).[562]

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560 ABD 4C 1354 at para 125.

561 Defendant's Reply Submissions at para 72.

562 ABD 12E 7884–7930.

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(c) Prof Nonhoff's evidence is potentially the most persuasive evidence that delaminated panels were found among the theatre panels in storage. However, I regard his evidence with scepticism. A cored sample of one of the GRP panels was tendered in evidence and I observed that, as Mr Wymond and Mr Maurieschat said (see [162] above), the inner skin was not smooth but had a matted and uneven texture from the glass fibres. Moreover, the aluminium honeycomb was effectively sealed in by the two skins which formed a U-channel around the perimeter of the panel (see [46] above). Even if there was delamination between one of the skins and the honeycomb, this would not have resulted in the delaminated portion bulging out from the panel. In Mr Maurieschat's words, "because of, first of all, the stiffness of the inner layer, you won't see a bubble". Moreover, the Z-strips would have prevented small areas of delamination from propagating.[563] I therefore find it difficult to believe that Prof Nonhoff would have been able to spot tiny "buckling deformations" of 1mm–2mm purely by sight, much less when the panels were still in their stillages. The panels were stored vertically within the stillages. Photographs of the stillages show that the panels were packed very closely together, suggesting that it would have been difficult to get a clear transverse view of the surface of the panels within each stillage.[564]

(d) I also do not accept Prof Nonhoff's evidence that extensive delamination occurred. As BFG points out, no survey was done of the panels at the Toll Warehouse, BFG was never invited to inspect the allegedly delaminated panels, and there are no records of the number of

563 NE (1 April 2016) at p 202 line 22 – p 203 line 3.

564 ABD M 30, 88, 89 and 90.

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panels found to be delaminated.[565] No photographs were taken of the delamination or deformation of panels in storage, save one photograph of a panel with its inner skin separated. Prof Nonhoff asserted that this photograph "illustrates the inadequate bonding between the inner layer and the honeycomb core". However, this panel was *cut* and its inner skin *pulled apart by hand*. Prof Nonhoff conceded during trial that it was possible to delaminate even a properly manufactured panel by hand, just that it would require "a lot of force".[566] In the absence of measurement or documentation, it cannot be known how poor the adhesion between the honeycomb and the inner skin was. Moreover, he and Mr Wymond agreed that it was possible to pull the inner skin off a cored sample with both hands.[567] I also note Mr Wymond's and Mr Maurieschat's views that a peeling action would subject the inner skin to a load that it would not ordinarily have been subjected to.[568]

(e) Surprisingly, despite the large volume of correspondence sent by BFG, there does not appear to have been any correspondence about the delamination of the theatre panels in storage. One would have thought that efforts to map the extent of delamination onsite would have been paralleled by efforts to do the same for the panels in storage. This would be all the more so after February 2010, by which time BFG had stated more than once that the installed panels had been damaged by workmen. The theatre panels were kept in the warehouse until April 2011 and

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565 Defendant's Closing Submissions at paras 570–572.

566 NE (1 April 2016) at p 22 line 21 – p 23 line 7.

567 NE (30 March 2016) at p 78 lines 6–24; NE (1 April 2016) at p 27 line 21 – p 28 line 3.

568 ABD 4C 1493 at para 49; ABD 3C 837.

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> Kalzip has not explained the total absence of any documented investigation into or examination of delamination in those panels.[569]

Kalzip's conduct of the arbitration

245 BFG also makes the following points in its submissions:

> (a) Kalzip's position in these proceedings is "diametrically opposite" to the position it took in the arbitration with MBS and the correspondence preceding the arbitration.[570]
>
> (b) Kalzip has assembled a new cast of factual and expert witnesses for these proceedings (with the exception of Prof Nonhoff, who was one of Kalzip's witnesses in the arbitration), which suggests that it engaged in "expert-shopping". Besides changing its cast of expert witnesses since the arbitration, Kalzip also substituted two of the three experts it had appointed for this Suit in November 2015. BFG invites the court to draw an adverse inference from Kalzip's sudden decision to substitute its experts.[571]

246 I have not placed any weight on these arguments in coming to my decision on the issue of delamination. As regards the first argument, the correspondence and pleadings that BFG has brought to my attention do not appear to deny that delamination occurred. Kalzip's position was that the design of the GRP panels carried an inherent propensity to delaminate, and that MBS (rather than Kalzip) was to blame for choosing and approving that design.[572]

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569 Defendant's Closing Submissions at paras 569–571.

570 Defendant's Closing Submissions at paras 104–126.

571 Defendant's Closing Submissions at paras 127–143.

572 Defendant's Closing Submissions at paras 108, 114 and 122.1.

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Kalzip did, however, repeatedly accept that delamination had occurred, which is consistent with its position on this issue in the present proceedings.[573] Although Kalzip may have denied *liability* on BFG's part as a matter of law, I do not think that precludes Kalzip from taking the position in these proceedings that BFG was in breach of the Sub-Contract. Indeed that may very well be one reason that prompted Kalzip to reach a settlement with MBS in the arbitration.

247 As for the second argument, I decline to draw an adverse inference against Kalzip. The fact that Kalzip had changed its cast of factual and expert witnesses cannot, without more, logically ground the inference that delamination occurred; this is an issue of fact that remained to be tested by all the factual and expert evidence available before me. Moreover, the authorities cited by BFG in its submissions do not support the drawing of an adverse inference. They only suggest that, where the court becomes aware that expert shopping has occurred, it may make the admission of fresh expert evidence conditional upon disclosure of the previous expert's report.[574] Indeed, in this case, the statements of Kalzip's witnesses in the arbitration were all adduced in evidence. As for Kalzip's substitution of two of its witnesses in November 2015, BFG could have, but did not, raise this issue then.[575] Had BFG then been able to persuade the court that there were concerns of expert shopping, it would have been possible to order the disclosure of the reports prepared by Kalzip's two previously appointed witnesses (if any). However, no objection was raised at that stage and it would be inappropriate for me now to discount the evidence of Kalzip's present witnesses on a mere suspicion that Kalzip's substitution of witnesses was improper.

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573 Defendant's Closing Submissions at paras 122.1, 122.4, 122.7, and 122.8.

574 Defendant's Closing Submissions at paras 138–142.

575 Plaintiff's Reply Submissions at para 31.

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My conclusion on the presence and extent of delamination

248 In conclusion, I reject Kalzip's contention that there was "extensive delamination" onsite. The four site surveys, which were conducted on the premise that the crunching noises were proof of delamination, are not reliable proof of the existence or extent of delamination. As I have repeatedly noted above (see [15], [25], [102] and [221]), there is no primary evidence that the panels were delaminated when they were removed from the site. Even though Kalzip claimed that the panels were suffering from widespread delamination, there is no evidence of them removing specific panels for testing. Even after the panels were removed from the Project, they were stored in the Toll Warehouse. Kalzip had access to these panels and did in fact remove some of the theatre panels for the Winwall tests. (In fact, Kalzip claims damages for the costs of storing the theatre panels in the Toll Warehouse.[576]) Notwithstanding that it had access to the panels, Kalzip did not take photographs of the MICE or casino panels (either while being installed or removed) to prove that they had delaminated, or send them for testing to establish inner skin delamination.

249 The evidence of some delamination came from the following:

(a) Prof Nonhoff's observations during his June 2010 visit to the Project that some panels deformed underfoot, and photographic evidence of delamination in the panels which he cored (see [208]–[209] above). However, I have some doubts about the reliability of the evidence based on the coring exercise (see [210(c)] above). Moreover, only two panels were cored. Although Prof Nonhoff claimed that he saw deformations of large areas "on a lot of panels"[577] on both the casino and

576 Plaintiff's Closing Submissions at paras 544–553.

577 NE (30 March 2016) at p 5 lines 10–13.

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MICE building roofs, the precise panels were not identified or documented. I have also expressed my doubts and reservations regarding Prof Nonhoff's evidence.

(b) Mr Mackay and Prof Nonhoff experienced panels deflecting underfoot (see [211] above). No photographs were taken. There is no evidence of how many or which panels exhibited this behaviour beyond the two core samples which Prof Nonhoff obtained. Mr Mackay did not say how many panels deflected underfoot.

(c) BFG's internal correspondence in end January and February 2010 drew a distinction between the emission of sounds and the problem of delamination (see [206] above). Kalzip alleges that BFG concluded that delamination had occurred on both the casino and MICE building panels *for reasons other than the sounds which were heard*.

250 That *some* delamination occurred is supported by the view of BFG's own expert, Mr Wymond. Notwithstanding that there was in his view a "complete absence of reports and diagnosis to support a claim of systemic delamination", Mr Wymond took the view that "panel damage had occurred and *this would include panel delamination* due to mishandling, due to lifting, due to overloading of the panels, due to jumping on the panels and a combination of any one or more of these" [emphasis added].[578] He also stated in his rebuttal report that Kalzip's mistreatment of the panels "would have caused damage to [them] as observed through panels making crinkling and crunching sounds, which in isolated cases may have included localized delamination".[579] However, such delamination would not have occurred over spans exceeding 500mm, due

578 NE (29 March 2016) at p 209 line 18 – p 210 line 14.

579 ABD 4C 1322 at para 30.

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to the presence of Z stiffeners located at 500mm intervals connecting the top and inner skins.[580] As I noted at [162] and [210(d)] above, Prof Nonhoff and Mr Maurieschat also agreed that delamination occurred only in very localised and limited areas of the Project roofs.[581]

251 Given the dearth of direct evidence of delamination, it is not easy to determine exactly which and how many panels delaminated. An examination of the various e-mails sent by BFG only shows the following:

(a) On 7 December 2009, Mr Attwood wrote to others in BFG that Kalzip was aware of three panels with big areas of delamination (see [125] above). He must have been referring to the casino building, since installation on the MICE building had not yet begun.[582] I do not accept this as evidence of delamination. This was *reported by Kalzip*, probably on the basis of sounds heard on the panels, which I have found were not evidence of delamination.

(b) On 11 January 2010, Mr Attwood e-mailed others in BFG that there were "around 6 places where delamination [had] taken place between front top face and aluminium honeycomb" (see [127] above). However, as I have said, this e-mail appears to allude to *outer skin* delamination, which is not the subject of Kalzip's claim against BFG. Moreover, the six areas had been identified based on the presence of crunching sounds.[583] I therefore do not take this as evidence that six panels had inner skin delamination.

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580 ABD 3C 803 at para 2.5.5, 3C 812 at para 49.

581 NE (1 April 2016) at p 10 line 18 – p 11 line 2.

582 ABD 1B 16 at paras 31–33.

583 ABD 2B 299 at para 42.

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(c) On 18 January 2010, Mr Attwood repeated his report that there were six to seven places where delamination had occurred, the largest measuring around 700mm in diameter (see [129] above). Mr Attwood then said that this appeared to be a case of outer skin delamination, which is not in issue here, though he seemed unsure (see [130] above). The e-mails do not explain what these reports of delamination was based on, and I accept Mr Attwood's evidence that they were based on the noises coming from the panels (see [164] above). I therefore do not take this as evidence that six panels had inner skin delamination.

(d) On 20 January 2010, Mr Attwood e-mailed others in BFG, saying that Kalzip had informally informed BFG about delamination of some panels after installation. BFG had "informally carried out" an "inspection of the panels" and identified six delaminated panels "at the peripheral area" in patches of approximately 0.5m by 0.5m (see [133] above). Again, this was probably referring to the same six panels *and* based on the sounds coming from the panels. I do not take this as evidence that six panels had inner skin delamination.

(e) On 27 January 2010, Mr Attwood reported to others in BFG that there were 20 delaminated panels on the MICE building and a further eight delaminated panels on the casino building (see [138] and [139] above). Mr Attwood explained that this was based on the panels producing a crunching sound when walked upon, which he assumed was evidence of delamination. I therefore do not take this as evidence that these panels had inner skin delamination.

(f) On 29 January 2010, Mr Kolhatkar e-mailed Dr Samer that "it [was] reported" that about 20% of the GRP panels had delaminated in

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areas of under 1m^2. However, he expressed doubts about this conclusion, suggesting that there "may not be actual [delamination] but the sound of [aluminium honeycomb] during walking may be *giving an impression of a debond*" [emphasis added]. In fact, Kalzip was apparently unable to show Mr Premamoorthy "an actual incidence of the debonding" (see [140] above). Moreover, there is no evidence of how the 20% figure was derived and this was not put to Mr Kolhatkar during trial. I therefore do not take this as evidence that 20% of the panels had inner skin delamination.

(g) On 1 February 2010, the BFG inspection team went onsite to investigate the allegations of delamination.[584] That same day, Mr Attwood reported *inter alia* that there was inner skin delamination in small areas due to initial high point loads which were subsequently enlarged by foot traffic and heavy load forces due to installation of the panels (see [146] above). There was no indication of the extent of the inner skin delamination but reading his e-mail does not give the impression that it was widespread. I note that Kalzip's own site survey of the casino roof (which I have not accepted) only marked 50 out of some 350 horizontal roof panels with alleged delamination.

(h) On 2 February 2010, Mr Kolhatkar e-mailed Mr Carter and said that about 20 panels on the casino building had delaminated but that panels on the MICE building showed no delamination signs and only "metallic noise coming out of [the aluminium honeycomb]" (see [147] above). By this time, Mr Kolhatkar had rejected the hypothesis that the sounds coming from the panels were proof of delamination and so the 20 panels must have exhibited other signs of delamination (see [206]

584 ABD 10E 6128.

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above). BFG's report following the site inspection of 3 February 2010 likewise reiterated that 20 panels on the casino building exhibited delamination (see [148] above). These e-mails could be said to be some evidence that 20 panels on the casino building had delaminated. Why they had delaminated is another matter.

(i) I should add that, although Mr Kolhatkar also told Dr Samer on 8 February 2010 that 60 panels on the casino building had to be repaired[585], he was unable to explain what this figure was based on. That figure is not corroborated elsewhere. Mr Kolhatkar "[did not] have any reference on what was the criteria used by [his] site team to establish delamination" and had significant difficulty recalling how he had derived the figure or what objective evidence it was based on.[586] Nor is there evidence of such other signs of widespread delamination as would have caused BFG's representatives to conclude that 60 panels delaminated. That is nearly double the number of panels that were found to emit crunching sounds during the 6 February survey two days earlier.[587]

252 I therefore find that the delamination on the casino building was limited to 20 panels. This is on the basis of BFG's internal e-mails, which would have been based on the site investigations undertaken by its team of trained personnel. BFG's conclusion that 20 panels had delaminated was not based on the sounds being produced by the panels but on other phenomena, such as panels deflecting underfoot.

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585 ABD 10E 6259–6260; Plaintiff's Closing Submissions at para 265(f).

586 NE (29 March 2016) at p 102 lines 10–17, p 103 lines 11–16.

587 ABD 1I 9.

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253 On the other hand, there is no reliable evidence of the extent of delamination on the MICE building. Though Mr Attwood sent an e-mail on 27 January 2010 stating that there were 20 delaminated panels on the MICE building, this was based on panels which exhibited a crunching sound when walked upon (see [138] above). His e-mail to Mr Anand on 6 February 2010 – around the time that BFG's internal correspondence began distinguishing between the sounds emitted and delamination – does not mention any delamination on the MICE building. It refers only to the "large and uniform crinkling sound" on the MICE building, in contradistinction to delamination on the casino building. Mr Attwood stated that BFG had already found a solution to the delamination problem, but did not know what to do about the MICE panels – suggesting that the two problems were different.[588] Though there is an e-mail on 8 February 2010 from Mr Rade to Mr Kolhatkar which states that the MICE building panels have "patches of delamination" (see [150] above), Mr Kolhatkar's email to Dr Samer just over an hour later clearly distinguishes the "delamination" on the casino building from the "sound of crumbling ALHC inside the panels while walking on the panels" on the MICE building.[589] An e-mail from Mr Kolhatkar on 11 February 2010 records that BFG's position as of that date was that the casino building had delamination whereas the MICE building had merely the sound of aluminium honeycomb (see [152] above). I have also explained above why the evidence does not permit me to conclude that there was delamination on the panels in storage which were to be installed on the theatre building (see [244] above). Kalzip has therefore not discharged its burden of proving delamination on the MICE building or of the panels in storage on a balance of probabilities.

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588 ABD 10E 6212–6213.

589 ABD 10E 6259.

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254 I now turn to consider the cause of the delamination, if any.

Issue 3: Causation of delamination

Burden of proof in causation of delamination

255 Assuming delamination occurred, was it for BFG to prove that it had manufactured the panels properly and the delamination had been caused by Kalzip's mishandling, or for Kalzip to prove the converse? The parties take contrary positions on this issue.

256 Kalzip submits that the burden lies on BFG to establish, as a defence, that Kalzip mishandled the panels and caused them to delaminate. If it fails to do so, "it must follow that the only plausible explanation for the delamination is the defective manufacturing by BFG".[590] BFG, on the other hand, submits that "the legal burden is on Kalzip to prove that BFG's manufacturing process caused delamination". Only when Kalzip "discharges its evidential burden by logically demonstrating with the evidence that the manufacturing process is the *prima facie* likely cause of delamination" does the "tactical burden" then shift back to BFG to disprove this on a balance of probabilities.[591]

257 It is helpful to consider the approach of the Court of Appeal in the case of *Anti-Corrosion Pte Ltd v Berger Paints Singapore Pte Ltd and another appeal* [2012] 1 SLR 427 ("*Anti-Corrosion*"), which BFG cited. In that case, the respondent was a paint manufacturer who had supplied paint to the appellant, a subcontractor, for use in a building project. Various internal surfaces of the building which had been painted with that paint subsequently developed serious discolouration and the subcontractor had to repaint those

590 Plaintiff's Closing Submissions at paras 234–236.

591 Defendant's Closing Submissions at paras 405–406.

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areas. It sued the paint manufacturer for its losses. One of the main issues in dispute was whether latent defects in the paint supplied had caused the discolouration.

258 The Court of Appeal found that the legal burden was on the appellant sub-contractor to prove that defects in the paint or its unfitness led to its discolouration. It was common ground between the parties that there were only three possible causes of the discolouration: (1) defects in the paint's formulation, (2) the condition of the internal surfaces being painted and (3) poor workmanship in applying the paint. The subcontractor adduced sufficient evidence to eliminate surface conditions and poor workmanship as causes of the discolouration, leaving defects in the paint or its unfitness as the probable cause (at [37]). At this stage, "Once the evidence logically demonstrated that defective paint was *prima facie* the likely cause of the discolouration, the tactical burden shifted to the Respondent to show that this was not correct on a balance of probabilities." The manufacturer could, for example, have adduced evidence that no complaints were received from other customers in relation to paint sold from the same batches. However, it did not do so. The *prima facie* likelihood that the discolouration was caused by defective or unfit paint was therefore unrebutted. It was also "reinforced" by evidence from the subcontractor's expert witness. The Court of Appeal said of her evidence, at [36]:

> While [the appellant's expert] did not *irrefutably* prove scientifically that there were defects in the paint, she convincingly established that the discolouration was not caused by poor workmanship or the surface conditions and therefore *logically* proved by the process of elimination that defects in the paint or its unfitness were the root causes of the discolouration.
>
> [emphasis in original]

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259 The Court of Appeal therefore found that the paint discolouration was more likely than not caused by defects in the paint.

260 In this case, Kalzip clearly bears the *legal* burden of proving both that the panels delaminated and that they did so because of BFG's defective manufacturing. (This is similar to *Anti-Corrosion*, where the subcontractor likewise bore the legal burden of proving that defects in the paint or its unfitness caused its discolouration.) Both the fact of delamination and BFG's causation of the same are essential to Kalzip's claim for breach in contract (see s 103 of the Evidence Act (Cap 97, 1997 Rev Ed) ("the Evidence Act") and *SCT Technologies Pte Ltd v Western Copper Co Ltd* [2016] 1 SLR 1471 ("*SCT Technologies*") at [17]). If BFG manages to establish that the panels delaminated because of the way in which they were subsequently handled and stored, rather than because they were manufactured poorly, it will not have proved a "defence" as such, but rather will have *disproved an element of Kalzip's claim*. The legal burden of proving both the fact and cause of delamination therefore rests on Kalzip from start to end.

261 By contrast, the evidential burden to produce evidence, which is "not so much a burden of proof as it is a 'tactical initiative which must be taken by a party if he is to succeed'" [internal citations omitted] (*SCT Technologies* at [18]), may shift back and forth. The following passage from *Britestone Pte Ltd v Smith & Associates Far East, Ltd* [2007] 4 SLR(R) 855 at [60] eloquently articulates the interaction between these two concepts:

> To contextualise the above principles, at the start of the plaintiff's case, the legal burden of proving the existence of any relevant fact that the plaintiff must prove and the evidential burden of adducing some (not inherently incredible) evidence of the existence of such fact coincide. Upon adduction of that evidence, the evidential burden shifts to the defendant, as the case may be, to adduce some evidence in rebuttal. If no evidence

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> in rebuttal is adduced, the court may conclude from the evidence of the plaintiff that the legal burden is also discharged and making a finding on the fact against the defendant. If, on the other hand, evidence in rebuttal is adduced, the evidential burden shifts back to the plaintiff. If, ultimately, the evidential burden comes to rest on the defendant, the legal burden of proof of that relevant fact would have been discharged by the plaintiff. The legal burden of proof – a permanent and enduring burden – does not shift. A party who has the legal burden of proof on any issue must discharge it throughout. Sometimes, the legal burden is spoken of, inaccurately, as "shifting"; but what is truly meant is that another issue has been engaged, on which the opposite party bears the legal burden of proof.

262 In this case, I accept that if Kalzip proves as a fact that the panels had delaminated, the tactical burden shifts to BFG to produce evidence to show that the panels delaminated because of some action or error not attributable to BFG. BFG has identified various such acts, for example, Kalzip's failure to store the panels appropriately; its failure to put in place a proper installation process; using the panels as working platforms; and so on. If BFG fails to prove that any of these could have caused delamination, then by process of elimination it will be more likely than not that the panels delaminated because they were not manufactured to the requisite standard. It would not be reasonable to require Kalzip to *further* prove that it did not mishandle the panels in other ways not specified by BFG, since that would require it to prove a negative. It would also be inordinately onerous to require Kalzip to positively prove that the panels were manufactured defectively or pinpoint the stage of manufacture which went wrong, since the details and documentation of that process are firmly within BFG's knowledge and possession. If Kalzip adduces sufficient evidence to discredit BFG's allegations that Kalzip or some other party was responsible for the delamination, the tactical burden then falls on BFG to rebut the *prima facie* likelihood that it is to blame. This is again similar to *Anti-Corrosion*: once other causes of discolouration had been eliminated on the evidence, the tactical

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burden fell on the paint manufacturer to show that the paint was *not* defective or unfit.

BFG's explanation of the cause of delamination

263 Before I analyse the causation issue, I state for the avoidance of doubt that I have disregarded Prof Nonhoff's evidence on structural issues, such as the adequacy of the support rail system and whether it could have contributed to delamination, and the possibility of twisting and bending of the panels during installation.[592] Counsel for BFG took objection to these aspects of Prof Nonhoff's evidence because Prof Nonhoff was presented as a GRP expert, not a structural expert. Counsel for Kalzip accordingly confirmed that Kalzip was content to look to Mr Green as its structural expert and that the court might disregard Prof Nonhoff's evidence insofar as it related to structural issues.[593] I have therefore limited my consideration of Prof Nonhoff's evidence to the GRP panels alone, and not its supporting structures.

264 With that, I turn to consider BFG's allegation that Kalzip's acts caused the delamination.

Tests by Loxon

265 One of BFG's contentions is that delamination can only have occurred onsite as a result of mishandling, because the panels were certified not to be delaminated when they left the factory.

