Commission of Inquiry into the Construction Works At and Near the Hung Hom Station Extension Under the Shatin to Central Link Project

MTRCL's Closing Submissions on Further Expert Evidence (for the Original Inquiry)

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I. Overview

1. It is clear from the ToR[1] that the CoI's principal concern is public safety and, as summarised in the Preface to the Interim Report[2], it is the CoI's primary objective to determine whether the as-constructed works "*were fit for purpose*" and "*put more directly, whether they were safe*"[3].

2. When the Interim Report was published in February 2019, the CoI was made aware of a number of ongoing investigations that were taking place to determine the safety of the D-wall and platform slab construction. One such investigation was the (revised) Holistic Proposal[4] submitted by MTRCL which was given Government approval on 5 December 2018[5]. Notwithstanding such ongoing investigations, on the basis of the extensive evidence received and considered during the Original Inquiry, the Interim Report made a finding that the D-wall and platform slab construction works were safe[6].

3. The findings from the extensive investigations and analyses carried out under the Holistic Proposal are set out in the Holistic Report[7].

4. The purpose of the Holistic Report is to ensure the as-constructed works complied with the relevant code, statutory and contractual requirements. The Holistic Report proposed that certain actions be carried out to cater for

[1] [**A2/884-885**].
[2] [**A2/717**].
[3] See Lo & Lo's letter dated 30 July 2019 [**OU5/3356**].
[4] [**G17/12970-12999**].
[5] [**G17/13008-13009**].
[6] [**A2/721**].
[7] [**OU5/3229-3350**].

the poor workmanship issues found and to achieve the safety level required in the HKCoP for meeting the requirements of the BO and the established good practice of engineering design, as well as complying with the NWDSM[8]. These actions are known as the Suitable Measures which are being implemented for the purpose of obtaining the ultimate approval of the works by the approval authorities so that the railway can be put into operation for use by the general public.

5. In respect of the matters set out in the Holistic Report, the CoI will be comforted by the fact that there is an overwhelming, unqualified majority view from the structural engineering experts (McQuillan for the CoI, Glover for MTRCL and Southward for LCAL) that the as-constructed works are safe and fit for purpose[9]. In other words, on the weight of the evidence, the matters identified in the Holistic Report should not deter the CoI from confirming its interim view that the as-constructed works are safe and fit for purpose.

6. Importantly, and as pointed out by Glover, few structures have been subjected to the degree of post-construction survey, inspection and opening up, or subjected to the sophisticated independent analysis and testing which has been carried out on the as-constructed works by a number of different parties and professional consultants. It is important to recognise that the findings which can be derived from these various activities have established beyond any reasonable doubt a high level of assurance in terms of the safety of the as-built works, *a fortiori* given that none of the findings have exposed any fatal flaws in the construction, despite the analysis and testing being subjected to very high forensic acceptance standards[10].

[8] § 42 of the Executive Summary of the Holistic Report **[OU5/3241]**.
[9] See Supplemental Memorandum of Agreement dated 2 January 2020 [**ER2/Item 19.2**].
[10] § 5.2 of Glover's CoI 1 Report [**ER2/Item 16.1**].

7. Lau (for the Government) holds a solitary, dissenting opinion, namely that "*without the implementation of suitable measures the as-built COI 1 structures are neither safe nor fit for purpose*"[11]. However, when cross-examined by CoI's Leading Counsel, Lau agreed that the investigations and analyses established a high level of confidence in terms of the overall safety of the as-built works and that there were no fatal flaws in terms of stability[12]. Lau further confirmed that his primary concern was rupture of section[13]. Rupture of section is a term referred to in paragraph 2.2.2.2 of the HKCoP[14]. As Lau accepts that the as-built works are safe in terms of stability[15], Lau's concern on rupture of section relates to the risk of local overstressing of individual structural elements "*without the risk of causing stability problems*"[16].

8. For the reasons set out below, Lau's dissenting opinion may largely (although not entirely) be explained by his insistence on equating: (1) code, statutory and contractual compliance (**"Compliance"**) on the one hand; and, (2) safety and fitness for purpose on the other.