266 Kalzip appointed a third-party consultant, Loxon, to serve as its onsite quality control inspectors. Kalzip identifies Loxon as Loxon Wandset Inc

592 ABD 1C 38 at paras 67 and 70.

593 NE (1 April 2016) at p 89.

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whereas BFG identifies Loxon as Loxon Philippines Inc[594], but there is no dispute about the identity of the company and I refer to it as "Loxon". Three personnel from Loxon were based at BFG's Philippines factory; according to Mr Premamoorthy they were there "from time to time" but according to Mr Zeeyad they were there "throughout the entire manufacturing period".[595] After checks and inspections by BFG's quality control personnel during and after the manufacture of the GRP panels, Loxon carried out inspections and verifications of the panels' quality and signed off on quality control records. These included documents titled "quality control sheet", "visual check sheet for gelcoat side" and "visual check sheet for lamination side"; one of each of these documents was produced per panel. Mr Bridger confirmed that all the panels produced at BFG's factory were inspected by Loxon before shipping to Singapore and that Loxon carried out visual and dimensional inspections.[596]

267 After the panels were de-moulded, they would be visually inspected for any humps, protruding fibres, dry patches and/or signs of de-bonding. The Visual Check Sheet for Lamination Side prompted the inspector to check for delamination, without stating how this was to be done. Kalzip submits that the test was purely visual.[597] However, both Mr Premamoorthy and Mr Zeeyad stated that the "Visual Check Sheet for Lamination Side" required Loxon personnel to perform a tap test on the underside of the panel to check for delamination, although the document itself did not stipulate such a requirement.[598] This involved using a wooden mallet to tap the skin while

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594 Plaintiff's Closing Submissions at para 359; ABD 1B 11 at para 22; Defendant's Closing Submissions at p 9; ABD 2B 200, 224 and 361.

595 ABD 2B 361–362 at paras 25–27; ABD 2B 201 at para 10.

596 NE (16 March 2016) at p 25 lines 5–21.

597 Plaintiff's Closing Submissions at para 359; Plaintiff's Reply Submissions at paras 279, 352 and 387.

598 NE (23 March 2016) at p 21 line 9 – p 22 line 2, p 23 line 3, p 28 lines 2–6; NE (24

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listening for sounds that might indicate some hollowness, which could suggest a lack of bonding. This was the only way of identifying delamination, since it could not be observed visually.[599] Mr Zeeyad had witnessed such tests being performed while at the factory.[600] The details of this inspection were then recorded in the Visual Check Sheet for Lamination Side.[601] I accept Mr Premamoorthy's and Mr Zeeyad's evidence, and the quality control documents signed off on by Loxon, as proof that the panels were in good condition (including no delamination) at the time that they left BFG's factory. Loxon was an independent third-party inspector and there is no evidence that Loxon protested the quality of the panels or raised any objections about the manufacturing process.

268 That said, I do note that Kalzip's case is not that BFG breached the Sub-Contract by supplying delaminated panels. Its case is that BFG supplied panels which *deflected excessively* under the loads they were required to bear under the Sub-Contract.[602] Delamination is only relevant insofar as panels which delaminated would have breached the deflection limits of the Sub-Contract (see [99] above). To establish breach, it need not be shown that the panels had already delaminated by the time they left the factory. Provided there was no mishandling or misuse of the panels by Kalzip, it need only be shown that the panels delaminated onsite under loads which they ought to have been capable of bearing.

March 2016) at p 45 lines 16–23, p 48 lines 9–19.

599 NE (23 March 2016) at p 27 lines 12–14.

600 NE (23 March 2016) at p 40, lines 6–9.

601 ABD 2B 404 at para 97.

602 Plaintiff's Reply Submissions para 284.

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269 BFG submits that I should draw an adverse inference against Kalzip for not calling Loxon personnel to give evidence in the proceedings.[603] I decline to do so. It was *BFG*, not Kalzip, which relied on the Loxon check sheet to establish that delamination had only occurred after the panels left the factory. Moreover, given what I have said in the foregoing paragraphs, I do not consider that the outcome of the Loxon tests would make or break Kalzip's case, so there is nothing suspicious or unreasonable about Kalzip's decision not to call Loxon personnel as witnesses.

Alleged mishandling

270 I now turn to BFG's allegations of mishandling and misuse of the panels by Kalzip. First, BFG submits that Kalzip mishandled the panels in the following ways:

(a) by failing to store them appropriately onsite;

(b) by failing to put in place a proper installation process or system;

(c) by placing and/or storing heavy materials atop the panels; and

(d) by using the panels as working platforms for installation.

271 Mr Green's view was that BFG had simply not supplied any positive evidence to demonstrate that the delamination was caused by any mishandling or other wrongdoing on Kalzip's part.[604] Generally, he considered that there was no reason to believe that the panels which exhibited delamination had been treated or handled any differently to those which did not delaminate. Moreover,

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603 Defendant's Closing Submissions at paras 696 and 748; Defendant's Reply Submissions at para 150.

604 NE (29 March 2016) at p 197 lines 3–25.

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some of the panels in storage had delaminated despite never having been installed. From this he concluded that delamination could not have resulted from storage, handling and installation methods, but must have arisen from shortcomings in the manufacturing process.[605]

272 However, Mr Green acknowledged that his belief that the panels were all subject to an identical installation process was based purely on a documentary review, and was not based on actual onsite installation, which he did not witness.[606] He also agreed that, insofar as the manufacture of the panels was concerned, that was something that Prof Nonhoff would pursue, and not he himself.[607]

273 Mr Wymond's position regarding the alleged mishandling was that Kalzip had not supplied any evidence that it had not mishandled the panels. He did not positively assert that the GRP panels were damaged by mishandling, as "very limited information" was available in relation to panel installation. Other than photographs taken during the installation process, there was no evidence either way of correct or incorrect handling during installation or storage. For example, there were no procedures or records addressing worker access, fall arrest lines, material loads or manner of storage. However, Mr Wymond thought that the GRP panels could in theory have been damaged by "installation processes that are normally routine" due to their large size. His view was not that Kalzip had definitely caused delamination, but that Kalzip had not shown sufficient evidence to disprove that possibility: "Kalzip/Corus have not provided evidence that they handled the [GRP] panels in a manner that could guarantee that they did not damage the panels".[608] He thought it unlikely that

605 ABD 1C 148 at para 56; ABD 2C 591 at para 3.22.

606 NE (30 March 2016) at p 199 line 20 – p 200 line 2.

607 NE (30 March 2016) at p 200 lines 13–19.

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panel damage was attributable to BFG, since the panels which had left BFG's factory had all been checked for quality control.[609]

274 Given my foregoing remarks about the evidential burden, I do not agree with Mr Wymond's approach to the question of whether Kalzip mishandled the panels. The onus was on BFG to adduce evidence to prove that Kalzip had done so.

(1) Failing to store them appropriately onsite

275 Although BFG initially pleaded that Kalzip had failed to store the panels appropriately onsite, it no longer pursues this submission. The structural experts agreed that, if delamination had in fact occurred, the storage of the GRP panels was unlikely to have contributed to it.[610] Mr Wymond qualified this at trial by saying that this was only true insofar as the stillages were not damaged, whereas he believed that one stillage had been damaged.[611] However, Mr Wymond was unable to explain how this stillage was purportedly damaged and could not refer to any part of his report to substantiate this view. He therefore accepted that it would be reasonable for the court to proceed on the basis that the storage challenge was no longer a live issue.[612] I need therefore say no more of this allegation.

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608 ABD 3C 813 at paras 57–58.

609 ABD 3C 815 at para 69.

610 ABD 4C 1515 at para 6; ABD 4C 1356 at para 137; NE (29 March 2016) at p 199 lines 11–16.

611 NE (31 March 2016) at p 74 at lines 5–14.

612 NE (31 March 2016) at p 75 lines 18–23.

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(2) Failing to put in place a proper installation process or system

276 There were two aspects of the installation process or system which were alleged to be deficient: (1) the frame used by Kalzip to lift the panels out their stillages and onto the roofs for installation (referred to as the "lifting frame" or "handling jig"), and (2) the misalignment of the support rails and the Z-clips on the GRP panels.

(A) KALZIP'S LIFTING FRAME

277 BFG had advised Kalzip to lift the GRP panels using a truss assembly with lightweight angles measuring 35mm by 40mm. Instead, Kalzip used a different lifting frame which involved a longitudinal beam with outriggers. Kalzip's lifting frame had much heavier and more substantial steel sections with tubes which were 120mm long and 8mm thick, and 80mm square tubes.[613] Kalzip also increased the number of suction cups to be used to lift the panels, from 24 (recommended by BFG) to 36 or 42 (depending on the size of panel).

278 BFG contends that Kalzip's handling jig design would have resulted in the panels delaminating due to twisting, and that Kalzip failed to advise and/or inform BFG about the handling jig proposed to be used for installation.[614] Mr Wong, who was involved in calculating the requisite forces required by the handling jig to lift the panels for installation, did not check if the panels would twist.[615] He conceded that an additional steel pipe, which BFG had provided in its design, would have been more rigid and less prone to twist.[616] In Mr Wymond's view, the GRP panels would "likely" have been damaged by

613 NE (29 March 2016) at p 198 lines 3–11.

614 ABD A 47–48 at paras 17.3 and 34.4.

615 ABD 1B 88; NE (16 March 2016) at p 62 lines 14–19.

616 NE (16 March 2016) at p 66 line 7 – p 67 line 16.

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Kalzip's design.[617] He thought that the GRP panels would have bent or twisted while being lifted due to unbalanced loading and movement of the lifting frame to accommodate the slope of the roof. There appeared to be some leeway for twisting given the gap of about 4mm between the 120mm-by-8mm box tube of the main section of the lifting frame and the 100mm-by-10mm arms extending laterally from it.[618] However, no calculations or tests were undertaken to verify the torsional stiffness of the Kalzip lifting frame.[619] Indeed, the experts agreed that there was insufficient information to assess the rigidity of the lifting frame in use.[620] This led Mr Wymond to take the position that Kalzip was unable to prove that it had *not* damaged the panels during lifting.[621]

279 Mr Green accepted that the truss design proposed by BFG would have been "marginally stiffer" than the beam design used by Kalzip and agreed that a sufficiently large twist could cause delamination, but did not think there was sufficient evidence that such a twist had in fact occurred,[622] though he also agreed that he could not reasonably rule out twisting merely from the three photographs of site lifting activity he had seen.[623] He considered that Kalzip's handling jig would have provided adequate stiffness and support. Moreover, whilst the handling jig was lifting the panel vertically, the difference in design between the two jigs would have made no difference to its ability to resist twisting; it was only when the panel was moved to a horizontal position that the panel design would introduce a risk of twisting. Even then, any increase in the

617 ABD 3C 813 at para 57.

618 NE (30 March 2016) at p 142 lines 1–19.

619 ABD 3C 827–828.

620 ABD 4C 1515 at para 7.

621 ABD 4C 1348 at para 90.

622 NE (30 March 2016) at p 146 lines 23 – p 147 line 2.

623 NE (30 March 2016) at p 149 line 10 – p 150 line 7.

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panels' twisting and bending as a result of Kalzip's handling jig would have been negligible. Mr Green considered it "impossible" for such movements to have damaged the GRP panels.[624] He also remarked, in passing, that he would have expected such twisting to affect the top panel as much as the bottom panel if not more so, since it was the top panel that was connected to the lifting jig.[625] That remark was answered by Mr Wymond, who pointed out that the resin bonded the aluminium honeycomb to the top layer much more strongly than to the bottom layer, as shown by Mr Maurieschat's shear testing, and so it was the bottom layer that was more vulnerable.[626]

280 Mr Wymond also relied on a finite element analysis, or sensitivity analysis, performed by Mr Kolhatkar and Mr Rade[627], which showed that *if* the panels were caused to twist by around 2°, that would induce shear stresses in excess of those which the panels were contractually required to bear.[628] However, this merely showed what would happen *if* the lifting frame were to twist. There was no basis for Mr Wymond to conclude that such twisting had in fact happened on the site.[629] Indeed, Mr Wymond agreed that his "investigations did and could not have allowed [him] to conclude that damage actually arose".[630]

281 I do not find that Kalzip's handling jig caused delamination in the GRP panels. The experts could only say that it was possible for twisting to cause the panels to delaminate; they were unable to establish that twisting occurred. Nor

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624 ABD 1C 151 at para 75.

625 NE (30 March 2016) at p 139 lines 17–24.

626 NE (30 March 2016) at p 145 lines 1–10.

627 NE (31 March 2016) at p 179, lines 13–20.

628 ABD 4C 1453–1455.

629 NE (31 March 2016) at p 171 lines 10–13; p 187 lines 20–24.

630 NE (31 March 2016) at p 163 lines 12–15.

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was this suggested by the factual witnesses. Mr Mackay gave evidence that he was on site to supervise the installation of the GRP panels, and that "[t]he panels did not exhibit any signs of delamination or twisting / bending during this installation process".[631] He witnessed at least about 70–80% of the panels being installed, since he was only absent during night lifting.[632] Mr Attwood likewise testified that he observed installation of the panels around mid to late November 2009 and that the installation proceeded smoothly and no complaints on the panels were brought to his attention.[633] Admittedly, the 29mm difference that Mr Wymond said would result from a twist of two degrees[634] may not have been easily observable. Nevertheless, there is no evidence at all that such twisting happened. In fact, as early as 9 December 2009, Mr Attwood was concerned that the lifting jigs was damaging the panels and said he would "try to establish" if this was so[635], but he did not adduce any evidence at trial that this was the case. Mr Green pointed out that the jig was used for all panels, yet only some suffered delamination.[636] That might well be because only some, and not all, panels were subject to such twisting. Nonetheless, on balance, I do not find that Kalzip's lifting frame resulted in delamination.

(B) MISALIGNMENT OF THE SUPPORT RAILS AND Z-CLIPS

282 Mr Green's and Mr Wymond's list of agreed issues stated, "The panels relied on aligning 60 clips approximately to be aligned and installed at the same time, the impact of any potential misalignment is unknown."[637] Mr Wymond

631 ABD 1B 19 at para 40.

632 NE (22 March 2016) at p 40 lines 2–3, p 165 lines 17–22.

633 ABD 2B 298 at para 38.

634 NE (31 March 2016) at p 170 lines 10–15.

635 ABD 9E 5841.

636 ABD 2C 594 at para 3.39.

637 ABD 2C 604 at para 10.

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explained that the rail system relied on straight sections of track being fixed to the flexible GRP panels so that the rails provided a level line of support for the panel clips to lock onto. The misalignment of clips would have led to uneven load sharing and to forces being induced between sets of misaligned clips.[638]

283 However, there is no evidence of such misalignment or complaints of this nature. BFG relies on a photograph which allegedly shows one worker "hammering" a Z-clip into place.[639] Mr Wymond's view was that this would have caused structural damage and resulted in excessive panel stresses not contemplated by the original design.[640] Mr Green disagrees. The photograph does show a panel being held about four feet above a surface by the jig and a worker with a hammer in or almost in contact with a tool in his right hand. That tool is likely to be a screwdriver or chisel-like implement. The other end of that tool is not very clear in the photograph but it is certainly directed to a point under the panel and at the location of one of the underside panel clips which attach the panel to the rails. However, from one still photograph, I cannot safely conclude that the clip was being forced with a hammer; it is equally possible that the worker was using it to tap rather than force an object into place.[641] If indeed force was being used I would expect to see others holding the panel to keep it from swinging with each blow but I do not see this. There was no explanation of what the worker was doing or why. I therefore do not accept that there was a problem of alignment.

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638 ABD 3C 824–825 at paras 103–105.

639 Defendant's Closing Submissions at para 653.

640 ABD 3C 804 at para 2.6.3; ABD 3C 829 at para 114; ABD 4C 1348; ABD 4C 1356 at para 139.

641 ABD 2C 595 at para 3.40.

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(3) Placing and/or storing heavy materials atop the panels

284 The third allegation of mishandling is that Kalzip placed and/or stored heavy materials atop the panels, and that these loads caused them to delaminate. For example, BFG alleges that the sub-frame for the GRP panels, the lifting jig for the GRP panels, bags of acid and a pressure washer were placed on the roof. Kalzip denies that these items were placed on the roof, and adds that even if they were, their weight would not have exceeded the loading requirements in the Sub-Contract.[642]

285 I find as a matter of fact that materials were placed and stored on top of the panels. In fact, Mr Mackay gave evidence that these items "are materials commonly seen during the installation [phase] at any construction site".[643] This is supported by the contemporaneous correspondence as well as site photographs:

(a) On 2 February 2010, Mr Kolhatkar e-mailed Mr Carter telling him that there were "several incidences" of the panels being used as "storage place for scaffolding panels" (see [147] above).

(b) On 8 February 2010, Mr Kolhatkar wrote to Dr Samer stating, "There are delamination in the panels where the panels have been used in excess of the design loads, like jumping on the panels from a height and also *use of panels as storage places for scaffolding* and as access walkways."[644] [emphasis added]

642 ABD 1B 37–39.

643 ABD 1B 37 at para 93.

644 ABD 10E 6259.

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(c) On 1 March 2010, Mr Kolhatkar wrote to Mr Carter stating that the panels had been used "as heavy traffic walkways *and storage areas* completely exceeding the specified loads on the panels" [emphasis added].[645] Mr Carter's reply does not deny that the panels were being used in such a way.[646]

(d) A photograph taken of the MICE building roof during construction shows that there were some box-shaped objects sitting on the panels in front of a tower crane. Mr Wymond described these as "crane boxes and building materials".[647] Another photograph taken of the roof shows more square-shaped materials sitting on installed panels along the border next to the adjacent bay.[648] A third photograph shows what BFG describes as "various items strewn across a GRP panel on the roof".[649]

286 There was, unfortunately, no evidence of what the materials depicted in the photographs were, how much they weighed, how long they were placed on the panels, or whether they would have caused the panels to delaminate.[650] One of these photographs was simply downloaded by Mr Wymond from the Internet.[651] It was understandably difficult for BFG to identify the materials being stored on the panels since BFG merely supplied the panels and was not involved in their installation or removal. However, it is clear that these

645 ABD 10E 6526.3.

646 ABD 10E 6526.2.

647 ABD 3C 829; ABD N 131.

648 ABD 4C 1339, photo 8.1.3.

649 ABD M 45; Defendant's Closing Submissions at para 661.

650 Defendant's Closing Submissions at paras 658–661; ABD 3C 829; ABD 4C 1339; ABD M 45.

651 Defendant's Closing Submissions at para 664.

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photographs were taken while the GRP panels were being installed, and they self-evidently show materials being placed on the panels. It is also worth noting that the Aedas report of 22 January 2010 contains the following notation at photograph 4.03: "The GRP panel surfaces have numerous markings, some have scratches and dents." A similar caption appears for photograph 4.06. Photograph 4.24 has the notation: "The GRP panel surfaces are marked with numerous scratches, dents, rust, paint, chips, glass sucker and foot prints." These remarks were recorded in an e-mail.[652] I am therefore unable to eliminate the possibility that the materials which were placed on the panels exerted loads upon them which they were not designed to withstand.

287 Mr Mackay made the counter-argument that a significant amount of delamination was recorded on the lower panels (*ie*, panel 10 onwards on most leaves), where the curvature was nearly 30°. It would have been impossible to store items there without them sliding off.[653] However, this is based on the four site surveys, which, for the reasons given above, I do not accept as evidence of delamination.

(4) Using the panels as working platforms for installation

288 BFG also complains that Kalzip inappropriately used the GRP panels as working platforms for installation.[654] The essence of this complaint is that Kalzip subjected the GRP panels to loads which they were never designed to bear, either as a result of placing items on them (regarding which see the preceding section) or as a result of persons walking on them (regarding which see [294]–[310] below).

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652 ABD N 90–100, 109.

653 ABD 1B 39 at para 93(f).

654 Defendant's Closing Submissions at paras 574–583.

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Defective design of the support rail system

289 The GRP panels were connected to the roof via three supporting rails running in the longitudinal direction of the panels. The rails were clamped without penetration to the Kalzip standing seam roof.[655] BFG contends that the support rail system designed and supplied by Kalzip was inadequate and caused the GRP panels to delaminate.[656]

290 Mr Wymond considered that the support rail system was dissatisfactory in that:[657]

(a) the rail top flange was too thin to carry the wind uplift from the GRP panel, as a result of which the clips disengaged from the rail flanges during testing of the mock-up by Winwall;

(b) excessive rail twisting and deformation was observed in the Winwall tests, indicating that the connection between the support rail system and the panel clips was structurally unsound; and

(c) there was misalignment between the panel clips and the support rails, as a result of which panels were forced onto the rails, which caused damage to the panel connections.

291 The structural experts were able to agree substantially on this issue:

(a) They both agreed that the GRP panels could not withstand design wind conditions. Mr Wymond stated that under conditions of maximum wind loading, the cladding support section would be unable to support

655 ABD 1C 99 at para 5.

656 ABD A 47 at para 34.2.

657 ABD 3C 813 at para 55.

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the panel edges correctly. Mr Green agreed with Mr Wymond that *if* the rail were subjected to the maximum (*ie*, design) wind uplift, this would overstress the rail and result in structural failure by bending. It did not have "enough Z or section properties to withstand the forces at maximum wind load".[658]

(b) The experts also both agreed that the rails were never *in fact* exposed to design wind conditions. Mr Green observed that the maximum wind speed in Singapore between 25 November 2009 and 31 March 2010 was 14.8 metres per second ("m/sec"), far below the basic wind speed of 33m/sec on which the maximum wind load was based. A wind speed of 14.8m/sec would have corresponded to a wind load only about 20% of the maximum design load of 2 kPa. According to Mr Green, the rail performed satisfactorily at this level and even up to 35% of the maximum design wind load.[659] Mr Wymond also stated in his expert report that there were "no significant wind events during the construction period when the [GRP] panels were installed".[660] Moreover, a set of four video clips showing rotation of the support rail did not reveal any panel delamination, suggesting that rotational movement of the support rail did not contribute to the delamination of panels onsite.[661]

(c) Both experts agreed that, *if* the GRP panels had indeed delaminated, that delamination would not have been caused by the support rail.[662]

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658 NE (30 March 2016) at p 106 lines 1–7, p 117 lines 17–25; NE (31 March 2016) at p 51 line 19 – p 52 line 7.

659 ABD 2C 592 at paras 3.29–3.30; ABD 2C 594 at para 3.35.2.

660 ABD 3C 826 at para 108.

661 ABD 2C 601 at para 3.75.

662 NE (30 March 2016) at p 117 line 25 – p 118 line 7.

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292 Given the experts' consensus that the support rails could not have contributed to delamination, I do not see any reason to find otherwise.

Incomplete specifications

293 BFG also pleaded that Kalzip had provided incomplete specifications in the Sub-Contract in that the specifications "failed to take into account all the loads from the installation perspective".[663] This was not mentioned as a separate defence in BFG's closing submissions and received barely any attention in BFG's reply submissions. BFG's argument is simply that the GRP panels delaminated because they were walked on during installation and Kalzip's four site surveys.[664] I therefore turn to the allegations of walking and jumping.

Walking and jumping on panels

294 There are two issues here: first, whether the panels were in fact walked and/or jumped upon; and secondly, whether that walking and/or jumping caused delamination.

(1) Whether the panels were walked and jumped on

295 Mr Mackay gave evidence that the GRP panels experienced very limited footfall and no jumping, for the following reasons:

(a) Uncompleted portions of the roof were generally accessed directly through the clerestory, and not over the installed GRP panels. This was both safer and easier.[665]

663 ABD A 47 at para 34.3.

664 Defendant's Reply Submissions at para 188.

665 ABD 1B 25 at para 59.

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(b) The lower panels on leaves 7 to 16 were at an incline of nearly 30°. Since rope harnesses were necessary, very few people were on these panels at the same time.[666]

(c) The height difference between the upper level GRP panels of a higher leaf and the upper panels of a lower leaf was approximately 0.8m. At this height, one would step (rather than jump) from the upper GRP panel to the lower GRP panel.[667] That said, the height difference varied from about 800mm to 1.8m.[668]

(d) Kalzip had strict safety regulations in place in the Project which required Kalzip and JRP safety officers to be onsite throughout installation. Nobody was permitted to jump off GRP panels. There were also access ropes if anybody needed to move between leaves.[669]

296 Having said that, it was not denied that the panels were in fact walked upon. Mr Mackay himself had walked on them while wearing safety gear and with a harness.[670] He also acknowledged that the workers would have to step on installed panels in the process of installing a new panel, though he said that in that case they would not be bunched up together in one spot but there would be four or five workers spread out along each side of the panel being installed, which would be 10–14m long.[671] Mr Attwood "observed personnel using the panels as walkways during installation onsite".[672] Mr Premamoorthy also gave

666 ABD 1B 25 at para 59.

667 ABD 1B 29 at para 71(a).

668 NE (22 March 2016) at p 88 lines 9–11.

669 ABD 1B 30 at para 72.

670 NE (22 March 2016) at p 48 lines 16–20.

671 NE (22 March 2016) at p 82 line 7 – p 83 line 13.

672 ABD 2B 299 at para 43.

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evidence that "many of the workmen at the MBS Project site were walking all over the GRP panels which had been installed" during his visit to the site on or around 13 January 2010, and as many as three to six men were standing on a single panel at a time.[673] Mr Zeeyad likewise stated that during his visits to the MBS project site in July–September and October–December 2010, he "had often seen workers traversing across the panels" and "jumping on the panels".[674] Mr Flook stated that during the core sampling exercise on 2 March 2010, "there were at least 12 people on any one or two panels at one time", and he and Mr Mackay both recalled Mr Carter jumping on the panels to see if any sounds came from them.[675] That the panels were being routinely walked upon – even on areas which were significantly sloping, which workers could comfortably access with a harness and rope support – is also supported by ample evidence (see [131], [138], [145], [147], and [209] above) and photographs.[676] The 2 March video also includes a clip of a worker walking on the panels.

297 As for jumping, Mr Attwood and Mr Mackay testified that they had not seen any jumping onsite.[677] I do not accept that. There was video footage of Mr Carter jumping on the GRP panels during the core sampling exercise on 2 March 2010. There was also other evidence of jumping, both as means of identifying delamination[678] (see, *eg*, [145] and [157] above) and as a means of navigating between panels during installation (see, *eg*, [147] and [285(b)] above). An e-mail sent by Mr Kolhatkar to Mr Carter on 1 March 2010 attached a video

673 ABD 2B 421 at para 136.

674 ABD 2B 213 at para 54.

675 ABD 2B 318 at para 20; NE (22 March 2016) at p 86 line 25 – p 87 line 8.

676 ABD M 43, 44, 46, 47 and 52.

677 NE (22 March 2016) at p 89 lines 22–23; NE (28 March 2016) at p 73 line 19 – p 74 line 10.

678 ABD 2B 422 at para 137.

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which, in Mr Kolhatkar's words, "clearly shows that people are jumping of[f] the panels[,] completely damaging the panels" and asserting that the panels "have been used as heavy traffic walkways and storage areas completely exceeding the specified loads on the panels".[679] Mr Carter replied to say that the video depicted one Kalzip representative who weighed 104kg replicating load testing on the panel, but did not dispute that the video showed the panel being jumped on.[680] I have also referred elsewhere to the Aedas report of 22 January 2010 and the photographic record and notations which clearly evidence this (see, *eg*, [286]). I thus accept that the GRP panels were walked and to a lesser extent jumped upon. I now turn to whether this activity could have caused them to delaminate.

(2) Whether walking and jumping could have caused delamination

298 Mr Wymond stated in his expert report that the workers walking over the panels would have subjected the panels to "a range of live loads and other construction related loads that have caused or exacerbated any defects in the panels".[681] In particular, panel damage or failure could be attributed to walking on the panels in such a way as to place them under loads exceeding those which they were required to bear under the Sub-Contract, namely: (1) superimposed loading from workers and materials, (2) toe pressing on panels, (3) heel pressing on panels and (4) jumping on panels.[682] His reasons were as follows:

(a) The crunching sounds were not distributed randomly. On the upper roof of the MICE building, for example, no crunching sounds

679 ABD 10E 6526.3.

680 ABD 10E 6526.2.

681 ABD 3C 870 at para 328.

682 ABD 4C 1347 at para 86.

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were detected on any of the panels in Bay 9. This could be explained by factors such as access constraints and installation sequence.[683]

(b) One video showed three workers standing next to each other. If each worker weighed approximately 80kg, that would have resulted in a local load of approximately 240kg (or 2.35 kN) over an area of approximately 1m^2.[684] In Mr Wymond's view, they were "a lot closer together than would be allowed by the 0.75 kPa loading requirement" and would have exerted a force between them "well in excess of 1.1kN". While he acknowledged that the three men did not fit within a circular area 150mm in diameter, he thought that each of them might potentially be exerting a load of that magnitude, and there would be an influence because they were standing so close together.[685]

(c) According to Mr Wymond, the 2 March video showed the workers doing a heel press or toe press on the panels. A finite element analysis performed by Mr Kolhatkar and Mr Rade showed that a toe press over a contact area of 80mm by 60mm would impose an in-plane shear stress of 13.55 MPa, while a heel press over a contact area of 70mm by 30mm would impose an in-plane shear stress of 19.16 MPa. By contrast, the Sub-Contract provided for a static load of 1.1 kN applied on a circular area 150mm in diameter, which would produce a stress of 8.267 MPa.[686]

299 In Mr Green's view, walking on the panels could not have caused delamination, for the following reasons:

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683 ABD 3C 831 at para 121; ABD 4C 1355 at para 128.

684 ABD 4C 1338 at para 57.

685 NE (30 March 2016) at p 166 lines 15–21; p 166 line 23 – p 177 line 1.

686 ABD 4C 1340.

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(a) Mr Green said that he had not seen more than five or six people distributed across a panel. It was difficult for him to understand how people walking on the panels could have caused delamination.[687] The 2015 Tests showed that properly manufactured panels could be walked on, and could support loads of between 1100 N and 2087 N, without delaminating.[688] Even having 10 people walk up and down a single panel in a line, as Mr Rade observed, would not have caused delamination. A line of 10 people would have their individual loads evenly spread, and it was unlikely that any individual would exert a load exceeding the design point load of 1.1 kN.[689]

(b) The very nature of the roof design meant that the panels had to be installed progressively; once each row of panels was installed, they would have had to be traversed in order to install the next row. Specification Revision C therefore required the trafficable areas of the panels to be capable of bearing maintenance loads (including person loadings and indirect loads from abseiling ropes) as well as live loads and wind loads. Indeed, BFG itself had undertaken tests to determine the effect of walking on the panels. During a static load test conducted on 24 November 2008, the test sample remained intact when walked on by a person weighing 112kg (see [73] above), showing that a correctly made panel would be capable of bearing that load without delaminating.[690] Moreover, while BFG had not been told which panels would be walked on for maintenance access, Mr Kolhatkar had

687 NE (29 March 2016) at p 200 lines 12–17.

688 ABD 2C 598 at para 3.62.

689 ABD 1C 145–146.

690 ABD 1C 145–146.

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discussed giving the panels antiskid qualities to increase the safety of maintenance personnel.[691]

(c) Some panels installed on the steepest part of the curved roof, which could not have been walked or jumped on, were also found to have delaminated (for example, sections of the roof where the panels were mounted at a 30° angle).[692] (I note, however, that this was based on the site surveys, which I do not accept as evidence of the extent of delamination.)

300 In Mr Green's view, while it was theoretically possible that using the panels as working platforms may have exacerbated an underlying failure, it would not have caused the panels to fail had they been manufactured with adequate strength.[693]

301 Mr Wymond disagreed that the panels were designed in the knowledge that they would be walked on. He thought that Kalzip need not have installed the panels in such a way that the workers were forced to traverse them to install each adjacent row; they could have started at the far end and worked their way inwards instead. There was in fact a photograph showing one panel being installed from the bottom up.[694] Alternatively, if it was necessary to traverse the panels, Kalzip could have installed a protective walkway.[695]However, Mr Mackay gave evidence that it would have been extremely difficult if not impossible for the panels to be installed in the reverse order because of the

691 Defendant's Closing Submissions at para 575; ABD 1C 148 at para 57.

692 ABD 1C 147 at para 53; ABD 2C 590 at para 3.17.

693 ABD 1C 147 at para 55; ABD 1C 148 at para 59.1.

694 ABD 3C 871 at paras 330–331; NE (31 March 2016) at p 149 lines 21–23.

695 ABD 4C 1353 at para 111.

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positioning of the scaffolding. It also made sense to install the lower panels last because, if they had to be redesigned or re-installed, they could be accessed via a small crane rather than a massive tower crane.[696] But even if that was so, there was no evidence before me that BFG *knew that* the panels would be installed in such a way that installed panels would have to be walked on for the purposes of installing each subsequent panel.

302 I recognise that Specification Revision C clearly contemplates people walking on the panels for maintenance purposes, and required the panels to be able to bear a point load of 110kg over a circular area 150mm in diameter. It appears that Kalzip and BFG were both aware that the panels would have to be able to be walked on. E-mails from Kalzip to BFG in 2008 record that Kalzip was to identify certain panels which maintenance personnel would have to walk on for maintenance access, and that BFG would apply an antiskid finish to those panels.[697] Although Kalzip did not eventually identify those panels, the fact remains that both parties were aware that the panels would be walked on.[698] Prof Nonhoff took the view that if the GRP panels had been manufactured with the capacity to bear the design loads specified in the Sub-Contract, it was impossible for any loads exerted upon the panels by walking, handling or storing things on the panels during installation to have caused delamination.[699]

303 That said, I accept that walking could have caused delamination in the panels, for the following reasons. Specification Revision C states that "only" the loads stated in Annexure 2 (see [51] above) need be considered in the design of the panels. I understand this to mean that, while it was expected that the

696 ABD 1B 20 at paras 42–43.

697 ABD 2B 251–252 at paras 94–97.

698 ABD 13E 8300, note 10.2; ABD 1B 26 at para 60.

699 ABD 1C 37 at para 62.

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panels would have to be walked upon, they were not expected to bear a load in excess of 0.75 kPa or of 1.1 kN over a circular area 150mm in diameter. In this regard, I note that BFG did warn Kalzip not to walk on the panels, and discussed the problem of walking and jumping internally:

(a) On 18 January 2010, Mr Attwood wrote to Mr Carter that:[700]

> BFG strongly recommend that all panels on site suffering from delamination are identified and protected with plastic and plywood on top in order to halt the ongoing damage being cause[d] by foot traffic in those are[a]s in particular the end areas nearest the vertical walls.
>
> Particular attention should be paid to avoid point loading during the installation of the edge trim panels, plywood should be used in these areas during this install as significant force is being used to force the edge trim panel curved top edge into the roof panels which are in most cases flatter.

Mr Carter replied on the same day, assuring Mr Attwood that Kalzip would arrange for plywood to be installed. This suggests that Kalzip accepted the possibility of damage to the panels as a result of foot traffic.[701]

(b) On 20 January 2010 (see [131] above), Mr Attwood wrote to Mr Carter that the panels were "being used as walkways", which was an "unusual working condition for the panels", which were "designed for occasional 1 man walking on the panels with a load spreader like a 2.4 x 1.3 m sheet of 25 mm plywood placed on the top of panels", and suggested that "Kalzip immediately stop use of installed panels as walkways to stop any further delamination of panels".[702]

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700 ABD 10E 6045.

701 ABD 10E 6045.

702 ABD 10E 6080.

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(c) On 21 January 2010, Mr Kolhatkar wrote to Mr Carter recommending that plywood spreaders be used if Kalzip intended to use the panels as walkways for the purpose of installation, as this was "not a maintenance load" and "exceed[ed] the limits of the load specification" in the Sub-Contract.[703] There is photographic evidence that Kalzip *did* use plywood spreaders[704], although there is no evidence how widely these were used.

(d) On 29 January 2010, Mr Kolhatkar e-mailed Dr Samer saying that one potential cause of delamination was that "[t]he panels, once installed, being used as walkable surface by site personnel is putting excessive deformations, causing the bottom skin to delami[n]ate".[705] On 8 February 2010, he again wrote to Dr Samer stating, "There are delamination in the panels where the panels have been used in excess of the design loads, like jumping on the panels from a height and also use of panels as storage places for scaffolding and as access walkways."[706]

(e) On 1 February 2010, Mr Attwood e-mailed others in BFG (see [146] above) stating that the casino roof had been subjected to "high [point] loads resulting in delamination".

(f) On 27 February 2010, Mr Kolhatkar wrote to Mr Carter that BFG's "preliminary assessment" of the problem following a joint survey of the site was that the "excessive handling and post installation loads were presented on the panel[s]", and that the "intended maintenance load

703 ABD 10E 6164.

704 Defendant's Closing Submissions at para 580.

705 ABD 10E 6127.

706 ABD 10E 6259.

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specified [had been] heavily exceeded as [the panels were] used as walkways during installation".[707]

(g) On 3 March 2010, Mr Kolhatkar wrote to Mr Carter that Kalzip and BFG were disagreed on the cause of delamination. According to Kalzip, the panels delaminated before delivery. According to BFG, "panels are delaminated in post delivery handling and usage".[708] On 7 March 2010, Mr Kolhatkar wrote to Dr Samer that "[b]oth [Kalzip] and MBS know that there has been blatant misuse of panels as walkways and panels have been excessively loaded".[709]

(h) BFG also referred to an e-mail from Mr Attwood to Mr Carter on 2 September 2009, but that e-mail appears to have warned Kalzip about walking *with* the panels in hand and not about walking *on* them.[710] The e-mail subject is "MBS handling proposal" and the text of the e-mail discusses MBS' "plan to walk the panels on the roof". This involved walking "with the panels in a horizontal position … the panels will not survive any shock loadings that would occur *if those handling the panel were to* [*falter*]" [emphasis added]. It is clear to me that the e-mail is about how the panels would be transported onto the roof in Singapore, and not about people walking on the panels.

304 I am persuaded on a balance of probabilities that the workmen, especially small groups of workmen, walking on the panels during installation would have imposed loads in excess of the Sub-Contract load requirements.

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707 ABD 10E 6390.

708 ABD 10E 6526.1.

709 ABD 10E 6635.

710 Defendant's Closing Submissions at para 576; Mr Attwood's AEIC at p 345.

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There was evidence that some panels bore the weight of as many as eight to ten people at one time (see [145] and [149] above). Mr Green said he had seen about six people distributed across a panel at a time, which he thought would not breach the loading requirement.[711] Mr Wymond thought that while *one* person standing on the panel would not exceed the design load, multiple people standing near each other would have an influence on each person's point load and therefore exceed the point load of 1.1 kN.[712] The nearer the workers were standing to each other, the greater this influence would be. There was one photograph of three workers squatting or kneeling very closely to one another on a small area of a panel.[713] It was unfortunate that Mr Wymond did not calculate the magnitude of this influence, or how many people could stand within a given area without violating the point load requirement. However, I accept on a balance of probabilities that having so many people on the panels at a time in such proximity to one another would have exceeded the Sub-Contract load requirements, which were intended only to allow a limited number of persons on the panels while walking on plywood spreaders to spread their weight.

305 However, I do not rely on Mr Wymond's analysis of toe press or heel press in coming to this conclusion. There was no evidence of anybody concentrating their weight on the heel or toes of one foot while on the panels. The persons in the 2 March video do not appear to be *deliberately* concentrating their weight on their heels or toes – at best, there would have naturally been some concentration of weight as it shifted back and forth across their feet in the normal course of walking. But I doubt that would have resulted in the person's

711 NE (29 March 2016) at p 200 lines 12–17.

712 NE (30 March 2016) at p 166 line 15 – p 167 line 8.

713 ABD N 102.

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entire weight (treated by Mr Wymond as a point load of 1.1 kN[714], or 110kg) being concentrated on the toes or heel of *one shoe*, much less on a tiny area of 7cm by 3cm (in the heel press scenario) or 8cm by 6cm (in the toe press scenario). Indeed, it would be very odd if the weight of just one person could, in the normal course of walking, exceed the loads specified in the Sub-Contract, which clearly contemplated footfall on the panels. Mr Wymond himself testified that walking on the GRP panels for a prolonged period would *not* cause delamination, since the 2015 Tests showed that a test panel did not delaminate even after undergoing 100 cycles of walking (see [196(a)] above).[715]

306 I also accept that jumping would have imposed a load in excess of the Sub-Contract requirements and could have caused delamination. Whereas Mr Green considered it impossible to quantify the force of a person "jumping" on the panel without knowing the weight of the person and the height from which they jumped[716], Mr Wymond thought it possible to estimate this using basic physics. The Sub-Contract provided for a static load of 1.1 kN applied on a circular area 150mm in diameter, which would produce a stress of 8.267 MPa. By contrast, Mr Wymond calculated that an 80kg person jumping onto the roof from a height of 0.9m (landing on an area measuring 200mm by 200mm) would impose an equivalent static load of 10.39 kN, and a person weighing 110kg jumping on a panel up to a height of 300mm would impose an equivalent static load of 7.03 kN.[717] If a 1.1 kN design load would impose a stress of 8.267 MPa (as shown by the finite element analysis), a load of 7 kN would impose a stress of 52.6 MPa. One jump would therefore exceed the 1.1 kN design load. Multiple jumps would generate resonant effects resulting in an even higher load.[718]

714 ABD 4C 1446 and 1447.

715 ABD 4C 1355 at para 133; ABD 3C 844 at para 160.

716 ABD 1C 147 at para 53.

717 ABD 4C 1342 at Table 8.3, ABD 4C 1488 and 1450.

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Jumping in this manner would therefore induce a dynamic load which did not accord with the loading requirements in the Sub-Contract.[719]

307 Kalzip submits that the independence and reliability of the finite element analysis are "highly questionable".[720] This analysis was appended to Mr Wymond's expert report, with no mention of authorship. The finite element analysis was only described as "BFG Shear Stress Assessment of ALHC to bottom skin".[721] It only came to light, on the third day of witness conferencing and after Mr Kolhatkar and Mr Rade had given evidence, that they were the authors of the analysis and not Mr Wymond. This fact was not disclosed in Mr Wymond's report, even though he knew that Mr Kolhatkar and Mr Rade were witnesses in the Suit. Moreover, Mr Wymond's involvement appeared to be limited to instructing Mr Kolhatkar and Mr Rade to carry out the analysis based on the load cases that he had described.[722] In omitting the authorship of the finite element analysis, Mr Wymond failed to comply with O 40A r 3(2)(*d*) of the Rules of Court, which states that an expert's report must "state the name and qualifications of the person who carried out any test or experiment which the expert has used for the report and whether or not such test or experiment has been carried out under the expert's supervision". Mr Wymond must have been aware of that requirement as it was re-stated in his own expert report.[723] Mr Kolhatkar and Mr Rade made no mention of the analysis in their AEICs and were not examined on it during trial, because they had both been released as witnesses by the time their authorship thereof came to light. This was

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718 ABD 4C 1354 at para 121.

719 ABD 3C 832 at para 122.

720 Plaintiff's Reply Submissions at para 686.

721 ABD 4C 1317.

722 NE (31 March 2016) at p 173 line 17 – p 181 line 4.

723 ABD 3C 797 at para 5; NE (31 March 2016) at p 182 lines 8–17.

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dissatisfactory since both Mr Kolhatkar and Mr Rade had a direct interest in the proceedings.

308 However, I am unable to disregard the conclusions of the finite element analysis for that reason alone. Although Mr Wymond had not conducted the analysis himself, he was aware of the input data because it had been provided in an earlier set of finite element analysis.[724] Moreover, Kalzip did not probe or call into question any of the actual analysis, preferring to focus its submissions on the non-disclosure of authorship.[725] It could have applied to recall Mr Kolhatkar and Mr Rade, but did not do so. In the circumstances, I accept that the workmen walking and jumping imposed a load on the panels exceeding what they were designed to bear. Accordingly, I find that walking and jumping onto the panels was a possible cause of delamination.[726] This is consistent with the Aedas report of 22 January 2010 (see [227] above), which recorded that delaminated panels were observed along the stepped roof area,[727] as well as with Mr Kolhatkar's e-mail to Mr Carter on 2 February 2010, which recorded that the casino panels "near the Edge Trim" showed delamination.[728]

309 Mr Mackay raises various arguments to explain why the delamination which was observed could not have been caused by jumping:[729]

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724 NE (31 March 2016) at p 177 lines 16–22.

725 Plaintiff's Closing Submissions at paras 116(a)(ii)–(iii); Plaintiff's Reply Submissions at para 686.

726 Plaintiff's Closing Submissions at para 341(c).

727 ABD N 98.

728 ABD 10E 6163.

729 ABD 1B 30 at para 73.

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(a) Leaf 8 was the highest point on the MICE building, so nobody could have jumped down onto it, and yet it exhibited the most excessive and widespread delamination based on the four site surveys.

(b) The GRP panels averaged 14m long. The delamination was observed in all areas of the panels, and some almost 6m from the nearest edge of the GRP panels. It was impossible for the workers to have leapt 1.8m down from leaf 9 to leaf 10 and then another 6m forward to the further end of the panel on leaf 10. (This assumes, however, that the workers must have leapt directly onto all the spots in which delamination was recorded.)

(c) Some of the delamination occurred on the panels which were so steeply installed that one could not walk on these areas without a support harness, much less jump onto them.

(d) Mr Mackay personally inspected the GRP panels on the MICE building roof on or around 22 January 2010, the morning after they were installed. It was unrealistic for someone to have jumped on them immediately after installation the night before.[730]

310 The points at [309(a)]–[309(c)] were put to Mr Attwood during cross-examination and he agreed with them.[731] However, Mr Mackay's arguments are premised on the four site surveys, which I have found are not an accurate record of delamination. I therefore am not persuaded by them.

311 Finally, I add that the Aedas report of 22 January 2010 (see [227] above) strongly supports the conclusion that some panels were damaged due to events

730 ABD 1B 31 at para 74.

731 NE (28 March 2016) at p 81 lines 15–25.

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which occurred after they left the BFG factory. The report observes that there were "numerous markings", including numerous scratches, dents, rust, paint, chips, glass sucker prints and footprints, on the surfaces of the GRP panels.[732] There is a photograph clearly showing a marking on a GRP panel that appears to have been made by a tri-base suction-cup grip commonly used to hold glass panes or other panels, and one can but wonder why it appears so prominently on the flat surface of a GRP panel. Although Mr Wymond and Mr Green attributed some of these marks to the suction cups from the lifting jig[733], these do not match the size and positions of the suction cups on the lifting jig.[734] Mr Wymond makes the point that records from Loxon of panels leaving the factory and photographs indicate that the panels were clean and wrapped in clear plastic for shipping, suggesting that any surface contamination or markings most likely occurred during installation from workers, materials and onsite contamination.[735] The panels could not have left the factory with these irregularities, since Loxon had carefully inspected the quality and finish of the panels before approving them for installation. Moreover, the panels would have been checked for such defects when being lifted out of their stillages, and I doubt that the workmen would have installed panels that were obviously unfit for installation.[736] For example, MICE panels which were damaged in transit were identified for repair and attended to.[737] Mr Kolhatkar's e-mail of 29 January 2010 also stated that "[t]he panels as randomly checked before installation also show[e]d no defects" (see [140] above). I therefore doubt very much that these panels were already in a delaminated state when they were installed onsite. The existence of these

732 ABD N 99 and 109.

733 NE (30 March 2016) at p 145 line 11 – p 146 line 10.

734 ABD M 19, 24 and 37.

735 ABD 3C 871 at para 336.

736 ABD 10E 6126; NE (30 March 2016) at p 120 line 19 – p 122 line 10.

737 ABD 13E 8106–8114.

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defects – particularly the presence of "dents" – suggests that they were damaged in the course of handling thereafter. Where the Aedas report discusses "delaminated" panels, it refers to them as "damaged delaminated GRP panels", "damaged, delaminated GRP panels", "damaged - delaminated panels" and "damaged / delaminated GRP panels".[738] The use of the word "damaged" alongside "delaminated" reinforces my view that the panels bore signs not only of delamination but also of having been damaged after manufacture.

312 This view is also consistent with the dearth of evidence that the theatre panels likewise had problems of delamination. If the problem of insufficient resin was widespread, one would expect that problem to have afflicted the theatre panels also. However, there was no reliable evidence of delamination in the theatre panels. I now turn to consider Kalzip's case on the cause of delamination.

Kalzip's explanation of the cause of delamination

313 Kalzip initially pleaded the following breaches by BFG in its Statement of Claim:[739]

> (a) failure to select and/or formulate the appropriate constituents of the GRP panels to meet the required structural and fire requirements;
>
> (b) failure to undertake a proper design of the GRP panels to avoid delamination of the panels, including but not limited to failing to prescribe a proper structure and geometry of the GRP panels;

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738 ABD N 98–100, 109.

739 Statement of Claim (Amendment No 3) at para 35.

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(c) failure to undertake and/or prescribe a manufacturing and/or assembly process that would be appropriate for sandwich construction of panels using an aluminium honeycomb core; and

(d) failure to take all necessary measures to ensure that the GRP panels supplied would comply with the fire and structural requirements.

314 There is ample evidence that the parties' GRP experts agreed that BFG selected appropriate constituents for the manufacture of the GRP panels.[740] There was very little discussion by the experts of (b) above. In its closing submissions, BFG ultimately relied on (c) alone: namely, that the panel delamination resulted from BFG's defective manufacturing process.[741] I turn to this now.

Manufacturing process

315 Two questions are pertinent here:

(a) Was the manufacturing process designed by BFG adequate to produce GRP panels that would comply with the Sub-Contract requirements?

(b) If so, was that process followed?