9. It is MTRCL's firm position that the as-built works are safe and fit for purpose. MTRCL does not agree with Lau's conclusion that the structures are unsafe without the Suitable Measures. Lau's opinion is effectively premised on Compliance. The difference between Compliance on the one hand and safety and fitness for purpose on the other was explained by Glover:-

> "*All I'm saying to you is those parameters were not recommended by us. In our reports, we do draw attention to the fact that we do think they are conservative. I wouldn't want you to run away with*

[11] [**ER2/Item 19.2**].
[12] Entire Inquiry [**T9/44:19-45:3**].
[13] Entire Inquiry [**T9/55:5-56:21**].
[14] [**H8/2838**].
[15] §30 of Lau's CoI 1 Report [**ER2/Item 17.1**].
[16] §31 of Lau's CoI 1 Report [**ER2/Item 17.1**].

the idea that they are massively, massively conservative, but they are conservative. So I don't want the Commission to believe that the updated design is something we said, "Yes, you've got to have this." If you wanted a parallel, I would say it was much more to do with a compliance design, in other words to try to demonstrate that the structure was compliant, and I have no problem with that at all, if that's what the objective was. But it's not my objective for this Commission. My objective for this Commission is to bring to your attention why I think the structure is safe and why I think it's fit for its purpose."[17]

10. It bears emphasis that insofar as any criticism is levelled against the "*correctness*" or the conservatism of the Holistic Report from a structural engineering perspective, the purpose of the Holistic Report is not to address structural safety *simpliciter* but to ensure that the as-constructed works achieve Compliance in the light of the issues concerning LCAL's poor workmanship and missing records[18].

11. However, there are a number of instances where Lau has: (1) failed to recognise the conservatism which the external consultants have themselves recognised; and, (2) advocated an even higher degree of conservatism than that adopted by the external consultants. These instances are dealt with in Sections IV to VI below. It should be emphasised at the outset that MTRCL's submissions on "excessive" conservatism are to address Lau's purported concerns, and should not be construed as a retraction from the conclusions set out in the Holistic Report. In any event, according to the Further SE Directions[19], the CoI is not concerned with assessing the reasonableness of the conservatism adopted in the Holistic Report.

[17] Entire Inquiry [**T10/78:12-79:2**].
[18] §§9-11 of Neil Ng's Witness Statement [**B21/26701**].
[19] [**OU8/10561-10562**].

12. As Leading Counsel for the CoI pointed out on Day 7 of the Combined Original and Extended Inquiries[20], the Further SE Directions were made against the background that the CoI did not want to find itself making the type of determination that might more appropriately be made in private dispute resolution avenues and wanted to focus, as required by its ToR, on the questions of safety and fitness for purpose and did not want to be drawn into matters of pure contractual compliance and statutory compliance, which it saw as falling outside of the primary remit of safety and fitness for purpose.

13. Pursuant to paragraph 5 of the SE Directions[21], MTRCL was directed to file structural engineering expert evidence in response to Southward's CoI 1 Report. Where, as here, Glover agrees with Southward on the important, primary conclusion that the as-built works are safe and fit for purpose, MTRCL does not regard it necessary or productive to address *in extenso* the differences between Glover and Southward (or for that matter McQuillan) in terms of how they each arrived at their conclusion. The primary concern of the CoI is whether the as-constructed works are safe and fit for purpose and individual experts may arrive at the same conclusion through their own different analyses. The only *proviso* is that MTRCL disagrees with Southward's view insofar as he contends that the as-constructed works are not only safe and fit for purpose but also achieve Compliance and points out that such an opinion, again, falls outside the scope of the Further SE Directions.