316 The manufacturing process was developed by Mr Anand, Mr Zeeyad, Mr Krishnamoorthy Benjamin (who led BFG's Production Team[742]) and Mr

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740 NE (30 March 2016) at p 30 lines 9–25, p 31 lines 23–24, p 34 line 21 – p 35 line 7; ABD 4C 1489 at para 20 (see also ABD 4C 1156 and 1158 at paras 14 and 18 respectively).

741 Plaintiff's Closing Submissions at paras 345 and 624(d).

742 ABD 2B 359 para 17; NE (23 March 2016) at p 209 lines 4–7.

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Premamoorthy.[743] Mr Premamoorthy's description of the manufacturing process, with which Mr Kolhatkar agreed, was as follows:[744]

(a) First, the mould was set up for the specific dimension of the GRP panel being produced. This was known as "mould blanking".

(b) Secondly, the mould was cleaned and conditioned using a release agent to ensure that it was free from dust and foreign particles and to facilitate removal of the GRP panels from the mould without being damaged. The mould was visually inspected to ensure that it was free from dust, foreign particles and scratches, and that the release agent had been properly applied.

(c) Thirdly, a gelcoat mixture (prepared by mixing a gelcoat with catalysts in specified proportions and at specified temperatures) was applied to the mould. This mixture was sprayed onto the mould to a thickness between 0.45mm and 0.60mm. Its thickness would be checked twice using a device known as a wet film thickness gauge. The gelcoat mixture would be left to dry for approximately 45 minutes until the surface was no longer wet. The gelcoat was then touched up at the corners of the panels with a return flange using a paint brush.

(d) To make the first layer (what would become the upper skin of the GRP panel), pregel putty was applied on all corners and radii of the mould. Glass fibre strips (225g/m^2 chopped strand mat, or CSM 225) were applied on the flanges of the GRP panels using a resin mixture. More CSM 225 was then applied to the flat surface of the mould (excluding the flange) using a roller. A second layer of CSM 225 was

743 ABD 2B 364 at para 32.

744 ABD 2B 369–404; ABD 2B 260 at para 118.

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then rolled onto the entire panel surface (including the flange). The entire laminate was then left to partially cure at normal environmental conditions for a minimum of one hour.

(e) Ferrules were then inserted into the panels. They were positioned using a ferrules bonding jig and bonded to the surface of what lay in the mould using an adhesive. After the locations of the ferrules had been checked again, sealant tape was applied on the mould perimeter.

(f) Gutter lamination was then performed with CSM 225, using the skin layer resin. This was followed by gutter laminate cutting with a knife.

(g) A ferrule cap was then screwed onto the tip of each ferrule to prevent the resin from entering and contaminating the ferrule. The ferrules were cleaned to remove any excess adhesive.

(h) The ferrules were then laminated with two layers of CSM 300 by using a bonding resin mixture.

(i) CSM 225 lamination was then performed on the surface and flanges by using the bonding resin mixture for honeycomb bonding. This concluded the preparation of the outer skin of the GRP panel.

(j) Next came the aluminium honeycomb core, which came in sheets of approximately 0.5m by 3m. A bonding resin mixture was applied to the wet laminate and the honeycomb sheets were laid into the laminate. To join adjacent honeycomb sheets together, CSM 225 Z-strips were placed under one honeycomb sheet and then laid atop the adjacent honeycomb sheet, using the same bonding resin mixture.

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(k) The panel was then prepared for vacuum-bagging, in order to adhere the aluminium honeycomb to the upper skin. A fibreglass solid plate was installed on each ferrule and another fibreglass plate installed to cover the pointed pins to prevent damage to the vacuum bag. Steel frames were also placed around the honeycomb sheets. Fibreglass flat sheets were then placed on strips of release film on top of the joints of the aluminium honeycombs to ensure that the joints lay flat.

(l) For the vacuum-bagging process, a bleeder cloth layer was applied on the whole area up to the vacuum holes. A plastic layer was then placed on the entire mould and sealed with sealant tape. After the vacuum lines and connection were checked for leakage, the vacuum power was switched on and the entire laminate left to cure under vacuum for a set time at a certain temperature.

(m) After curing, the vacuum power was turned off and the vacuum materials were removed. A bonding check was done by the quality control team visually inspecting the product and pulling and shaking it by hand. In preparation for the second vacuum-bagging process later on, sealant tape was applied around the mould perimeter again.

(n) The second layer (which would become the inner skin of the GRP panel) was then made. Glass fibres and the last layer resin mixture were applied to the CSM 225 Z-strips lying atop the honeycomb joints in order to help them bond to the inner skin. (The last layer resin mixture had higher acceleration for a faster gelling time, so as to prevent the resin from dripping down during and after lamination.) The inner skin comprised three layers of material. First, the last layer resin mixture was applied to one ply of CSM 225 outside the mould ("pre-wetting" the

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CSM 225), and the wet CSM 225 was transferred immediately onto the honeycomb. Using the last layer resin mixture, this CSM 225 was then overlaid with one ply of another glass fibre (300g/m^2 woven roving, or WR 300) followed by another ply of CSM 225. The WR 300 and the second layer of CSM 225 were not pre-wetted before being laid flat over the first layer of CSM 225.[745]

(o) In preparation of the second vacuum-bagging process, steel frames were placed around the honeycomb to press the glass fibres down onto the resin mixture. A release film layer was placed on the compound, including the flanges. Fibreglass plates and solid plates were placed on each ferrule and fibreglass flat sheets were placed atop the honeycomb joints, as at (k) above. The vacuum-bagging process was repeated and the panel was thereafter left to cure under certain parameters. Generally this required a minimum of four hours' curing at a room temperature of 25°C, although the time could be reduced by up to 30 minutes depending on the room temperature. Mr Premamoorthy stated in his AEIC that all the GRP panels used for the Project had in fact been left to cure overnight, but during cross-examination changed this to "most" panels.[746]

(p) The panel was then labelled and de-moulded using a handling jig. It was inspected for delamination and then trimmed to remove unwanted excess fibres. The gelcoat side was smoothed with sandpaper.

317 In my view, the manufacturing process described above was adequate and cannot be blamed for any delamination that occurred. This was supported by the evidence of both parties' GRP experts.

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745 NE (23 March 2016) at p 129 line 11 – p 130 line 15.

746 NE (23 March 2016) at p 162 lines 6–14, p 166 lines 8–12.

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318 Mr Maurieschat considered that, based on his review of BFG's manufacturing process, BFG "had undertaken proper material and process design as well as quality control checks to avoid delamination of the panels".[747] The manufacturing process was appropriate for the manufacturing of aluminium honeycomb cored sandwich panels of large size (in this case, about 30m^2).[748] BFG's manufacturing facilities had numerous quality control checks in place at every step of the manufacturing process.[749] Most significantly, Prof Nonhoff stated that the manufacturing process as described by Mr Premamoorthy was "adequate", though he emphasised the importance of each step being carried out.[750]

319 The second question, which was a key point of disagreement between Prof Nonhoff and Mr Maurieschat, was whether the manufacturing process described in Mr Premamoorthy's AEIC had actually been followed in 2009–2010. Unfortunately, there were no copies of the PCS, which was the sole contemporaneous document recording key parts of the manufacturing process.[751] For this reason Kalzip submits that there is no credible evidence that BFG followed its own manufacturing process.[752] Prof Nonhoff concluded that the manufacturing process had not been followed, given his own inspection of the delaminated panels on 21 and 22 June 2010, when he found that the inner face sheet was inadequately bonded to the honeycomb core.[753] In particular, it was

747 ABD 4C 1155 at para 10.

748 ABD 4C 1203 at para 153.

749 ABD 4C 1159 at para 23.

750 ABD 1C 34 at para 53.

751 NE (23 March 2016) at p 225 line 19 – p 225 line 2; NE (24 March 2016) at p 18 lines 1–4, p 29 line 24 – p 30 line 3.

752 Plaintiff's Reply Submissions at paras 349 and 355.

753 ABD 1C 33 at para 52.

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clear to him from his inspection of more than 10 panels that insufficient resin had been used and that the vacuum-bagging process must have been inadequate in some way.[754] Mr Maurieschat, on the other hand, was satisfied that "all steps were precisely followed as per [Mr Premamoorthy's] AEIC as well as several inspection reports by Loxon and visits by Kalzip".[755]

320 I also note that each and every panel which was installed on the Project had been signed off by Loxon (see [266] above), a third-party consultant hired by Kalzip to see to it that the panels were manufactured properly and in a satisfactory condition when they left the factory. Loxon was heavily involved in the supervision of the manufacturing process. Loxon personnel would be present at the blanking and preparation of the moulds, at the lamination process, at the vacuum-bagging process, at demoulding, at trimming and at finishing time. They would, finally, inspect each panel after it was produced, ensure conformity with the criteria set out in the quality control sheet, and approve it for delivery.[756] There is no reason at all to doubt that Loxon personnel would have fulfilled their duties prudently and competently. Loxon's quality control process was very well-documented, as shown by their weekly reports. It is therefore unlikely that the panels installed had widespread manufacturing defects.

321 There are, essentially, four strands to Kalzip's claim that the manufacturing process was not followed. I take these in turn.

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754 ABD 1C 34 at para 53.

755 ABD 4C 1491 at para 36.

756 Defendant's Closing Submissions at paras 738–746.

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(1) Quantity of resin used

322 A key point of disagreement between the parties, and between their respective GRP experts, was whether sufficient resin was used in manufacturing the GRP panels. Both Prof Nonhoff and Mr Maurieschat agreed that the more resin between the honeycomb and the last layer of the inner skin, the stronger the bond would be between the honeycomb and the skin.[757] Prof Nonhoff emphasised the special importance of (1) ensuring a surplus of resin so that sufficient resin would penetrate the edges of the honeycomb core, and (2) ensuring that the inner and outer faces were vacuum-bagged and subsequently baked.[758] Prof Nonhoff thought that insufficient resin had been used whereas Mr Maurieschat disagreed.

323 Prof Nonhoff testified at trial that if there was enough resin in the panel, you would see an imprint of the honeycomb, but if resin was insufficient, you would only see a smoother print.[759] He claimed that on one of the sample GRP panels he reviewed, the inner face sheet left only an imprint of the honeycomb and was easily removable by hand, suggesting that inadequate resin had been applied during manufacturing.[760] However, Prof Nonhoff has not produced any photographs showing this. In fact the photograph of the panel which Prof Nonhoff pulled apart by hand quite clearly showed the imprint of the aluminium honeycomb on the detached skin.[761] The imprint is also discernible from the photograph Prof Nonhoff took of the perimeter of a cored hole.[762] Separately,

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757 NE (30 March 2016) at p 91 line 3 – p 92 line 4.

758 ABD 1C 33 at para 51.

759 NE (30 March 2016) at p 94 lines 5–16.

760 ABD 1C 34 at paras 54–55.

761 ABD 2C 571.

762 ABD 2C 568.

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one of the samples cored during Prof Nonhoff's visit in June 2010 was photographed. According to Prof Nonhoff, this photograph showed that the edges of the exposed honeycomb core were shiny and clean, suggesting that delamination resulted from insufficient resin being used during the manufacturing process.[763] However, because the photograph depicts the honeycomb from the top (rather than at an angle), I am unable to tell whether there in fact was any resin on the edges of the honeycomb. Both Mr Green and Prof Nonhoff also observed that the coring video adduced by Kalzip showed that the core samples of delaminated panels did not have any visible resin on the aluminium honeycomb core.[764] Again, with respect, I could not see that this was so.

324 However, there is evidence that there was variation in the weight in some parts of the panels. The 2 March video stated the following weights of five cored samples[765]:

Panel	Condition of core sample	Weight/m^2
Casino building roof, leaf 13, panel 13	Delaminated	10.41kg
Casino building roof, leaf 13, panel 13	Good	14.39kg
MICE building roof, leaf 15, panel 9	Good	10.84kg
MICE building roof, leaf 16, panel 5	Delaminated	7.64kg
Mock-up panel no 2	Good	14.76kg

763 ABD 2C 569–570 at paras 12–13.

764 NE (30 March 2016) at p 9 lines 22–25; NE (29 March 2016) at p 203 line 21 – p 204 line 4; NE (30 March 2016) at p 178 line 24 – p 179 line 4.

765 NE (30 March 2016) at p 9, lines 5–10.

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325 I note that the 2 March video states "L16-P9" (*ie*, panel 9 of leaf 16) at 04:03 and 04:52 (the black stillframes stating the sample weights). However, during the actual coring, the sample is annotated onscreen as "L16-P5" (*ie*, panel 5 of leaf 16) (at 02:19) and that is how the sample is subsequently labelled (at 03:24) and described by Mr Carter (at 08:35). This creates some doubt as to which panel was cored, and is illustrative of the lack of precision in the evidence that Kalzip canvassed to support its allegation of delamination.

326 There was a difference of 3.98kg/m^2 between the non-delaminated and delaminated panels from the casino building roof, and a difference of 3.2kg/m^2 for panels from the MICE building roof. In his expert report, Prof Nonhoff opined that the difference in mass between the delaminated and non-delaminated panels was due to BFG having used less resin than required in manufacturing the panels which eventually delaminated.[766] He considered that the variation in weight could *only* be explained by differences in the quantity of resin applied to each panel.[767] As I have said at [236]–[239] above, I do not accept the 2 March 2010 coring exercise as proof that delamination occurred, since the delamination of those core samples could have been contributed to by the force applied during coring. However, I accept that the samples which were found to have delaminated after coring were lighter than the samples which did not.

327 The correspondence within BFG in the wake of the 2 March 2010 core sampling exercise shows that there was some concern about panel weight. On 7 March 2010, five days after the core sampling exercise, Mr Premamoorthy wrote to Dr Samer as follows:[768]

766 ABD 1C 34 at paras 54–55.

767 NE (30 March 2016) at p 9 lines 11–13.

768 NE (29 March 2016) at p 118 lines 18–24; ABD 10E 6636.

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> The particular panel in question is MICE panel which as per [Kalzip], the cut sample weighs 7.5 kg/m2. As per BFG Philippines records, the panel input materials data convert to 10 kg/m2. This information about low weight thin skin panels was revealed by [Kalzip] to BFG late night before MBS meeting. … Unfortunately our panels at site have real problems of low weight and delamination of back skins. …
>
> …
>
> So the actual technical problem is that there are some panels that have not been manufactured upto the required level of quality.
>
> …
>
> (Moorthy, I am attaching an interim report sent by Zeeyad in August 09 where large panels show 11.5 kg / m2 and smaller panels of 22 m2 areas show 13-14 kg / m2. You need to check why this came down to 9.5 kg / m2 on MICE)

328 I note also that insufficient resin was cited as a possible reason in some contemporaneous correspondence (see [117] above).

329 Prof Nonhoff also took cognisance of observations made by Arup regarding the delaminated fire test samples received at BRE and Exova Warringtonfire:[769]

> In terms of the samples that had delaminated, the rear GRP sheet had simply not been bonded sufficiently to the honey comb aluminium core and the GRP had simply detached. The GRP sheet was not damaged in anyway and there was no evidence of mechanical damage.

330 BFG makes two counter-arguments:

(a) First, it is more useful to look at the weight of full-sized panels, rather than the weight of cored samples. The evidence suggests that the panels did not have a weight problem.[770]

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769 ABD 2C 570 at para 13; ABD 30L 21965 and 21968.

770 Defendant's Closing Submissions at paras 776–782; Defendant's Reply Submissions at paras 128–130.

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(b) Secondly, even if the panels varied in weight, that does not necessarily mean that inadequate resin was used.[771]

331 I address these in turn. First, Mr Maurieschat's expert report included a table, which he claimed showed that the amount of resin used for inner skin lamination in 2009–2010 and 2015 "were very similar". The table was "supported by production records of 2009-10 and 2015".[772] The table compared the resin per square metre of the bottom layer of 10 panels produced for the Project against the same for one panel produced in 2015. As far as I can tell, the resin quantities for these panels appear to have been taken from panel-wise material consumption reports exhibited in Mr Premamoorthy's fourth affidavit.[773] Mr Maurieschat also observed that the weight of each GRP panel produced was compared with the specified weight and recorded in a document titled "Panel weight record list MBSIR Podium Theatre" showing that the panel weights were within limits.[774]

332 Mr Premamoorthy also did not accept that BFG's panels were underweight. In a second e-mail to Dr Samer on 11 March 2010, he wrote:[775]

> … [T]here's no way that the panel weight is below 9.5-10kgs/m2 because we monitor the weight to ensure that it complies with the required weight/m2, but this is manual process. Also, cutting a small portion of the panel will not substantiate an accurate result on the weight/m2 of the entire panel, since Fibre thickness is not even, so as the resin applied, which we all know very well.
>
> Having enlightened above you may be contemplating to know the root cause of it. My opinion is that the aluminum

771 Defendant's Closing Submissions at paras 783–787.

772 ABD 4C 1203 at para 152.

773 Mr Premamoorthy's affidavit affirmed on 22 September 2016 at pp 186–195, p 212.

774 ABD 4C 1493 at paras 47–48.

775 ABD 11E 6888.

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> honeycomb and the k133 Resin that we used. Aluminum will not bond well with GRP … In addition to that, whenever we use K133 Resin, we always ended up with problems. Maybe you don't agree with that but that is my opinion.
>
> …

333 Having considered the evidence, I accept that the answer lies in the first paragraph of Mr Premamoorthy's e-mail set out above. There were weight records for each panel produced.[776] If too little resin was used for a panel, this would have been evident from the record. But this would only have ensured that the total weight of the entire panel was within an acceptable range. Because application of the resin was a manual process, it would still have been possible for some parts of the panel to have less resin and others more. This can be seen from the table at [324] where two core samples were obtained from leaf 13, panel 13 of the casino building. One weighed 10.41kg and the other 14.39kg. This would be consistent with Prof Nonhoff's view that the *specific instances* of delamination which he observed were due to insufficient resin between the inner skin and the aluminium honeycomb. Even on Kalzip's case, delamination was confined to certain areas *within* a panel – it did not necessarily affect the entire panel.

334 My conclusion is also supported by an e-mail from Dr Samer to Mr Kolhatkar on 7 March 2010, in which he observed that "it is very easy to pour resin on a laminate and then spread it unevenly so that certain sections are resin rich while others are resin starved" and that "[t]he result of such poor workmanship would be a product that in total meets the weight requirements since the overweigh[t] and underweight laminate sections average out". He considered that that was "probably what we are seeing".[777]

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776 ABD 4C 1174 at para 80(c); ABD 4C 1493 at para 47.

777 ABD 11E 6675.

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335 BFG's second counter-argument is that, even if the panels varied in weight, this does not mean that insufficient resin was to blame. A set of slides which BFG prepared for presentation to MBS lists various possible reasons for variations in the thickness of the panels, including density variation in raw materials; process limitations of manual lamination; variations in environmental conditions that would affect the vacuum levels; the fact that there was an inherent manufacturing variation in glass fibres of 8%; variations in the viscosity of the resins, due to changes in ambient temperature, storage, shelf life and the cut size of the retardant fillers mixed in the resin; variation in processing; and variations in ambient atmospheric temperature and the barometric pressures in the shop floor. The slides also included actual records of the weight and thickness of panels manufactured by BFG which indicated that the variations in weight were within 9–11kg/m^2 and the variations in thickness were within a tolerance of 1.5mm.[778] Mr Wymond and Mr Maurieschat also opined that the variance in the weight of the panels could be explained on other bases. For example:[779]

(a) laps in fibreglass sheets required added resin, and this would lead to an increase in mass;

(b) core samples cut through GRP Z stiffeners would have a greater mass than samples cored through the honeycomb alone;

(c) product variations occurred to panel weights due to different temperatures and cure rates in the factory.

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778 ABD M 256–259; ABD 2B 271 at para 154; Defendant's Reply Submissions at para 130.

779 ABD 3C 834 at para 124; ABD 3C 803 at para 2.5.3.

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336 Against this, I note that during cross-examination, Mr Kolhatkar agreed that weight *was* indicative of resin use:[780]

> Q. I'd also suggest to you that the concern as to varying weights was because it was indicative of the resin content in these panels. You can agree or disagree.
>
> A. Yes, if the weight was less, that would indicate the resin would be less because glass and aluminium would be relatively constant width parameters in the panels.

337 On the whole, I agree that the amount of resin used is not *determinative*. Mr Kolhatkar explained in re-examination that GRP panels require resin at different stages of the manufacturing process, and the bond between the inner skin and the aluminium honeycomb depends specifically on the resin applied at the interface of those two layers – not the resin forming part of the skins themselves.[781] However, the total amount of resin used per panel may still be *indicative* of how much resin was available at that interface between the inner skin and the aluminium honeycomb. Indeed, Prof Nonhoff made the point that resin which is soaked up by the dry glass fibre "reduce[s] the quantity of resin available to make a bond with the honeycomb core", thus making it imperative that there was a "surplus of resin in the glass fibre to ensure adequate bond".[782]

338 On the totality of the evidence, I find that insufficient resin may possibly have caused the panels to be more susceptible to delaminate due to a weaker bond between the inner skin and the aluminium honeycomb. But that would have occurred in specific areas and would not have been widespread through an entire panel. That said, there is no evidence that any particular panel had insufficient resin to bond with the aluminium honeycomb which consequently

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780 NE (29 March 2016) at p 169 lines 14–17.

781 NE (29 March 2016) at p 185 lines 1–21.

782 NE (30 March 2016) at p 8 lines 3–10.

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resulted in that panel becoming delaminated, independently of mishandling or misuse onsite by workmen.

339 I should add that I do not base my finding on Prof Nonhoff's view on the thickness of the resin. He observed that the inner layers of delaminated GRP panels in 2009–2010 were typically only 1.8–2mm thick, whereas the mass of resin on the bottom panel ought to have been at least 2.9mm thick (without glass layers).[783] However, this was predicated on the erroneous assumption that it was not necessary to include fire retardant in the resin mix applied to the inner skin.[784] Mr Maurieschat calculated that, taking into account that the resin mix for the inner skin had to include fire retardant, this would give a thickness of 1.93mm.[785] Prof Nonhoff agreed that if fire retardant were required for the inner skin, then the thickness of resin on the bottom panel would go down to nearly 2mm.[786]

(2) Type of resin

340 Apart from the *sufficiency* of resin, Kalzip suggests that the *type* of resin used may have been problematic.[787] For this it cites the e-mail from Mr Premamoorthy to Dr Samer on 11 March 2010, in which Mr Premamoorthy attributed the "root cause" of delamination to "the aluminium honeycomb and k133 Resin that we used" (see [332] above).[788]

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783 ABD N 84 at para 18; ABD 2C 577 at paras 32–34.

784 NE (1 April 2016) at p 47 lines 7–11.

785 NE (1 April 2016) at p 47 lines 15–19; p 55 line 22 – p 56 line 6; ABD N 128.

786 NE (1 April 2016) at p 55 lines 11–13; p 56 line 19 – p 57 line 6.

787 Plaintiff's Closing Submissions at para 354(c).

788 NE (23 March 2016) at p 196 lines 15–25.

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341 I do not accept that this could have caused delamination. Mr Premamoorthy's supposition was not supported by the other evidence. For example, Dr Samer rejected Mr Premamoorthy's explanation for why delamination had occurred. In his reply to Mr Premamoorthy's e-mail, Dr Samer wrote:[789]

> Dear Moorthy
>
> If what you say is true.... and I at this stage cannot agree that this is the case … then it would be very strange that the Theater panels are perfect, the Casino panels are mostly Ok but the MICE panels are horrible.
>
> This inco[n]sistency cannot happen from a process problem and is more indicative of a manufacturing defect.
>
> Come on Moorthy, the delaminated skins are very dry …..
>
> I am not sure you have a strong case at all.

342 Mr Kolhatkar, too, disagreed that the use of the resin was problematic. He explained that this resin had been used in several projects "including a very large roofing project in Bahrain", and had not always posed a problem.[790] Finally, the parties' GRP experts (including Prof Nonhoff) firmly agreed that BFG had selected appropriate constituents for the manufacture of the GRP panels.[791] In the circumstances, I do not find that the type of resin used in manufacture was inappropriate or deficient.

(3) The vacuum-bagging process and curing time

343 Kalzip suggests that the vacuum-bagging process was not carried out properly. It emphasises that the vacuum-bagging process was "completely new"

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789 ABD 11E 6887–6888.

790 NE (28 March 2016) at p 222 lines 1–12.

791 NE (30 March 2016) at p 30 lines 9–25, p 31 lines 23–24, p 34 line 21 – p 35 line 7; ABD 4C 1489 at para 20 (see also ABD 4C 1156 and 1158 at paras 14 and 18 respectively).

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for BFG's Philippines factory and staff from its Bahrain factory had to be flown in to train the Philippines staff.[792] Moreover, Mr Premamoorthy agreed that the manufacturing process was almost entirely manual, and required each worker to correctly carry out each step of the manufacturing process to ensure consistency.[793]

344 There are two aspects of the vacuum-bagging stage which Kalzip attempts to cast doubt on: (1) the pressure applied during the vacuum-bagging, and (2) the time for which the panels were left to cure.[794] To ensure sufficient adhesion between the aluminium honeycomb and the two skins, it was important to maintain the correct pressure during vacuum-bagging and allow the panels to cure for sufficient time. Mr Maurieschat explained that if the pressure in the vacuum bagging process was decreased too fast, it could affect the curing and that would affect the ability of the resin to bond the GRP skin to the aluminium honeycomb.[795]

345 I do not accept that there was any problem with the pressure applied during vacuum-bagging. Mr Maurieschat agreed that it was difficult to satisfy himself that the vacuum-bagging process was properly carried out in 2009 because he had not seen any documentation showing how the pressure was applied.[796] That said, it would have been easy to detect a leak between the seal and the mould, and it was not difficult to train workmen in the vacuum-bagging process.[797] Though it "appeared" to Prof Nonhoff "that the vacuum bagging of

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792 NE (23 March 2016) at p 205 line 15 – p 206 line 1; NE (28 March 2016) at p 216 lines 3–13.

793 NE (23 March 2016) at p 92 line 1 – p 93 line 7.

794 Plaintiff's Closing Submissions at para 351.

795 NE (23 March 2016) at p 113 lines 16–23, 118 lines 11–25, p 154 lines 16–19; NE (1 April 2016) at p 148 line 21 – p 149 line 22.

796 NE (1 April 2016) at p 149 line 23 – p 150 line 21.

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the inner sheet of the panels was insufficient", he did not expand on this.[798] I find that the vacuum-bagging process was not a very technical and intricate process. An insufficient seal anywhere would readily show up on the pressure gauges.

346 I am also unable to find that insufficient curing time was given.

347 Mr Premamoorthy agreed that, if there was insufficient curing time, that would compromise the bond of the aluminium honeycomb to the skins.[799] He agreed that it was particularly important to ensure adequate cure time for the second vacuum bagging because BYK W-980, which was used as an additive, cured quite slowly.[800] The cure time should therefore be four hours, subject to a reduction of up to 30 minutes depending on temperature.[801] In fact, this was why BFG tried to leave the panels to cure overnight. This was the case for most of the panels but if the manufacturing began early in the morning it could end by around eight or nine at night, and the panel need not be left to cure overnight (see [316(o)] above). It would still have taken more than 12 hours to manufacture.[802]

348 Mr Premamoorthy acknowledged that the curing time for the first vacuum-bagging process was not always four hours. The actual duration of curing would have been significantly influenced by the temperature that day, and could be as few as two or three hours.[803] Mr Maurieschat agreed that the

797 NE (23 March 2016) at p 119 line 25 – p 120 line 11, p 212 lines 9–18; NE (24 March 2016) at p 61 lines 9–25.

798 ABD 1C 34 at para 53.

799 NE (23 March 2016) at p 154 lines 16–19; NE (24 March 2016) at p 90 lines 17–21.

800 NE (24 March 2016) at p 89 lines 6–17, p 92 lines 12–22; ABD M 250.

801 NE (24 March 2016) at p 93 lines 11–19; ABD 2B 401.

802 NE (23 March 2016) at p 118 lines 11–25, p 161 lines 12–24, p 163 lines 6–14.

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curing time should be four hours, assuming a temperature of 25 degrees, but could vary depending on the ambient temperature and might be even shorter than three and a half hours. Unfortunately, there was no evidence as to how long the panels were cured; the PCS, which would have recorded curing time, were not in evidence. Nor was the mixing room temperature record, which would have recorded the temperature on the day of the cure.[804] However, this relates to the *first* vacuum-bagging process (between the outer skin of the GRP panel and the aluminium honeycomb core), whereas it is the *second* vacuum-bagging process which would have affected the bond between the honeycomb and the inner skin. In that regard, there was no evidence that insufficient time was given for curing after the second vacuum-bagging process.

(4) Over-production of panels

349 Kalzip submits that BFG cannot have complied with the manufacturing process because it was producing more than six panels a day. This was based on there being only six roof moulds and each panel taking approximately 13 hours to manufacture.[805] Mr Premamoorthy agreed that the entire manufacture of a GRP panel would ordinarily take approximately 13 hours.[806] Given six roof moulds, it was impossible to produce more than six roof panels per day. The quality control sheets showed, however, that BFG had in fact produced up to seven panels from 27 July to 19 October 2009, and up to nine panels from 20 October to 18 December 2009.[807]

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803 NE (23 March 2016) at p 110 line 21 – p 113 line 14, p 115 line 24 – p 116 line 4.

804 NE (23 March 2016) at p 115 lines 3–5, p 115 line 24 – p 116 line 4.

805 Plaintiff's Closing Submissions at para 356.

806 NE (23 March 2016) at p 160 lines 3–8.

807 ABD N 58.

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350 I do not accept this submission because it appears that there were more than six roof moulds. Mr Premamoorthy originally stated in his AEIC that "[a] total of ten (10) moulds were prepared by BFG's project team", comprising *six* moulds for roof panels, one mould for the fascia panels and three moulds for the return panels. This was supported by a "Mould Status Report" dated 20 March 2009.[808] He also confirmed at trial that "10 moulds were constructed specifically for … the podium project", that "we had 10 moulds" and that BFG "had 10 moulds which [they] were approved to use for the Marina Bay Sands projects".[809] However, it surfaced at trial that BFG had produced additional moulds to produce roof panels in order to meet the delivery schedule. This was attested to by Mr Premamoorthy and substantiated by e-mails and Loxon weekly reports. One such report recorded an activity described as "Monitor Assembly of additional mould" from 8am to 5pm on 9, 10, 11, 12, 13 and 15 October 2009.[810]

351 Kalzip submits that there were at most *two* additional roof moulds, which would have enabled BFG to produce up to eight roof panels a day. Kalzip submits that BFG was only able to produce nine panels a day because it must not have left the roof panels to cure overnight.[811]

352 I disagree that there were only two additional roof moulds. Mr Premamoorthy originally testified under cross-examination that BFG had produced "around four to five extra moulds" or "something four or five, three

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808 ABD 2B 368 at para 43; Mr Premamoorthy's AEIC at pp 179–181.

809 NE (23 March 2016) at p 49 lines 12–23, p 50 lines 4–11, p 52 lines 10–21, p 112 line 12, p 166 lines 22–24.

810 ABD 1K 634; NE (23 March 2016) at p 170 lines 2–9; NE (24 March 2016) at p 112 lines 2–4.

811 Plaintiff's Closing Submissions at paras 356(d) and 357.

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or four".[812] In re-examination, he was brought to an e-mail sent by Mr Kolhatkar to Mr Zeeyad on 6 October 2009:[813]

> Dear Zeeyad,
>
> Please proceed with *manufacturing of 2 production moulds* for roof panels as per the existing 6 moulds. …
>
> With these *2 moulds* all the MICE and CASINO panels except MICE Containers 10, 11, 12, 13 must be shipped out from the plant by 16th December.
>
> We shall advice you if [Kalzip] agree for *further additional 2 moulds* to complete all CASINO and MICE Deliveries by 16th December.
>
> [emphasis added]

353 Mr Premamoorthy was then asked:[814]

> Q. On the face of this e-mail, are you able to tell us how many production moulds were additional?
>
> A. It's two production moulds additional.

354 Even assuming there were in fact only two additional moulds, this would have made nine moulds in total. A Loxon weekly report in August 2009 recorded that "BFG add 1 master mold for production of GRP Panel, a total of 7 panels for GRP Roof and 21 for Edge Trim Panel every day in Production".[815] This means that one additional mould must already have been produced in or before October 2009. With two further moulds thereafter, this would have brought the total to nine moulds.

355 But it seems there may have been even more than nine. The final paragraph of the e-mail at [352] above referred to *another* two additional

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812 NE (23 March 2016) at p 170 lines 2–9, p 174 lines 20–25.

813 ABD N 119.

814 NE (24 March 2016) at p 109 lines 23–25.

815 ABD 1K 449.

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moulds pending Kalzip's agreement. That the number of additional moulds was four is also suggested by another letter sent by BFG to Mr Carter on 6 October 2009 which proposed "Additional *4 Nos.* roof panel moulds similar to existing 6 moulds already approved" [emphasis added].[816] When this was shown to Mr Premamoorthy, he clarified his evidence accordingly:[817]

> Q. Are you able to tell us from this document what are the additional moulds that are proposed, if any?
>
> A. This is for the roof, I think, *because we asked for four*, because to keep additional, because it has to be rotated, the mould. That's for the roof, I remember now.
>
> [emphasis added]

356 This is also confirmed by other e-mails on 5 and 6 October 2009, in which Mr Kolhatkar wrote to Mr Carter that "If we need to complete all MICE shipments by 20th December … we will need 4 extra moulds to be manufactured immediately". At Mr Carter's request he attached "the formal proposal for extra 4 moulds from BFG HO".[818]

357 BFG's alternative counter-argument is that even if it only had six roof moulds, it was possible for two moulds to produce three panels each day. It relies on a table ("D10") produced by Mr Maurieschat which allegedly shows that two moulds could produce up to three panels in a 24-hour period.[819] I doubt this counter-argument and, given my finding that there were enough roof moulds to produce up to nine panels a day, it will have little bearing on the result. Nonetheless, for completeness, I briefly explain why this counter-argument does not hold water.

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816 ABD 9E 5611.1.

817 NE (24 March 2016) at p 111 lines 1–7.

818 ABD N 121–122.

819 Defendant's Closing Submissions at para 761; ABD N 127.

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358 First, Prof Nonhoff agreed that it was possible to produce three panels with two moulds in a day if the timings proposed in D10 were accurate, but he expressed doubts about whether the stages of production could realistically be accomplished within such short periods of time:[820]

> PROF NONHOFF: All the information on the paper are only theory and if they are really true, then it is possible but without any problems in between to produce three panels with two forms. My problem is that the timings, example, for the BL [bottom layer], for S [trimming or cleaning the mould] and -- for S [trimming or cleaning the mould] --
>
> PROF NONHOFF: (In English) It's one hour. For this 40 square metre, very short time. The next is for the bottom layers, it is 3mm and then you must -- between curing, and then you must do the next layers for the honeycombs. I'm sure you need much more than one hour. And for the layer with the honeycombs, then you must make the vacuum bagging right, I think it's one hour to less.
>
> The other point is three and a half hours is a minimum what you must have for curing, otherwise you get some problems with the resin.

359 Mr Maurieschat thought that it was practical to manufacture three panels with two moulds in 24 hours. However, he also admitted that D10 did not reflect all the stages of manufacturing:

(a) It omitted the time that would be required for preparing the gelcoat; spraying the gelcoat mixture into the mould; and drying the gelcoat, which Mr Premamoorthy had said would take about 45 minutes. Mr Maurieschat estimated that these steps would require another hour.[821]

(b) It omitted the time required for identifying the location of the ferrules and laminating them. Mr Maurieschat estimated that these steps would require another 30 minutes.[822]

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820 NE (1 April 2016) at p 40 line 10 – p 41 line 2.

821 NE (1 April 2016) at pp 188–189, p 190 lines 5–9.

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360 Mr Maurieschat sought to downplay the significance of these omissions, because the manufacturing team was trained in the manufacturing process and so would be able to perform the steps slightly faster than estimated.[823] However, he conceded that he was not directly involved in the training of the manufacturing staff and simply assumed this.[824]

361 In the circumstances, I do not rely on D10 as evidence that three panels could have been (or were) produced with two moulds in a 24-hour period. But given what I have said above regarding the additional moulds produced for the Project, I do not find that the daily rate of production shows that BFG did not fully comply with the manufacturing process.

BFG's lack of experience manufacturing panels of this size and composition

362 To support its case that the delamination was attributable to poor manufacturing, Kalzip submits that BFG's factory in the Philippines faced quality control issues and was inexperienced.

363 Mr Kolhatkar gave evidence that prior to the Project, BFG had experience dealing with aluminium honeycombs but its factories in both Bahrain and the Philippines did not have expertise manufacturing aluminium honeycomb cored panels to such a *large size*. The roofs and roof components it had manufactured prior to the Project did not have aluminium honeycomb as the core. The aluminium honeycomb products BFG had previously produced would have had different end uses, for example as a cabin door or jetty.[825] An e-

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822 NE (1 April 2016) at p 190 line 10 – p 191 line 4.

823 NE (1 April 2016) at p 42 line 15 – p 43 line 12, p 191 line 22 – p 192 line 5.

824 NE (1 April 2016) at p 192 line 6 – p 193 line 1.

825 NE (23 March 2016) at p 202 lines 10–19; NE (28 March 2016) at p 190 line 13 – p 192 line 7, p 230 line 23 – p 232 line 19, p 233 lines 14–23.

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mail from Mr Kolhatkar to Dr Samer on 29 January 2010 also states that "Aluminium Honeycomb cored FRP panels proposed for the project were a new development at BFG" and "initial trials with the material were rigorously undertaken at BFG Bahrain as well as BFG Philippines" because "the level of confidence was not established".[826] On 30 April 2010, an e-mail from another BFG staff member to Mr Benjamin Krishnamoorthy, who was in charge of production at the BFG Philippines factory, stated:[827]

> We would like to inform you that we are facing problems in PODIUM PRODUCTION, because our consumption now is higher than our standard ratio. We conduct investigation and we found out that the reason of over consumption is *because our people in podium are not that skilled in this project.* We are trying to control the material to maintain the standard weight but still there is an over consumption. So if we will encounter problem or complains regarding the quality of this project, we will not be liable with it.
>
> [emphasis added]

364 Notwithstanding BFG's point that this particular problem of over-consumption had to do with the production of panels which were *too heavy* (rather than too light)[828], the fact remains that BFG personnel were not well-versed with the manufacturing process in the initial stages.

365 BFG's lack of experience is consistent with my finding that shortcomings in manufacturing (particularly insufficient resin at some areas) *may* have contributed to the panels' susceptibility to delaminate. I do not, however, place any weight on an e-mail on 25 November 2007 which Kalzip cites, which records that Salvatore – the operational director of BFG's Bahrain factory – was "upset with Philippines Quality level and the problems we already

826 ABD 10E 6126.

827 ABD 12E 7613.

828 Defendant's Reply Submissions at para 140.

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have on Floor panels". This complaint was made before the Sub-Contract was entered into, in relation to an unrelated project which BFG was working on, and I agree with BFG and Mr Premamoorthy that it is not useful to consider it in the context of this Suit.[829]

Failure to produce the PCS

366 Kalzip invites the court to draw an adverse inference against BFG under s 116 of the Evidence Act for its failure to produce more of the PCS from the 2009–2010 production run. Kalzip submits that BFG has refused to provide the PCS because they are likely to show that the 2009/2010 production process was not carried out properly.[830] Section 116 states:

> **Court may presume existence of certain fact**
>
> **116.** The court may presume the existence of any fact which it thinks likely to have happened, regard being had to the common course of natural events, human conduct, and public and private business, in their relation to the facts of the particular case.

367 Illustration (*g*) states that the court may presume "that evidence which could be and is not produced would if produced be unfavourable to the person who withholds it".

368 Prior to the trial, BFG had only seen two types of PCS: one was a blank PCS template and the other PCS was for a panel which was used in a specific wind load test (not one of the GRP panels produced for installation).[831] Kalzip's lawyers wrote to BFG's lawyers on 1 March 2016 to ask for discovery of all

829 ABD 2E 1221; Plaintiff's Closing Submissions at para 354(a); Plaintiff's Reply Submissions at para 380; Defendant's Reply Submissions at para 139; NE (23 March 2016) at p 207 lines 13–24.

830 Plaintiff's Closing Submissions at paras 363–370; Plaintiff's Reply Submissions at para 424.

831 ABD N 57; NE (23 March 2016) at p 157 lines 3–11; ABD 15K 11560.

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PCS generated by BFG during the Project, including both the 2009–2010 and 2015 production runs.[832] On 2 March 2016, the Assistant Registrar directed BFG to respond by 4 March 2016 whether it would be providing discovery of the PCS sought and, if so, to produce them by 8 March 2016. On 4 March, BFG's lawyers informed Kalzip's lawyers that BFG "no longer retain[ed] any physical hard copies of the PCS" and were "checking to confirm if any [soft] copies of the PCS might be available". On 7 March 2016, the parties came before me and I directed BFG to file an affidavit to explain the two PCS that had been disclosed.

369 On 18 March 2016, BFG filed a second affidavit by Mr Premamoorthy which explained that it was "not [BFG's] company policy" to retain physical copies of the PCS approximately only two years after the completion of production due to space constraints and the costs of retention. Moreover, once Loxon signed off on the quality control sheets and approved the panels, internal quality control documents like the PCS were deemed no longer relevant. He confirmed, both on affidavit as well as in oral evidence, that no hard *or scanned* copies of the PCS remained from the period of 2009–2010.[833] Mr Premamoorthy also confirmed at trial that no PCS from the 2009 production run, and only one PCS from the 2015 production run, had been given to BFG's experts.[834] As will be seen, both these assertions turned out to be untrue.

370 Contrary to Kalzip's letter dated 4 March 2016 and Mr Premamoorthy's third affidavit, Mr Premamoorthy testified at trial on 24 March 2016 that PCS from the 2015 production run should in theory be available.[835] He explained that

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832 Mr Premamoorthy's affidavit, affirmed on 22 September 2016, p 43.

833 Mr Premamoorthy's affidavit, affirmed on 18 March 2016, paras 6, 7, 11, 14 and 15; NE (23 March 2016) at p 225 lines 11–14; p 231 lines 16–23; p 232 lines 20–25.

834 NE (24 March 2016) at p 14 line 13 – p 15 line 1.

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he had misunderstood Kalzip's request as a request for PCS generated in the 2009 production run *only*, and not the 2015 production run. According to BFG's two-year destruction policy, the 2015 PCS should not yet have been destroyed.[836] In my view it is very clear from Kalzip's letter of 1 March that it was requesting the PCS from *both* the 2009–2010 and 2015 production runs and Mr Premamoorthy had no reason to construe it as otherwise.[837] However, I do not think he was deliberately concealing the 2015 PCS, since they surfaced only because of his own testimony at trial that they ought to be in BFG's possession.

371 On 29 March 2016, BFG took out Summons No 1506 of 2016 ("SUM 1506") seeking leave to file a fourth supplementary list of documents ("4SLOD") and for the documents listed therein to be admitted in evidence. The summons was supported by a third affidavit from Mr Premamoorthy, affirmed on 29 March 2016. The documents in question included one of each of the following for nine panels produced in 2015 (serial numbers 2 to 7 and additional samples #1 and #2):[838]

(a) a quality control sheet;

(b) a visual check sheet for gelcoat side;

(c) a visual check sheet for lamination side;

(d) a process control sheet;

(e) a ferrules dimension location checking;

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835 NE (24 March 2016) at p 68 line 4 – p 71 line 3.

836 Mr Premamoorthy's affidavit, affirmed on 22 September 2016, para 23; NE (24 March 2016) at p 73 lines 12–18.

837 Mr Premamoorthy's affidavit, affirmed on 22 September 2016, p 43.

838 Mr Premamoorthy's affidavit, affirmed on 29 March 2016.

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(f) a mould visual inspection report; and

(g) a mould dimensional inspection report.

372 On 1 April 2016, during witness conferencing, Mr Maurieschat stated that BFG had given him a copy of a PCS from 2009/2010 for review (see [192] above). He also said that Mr Premamoorthy had told him in January 2015 that PCS remained for the other panels.[839] Mr Premamoorthy subsequently denied telling Mr Maurieschat this[840], although he did say that at the time of his AEIC in November 2015 he himself believed that all the PCS existed, and only afterwards remembered that there was a company policy of destroying the documents after two years.[841]

373 On 1 August 2016, Kalzip wrote to BFG "to confirm" that it sought production from Mr Maurieschat of various documents which he had claimed during trial to have in his possession. These comprised one PCS from the 2009 production run, the ten panel-wise material consumption reports, and five panel weight record lists.[842] On 22 September 2016, after parties had exchanged written submissions in SUM 1506, Mr Premamoorthy filed a fourth affidavit seeking leave for the documents listed in an updated draft of BFG's revised 4SLOD to also be admitted in evidence. These further documents comprised:[843]

(a) 11 panel-wise material consumption reports for panels produced in 2009;

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839 NE (1 April 2016) at p 154, p 156 lines 18–24, p 160 line 12 – p 161 line 12.

840 NE (3 October 2016) at p 14 line 21.

841 NE (24 March 2015) at p 5 line 17 – p 6 line 1; NE (3 October 2016) at p 15 lines 12–25.

842 ABD N 150–151.

843 Mr Premamoorthy's affidavit, affirmed on 22 September 2016, at paras 51–52.

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(b) a further ten panel-wise material consumption reports for panels produced in 2009;

(c) one PCS for a GRP panel produced in 2009 (the same PCS which Mr Maurieschat had referred to during witness conferencing on 1 April 2016);

(d) 94 dispensing daily mixing reports for panels produced in 2009;

(e) 11 resin mixture monitoring record for panels produced in May–July and October 2015;

(f) quality control documents for two panels manufactured in October 2015 for fire tests (comprising one mould dimensional inspection report; one mould visual inspection report; one process control sheet; one visual check sheet for lamination side; one visual check sheet for gelcoat side; one quality control sheet; and one resin mixture monitoring document for each of the two panels); and

(g) 11 panel-wise material consumption reports in respect of panels produced in May–July and October 2015.

374 I heard SUM 1506 on 3 October 2016. As counsel for Kalzip pointed out, the documents were sought to be admitted very late in the day, after all the witnesses had given evidence (with the exception of the parties' fire experts, and Mr Maurieschat and Mr Premamoorthy who were recalled to give further evidence on specific points). I therefore gave BFG leave to file a 4SLOD comprising *only* the 11 panel-wise material consumption reports from 2009 and the single PCS from the 2009 production run (see [373(a)] and [373(c)] above), and none of the other documents listed at [371] and [373].

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375 Mr Maurieschat gave further oral evidence on 3 October 2016. He explained that he had received the single PCS from the 2009 production run by e-mail from Mr Kolhatkar on 4 October 2015.[844] According to Mr Premamoorthy, the PCS along with other documents had been kept by a colleague (Mary Ann Bautista, or "Mary Ann") in an arch file since around March or June 2010. Mary Ann used to be the "Production Clerk and Material Controller" for the Project and had been working in Factory 2 since 2011. During March to June 2010, Mr Anand was working on several submissions to be made to Kalzip to help Kalzip convince MBS that the panels could be used on the Project (see [12] above). As part of this process, Mr Anand asked Mary Ann to retain in an arch file some hard copies and some soft copies of such documents as he might require to take to Kalzip for meetings regarding the submissions he was preparing at the time. Mary Ann did so. His colleague, Mr Mohammed Naeem ("Mr Naeem"), informed Mr Premamoorthy in or around May 2015 that during Mr Maurieschat's visit he had approached Mary Ann to assist in the search for documents, and she produced the materials in the arch file.[845]

376 In Kalzip's closing submissions, it emphasised that BFG "changed its position" from insisting that no PCS remained to claiming that "one single piece of PCS" out of over 3,000 was "conveniently filed away by BFG" and that this one PCS was "coincidentally" for a non-delaminated panel.[846] I note that counsel for Kalzip made the other following points at trial:

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844 NE (3 October 2016) at p 66 lines 4–10; ABD N 235 at para 2(b).

845 Mr Premamoorthy's affidavit, affirmed on 18 March 2016, para 32; Mr Premamoorthy's affidavit, affirmed on 22 September 2016, para 32.

846 Plaintiff's Closing Submissions at para 365(j).

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(a) It was strange for BFG not to have retained the PCS despite knowing that there could be a claim for breach of the Sub-Contract, given that the PCS was the key document for verifying the manufacturing process.[847] As early as March 2010, BFG was receiving letters from Kalzip's lawyers alleging that the manufacturing process was defective and caused delamination.[848] In May 2010 BFG was notified of a claim for supplying defective panels.[849] BFG received Kalzip's letter of demand in May 2013.