14. In the light of the structural experts' evidence on coupler connections, MTRCL also does not regard the differences between the two statistical experts, namely Wells (for LCAL) and Yin (for the Government), as

[20] Entire Inquiry [**T7/9:3-20**].
[21] [**OU7/9691-9692**].

significant on the important issue of whether the as-constructed works are safe and fit for purpose, for the following reasons:-

(1) According to Glover, as part of his 'reality check', his methodology based on an engineering judgment (adopting the Government Acceptance Criteria of 37mm engagement and including a wider set of data) yielded results which are broadly consistent with the results generated by his application of the statistical methodologies advocated by Wells and Yin[22]. Glover's 'reality check' confirms the soundness of Arup's statistical analysis which gives a pass rate of 88% for a single-sided connection and a pass rate of 77% for a two-sided connection if an acceptance criteria of just 32mm engagement is adopted[23].

(2) Importantly, and as acknowledged by Yin[24] and Wells[25], the acceptance criteria for coupler connections from a safe and fitness for purpose perspective is ultimately an engineering judgment and it is not a matter to be decided by statisticians.

(3) McQuillan is even less reliant on the methodologies advocated by Wells and Yin. He is of the opinion that "*the diverging statistical analyses and expert reports do not provide to [him] as a non-statistician with definitive failure rates and consequential strength reduction factors. In other words, they do not inform [his] structural engineering opinion. [He] needs instead to consider matters from an engineering perspective based on extensive experience*"[26].

15. The above opening remarks provide a synopsis of the focus and direction of these submissions.

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[22] §§7.33-7.36 of Glover's CoI 1 Report [**ER2/Item 16.1**].
[23] §§7.37-7.38 of Glover's CoI 1 Report [**ER2/Item 16.1**].
[24] Entire Inquiry [**T5/8:20-9:13**].
[25] Entire Inquiry [**T3/46:20-50:5**].
[26] §36 of McQuillan's Supplemental CoI 1 Report [**ER2/Item 15.1**].

II. Recap of the parties' respective positions

16. The Holistic Report was submitted to the CoI on 18 July 2019[27]. By Lo & Lo's letter dated 30 July 2019[28], the CoI expressed a concern over the use of the phrase "*MTRCL considers that for the purpose of the ongoing construction activities, the station is structurally safe*" in various paragraphs of the Holistic Report ("**Qualification**") and, in particular, the Government's interpretation of the Qualification, namely:-

> "*Our understanding of those statements is that the as-built structure is able to sustain the ongoing construction activities on site and the implementation of the suitable measures as proposed in the said Final Report.*"

17. By the same letter, Lo & Lo sought clarification on the Qualification from MTRCL and the Government by 2 August 2019.

18. In Mayer Brown's letter dated 2 August 2019[29], MTRCL explained its understanding of the Qualification in the following terms:-

> *"The current view of MTRCL's independent expert is that the structural integrity of the main structural elements of the station box are fit-for-purpose and importantly, are safe…*
>
> *Unsurprisingly, in matters of subjective professional judgement different views were held by different professionals; some believed that an unqualified statement that the works are "safe" connotes that they are compliant with all relevant codes. There is common ground between the parties that the structure is not yet code compliant. The language used in the Holistic Report reflects this consultation process and the divergence of opinion."*

[27] [**OU5/3208-3210**].
[28] [**OU5/3356-3373**].
[29] [**OU5/3374-3376**].

19. In Lo & Lo's letter dated 7 August 2019[30], the CoI stated that as a number of matters had arisen as a result of the investigations under the Holistic Proposal which had not been explored in the Original Inquiry, it considered that if further structural engineering expert evidence was considered necessary by the parties, it would only be assisted if such further evidence was confined to the topics in the Holistic Report. Three major topics and five other minor defects were identified.

20. The three major topics were: (1) engagement of couplers and rebar (connection of the D-wall via capping beams to the EWL Slabs in Area A and HKC); (2) shear links; and, (3) the horizontal construction joint between the EWL Slab and the D-wall panels in Areas B and C.

21. The five minor defects were: (1) honeycombing (EWL); (2) gaps between the wall/ column/ hanger wall and the EWL slab soffit; (3) corrosion; (4) water seepage; and, (5) further rebar cutting (NCR 157).