(b) BFG's explanation that the PCS lost relevance after Loxon signed off on the quality control sheet was incredible. By the same logic, the mould visual inspection report and the mould dimensional inspection report ought also to have become irrelevant, yet these (one for each panel produced in 2009) were nevertheless retained.[850]

(c) As for space constraints, the PCS for 3,421 panels would have only required five arch files.[851]

(d) The alleged company policy of retaining documents for two years was inconsistent with BFG's Quality Assurance Plan, which stated that the "serial test report/control checklist/sample" was to be maintained for three years from the date of manufacture.[852]

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847 NE (24 March 2016) at pp 29–30.

848 ABD 11E 7207; NE (24 March 2016) at pp 27–28.

849 ABD 12E 7859, NE (24 March 2016) at p 29 lines 5–7.

850 NE (24 March 2016) at p 19.

851 NE (23 March 2016) at p 235 lines 2–15.

852 ABD 1K 347, 360; NE (24 March 2016) at p 16 lines 6–13.

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377 I decline to draw an adverse inference against BFG. Illustration (*g*) to s 116 was discussed in *Cheong Ghim Fah and another v Murugian s/o Rangasamy* [2004] 1 SLR(R) 628 in the following terms at [39] (cited with approval in *Surender Singh s/o Jagdish Singh and another (administrators of the estate of Narindar Kaur d/o Sarwan Singh, deceased) v Li Man Kay and others* [2010] 1 SLR 428 at [147]):

> … Section 116(*g*) encapsulates a common sense rule. In the scheme of our adversarial litigation procedures, it is perfectly permissible for a party not to call witnesses or adduce evidence on any material point in issue. Section 116(*g*) mirrors the common law approach that a party cannot take issue with the raising of inferences about matters that the party has chosen to consciously conceal or hold back. The inference must, it has to be emphasised, be reasonably drawn from the matrix of established facts. Satisfying the court as to the availability and materiality of the evidence is a necessary prerequisite to any application of s 116(*g*). For example, it has often been said if there is a reasonable explanation why a witness, who is out of the jurisdiction, cannot give evidence, the inference may not be raised. Having said that, in today's advanced technological context, replete with video-conferencing facilities and the like, older authorities on this point may need reconsideration.

378 Illustration (*g*) only permits the court to draw an adverse inference that evidence would be unfavourable if the evidence is *available*, *ie*, if it "*could be* and is not produced" [emphasis added]. I am not confident that BFG is able to produce the other PCS for the panels manufactured in 2009. Though BFG may be criticised for not preserving the relevant documentation, there is no objective evidence that the PCS actually exist. To the contrary, there is evidence that BFG has a policy of destroying documents once a certain period of time has elapsed after manufacture. While the PCS may only have occupied five arch files, they were a small part of the documentation that BFG had to handle – approximately 50,000–100,000 quality control and other documents for each project, and as many as 30–35 projects at any point in time.[853] Its policy of destroying

[853] NE (23 March 2016) at p 235 lines 6–15, p 237 lines 10–13; Mr Premamoorthy's

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documents was therefore understandable. BFG has also explained that the PCS was destroyed because it was designated for "Internal Use only".[854] This explains why the mould visual inspection report and the mould dimensional inspection report (see [376(b)] above) were *not* destroyed.

379 Though it is regrettable that the sole PCS which was discovered in 2016 was not disclosed earlier, I do not attribute this to any deliberate concealment on BFG's part. BFG did produce a substantial amount of other quality assurance documentation.[855] The PCS were produced very many years ago, and BFG's explanation of how that particular PCS came to be preserved is not implausible. Nor has it been proved that Mr Premamoorthy lied deliberately in his affidavit on 18 March 2016 that no PCS remained from the 2009–2010 production run. He was, after all, not the one who had sent the PCS to Mr Maurieschat. Though Mr Premamoorthy was told in May 2015 by Mr Naeem that he had approached Mary Ann for documents[856], there was no evidence that Mr Premamoorthy followed up on this or that he knew that the PCS was amongst Mary Ann's documents. There is therefore insufficient evidence for me to conclude that BFG either deliberately destroyed or is deliberately concealing the PCS. I have also explained why I do not think the late discovery of the nine PCS from the 2015 production run was the result of deliberate concealment.

380 Moreover, there is little reason to infer that if the PCS were produced, they would have been unfavourable to BFG. Each PCS was signed off by Loxon, whom Kalzip had engaged for the very purpose of keeping watch over

affidavit, affirmed on 22 September 2016, para 53.

854 Defendant's Closing Submissions at paras 833–834; Defendant's Reply Submissions at para 152.2.

855 Defendant's Closing Submissions at para 829; Defendant's Reply Submissions at para 152.2.

856 Mr Premamoorthy's affidavit, affirmed on 18 March 2016, para 32.

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the quality of the panels manufactured. If there were many PCS with anomalies or deficiencies, Loxon would *not* have signed off on these and would invariably have reported back to Kalzip separately. For these reasons, I decline to draw an adverse inference against BFG.

My conclusion on the cause of delamination

381 I earlier explained that, if Kalzip proves as a fact that the panels underwent widespread delamination, the tactical burden shifts to BFG to show that the panels delaminated because of some action or error not attributable to itself. If BFG fails to prove that any of these could have caused delamination, then by process of elimination it will be more likely than not that the panels delaminated because they were not manufactured to the requisite standard (see [262] above). If, however, BFG adduces enough evidence to disprove that the delamination was probably due to defective manufacturing, then Kalzip will have failed to prove on a balance of probabilities that BFG breached the Sub-Contract by supplying GRP panels which deflected excessively.

382 I have found that BFG had proved that the panels had been walked and jumped on, and that the workmen walking and jumping on the panels exerted a force in excess of the design load of the Sub-Contract (see [304], [306] and [308] above). This could have caused the panels to delaminate. I also found that items and materials had been placed and stored on the installed panels (see [285] above). There is also independent evidence from Aedas of numerous scratches, dents, rust, paint, chips, glass sucker and footprints on the GRP panel surfaces. This is backed up by the photographs in Aedas' report of 22 January 2010. However, there is no evidence as to how many panels were jumped on or whether these were the same panels that exhibited signs of delamination. I also found that the use of insufficient resin during BFG's manufacturing process

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could have made the panels more prone to delaminate (see [322]–[339] above).

383 The evidence does not enable me to say which of these causes was predominantly responsible for the evidence of delamination which I have enumerated at [249] above. Nor does the internal correspondence within BFG enable me to make such a finding, because it does not show that BFG unequivocally accepted that its own manufacturing process was to blame. On the contrary, BFG at first repeatedly laid the blame at Kalzip's door for mishandling and misuse of the panels (see [303] above). Subsequently, when Kalzip confronted BFG with evidence that some cored samples were underweight, BFG was forced to recognise both manufacturing inconsistency and mishandling as potential causes of the delamination. But while BFG may have had internal doubts about the integrity of its manufacturing process, there is no evidence of BFG accepting (either internally or *vis-à-vis* Kalzip) that that process had caused the delamination. Whereas Dr Samer expressed the view that the state of the panels was "indicative of a manufacturing defect", he did not give evidence, and Mr Premamoorthy disagreed with his view. In an internal e-mail on 7 March 2010, Mr Kolhatkar suggested sending panels which had not yet been installed for load testing, so as to determine whether the delamination on the installed panels was attributable to misuse or defective manufacturing:[857]

> So the actual technical problem is that there are some panels that have not been manufactured upto [*sic*] the required level of quality. We are doing a muffle furnace burn off of some of the skins received from [Kalzip] to prove to [Kalzip] that actual layup is same as designed. Should this test get through successfully, I have been insisting that we take the risk and go through a full scale load test on the panels that have not undergone the installation misuse i.e. panels in containers. If we pass this load test, which if panels are made to designed layup, they would as per initial test results, then BFG gets in strong position to state

857 ABD 10E 6635.

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> that the misuse is the root cause. Should the test fail, then manufacturing defect would be taken as root cause. As [Kalzip] are almost sure that panel will pass, they have completely denied taking this route.

384 In other words, BFG was undecided whether the defective manufacturing and/or the misuse (in terms of the panels being walked and jumped on and having items and materials placed or stored on them) was to blame. BFG thus proposed that panels which had not yet been installed be tested for delamination.[858]

385 It may well be the case that either or both these causes contributed to the panels delaminating. Having considered and weighed all the evidence put before me and for the reasons set out above, my conclusions are as follows:

(a) Kalzip has not proved its case that there was widespread inner skin delamination. The only such delamination which it can be said to have proved is of 20 panels on the casino building roof. This is based on Mr Kolhatkar's e-mails to Mr Carter on 2 February 2010 and to Dr Samer on 8 February 2010, as well as the site investigation report attached to the latter e-mail (see [147] and [148] above).

(b) Kalzip has shown that there was some inconsistency in BFG's manufacturing process from its coring of what were effectively four samples (see [324] above; the fifth cored sample was from the mock-up). There were two core samples from panel 13 of leaf 13 of the casino building, and one core sample each from leaf 15, panel 9 and leaf 16, panel 5 of the MICE building. The differences in weight between the core samples indicate that parts of some panels received insufficient resin during manufacture. This does not detract from the views I have

858 ABD 10E 6526.1, 6526.7.

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expressed concerning the conclusions that may reliably be drawn from the coring process, in particular that it does not establish delamination.

(c) The four core samples also do not prove, on balance, that BFG's manufacture of the GRP panels was systemically defective.

(d) There is no evidence that the cored casino panel (leaf 13, panel 13) was one of the 20 delaminated panels. There is also no evidence that inadequacy of resin was the cause of that panel, or any of the 20 panels, delaminating. I have mentioned above, *inter alia*, Loxon's presence at the BFG plant and its sign-off on each panel produced by BFG. There is a complete lack of evidence of any particular panel suffering inner skin delamination as a result of defective manufacture.

(e) Importantly, there is evidence that the GRP panels on the casino building were mistreated and misused by workmen onsite after being installed. They were subjected to loads in excess of those which they were designed to bear as a result of being jumped on and walked on. Materials were also placed or stored on them. On balance, I am persuaded that such mistreatment and misuse was the, or the major, cause of delamination. I am unable to conclude that any of the 20 panels (or any others which may have delaminated) delaminated as a result of defective manufacture.

(f) I find that these 20 panels may never have suffered inner skin delamination, notwithstanding some possible inconsistencies in manufacture, but for the mistreatment and misuse by workmen. In other words, I am unable to find, on balance, that the panels with delaminated inner skins (if any) would not have delaminated but for the inadequacy of resin used. As Kalzip bears the legal burden of proving this, I find

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that it has failed to establish that BFG breached its obligations under the Sub-Contract.

Issue 4: Implied terms

386 Kalzip pleaded and relied on three terms implied pursuant to the SGA (see [29] above). On Kalzip's case, the breach of the implied terms depends on Kalzip establishing that the panels (1) exceeded the deflection limits in the Sub-Contract due to having delaminated as a result of defective manufacturing and/or (2) failed to comply with the fire safety requirements in the Sub-Contract. It is not Kalzip's case that the implied terms were breached for any other reasons.

387 This is supported by the pleadings and closing submissions. In Kalzip's Statement of Claim (Amendment No 3), it pleaded that "in breach of the terms implied by the various Sections of the Sale of Goods Act (Cap 393) … the Defendant failed to provide GRP panels which were fit for purpose, of satisfactory quality, free from defects and safe".[859] BFG requested the following further and better particulars: "the details and/or particulars of the failure of the GRP panels to be fit for purpose", "the details and/or particulars of the failure of the GRP panels to be of satisfactory quality", "the details and/or particulars of the failure of the GRP panels to be free from defects", "the details and/or particulars of the failure of the GRP panels to be safe", and "the facts, matters and circumstances relied on by the Plaintiff for the allegation that the Defendant failed to provide GRP panels which were fit for purpose, of satisfactory quality, free from defects and safe". Kalzip's response to all of these questions was, "Please see paragraph 33 of the Statement of Claim."[860] Paragraph 33, under the

859 Statement of Claim (Amendment No 3) at para 36.

860 ABD A 80–81.

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heading "The defective GRP Panels", asserts that the panels were defective and/or non-compliant with the express and implied terms of the Sub-Contract in the three following ways: (1) delamination of the inner skin from the honeycomb core; (2) inability to meet the loading and structural performance requirements; and (3) inability to meet the fire safety requirements.

388 Kalzip's closing submissions likewise focus on establishing that the panels delaminated and/or failed to comply with the fire safety requirements. The 323-page closing submissions only discuss the implied terms briefly under Section 5 ("Remedies sought by Kalzip"), under the sub-section titled "Total failure of consideration", to support Kalzip's claim in restitution for recovery of the sums paid under the Sub-Contract. Kalzip's aide-memoire for its oral closing submissions likewise only mentions the implied terms at para 16: "Kalzip further entitled in-principle to claim in restitution for contract price for total failure of consideration". Kalzip's argument is that, because the GRP panels supplied by BFG breached the technical requirements of the Sub-Contract (*ie*, by deflecting excessively due to delamination and/or not complying with the fire safety requirements), Kalzip did not receive any part of the consideration which it bargained for. This benefit or consideration "was that the GRP panels from BFG would comply with all of the technical requirements and specifications prescribed by the Sub-Contract and thus be acceptable to MBS".[861] In other words, the implied terms under the SGA are only relevant insofar as Kalzip is able to prove that the panels delaminated or failed to comply with the fire safety requirements of the Sub-Contract. Indeed, to establish that it did not receive the whole consideration under the Sub-Contract, Kalzip asserts that the panels "failed to comply with all of the technical requirements and

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[861] Plaintiff's Closing Submissions at paras 607–611; see also Plaintiff's Reply Submissions at para 578.

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specifications prescribed by the Sub-Contract with the consequence that MBS rejected them for installation".[862]

389 BFG also appears to have understood Kalzip's case in this way. Its closing submissions only address the implied terms on the assumption that the plaintiff is able to establish delamination. Pages 348 to 356 of BFG's closing submissions thus advance the argument that *even if* the panels had delaminated, that would not entail any breach of the implied terms. In its 274-page reply submissions, Kalzip responds to this argument under the section titled "BFG's contention that even if the panels were delaminated, BFG is not in breach of the implied terms". That is the only section of Kalzip's reply submissions in which the implied terms are discussed. Again, the breach of the implied terms is characterised solely in terms of delamination and fire safety. This is shown by paras 447–448 and 456–457 from the relevant section of Kalzip's reply submissions, which state:

> 447. … BFG agreed and represented under the Sub-Contract that it could produce GRP panels that satisfy the requirements stipulated in the Sub-Contract (including the *structural performance requirements* and *fire safety requirements*).
>
> 448. The risk therefore remained on BFG to deliver GRP panels that were fully *in compliance with the requirements of the Sub-Contract* regardless of the contract price. This, as the evidence has shown, it failed to do so. BFG therefore cannot credibly claim that the GRP panels delivered were of satisfactory quality.
>
> …
>
> 456. It is Kalzip's case that the GRP panels would have to comply with all of the contractual requirements in the Sub-Contract in order to satisfy the purpose for which they were purchased.
>
> 457. Insofar as BFG is found to be in breach of any of the *contractual structural performance or fire safety requirements* or both, the GRP panels supplied by BFG clearly could not have been fit for the purposes intended under the Sub-Contract.

862 Plaintiff's Closing Submissions at para 613.

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[emphasis added]

390 I have found that BFG did not breach the technical requirements and specifications of the Sub-Contract by supplying GRP panels which either delaminated or failed the fire safety requirements as a result of defective manufacturing. In the circumstances, Kalzip has not established its case regarding the breach of implied terms.

Issue 5: Fire safety requirements

The requirements

391 The parties and their fire experts agreed that the Sub-Contract required the GRP Panels to meet the following fire safety requirements:[863]

(a) to achieve a weighted toxic fume sum of less than 1 when tested to Annex B.2 of the BS 6853:1999 standard; and

(b) to meet Class 0 as defined by the 2000 Edition of the UK Building Regulations Approved Document B with 2002 amendments ("Approved Document B"), which in turn required the GRP panels to:

(i) have a Fire Propagation Index, as defined by BS 476-6:1989+A1:2009 ("BS 476 Part 6"), of less than 12, and a sub-index i_1 of less than 6; and

(ii) have a flame spread rating of Class 1 as defined by BS 476:Part 7:1997 ("BS 476 Part 7").

392 Compliance with Class 0 was also significant to obtaining the waiver issued by the Fire Safety and Shelter Department, without which the GRP panels

863 ABD 4C 1295; ABD 1D 42 and 84; Plaintiff's Closing Submissions at paras 147(a) and 373–374; Defendant's Closing Submissions at para 153.

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could not have been installed. Showing that the GRP panels achieved Class 0 classification enabled them to be listed in the Product Listing Scheme, which listing was a condition of the waiver.[864]

393 The BS 476 Part 6 test, which tests propensity to propagate fire, involves placing a small sample of material in an oven and measuring the increase in temperature over a given period of time when the material is heated in the presence of a pilot flame. Subindices i_1, i_2 and i_3 measure the rise in temperature from ½ to 3 minutes, from 4 to 10 minutes and from 12 to 20 minutes (averaged for three samples) respectively. The Fire Propagation Index, I, is the sum of the three subindices. To achieve a rating of Class 0, a material must have an i_1 of six or less and a Fire Propagation Index of 12 or less.

394 The BS 476 Part 7 test, which tests the propensity for flame spread over the surface of the product, involves mounting a sample on a frame which is then swung into position at a right angle to a radiant panel. The radiant panel heats the surface of the sample, causing it to emit gases as the surface breaks down. A gas pilot flame is located near the corner of the sample nearest the radiant panel, causing any flammable gases emitted by the sample to combust, leading to a flame on the surface of the sample. The material is classified as Class 1, 2, 3 or 4 based on how far the flame spreads at various time intervals.[865]

395 I note that BFG submitted that the BS 476 Part 3 test was a more appropriate test for the GRP panels.[866] However, even if true, this is irrelevant to the present case, since the Sub-Contract clearly provided for the BS 476 Part 6 and 7 standards.

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[864] ABD 4C 1308 at paras 5.3 and 5.4.

[865] ABD 1C 176–184.

[866] Defendant's Closing Submissions at paras 365–371.

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396 The parties each called a fire expert. Kalzip called Prof Lygate, the Principal Investigator with International Fire Investigators and Consultants Limited. BFG called Dr Crowder, the Head of Fire Investigation and Expert Witness Services at BRE Global ("BRE").[867]

397 It is not in dispute that the GRP panels complied with the BS 6853:1999 standard, but Kalzip claims that the GRP panels did not meet the BS 476 Parts 6 and 7 standards. The following tests were carried out on GRP panel samples and their reports were in evidence before me:[868]

	Report date	**Testing organisation**	**Whether achieved Class 0**
1	30 June 2005	**Qinetiq** Report nos HAF111v2 and HAF143	Yes
2	31 May 2008	**TUV SUD PSB** Report nos S08MEC03047/1A/OKH and S08MEC03047/2A/OKH	Yes
3	30 July 2008	**TUV SUD PSB** Report nos S08MEC03047/1A/ADD/OKH and S08MEC03047/2A/ADD/OKH	Yes
4	11 November 2009	**TUV SUD PSB** Report no 0719162263/2/YWA	Yes
5	11 November	**TUV SUD PSB**	Yes

867 ABD 4C 1311.

868 ABD 1C 186 (para 6.1.1) and ABD 1C 190 (para 6.2.7).

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	2009	Report no 0719162263/1/OKH	
6	14 April 2010	**TUV SUD PSB** Report no 719173712-MEC10-MW	No
7	18 June 2010	**BRE Global** Report no 263600	Yes
8	28 June 2010	**BRE Global** Report no 263603	
9	27 July 2011	**BRE Global** Report nos 272253, 272257, 272254, 267824, 272247, 272248, 272249, 272250, 272251, 272252, 272255, 272256	No
10	2 September 2011	**TUV SUD PSB** Report nos 7191015369-MEC11/A1-OKH, 7191015369-MEC11/B1-OKH, 7191015369-MEC11/C1-OKH, 7191015369-MEC11/D1-OKH, 7191015369-MEC11/E1-YWA, 7191015369-MEC11/F1-YWA	No
11	5 September 2011	**Exova Warringtonfire** Report nos 306954, 306955, 306956, 306957, 306958, 306959, 306960, 306961, 306962, 306963, 306964, 306965	No
12	6 September 2011	**TUV SUD PSB** Report nos 7191015369-MEC11/A2-YWA, 7191015369-MEC11/B2-YWA, 7191015369-MEC11/C2-YWA, 7191015369-MEC11/D2-YWA	No

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13	7 September 2011	**TUV SUD PSB** Report nos 7191015369-MEC11/E2-YWA, 7191015369-MEC11/F2-YWA	No
14	10 April 2012	**TUV SUD PSB** Report nos 7191030245-MEC12/A1-MHA, 7191030245-MEC12/B1-OKH, 7191030245-MEC12/C1-MHA, 7191030245-MEC12/A2-YWA, 7191030245-MEC12/B2-YWA, 7191030245-MEC12/C2-YWA	No
15	26 November 2015	**BRE Global** Report nos P100323-1009-4 Issue 1, P100323-1009-2 Issue 1	No

398 I note at the outset that the experts both agreed that the tests were undertaken by laboratories whose test procedures and quality control procedures are accredited, monitored and assessed by independent agencies, and that – to the extent that they could judge – the tests were undertaken and reported in accordance with the relevant standards.[869]

399 Test report no HAJ210 issued by Qinetiq on 11 August 2008 is not included in the table above, and I had no regard to it, because it tested fire performance against the BS 6853 standard, and not the BS 476 Parts 6 and 7 standards.[870] The two reports issued by Qinetiq on 30 June 2005 (s/n 1 of the table at [397] above) are also irrelevant because the samples used for those tests were panels provided to the London Underground Project and are irrelevant in terms of any discussion concerning how the panels produced by BFG actually

869 ABD 4C 1295–1296.

870 ABD 2C 722 at para 7.

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performed.[871] The fire tests conducted in 2008, 2009 and April 2010 (s/n 2–8 of the table at [397] above) ("the 2008–2010 tests") showed that the test specimens met the fire safety performance requirements of the Sub-Contract.[872] On the other hand, the fire tests conducted in June 2011 and 2012, after the GRP panels were installed (s/n 9–15 of the table at [397] above) ("the 2011–2012 tests"), showed that the test specimens obtained from GRP panels taken from the buildings in the Development failed to achieve a Class 0 rating. Unsurprisingly, Kalzip relied on the 2011–2012 tests to submit that the GRP panels did not meet the Sub-Contract requirements, while BFG relied on the 2008–2010 tests to show that they did. Much of the experts' disagreement focused on the extent to which the tested panels were representative of the actual GRP panels supplied by BFG (and, by extension, how reliable the test results were in showing the panels' ability to meet the Sub-Contract requirements).

400 Kalzip submits that the 2008–2010 tests are not reliable because of doubts as to the provenance of the tested panels and because the manufacturing process which they underwent (in particular, the use of oven curing) was not identical to that of the GRP panels used in the Project.

401 BFG submits that the 2011–2012 tests are not reliable because the samples were not representative of the installed panels, due to (1) the absence of edge-sealing on the samples tested; (2) the fact that some of the test samples became delaminated after being removed from the site; and (3) the fact the tested panels were aged or exposed to the external environment, which could have led to contamination, leaching or degradation of fire retardant components.[873] Dr Crowder considered that the first factor was the most significant, followed by the second, then the third.[874]

871 ABD 2C 701 at para 129; NE (5 October 2016) at p 92 lines 14–22.

872 ABD 4C 1303 at para 2.

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The 2008–2010 tests

The 2008 tests

402 The 2008 fire tests (s/n 2 and 3 of the table at [397] above) predated the Sub-Contract itself. Dr Crowder agreed that, since they were not taken from the production run but specially manufactured for the purpose of testing and demonstrating performance, their representativeness could not be assumed without further evidence. He had not seen any such evidence.[875] Mr Kolhatkar, who was in charge of the GRP panel design, gave evidence that the lay-up of the GRP panels tested in 2008 was different from that of the GRP panels manufactured in 2009 for the Project.[876] The panels tested in 2008 were 20mm thick (with an upper skin comprising CSM and biaxial glass, and a 12mm-thick honeycomb core), whereas the GRP panels used in the Project were 24mm thick (with an upper skin comprising only CSM, and a 20mm-thick honeycomb core).[877] (Though the parties initially agreed for the panels to be 22mm thick, it appears that the panels supplied were 24mm thick. BFG claims that the parties expressly agreed to increase their thickness. However, nothing turns on this.[878]) Prof Lygate commented that the thickness of the top layer of the GRP panel, as well as the thickness of the honeycomb, might affect fire performance.[879]

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873 Defendant's Closing Submissions at paras 321 and 334.

874 ABD 4C 1281 para 43.

875 NE (5 October 2016) at p 93 line 25 – p 95 line 5.

876 Plaintiff's Closing Submissions at para 469.

877 Plaintiff's Closing Submissions at para 470; ABD 9E 5528–5530; NE (29 March 2016) at p 135 line 18 – p 137 line 19; NE (4 October 2016) at p 20 lines 16–17.

878 Defendant's Closing Submissions at paras 98–99.

879 ABD 4C 1304 at para 3.5; NE (4 October 2016) at p 21 lines 7–12, p 31.

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403 The 2008 tests predated the manufacture of the GRP panels used in the Project. BFG focused on the 2009 and 2010 tests, which Dr Crowder thought would be more probative than the 2008 tests, in its submissions.[880] I therefore decline to place any reliance on the 2008 tests and turn to the 2009 and 2010 tests now.

The November 2009 fire tests

404 Kalzip points out that the panels tested in the November 2009 fire tests (s/n 4 and 5 of the table at [397] above) had been manufactured in Bahrain, whereas the actual GRP panels supplied for the Project had been manufactured in the Philippines.[881] Moreover, the 2009 test samples in Bahrain had been oven-cured at 100°C for five hours[882], whereas the GRP panels were left to cure at room temperature for a minimum of 3½ hours.[883] Kalzip submits that the results of the November 2009 fire tests cannot be relied on for this reason.[884] When these differences were posed to Dr Crowder, he accepted that the 2009 test specimens could not be *assumed* to be representative of the GRP panels.[885] Prof Lygate's expert reports did not discuss the effect of oven curing on the November 2009 fire tests, although he did express the view that oven curing a sample improves its fire performance.[886] This might suggest that the 2009 test specimens performed better in the fire tests than the actual GRP panels would have.

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880 Defendant's Closing Submissions at para 281.

881 Plaintiff's Closing Submissions at para 481.

882 NE (29 March 2016) at p 133 line 25 – p 134 line 5; ABD 9E 5530.

883 Plaintiff's Closing Submissions at para 476.

884 Plaintiff's Reply Submissions at para 161.

885 NE (5 October 2016) at p 98 lines 10–13.

886 NE (5 October 2016) at p 5 lines 2–5.

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405 I do not consider the November 2009 fire tests to be unreliable simply because the test panels were manufactured in Bahrain rather than the Philippines. No evidence was led to show that the manufacturing process was different (save for oven curing, below), or that the difference in place of manufacture would have caused any qualitative difference in the fire performance of those panels. To the contrary, Kalzip's position prior to and during the arbitration was that the November 2009 fire tests were reliable. In a status report dated 4 June 2010, from Kalzip to MBS, Mr Carter wrote that during the qualification process for the GRP panels, samples were fire-tested and achieved the desired results.[887] During the arbitration itself, Mr Carter stated in his rebuttal witness statement that BFG's test panels had passed the November 2009 fire tests and that the results were approved by MBS.[888] The November 2009 fire tests are also referred to on the Product Listing Scheme website for BFG's GRP panel.[889]

406 As for oven curing, I note that Dr Crowder commissioned a fire test in 2015 to determine the effect of oven curing (s/n 15 of the table at [397]). He found that the result was marginally worse where oven curing had been applied. However, Dr Crowder cautioned against concluding that oven curing definitively worsened fire performance given the variability of fire testing. The conclusion that he drew from the test was that oven curing "made no appreciable difference" in the two suites of tests.[890] During witness conferencing, Dr Crowder stated that he had seen no documentary evidence showing that the GRP panels supplied to the Project had been oven-cured for four to five hours at 60°C in accordance with BFG's sample preparation methodology,[891] although he had

887 ABD 12E 7882.

888 ABD 12L 7905 at para 19; ABD 12L 8039–8051.

889 Defendant's Closing Submissions at para 161; ABD 26L 18748.

890 NE (5 October 2016) at p 7.

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proceeded on that basis for the purposes of the 2015 tests. Dr Crowder accepted that if no information was in fact available to the court about the conditions of oven curing, that would affect the reliability of the 2015 tests.[892]

407 I do not accept the 2015 test commissioned by Dr Crowder as proof that the presence or absence of oven curing makes no appreciable difference to fire performance. Pursuant to the scientific method, Dr Crowder initially planned to carry out 16 tests, each a permutation of four different variables: (1) whether the samples were new or old, (2) whether they were edge sealed, (3) whether they were oven cured and (4) whether they were delaminated. The results could be compared with each other to investigate the effect of each variable in isolation. However, due to unforeseen circumstances and time constraints, Dr Crowder was only able to perform two tests, both of which were on new, non-edge-sealed, non-delaminated samples. One set of samples was oven-cured and the other was not.[893] The two tests could be compared to gauge the effect of oven curing on this pair of panels, which were the same in respect of the other three variables (thus isolating the variable of oven curing). It was from this comparison that Dr Crowder deduced that oven curing produced no appreciable effect on fire performance. However, since the other 14 intended tests could not be carried out, Dr Crowder lost the opportunity to see if the same result was observed in relation to pairs of panels which were (1) new, edge-sealed and non-delaminated; (2) new, edge-sealed and delaminated; (3) old, edge-sealed and non-delaminated; (4) old, edge-sealed and delaminated; (5) old, non-edge sealed and delaminated; and (6) old, non-edge-sealed and non-delaminated.[894]

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891 ABD 4C 1313.

892 NE (5 October 2016) at pp 120–123.

893 NE (5 October 2016) at pp 134–135; ABD N 337.

894 ABD N 337.

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408 Dr Crowder accepted that the 2015 test was therefore "necessarily limited by the fact that the scientific methods were not followed in whole", and the conclusions that could be drawn from the evidence were likewise limited. He agreed with counsel's suggestion that the 2015 tests were not a scientifically reliable series of tests from which appropriate conclusions could be drawn.[895] Dr Crowder also stated that, apart from the 2015 tests, there was no evidence one way or another to confirm whether oven curing had an impact on fire performance.[896]

409 This left me with no clear evidence that oven curing *was* material to fire performance. Kalzip, which bore the burden of proving on a balance of probabilities that BFG had breached the fire safety requirements in the Sub-Contract, offered no evidence in that regard and submitted that the issue of oven curing was a "red herring in these proceedings" and that there was no utility in engaging in an analysis of the effects of oven curing.[897] I therefore find that Kalzip did not manage to show that the November 2009 tests were unreliable simply because the panels were oven cured.

The June 2010 fire tests

410 Kalzip submits that there is no basis to suggest that the test specimens for the June 2010 fire test (s/n 7 and 8 of the table at [397] above) were taken from the production run and therefore representative of the GRP panels.[898] However, Mr Carter's rebuttal statement in the arbitration stated that the panels used in the June 2010 fire test were taken from the factory, from a batch which

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895 NE (5 October 2016) at p 137 lines 1–11.

896 NE (5 October 2016) at p 160 lines 1–3.

897 Plaintiff's Closing Submissions at paras 479 and 480.

898 Plaintiff's Reply Submissions at para 181.

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was considered to be representative of the panels installed on the roof, and had sealed edges.[899] A letter from Kalzip to MBS on 28 September 2010 likewise stated that the June 2010 fire tests were "carried out on panels from an original batch, representative of the panels installed/delivered on the project".[900] This was in line with what Dr Crowder considered to be the "best practice approach to sample selection for fire testing".[901] The June 2010 tests were witnessed by representatives from Kalzip and BFG.[902] Moreover, Kalzip had engaged Prof Nonhoff to conduct spectrometry testing in order to ascertain whether the panels used in the June 2010 were the same as those installed on the roof. Three samples were submitted – one retained from the June 2010 fire tests, one retained from the original 2009 selection procedure, and one taken from the MICE roof – and Prof Nonhoff's Energy-dispersive X-ray spectroscopy (EDX) Analysis Report concluded that all three were of "nearly identical chemical composition".[903] A test carried out by Smithers Rapra Technology on 11 July 2011 showed that the panels from the three buildings were chemically similar to one another.[904] The experts agreed that chemical composition was one variable (of many) that was relevant to the representativeness of the panels.[905]

411 Kalzip also submits that the June 2010 fire tests were "inherently unreliable" because there was no evidence, apart from what Kolhatkar had purportedly told Dr Crowder, that the material used to seal the edges of the test samples was the same as the material used to construct the GRP panels for the

899 ABD 12L 7906 at para 27.

900 ABD 13E 8502.

901 ABD 4C 1272 at para 12.

902 ABD 13E 8179 at para 54; ABD 12L 7907 at para 29.

903 ABD 1C 90–91.

904 ABD 2C 702, para 140; ABD 2C 687, para 82.

905 Plaintiff's Reply Submissions at para 183.

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Project.[906] Moreover, the samples did not have a U-channel (or gutter) along the edges, which the actual GRP panels had.[907] Prof Lygate stated that this would have had an effect on fire performance.[908] Dr Crowder also said that, "ideally", the test samples would have "replicated along at least one edge … some sort of detail to match what's on the panel".[909] Kalzip submits that, if I were to accept BFG's submission that the test samples had to be edge-sealed in order to be representative, then the June 2010 fire tests were likewise unreliable because the samples tested lacked the gutter detail.[910]

412 This did not advance Kalzip's case. The samples tested in the 2011–2012 tests did not have a gutter detail either.[911] If I were to accept BFG's submission that edge sealing and detail are relevant to fire performance, then that would suggest that *neither* the June 2010 fire tests nor the 2011–2012 tests were reliable. Kalzip, as the plaintiff, would then have failed to prove breach of the fire safety requirements on a balance of probabilities. On the other hand, if I were to find that edge sealing and detail are irrelevant to fire performance, then there would be no reason to doubt the reliability of the June 2010 fire tests.

The 2011–2012 tests

413 The panels used for the 2011–2012 tests were taken from the GRP panels removed from the Project.[912] However, BFG submits that the performance of the test samples in the 2011–2012 tests was not representative

906 Plaintiff's Closing Submissions at para 489.

907 ABD 1I 131 and 29L 21083; NE (5 October 2016) at p 102.

908 NE (4 October 2016) at p 80 lines 4–18.

909 NE (5 October 2016) at p 101 lines 12–14.

910 Plaintiff's Closing Submissions at paras 487–488.

911 Defendant's Reply Submissions at para 224.1.

912 Plaintiff's Closing Submissions at para 433.

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of the panels from which those samples were cut, because of (1) the absence of edge sealing, (2) the fact that the panels had delaminated, and (3) exposure to the environment and ageing.

The significance of edge-sealing

414 Dr Crowder, BFG's expert, expressed concern that "very little information" was available concerning the condition of the samples used in the 2011–2012 tests. He thought that differences in material composition, physical composition and mechanical composition of the panels could have contributed to variations in fire performance.[913] In particular, he considered that the 2011–2012 tests were not reliable because the test samples were not edge-sealed and therefore not representative of the GRP panels supplied under the Sub-Contract, which were edge-sealed. Prof Lygate, on the other hand, stated in the experts' memorandum of agreed and disagreed issues that the absence of edge sealing had no significant impact on whether or not the samples passed or failed the BS 476 Part 7 test.[914] However, he clarified at trial that he could not opine one way or another:[915]

> PROF LYGATE: I think my opinion is that it is impossible to determine the exact effect of edge sealing on the fire performance of the panels without a detailed scientific test.
>
> MR SOH: You haven't undertaken any scientific tests yourself, right?
>
> PROF LYGATE: I have not.
>
> MR SOH: Hence, wouldn't it be fair to say that your opinion, as of today, before this court, is that you can't possibly tell the court one way or the other whether edge sealing would have an effect on the outcome of the fire test?

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913 ABD 2C 702 at para 139.

914 ABD 4C 1304 at paras 3.4 and 3.5.

915 NE (4 October 2016) at p 79 line 16 – p 80 line 3.

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PROF LYGATE: That's correct.

415 Significantly, the experts agreed that flaming along the top edge of the sample would worsen the test sample's performance in the BS 476 Part 7 test. Dr Crowder explained that where there was no edge sealing, a greater quantity of flammable gases would be released via the unsealed edges of the samples, creating a greater risk of ignition. The court was shown two videos in which flashing flames could be seen along the top edge of test samples and then shooting down, which Dr Crowder took as evidence of ignition along the unsealed edges. He took the view that the flames had been caused by additional gases leaving the unprotected edge of the sample and coming around underneath the sample holder. The flaming provided a pilot ignition source for any flammable gases produced across the surface of the sample. Such ignition would then throw additional heat into the panel, further exacerbating the production of volatile gases, which were in turn more likely to ignite. This would increase the amount of time during the test that flaming would be present across the entire sample.[916] Prof Lygate agreed with Dr Crowder's interpretation of the videos, acknowledged that flaming occurred at the top edge of some of the test samples, and accepted that such flaming had the capacity to ignite flammable gases lower down the sample which were not hot enough to auto-ignite.[917] After being shown the videos, he agreed that "flaming at the top edge has an effect".[918]

416 Kalzip pointed out that BS 476 Part 7 expressly states that flash flaming does not influence the classification of flame spread, as follows:[919]

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916 ABD 4C 1277–1278 at para 34; NE (4 October 2016) at p 157 lines 15–23.

917 NE (4 October 2016) at pp 145–146 and p 159 lines 13–16.

918 NE (4 October 2016) at p 163 lines 15–16.

919 Plaintiff's Reply Submissions at paras 74(b) and 129; ABD 1D 100.

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> **9.2.2** Throughout the test, carefully observe the behaviour of the product and make a note of the following phenomena:
>
> a) flashing;
>
> b) transitory flaming.
>
> …
>
> NOTE. These observations do not influence the classification of surface spread of flame.

However, whether flashing or transitory flaming affects the classification under the test is not to the point. It is not in dispute that the classification under Part 7 depend on the progress of flame spread along the tested surface, and not on the presence of flashing *per se*. The pertinent question is whether flash flaming shows that the progress of flame spread was affected by the lack of edge sealing affected. The expert evidence suggested that it did.

417 Prof Lygate contended that although the test panels were not edge-sealed, the edges of each specimen were nevertheless protected by the 20mm (+/-5mm) cover provided by the specimen holder frame.[920] Both experts agreed, however, that the specimen holder frame would not have the same effect as edge sealing, because the sample holder does not hermetically seal the specimen as the sample may not press perfectly against it.[921] Prof Lygate referred to an Exova Warringtonfire test report no 306954 (dated 5 September 2011) in which six sample panels had been tested. A white border could be seen around three of the panels, where the specimen holder frame had protected the border of the specimen. On the other three panels, however, the border was blackened by scorch marks, perhaps because flammable gases had pushed past the honeycomb to the top edge or because the face of the specimen was not pressed hard against the specimen holder. Similar scorch marks were seen in

920 ABD 2C 616 at para 2.27.

921 ABD 4C 1288 at para 82.3; NE (4 October 2016) at p 86, p 113 lines 15–22.

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photographs taken of other test panels.[922] This showed that the specimen holder frames alone could not be relied on to protect the specimens from being burned at the edges. Kalzip accepted this.[923]

418 Prof Lygate also relied on test report no 306954 to suggest that there was no correlation between flame spread and the damage pattern observed on the top edge of the specimen. All six panels showed a flame spread exceeding the Class 1 limit of 165mm within 10 minutes, regardless of whether the border was fully protected or not,[924] and there was no obvious correlation between whether the border was protected and the degree of flame spread.[925] I bear in mind, however, that both experts agreed that fire testing depends on a complex interaction of factors (including geometry, manufacturing method, curing, thickness and the chemical properties of the samples), thus requiring the tests to be conducted and aggregated across a group of specimens rather than just one or a few in order to be reliable.[926] Besides his observations in relation to test report no 306954, Prof Lygate did not conduct any broader analysis or research to support his hypothesis that there was no correlation between border protection and flame spread. Dr Crowder maintained that no firm conclusion could be drawn about the lack of correlation between edge sealing and flame spread from a sample size of six alone.[927] I accept Dr Crowder's evidence in this regard. Moreover, as I have said, Prof Lygate accepted (in relation to the two videos shown to the court) that flaming along the edges of the test panels did have an effect on flame spread. This appeared to be at odds with his articulated

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922 ABD N 295–300; Plaintiff's Closing Submissions at para 245.

923 Plaintiff's Reply Submissions at para 141.

924 NE (5 October 2016) at p 33 lines 7–11.

925 ABD 2C 620–621.

926 ABD 4C 1304 at para 3.5; NE (4 October 2016) at p 138 lines 3–17.

927 NE (4 October 2016) at p 153.

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view that flaming along the blackened borders of the test panels bore no correlation to flame spread.

419 Prof Lygate also suggested that the test panels were "in effect edge sealed" by the aluminium honeycomb lattice itself,[928] provided that the upper and lower surfaces were bonded.[929] Dr Crowder agreed in principle, but pointed out that the panels tested by two of the three testing houses had delaminated sometime between removal from the building roofs and transportation to the testing house (see [437] below), and as such were no longer representative of the actual GRP panels.[930] Dr Crowder also pointed out that the cut edges of each test sample would break one row of the honeycomb cells and expose them directly to the heat, while also allowing heat exposure into the next layer of cells down. Even though the rest of the cells would be hermetically sealed (assuming no delamination), Dr Crowder considered that the exposure would worsen the sample's fire performance, particularly given that the size of the honeycomb cells was significant in relation to the size of the overall samples.[931] While Kalzip sought to discredit this evidence in its submissions by pointing out that the exposed cells would amount to just 3% of the length and 12% of the width of the test sample, which was not "significant", this was not put to the expert witnesses.[932] The submission that these percentages were not significant was not supported by any scientific research.

420 It is not in dispute that the BS 476 Parts 6 and 7 standards do not expressly require test samples to be edge-sealed, unlike, for example, BS 476

928 ABD 2C 618 at para 2.31; NE (4 October 2016) at p 82 lines 9–19.

929 NE (4 October 2016) at p 29 lines 4–8.

930 NE (4 October 2016) at pp 47–48.

931 NE (4 October 2016) at pp 83–84; NE (5 October 2016) at pp 168–169.

932 Plaintiff's Reply Submissions at para 98.

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Part 3, which requires the edge of the specimen to be protected by an air seal.[933] Prof Lygate pointed out that BS 476 Part 7 says at para 5.1 that the test specimens "shall be representative of the *exposed surface* of the product" [emphasis added], which he took to mean *solely* the surface – and not the edges – of the panel from which the specimen was extracted. Since the test specimen would be cut from the product being tested (in this case the GRP panels), it would necessarily have exposed edges.[934] However, Prof Lygate conceded at trial that cutting test samples from the edges of the panels (which would have been edge-sealed) would be representative:[935]

> COURT: … In a sense, Professor Lygate, it does make sense to me that if you want a representative sample to test, then some sample should be cut at the end or in the middle. Not all from the middle. … I'm just asking: from my point of view, if I want to test those panels, I should have cut some from the edge as well as some from the middle?
>
> PROF LYGATE: You could have done so, your Honour, and that would have been a representative sample.

421 Indeed, Prof Lygate subsequently conceded that edge sealing would have had an effect on fire performance:[936]

> MR SOH: I would suggest to you that, clearly, there is a possibility, from the discussion that we've had on the representative condition of the panel and his Honour's discussion earlier, that your PowerPoint slide showed the cutting of panels from the middle, and that you accepted we could cut from the edge. Do you remember that part?
>
> PROF LYGATE: Yes, I do.
>
> MR SOH: Given that context, would you accept that edge sealing would have an impact on the fire test results?

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933 ABD 4C 1301 at para 1.19; 2C 611 at para 2.10.

934 NE (4 October 2016) at p 23.

935 NE (4 October 2016) at p 73 lines 6–14.

936 NE (4 October 2016) at p 80 lines 14–18.

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> PROF LYGATE: Yes, I would accept that and explain that it depends what sort of edge we're talking about. If we had tested a sample with the gutter edge as manufactured, I would expect it to perform differently to a sample with an exposed edge.

422 Prof Lygate also accepted that, even if samples with a gutter edge were used, such samples would still not be representative of the panels on site, because there are no exposed edges on any of the panels actually installed.[937]

423 Prof Lygate subsequently said that he considered the edges of the panel to be "irrelevant during the fire test".[938] However, he did not elaborate or reconcile this statement with his earlier comments which I have excerpted above. Kalzip stated in its submissions that Prof Lygate's evidence was that "edge sealing may have an effect on the fire performance of the panel, but any such effect would not be substantial".[939] Moreover, by arguing that the specimen holder frame and aluminium honeycomb effectively edge-sealed the test panels, thus preserving the reliability of the 2011–2012 tests, Prof Lygate implicitly acknowledged that the *absence* of any protection at the edges whatsoever would have affected fire performance.

424 Kalzip makes much of the fact that the BS 476 Parts 6 and 7 standards do not require edge sealing. Its reasoning is essentially that because those standards do not expressly require edge sealing, edge sealing must therefore be irrelevant to flame spread. However, I am not convinced of this. Dr Crowder gave evidence that the BS 476 Part 6 and 7 standards were outdated in this regard and were "in the process of being superseded by European test methods", which do require edge sealing.[940] In particular, the European standard BS EN

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937 NE (4 October 2016) at p 81 lines 3–7.

938 NE (4 October 2016) at p 113 line 23 – p 114 line 2.

939 Plaintiff's Reply Submissions at para 74(a).

940 NE (4 October 2016) at p 45.

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ISO 11925 Part 2:2010 states at para 5.4.4, "If a product is installed with covered edges, but can also be used with unprotected edges, tests shall be performed on both covered and uncovered specimens." Another European standard, BS EN ISO 13823:2010, states at para 5.3.2, "The exposed edges of the products and the joint in the corner may be protected using additional products, if this is in accordance with its end use application."[941] These same provisions were present in the 2002 versions of the two standards.[942] Kalzip's response to this is that the Sub-Contract specifically incorporates the BS 476 Parts 6 and 7 standards, and not the European standards.[943] However, that misses the point. It is not alleged that the European standards are directly applicable to the Sub-Contract. The question is whether the lack of edge sealing, although not expressly required under the British standards, could have contributed to the test panels' failure to achieve Class 0 under the BS 476 Parts 6 and 7 standards in 2011 and 2012.

425 Dr Crowder, who works with the regulator in the UK on test methods and building regulations, gave evidence that the issue of edge sealing may originally have been overlooked by the standards committees because GRP panels were a novel, engineered product. While composite materials existed in the 1950s and 1960s, this was only in relation to the aircraft industry. Such materials only became common in relation to building construction materials in the 1990s. Approved Document B only began considering the specific properties of products with insulating cores in 2000, whereas the BS 476 Part 6 standard was most recently updated in 1997 and Part 7 in 1989 (save a minor amendment not affecting fire performance in 2002).[944] By that time, it was

941 ABD 4C 1277 at para 28.

942 NE (4 October 2016) at pp 95–96.

943 Plaintiff's Closing Submissions at paras 397(b)(i) and 405; Plaintiff's Reply Submissions at paras 110–111.

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already contemplated that the European standards would supersede the British standards.[945] This is evident from the 2000 edition of Approved Document B states, "For materials/products where European standards or approvals are not yet available and for a transition period after they become available, British Standards may continue to be used."[946] Approved Document B considers Class 0 under the British standards to be interchangeable with Class B under the European standards.[947] Since the decision was made to phase out the British standards in favour of the European standards, it was not deemed worthwhile to reconvene the standards committee to update the British standards.[948] Significantly, Prof Lygate accepted Dr Crowder's evidence that the British standards were not updated beyond 1997 because of the anticipated adoption of the European standards, recognising that Dr Crowder had "more intimate knowledge of the code-making process".[949] Moreover, Prof Lygate accepted that these European standards were "relevant" when applying the BS 476 Parts 6 and 7 standards.[950]

426 Kalzip also submits that the British standards are markedly different from the European standards in that they measure different characteristics of fire performance, incorporate a different testing methodology and use different measurements.[951] Kalzip tendered a paper published on the website of the UK

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944 NE (4 October 2016) at p 45.