22. Lo and Lo invited the parties to indicate whether they wished to adduce further structural engineering expert evidence on the three major topics and the five other minor defects.

23. By OMM's letter dated 7 August 2019[31], LCAL indicated that it wished to adduce further expert evidence on the three major topics set out at paragraph 20 above, on the basis that:-

> "*Any additional works that arise out of the Reports may need to be performed by Leighton or will otherwise impact Leighton as the Main Contractor for the SCL 1112 project. It is therefore necessary for an independent structural engineering expert to consider and make an assessment of the suitable measures proposed in the Reports. Such expert evidence will assist the Commission in*

[30] [**OU5/3354-3355**].
[31] [**OU5/3380-3382**].

evaluating the Reports and making its own recommendations on the proposed suitable measures for the purposes of its Final Report."

24. MTRCL's position, as set out in Mayer Brown's letter dated 13 August 2019[32], was as follows:-

> "*…Insofar as there will be any challenges or criticisms made by any of the Involved Parties on the Eight Topics or any of the contents in or relating to the Holistic Report (as it seems to be case at least so far as Leighton is concerned), MTRCL will seek leave to adduce such expert evidence from a structural engineering expert as is necessary to assist the Commission in considering and evaluating any such challenges or criticisms and making such findings thereon as are considered necessary and appropriate…*"

25. In contrast to LCAL's position, in DOJ's email dated 14 August 2019 the Government took the position that the further expert evidence would not be necessary. The justification for this stance was put in the following terms:-

> "*In light of the said agreement to implement the "suitable measures" as recorded in the Holistic Report, we are of the view that further structural engineering or statistical expert evidence, or arguments on the details of the assessment performed by MTRCL or the "suitable measures" proposed (which in any event are yet to be further developed) would not be necessary. <u>In particular, further arguments on the question of whether the Station (without the implementation of "suitable measures") can generally be described as "safe" without making any reference to agreed design standards, benchmark or any statutory requirements in Hong Kong would not</u>*

[32] [**OU5/3424-3425**].

<u>be helpful to the Commission or the public</u>. Moreover, as the Government and MTRCL have agreed to proceed with the "suitable measures", the question of whether some or all of the "suitable measures" proposed are necessary in the circumstances (whether under the Contract or otherwise) would, in our view, be primarily a matter of civil liability, which ought to be resolved in a separate forum."

26. It can therefore be seen from the above correspondence that there were differences between the parties on the necessity of further structural engineering expert evidence even at the outset when the SE Directions were debated. Specifically:-

(1) MTRCL's focus, consistent with the CoI's mandate, was on the structural integrity of the as-built works from the perspective of safety and fitness for purpose;

(2) LCAL sought to vindicate itself through the CoI by challenging the Suitable Measures; and

(3) The Government's position was to equate safety and fitness for purpose with Compliance and, as such, contended that structural engineering expert evidence was not required.

27. In the event, the CoI gave Directions on Statistical Expert evidence on 25 August 2019[33] and by the SE Directions[34] on the three major topics. There is no contention by any of the Interested Parties that the five minor defects identified in the Holistic Report have any structural significance.

28. Subsequently the CoI issued the Further SE Directions on 12 October 2019[35]:-

[33] [**OU6/3921-3923**].
[34] [**OU7/9691-9692**].
[35] [**OU8/10561-10562**].

"2. It is further directed, however, that in relation to the SE Expert evidence to be adduced pursuant [to] paragraph 1 above:

(a) the SE experts should focus on whether the as-constructed works are safe and fit for purpose from a structural engineering perspective; and only if they are considered not safe or fit for purpose that such experts should then provide their opinion on whether the suitable measures (as agreed in the Holistic Report or Verification Report, or subsequently) are necessary for safety from a structural engineering perspective; and

(b) the SE experts shall not be required to look into the question of whether the suitable measures (as agreed in the Holistic Report or Verification Report, or subsequently) are required for statutory or code compliance."

29. It is plain that the concepts of Compliance on the one hand and safety and fitness for purpose on the other are delinked.

30. Despite the making of the Further SE Directions, from the manner in which the parties' have presented their further expert evidence it might be thought that the parties have held on to the differences identified in paragraph 26 above.

III. Compliance v. safety and fitness for purpose

31. Each of Southward, Glover[36] and McQuillan[37] is of the view that a structure can be safe and fit for purpose but not achieve Compliance. One of the clearest illustrations was given by Southward in the following exchanges with the Chairman and Commissioner Hansford[38]:

[36] §5.13 of Glover's CoI 1 Report [**ER2/Item 16.1**].
[37] McQuillan's Presentation Slide No. 10 [**ER2/Item 15.3**].
[38] Entire Inquiry **[T7/122:3-123:8]**.

"CHAIRMAN: And if you are looking to determine what is safe and what is fit for purpose, in those circumstances, the easiest way to do so is to look and see whether there's compliance with the relevant codes?

A. I think compliance with the codes covers a broader topic than whether a structure is just safe or not. A code may say, "We want to have this particular detail in this way", but another code elsewhere won't have that same peculiar requirement, but yet the one without that peculiar requirement is still safe. So you could take the one without the peculiar requirement, take it here, where there is that peculiar requirement, so okay, there is a conflict, but it doesn't mean that what is built is not safe.

COMMISSIONER HANSFORD: That's a very good example, is it not, of something being safe but not being compliant, because of that peculiar requirement?

A. Yes.

CHAIRMAN: I think that's what I'm trying to -- in my own head, to see -- because to me it would seem if you say a window in a particular jurisdiction must be of minimum size to allow for air, that's got very little to do with safety or even necessarily fit for purpose. It may be able to do whatever you need, fit for slightly different, but there are all sorts of impositions for different reasons. But if we go down to the question of safety and fit for purpose then, again you would say you would have to look at what the provisions are and weigh that against the objective reality, engineering reality?

A. Yes."

32. At the hearing on 11 October 2019, the CoI heard submissions from MTRCL, the Government and LCAL which led to the making of the Further SE Directions. It is pertinent to note the following exchange between the CoI and Leading Counsel for the Government[39]:-

> "*CHAIRMAN: But let's approach it from another angle. Let's approach it from the angle that in fact one of the engineers, as indeed I think on the last occasion I think there were certain reservations by one engineer relating to particular aspects of the design which had caused him concern -- let's say one of the engineers comes forward and says, "You know, I think there's a fundamental problem with the shear links and I've had a look at what government intends to do in order to ensure code compliance; I don't think it's going to be sufficient. I think you've got a major structural problem here", and he comes up and we have convincing argument. Now, isn't that evidence of some value? Because you are looking then at a question of, from an engineering perspective, are there concerns as to safety, and yes, there are, and perhaps code compliance which itself is concerned with safety will not be sufficient. So what I'm saying is that surely there can on occasions, although you cannot delink them entirely, they don't inhabit separate galaxies. Of course they are linked. But with one particular specific unique structure and the generalisation of code compliance, the two can be viewed perhaps separately, for purposes of safety and fit for purpose, without necessarily the one having to reduce the effectiveness of the other.*
>
> *MR KHAW: Yes.*

[39] Entire Inquiry [**T6/42:20-44:7**].

CHAIRMAN: That's not a statement, that's just a question to get your views.

MR KHAW: I have nothing further to add on this point, save and except that I only wish to, with no disrespect, give a kind of note of caution. If one is trying to segregate the question of safety, any elements of safety from code compliance, then it is necessary to set out certain objective benchmarks.

COMMISSIONER HANSFORD: Understood.

CHAIRMAN: Yes, understood. I would say, Prof Hansford has said that too"

33. MTRCL makes two observations in relation to the above exchange. First, the Chairman's (then) tentative view that Compliance on the one hand and safety and fitness for purpose may be looked at separately is now supported by the views of Southward, Glover and McQuillan. Secondly, at the hearing on 11 October 2019 the Government had made a clear indication that certain objective benchmarks must be set out for the purpose of assessment of safety.