945 NE (4 October 2016) at pp 46–47.

946 ABD 4C 1276 at para 24.

947 ABD 4C 1276 at para 26; see also ABD N 313.

948 NE (5 October 2016) at p 65 lines 12–18.

949 NE (4 October 2016) at p 74 lines 8–10.

950 NE (4 October 2016) at p 96 line 19.

951 Plaintiff's Closing Submissions at para 397.

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Government, titled "The impact of European fire test and classification standards on wallpaper and similar decorative linings", which states at p 4:[952]

> The fire test methods BS 476 Parts 6 and 7 measure different characteristics of fire performance from the European fire test methods BS EN 13823 and BS EN ISO 11925-2. In particular, the BS 476 tests are material tests where the fire performance is determined by the characteristics of the surface of the material [whereas] the [Single Burning Item] test [used in BS EN 13823] is a test of the performance of the construction product in an arrangement representative of end use. That is, it is tested with joints, air gaps and/or fixings that are typical of its end use application and the level of thermal exposure in the test method resulting from direct flame contact means that the construction product is tested through its thickness.

427 Dr Crowder gave a considered response to this. He acknowledged that there were differences between the two standards, but carefully explained why these differences did not mean that regard should not be had to the European standards' approach to edge sealing. The difference in methodology employed by the British and European standards was due to advancements in the understanding regarding composite products. The British standards considered flame spread on a surface in a linear laminar way, whereas the European standards required manufacturers to look at a joint detail between two panels in a corner arrangement and determine whether the joint detail might worsen fire performance.[953] The European standards therefore employed a methodology that emphasised end use. While the British and European standards utilised different measurements (temperature and energy respectively), it was possible – with a certain amount of engineering judgment – to do a direct comparison between the two.[954] Prof Lygate did not dispute these views. In fact he agreed that there was a correlation between the two standards[955], and that the BS EN ISO 13823

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952 ABD N 313–314.

953 NE (5 October 2016) at pp 82–83.

954 NE (5 October 2016) at p 84 lines 2–9.

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test was "more indicative of real life" in terms of having two wall surfaces and an ignition source in the corner, rather than having just one panel.[956]

428 I note moreover that Appendix B to the BS 476 Part 6 standard expressly recognises the importance of understanding how the whole structure of the material – rather than merely the surface – may affect fire performance when testing composite materials such as those with insulating cores (GRP panels are such a material). Appendix B states:[957]

> **Appendix B Effect of thermal characteristics on the performance of assemblies**
>
> With thin materials or composites, particularly those with a high thermal conductivity, the presence of an air gap and the nature of any underlying construction may significantly affect the ignition performance of the exposed surface. Increasing the thermal capacity of the underlying construction increases the "heat sink" effect and may delay ignition of the exposed surface. … The influence of the underlying layers on the performance of the assembly should be understood and care should be taken to ensure that the result obtained on any assembly is relevant to its use in practice.

429 Annex B of the BS 476 Part 7 standard contains identical text.[958] Dr Crowder explained that Appendix B recognises that the effect of underlying layers needs to be considered in evaluating a product's surface performance.[959] Prof Lygate suggested that the omission of any reference to edge sealing in Parts 6 and 7, *despite* the fact that Appendix B advises on the testing of composite materials, made it clear that the British Standards Institute did not consider edge sealing necessary.[960] However, as I have said, the question is not whether the

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955 NE (5 October 2016) at p 87 line 23.

956 NE (5 October 2016) at p 90 lines 12–21.

957 ABD 1D 59.

958 ABD 1D 103.

959 NE (5 October 2016) at p 188 line 22 – p 189 line 12.

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British standards *require* edge sealing, but whether the fact that they do not can be taken as proof that edge sealing is irrelevant to fire performance. I have difficulty accepting that proposition, given that Appendix B expressly recognises that the interaction between the underlying structure and the exposed surface can be material to fire performance.

430 I also note that Dr Crowder's position on edge sealing is aligned with that of Mr Jeremy Martin ("Mr Martin"), Kalzip's fire expert in the arbitration.[961] Mr Martin's report states:[962]

> **G. On the basis of the 2011 / 2012 test results can it be concluded that the GRP Panels could not be repaired and had to be removed for fire safety reasons?**
>
> …
>
> 59. … [T]he edges of the panels should be sealed, as per the original fire testing, to ensure that a true comparison can be drawn between the results and to reflect the as built conditions. In the absence of such a comparative study there would appear to be potential differences in the materials tested which may be influencing the results presented.
>
> 60. I would expect the panels with edge sealing and in a non debonded state to perform differently from debonded and non edge sealed panels. …
>
> [bold and underline in original]

431 I note that Mr Jeremy Martin was not called as a witness in the Suit and was therefore not cross-examined on this report. However, the parties adduced his report in evidence before me and it was referred to by BFG in its closing submissions. The paragraphs which I have reproduced from his report speak for

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960 ABD 4C 1301 at paras 1.19–1.20; 2C 613 at para 2.17; NE (4 October 2016) at p 25 lines 16–22.

961 Defendant's Closing Submissions at para 164.

962 ABD 29L 20864.

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themselves, and Kalzip's reasons for disagreeing with his view would have been fully ventilated in its submissions.

432 Kalzip submits that BFG is unable to propose any edge sealing method that would ensure that the tested samples remain representative of the GRP panels produced for the Project.[963] This is based on Prof Lygate's evidence that edge-sealing the panels using the methods proposed by BFG – which differed from the manner in which the supplied GRP panels were edge-sealed – would in fact alter the fire properties of the test specimens such that they would no longer be representative of the supplied GRP panels.[964] However, that is neither here nor there: the question is not what *could* have been done to edge-seal the test panels to make them representative of the actual GRP panels, but whether the fact that the test panels were *not* edge-sealed meant that they were in fact unrepresentative. I therefore did not find this argument helpful.

433 To be clear, I make no finding as to the exact effect of edge-sealing upon the test samples' fire performance. The experts agreed that it was "impossible to determine the exact effect of edge-sealing on the fire performance of the panels without a detailed scientific test, which ha[d] not been carried out".[965] Both experts considered that the scientific method should have been, but was not, used to identify whether and the extent to which edge-sealing (and the other factors described below) contributed to the panels' fire performance during testing.[966] Dr Crowder thought there ought to have been "an extensive study when samples from the original panels were still available to determine the

963 Plaintiff's Closing Submissions at para 419; Plaintiff's Reply Submissions at paras 146–151.

964 ABD 2C 609 at para 2.3, 610–611 at paras 2.6–2.8.

965 ABD 4C 1300 at para 1.16.

966 ABD 2C 663; ABD 2C 623 at para 2.45.

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underlying cause of the difference in performance between installed panels and pre-installation panels".[967] However, it was no longer possible to carry out such testing as all samples would have aged since their original manufacture and no panels from the Project remained available for testing or inspection.[968] Dr Crowder therefore felt unable to conclude whether BFG complied with the fire safety requirements of the Sub-Contract. He stated in his expert report:[969]

> The lack of data in the remaining boxes means, in my opinion, there is not currently sufficient data on which an opinion could be based regarding the reasons for the test results obtained at the various stages of the project. It is therefore my opinion that it is not currently possible to reach a definitive opinion on whether BFG complied with the specifications relevant to fire performance of the panels. The reason for this is that the lack of edge sealing and the delamination could both be sampling issues.

434 Kalzip sought to pin the blame on BFG for failing to undertake the necessary tests in order to demonstrate that edge sealing would have met the fire safety requirements of the Sub-Contract, given that BFG was the manufacturer of the GRP panels and could easily have manufactured suitably representative panels for fire testing.[970] However, Dr Crowder explained at trial that he had initially planned to carry out these tests, but was unable to because a number of panels were destroyed with failed or aborted attempts to recreate delamination. He then had insufficient time to make alternative arrangements because of a period of hospitalisation which rendered him inaccessible to BFG for over six months.[971] In the circumstances, I draw no adverse inference against BFG for its failure to test the effect of edge sealing in accordance with the scientific method.

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967 ABD 4C 1269 at para 8.3.1.

968 ABD 2C 698 at para 118.

969 ABD 2C 697 at para 114.

970 Plaintiff's Closing Submissions at paras 420–422.

971 NE (5 October 2016) at pp 131 and 135.

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Although the *exact effect* of edge sealing cannot be determined, I am satisfied on the basis of the expert evidence that it did have *some* effect on fire performance in the 2011–2012 fire tests, and in my view it has not been proved on a balance of probabilities that the GRP panels supplied to the Project failed to comply with the fire safety requirements.

435 For the avoidance of doubt, in reaching this conclusion, I have not placed any weight on BFG's argument from para 4.3 of BS 476 Part 6.[972] Paragraph 4.3, titled "Edge effects", states:

> Where the specimen is backed by an air gap (see appendix B), ensure that the perimeter of the specimen will not permit flame to penetrate into the cavity. Similarly, where a flame-retardant coating is applied to a surface, the edge detail shall be such as to prevent ignition of the underlying layers.

436 BFG relied on this to submit that edge sealing is important to the British standards. I do not think this is particularly convincing. First, para 4.3 appears in Part 6, whereas the bulk of Dr Crowder's analysis focused on the relevance of edge sealing in Part 7 (flame spread, rather than fire propagation). Secondly, para 4.3 specifically refers to the air gap *behind* the specimen, rather than edge sealing along its *edges*, which BFG itself submits are "two very different things".[973]

The significance of delamination

437 The fire tests were conducted at three testing houses: BRE, Exova Warringtonfire and PSB. The fire experts agreed that there was no delamination of the samples used in the 2011–2012 fire tests at the time they were removed from the site.[974] However, observers from Arup who inspected the panels before

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[972] ABD 1D 46; Defendant's Closing Submissions at paras 183–191.

[973] Defendant's Closing Submissions at para 179.

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testing observed delamination in the panels tested by BRE and Exova Warringtonfire (s/n 9 and 11 of the table at [397] above). They recorded the following notes: "Some samples were tested in this delaminated state, but it did not appear to affect the results of the test as only the front face of the sample is exposed to the heat source of the test in both the part 6 and part 7 test."[975] Other observers from Arup recorded that the panels tested by PSB, the third testing house, were "in good condition"; no delamination was recorded. Dr Crowder interpreted this as silence as to whether delamination had occurred or not, whereas Prof Lygate understood this to mean that delamination had not occurred in the panels tested by PSB.[976]

438 In Dr Crowder's view, the observations regarding the panels tested by BRE and Exova Warringtonfire meant that something had caused the test panels to become delaminated in between their removal and the testing, such that they were no longer representative of the (non-delaminated) GRP panels installed for the Project. He considered that adhesion between the layers of the panel "would have had a potentially significant impact on fire performance", although it was "important to confirm the precise nature of any delamination so that this could be accurately replicated in the samples for testing".[977] Dr Crowder considered that delamination affected fire performance both by (1) allowing movement of volatile gases between cells in the aluminium honeycomb, thereby exacerbating the issue of edge flaming, and (2) by reducing the amount of energy that could be transmitted through the panel from the front face, across the aluminium and to the rear face, thereby increasing the build-up of heat in the front face.[978]

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974 ABD 4C 1297 at para 1.12(a).

975 ABD 30L 21965 and 21968; 2C 625 at para 3.2(b).

976 NE (5 October 2016) at pp 21 and 144.

977 ABD 2C 692 at para 91.6.6.

978 ABD 4C 1282 at para 43.2.

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439 Prof Lygate's views underwent some evolution. In his first report, Prof Lygate took the view that delamination had a serious impact on fire testing. This was because the aluminium core absorbed heat and conducted it away from the flame front advancing over the surface of the material, thereby inhibiting and slowing flame spread. If the material were to delaminate, the core would not conduct the heat away from the top layer and the delaminated layer would be ignited more quickly and the flame would spread more quickly over the surface where the panel had delaminated.[979] In his second report, Prof Lygate changed his opinion and took the view that delamination of the rear face of the panels would have had no effect on the panels' performance in the tests conducted by BRE and Exova Warringtonfire.[980] During witness conferencing, Prof Lygate distinguished between three types of delamination – inter-skin delamination of the outer skin, delamination of the outer skin from the aluminium honeycomb, and delamination of the inner skin from the aluminium honeycomb. The delamination observed at BRE and Exova Warringtonfire was of the third type, which in Prof Lygate's view did not really affect the outcome of the Part 7 test, since that test focused on the flame spread over the top surface of the panels. However, it seemed that Prof Lygate accepted that inner skin delamination could still have *some* effect on flaming at the top edge:[981]

> MR SOH: … [I]f there were bottom skin delamination, wouldn't there be an avenue for that escape of combustible gases and the feedback loop via ignition at the top, the flaming that we looked at extensively yesterday? Agree/disagree?
>
> PROF LYGATE: *Yes, I agree with that*, but in kind you have, rather than volatiles being driven by pressure up into the gap, they're escaping over a much greater area, to the back of it. So I think bottom skin delamination is *much less of an issue* than inter-skin delamination of the top surface.

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979 ABD 1C 197.

980 ABD 4C 1297.

981 NE (5 October 2016) at pp 18–19.

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[emphasis added]

440 When pressed on whether he was changing his position, Prof Lygate maintained that inner skin delamination had no effect on the failure of the fire test. However, that appeared to contradict his evidence (see the portions italicised above), and he offered no explanation for this. Dr Crowder questioned Prof Lygate's position that inner skin delamination had no effect on fire performance, on the basis that any sample tested in a Part 7 test would be backed up by a board, thus forcing the gases out from the top. Even assuming an air gap between the specimen and a board, any gas escaping from the back of the specimen would still be "driven out towards the front".[982] This suggested that inner skin delamination could contribute to flaming on the top edge. Prof Lygate did not contradict or respond to these comments. I note, moreover, that Prof Lygate had earlier made the point that the aluminium honeycomb lattice would only provide a hermetic seal for the volatile gases "provided there [was] an adequate bond between the top and bottom surfaces".[983] This necessarily meant that the hermetic seal would be broken in the event of delamination and would be inadequate to seal the sample. I therefore drew the conclusion from the expert evidence that delamination *would* have an effect on fire performance.

441 Kalzip sought to rebut this point by pointing out that the samples tested by the third testing house, PSB, failed the fire tests notwithstanding that no delamination was recorded. But there is insufficient evidence for me to find as a matter of fact that those samples were non-delaminated. As the Arup observers who had inspected those samples were not called as witnesses, there was no opportunity to clarify with them whether "in good condition" meant that there was no delamination. The Arup personnel who had inspected the panels tested

982 NE (5 October 2016) at p 20 lines 2–14.

983 NE (4 October 2016) at p 28 lines 21–23.

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by BRE and Exova Warrington were different from those who had inspected the panels tested by PSB, and it was suggested that the former persons simply recorded their observations in greater depth while the latter persons were simply more brief.[984] Kalzip also made the point that one of the Arup personnel who recorded that the PSB panels were "in good condition", Alex Wong, was a façade designer at Arup and had prepared a report in 2008 regarding "cracking" sounds emanating from the GRP panels, and that Arup had also prepared a report to BFG in 2009 regarding delamination of the GRP panels and knew this was a concern. This might suggest that Alex Wong would have recorded delamination had he observed it.[985] However, that is speculative. Moreover, it is not known whether the observers were instructed to look out for delamination, or how closely they surveyed the test panels. Kalzip suggested that all the observers came from Arup and would likely have been operating the same way, but did not adduce any evidence to substantiate that assertion. In the circumstances I am unable to conclude that the panels tested by PSB were in fact non-delaminated. In any event, even if they were, that would not necessarily show that delamination has no effect on fire performance. The samples might have performed even worse had they been delaminated. The samples could also have failed the fire tests for other reasons, for example, because they were not edge sealed. The same point applies in relation to the non-delaminated panels tested in 2015, which also failed to achieve the Class 1 standard under BS 476 Part 7 notwithstanding the absence of delamination.[986]

442 Having had the benefit of the expert evidence, I consider that delamination generally does have an effect on fire performance. By contrast,

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984 NE (5 October 2016) at p 140 lines 9–16.

985 Plaintiff's Closing Submissions at para 440.

986 Plaintiff's Closing Submissions at para 442; ABD 2C 625 at para 3.2(c).

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there is no clear evidence that delamination did *not* affect the 2011–2012 fire tests.

The significance of exposure or ageing

443 Contrary to the standard practice of taking samples from production for testing, the samples used in the 2011–2012 fire tests were taken from the roof of the Development, and were aged and/or had been exposed to the external environment for some time. Dr Crowder stated that it was "not normal for standard tests to be carried out on products which have been installed on buildings and removed". Although such tests could "provide extremely useful evidence regarding the performance of installed systems", they had to be "considered in light of the fact that they [would] have aged since installation".[987] This was aligned with the evidence of both fire experts in the arbitration; Mr Martin even stated that post-installation tests should be considered unreliable.[988] Prof Lygate, however, disagreed that it was inappropriate to test fire performance post-installation.[989]

444 However, Dr Crowder considered that the possibility of panel degradation or ageing was "unlikely to be solely responsible for the drop in performance in samples tested in 2011/2012", though he considered it possible that the physical and mechanical compositions of the test panels had been altered as a result of mishandling onsite, damage and/or the presence of contaminants.[990] Dr Crowder was careful not to overstate the strength of his conclusion on this point. He accepted that not all products age in the same way,

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987 ABD 2C 704 at para 151.

988 Defendant's Closing Submissions at para 336.

989 NE (4 October 2016) at p 97 lines 10–15.

990 ABD 2C 703 at paras 143 and 144.

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and in fact ageing could improve as well as worsen fire performance. He stated that he had not himself analysed the panels so as to be able to form a view as to the effect of ageing on these particular panels, and agreed that whether it had any impact at all was "quite speculative".[991] The tests commissioned in 2015 only tested new panels, and therefore did not test the effect of ageing on fire performance.

445 Kalzip points out that cl 2.1.2 of Specification Revision C provides that the installation is to perform satisfactorily, in terms of the durability of the finishes, for 15 years with minimum maintenance (apart from regular cleaning) and 25 years with reasonable routine maintenance. It was also an express requirement of the FSSD waiver that the GRP panels were to be listed on the Product Listing Scheme, which required products to be tested annually to ensure ongoing compliance with the requirements of waiver.[992] In other words, the GRP panels ought to be able to fulfil the fire safety requirements notwithstanding any ageing or exposure to the environment, since such ageing and exposure are necessarily contemplated by the Sub-Contract. However, I agree with BFG that these are not relevant. Clause 2.1.2 relates to the durability of finishes, and not fire performance. Moreover, the Product Listing Scheme requires annual retesting of the product *from the production line* and not of the product post-installation.[993] In any event, there is insufficient evidence for me to conclude that exposure and ageing contributed to the panels failing the 2011–2012 fire tests.

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991 NE (5 October 2016) at p 183 lines 14–20; p 184 lines 13–18; p 185 lines 1–9.

992 Plaintiff's Closing Submissions at para 448, citing ABD 1D 278 and NE (4 October 2016) at pp 56–57.

993 Defendant's Reply Submissions at para 231.

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Conclusions on Issue 5

446 Kalzip urged me to accept the reliability of the 2011–2012 tests given the dearth of evidence of the "exact effect" that edge sealing, delamination and ageing would have had on the test samples.[994] However, by the same token, the 2008–2010 tests should also be regarded as reliable, given that there was as much (or less) uncertainty regarding the exact effect that oven curing and/or the provenance of the panels had on them.

447 I find, on the basis of the expert evidence, that the lack of edge sealing and the presence of delamination contributed to the samples' performance in the 2011–2012 fire tests, although I am unable to identify the exact degree of the contribution. I also find that the 2008–2010 tests were likely affected by the fact that the test samples lacked a gutter detail, although I am again unable to identify the degree to which they were affected. I am not satisfied that the test panels would have performed better in the 2008–2010 tests simply because they were oven cured or manufactured in Bahrain.

448 On the whole, the evidence does not show on a balance of probabilities that the GRP panels supplied by BFG failed to meet the fire safety requirements in the Sub-Contract.

Issue 6: BFG's liability in principle

449 The parties are not agreed on whether I should decide BFG's liability in principle for the various heads of claim at [31] and [32] above. Kalzip submits that, should I find that BFG breached the terms of the Sub-Contract, I should decide BFG's liability in principle for the heads of claim so that the second

994 See, *eg*, Plaintiff's Closing Submissions at para 453; Plaintiff's Reply Submissions at para 74(a).

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tranche of the bifurcated trial may deal solely with the quantification of such heads of claim as are allowed. BFG, on the other hand, originally opposed the inclusion of liability for specific heads of claim in the list of issues for the first tranche.[995] However, BFG does not maintain this objection in its closing submissions, stating only that it "reserves the right to address the quantum of each of the costs and expenses claimed by Kalzip" at the second tranche.[996] Nonetheless, the issue does not arise since I have found that Kalzip has not proved its claim on a balance of probabilities that BFG breached the Sub-Contract. Kalzip's case hinges on the assertion that BFG supplied panels which delaminated as a result of poor manufacturing and did not meet the fire safety requirements of the Sub-Contract; it did not plead that the panels were defective in other ways or not fit for purpose for other reasons. Kalzip's claim in restitution is likewise premised on the failure of the GRP panels to comply with the technical requirements and specifications prescribed by the Sub-Contract and the terms implied therein.[997] Given my findings, Kalzip's claims in contract and restitution must necessarily be dismissed.

450 I add that, even if I had found that some panels were delaminated, Kalzip would still have failed to establish total failure of consideration. Total failure of consideration only occurs "when one party has not enjoyed the benefit of *any part of what it bargained for*", judged from the perspective of the payor plaintiff [emphasis added] (*Ooi Ching Ling v Just Gems Inc* [2003] 1 SLR(R) 14 at [43]). Even on Kalzip's case, not all the panels delaminated. Kalzip attempts to circumvent this by defining the "consideration" in terms of MBS' *acceptance* of the panels, as MBS rejected all of the GRP panels (even those which were

995 ABD A 186, 190.

996 Defendant's Closing Submissions at para 1019.

997 Plaintiff's Closing Submissions at para 613.

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not delaminated).[998] But the consideration cannot be defined solely in terms of MBS' decision to accept or reject the panels, since that would entitle Kalzip to restitution as long as MBS rejected all the panels on any pretext, however unreasonable. Rather, the consideration which Kalzip stood to gain from the Sub-Contract was BFG's design and supply of GRP panels which complied with the Sub-Contract's technical requirements. Given that BFG did in fact design, manufacture and supply panels which were not delaminated or defective, the failure of consideration would not have been not been total. I would therefore have dismissed Kalzip's claim in restitution in any event. For the same reason, there is no need for me to decide whether Kalzip is entitled to bring claims for breach of contract and in restitution concurrently. This issue is best addressed, if it becomes necessary, at another time.

Conclusion

451 In summary, my key findings (read with [385] above) are as follows:

(a) The structural tests carried out by BFG and Winwall from 29 September 2008 to 24 September 2010 do not establish that the GRP panels failed to meet the structural and loading requirements in the Sub-Contract (see [64]–[98] above).

(b) The four site surveys, and the correspondence relied on by Kalzip, do not establish that there was widespread delamination as they were based largely on the sounds emitted by the panels. The 2015 Tests establish that these sounds are not proof of delamination (see [183]–[207] above).

998 Plaintiff's Closing Submissions at paras 611, 613 and 617.

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(c) A number of GRP panels on the roof of the casino building exhibited inner skin delamination. This was supported by evidence of the panels deflecting underfoot when walked upon (see [211]–[226] above).

(d) Although there is no unequivocal evidence of which panels suffered these signs of delamination, I find that 20 panels on the casino building roof delaminated. It has not been proved on a balance of probabilities that any of the panels on the MICE building, or the panels in storage, delaminated (see [248]–[252] above).

(e) The delamination may have been caused by misuse (particularly by workers walking and jumping on the panels) and/or by insufficient resin being used during manufacturing. The evidence does not permit me to determine which was the more proximate cause. It has not been proved on a balance of probabilities that the delamination resulted from BFG's manufacturing process. I therefore find that BFG is not liable to Kalzip for breach of the deflection or structural loading requirements in the Sub-Contract (see [294]–[311], [322]–[339] and [383] above).

(f) Kalzip also has not proved on a balance of probabilities that the GRP panels supplied by BFG failed to meet the fire safety requirements in the Sub-Contract (see [446]–[448] above).

(g) The foregoing findings obviate consideration of BFG's liability in principle for the various heads of claim (see [449] above).

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452 I therefore dismiss Kalzip's claim in entirety and no further tranche of the trial need be held. I will hear the parties on costs.

Quentin Loh
Judge

Mohan Pillay, Yeo Boon Tat, Joanna Seetoh and Ang Wee Jian (MPillay) for the plaintiff;
Soh Lip San, Tan Yu Inn Shannon and Rebecca Lim (Rajah & Tann LLP) for the defendant.

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