IV. Lau re-linking Compliance with safety and fitness for purpose

34. Given the Government's clear stance set out in Section II above and, in particular, its position that it is unhelpful to consider whether a structure is "safe" without making any reference to agreed design standards, benchmark or any statutory requirements in Hong Kong (as set out in paragraph 25 above), Lau's attempt to re-link Compliance with safety and fitness for purpose is not surprising. In this context it should be noted that paragraph 34 of Lau's CoI 1 Report states as follows[40]:-

[40] **[ER2/ Item 17.1].**

"*In my opinion, it follows that it is only appropriate to adopt the set of minimum factors of safety as stipulated in the Concrete Code in evaluating the safety of the HUH structure. In the circumstances, I tend to think that for the present discussion, reference to any other standards is arbitrary. It is because (a) this is not a forum for any debate on whether the applicable codes in Hong Kong should be subject to review; and (b) without setting out the relevant parameters for the purpose of assessing safety and fitness for purpose, any dogmatic reference to other codes or standards adopted in other countries will not lead to any fruitful discussion*."

35. As has been pointed out in paragraphs 9 and 10 above, MTRCL acknowledges that certain conservatism is present in the parameters adopted in the Holistic Report. However, the focus of the Holistic Report is not on safety and fitness for purpose but on Compliance.

36. As pointed out by Glover, Lau's insistence to re-link Compliance to safety and fitness for purpose has given rise to two problems in Lau's evidence.

37. First, Lau is driven to resort (exclusively) to qualitative statements. As explained by Glover[41]:-

"*The structures are, on a structural integrity and performance basis, fit for purpose in that they are -- picking up some of the words that Dr Lau uses -- stable, robust and they are durable.*

Both Prof McQuillan and Mr Southward are also of that view, and that's as stated in the joint experts' statement that Mr Boulding referred to. Dr Lau does not agree and has reservations. I say "reservations" because he does not disagree carte blanche, he has specific reservations, and I'd like to deal with them as I go through

[41] Entire Inquiry [**T10/61:5-62:15**].

the presentation, to see to what extent I have properly addressed them, and I'm clearly open, through cross-examination, for clarification on that. My opinions are not based on considerations of code or contract or statutory requirements. They are just simply my engineering appraisal of the information and data that I have before me.

I would like then to continue with –

COMMISSIONER HANSFORD: Sorry, you had a final sentence there which I think is also rather important.

A. Okay. The structure can be considered safe and fit for purpose but it doesn't have to be fully compliant with either the code, the contract or any other statutory instrument. It's a demonstration of physical laws and tests and investigations. It's evidence, basically.

So, put another way, my approach is an evidence-based approach. I try, in my evidence that I am giving to you, not to rely on hearsay or "I feel it's all right". I try to deal with some quantitative facts.

That is one of the problems of the hearing over the last days: there has been a hell of a lot of qualitative statements made, and I think for the layperson that must be virtually impossible to come to terms with, because there's nothing tangible to hold onto. It's, "I feel it's okay." Well, that's not good enough, in my book."

38. The qualitative nature of Lau's "reservations", for example, those related to the possibility of cracks, can be further illustrated by the objection raised by Leading Counsel for MTRCL during the Government's cross-examination of Glover[42]:-

[42] Entire Inquiry [**T11/51:21-52:23**].

"CHAIRMAN: Then that's my second question: are you yourself, on what you know of the structure overall, particularly the external side of the D-walls, concerned about the issue of possible corrosion over an extended period of time to the steel inside the D-walls?

A. No. The diaphragm wall has been designed competently, constructed very competently, lots of photographic records of what was constructed. We now have the benefit of the cores of the concrete which demonstrates it's very dense. Remember my comment earlier about density of concrete being the most important thing in terms of corrosion protection. No, I don't have

concern.

MR BOULDING: Sir, I don't want to be pedantic but it is an important point. My learned friend Mr Chow put the question on the basis -- and perhaps I can read:

"Dr Glover, you recall that part of Dr Lau's evidence is that there is a need to install dowel bars, and the reason that he gave in evidence is that because of the cracks on the outside of the wall ..."

Now, it's important to point out that his evidence was not that there were in fact cracks but there might be cracks. I see the professor is nodding.

COMMISSIONER HANSFORD: Yes.

MR BOULDING: It's an important point, in my submission.

COMMISSIONER HANSFORD: Yes. I think his evidence – please correct me if I've got it wrong -- is that there is a risk that cracks might occur."

39. Secondly, Lau's insistence on re-linking safety with Compliance has given rise to an important methodological difference between himself and the

other three structural engineering experts. As explained by Lau when he was cross-examined by LCAL's Leading Counsel on the appropriateness of using *in-situ* concrete strength for the purpose of structural assessment[43]:

> *"But in our case, we are not doing that. In our case, we are checking the design for the rest of the design working life of the building. If the designer asks for grade 40 concrete, we should check the structure based on grade 40 concrete, rather than based on all the concrete cube tests, right, from the cube test. This is not what we do for a normal design of a building. But when they are doing the forensic investigation, I can understand why they want to do it that way. They want to find out exactly what is the strength in the structure. In that case, you still have to core the concrete, to core the structure, to find out the strength, rather than using the concrete cube test results, because they are not relevant. They are only relevant as far as the material is concerned. They are not relevant as far as the workmanship in curing is concerned.*
>
> *Do you take my point?*
>
> *CHAIRMAN: I do. Thank you very much.*
>
> *A. I hope I can explain it to you, because this is a big --*
>
> *CHAIRMAN: No. I understand it. Thank you very much.*
>
> *A. There's a big difference between me and the other experts on this very point."*

40. In other words, Lau's evidence was to the effect that whilst it might be appropriate to use the *in-situ* concrete strength for the purpose of forensic

[43] Entire Inquiry [**T10/18:13-19:11**].

investigation, Lau was of the view that it was inappropriate to do so when carrying out design checking.

41. In a similar vein, in the case of soil stiffness, Lau explained as follows[44]:-

> "*Now, Atkins assume the stiffness is E equal to 1 times N. N is the value from the static penetration test during one investigation stage. Then when OAP analyse it based on 1 times N, we have more or less the same stresses in the whole structure, and then OAP, in order to make it more aggressive, they changed it again using E equal to 1.5 N. As soon as you use 1.5 N all the stresses inside the structure will be lower. Then OAP try to keep -- and OAP, Dr Glover, criticised Atkins by being too conservative, because they use a different parameter in the computer model, and this equal to 1 times N is required by government. This is required by Hong Kong government. You have the design based on equal to 1 times N. So you need to understand the whole thing before you criticise Atkins or -- you cannot criticise Atkins just by using equal to 1.5 N.*"

42. However, and as Glover explained, the engineering assessment of whether the as-built works are safe and fit for purpose is a forensic exercise[45]:-

> "*So if I then move on to the second slide, which is the engineering assessment. I want to emphasise these points because this is really a principle of approach. The first thing is it is a forensic analysis. By definition it is. This is not a design exercise. I'm looking at -- not complete, because people will misunderstand my statement -- an as-constructed form, and I'm looking at it dimensionally, I'm looking at it in terms of its material properties, and just the general loadings, et cetera. So that's where I'm coming from.*

[44] Entire Inquiry [**T10/41:9-25**].
[45] Entire Inquiry [**T10/62:16-63:22**].

I've already made the point in the second bullet point, which is that the situation at the inception and the design stage is very different from that where you've got all these unknowns and uncertainties I was describing, and these all have to be allowed for, as a designer, at the outset. It's too late thinking about it when the thing is constructed, as I think you will see. But in the post-construction stage, many of these unknowns and uncertainties become knowns and certainties, and they provide a more confident basis for evaluating the safety and performance of the structure, particularly regarding its loading and its materials. I would also add its geometry. Geometry is very, very important in such a very large structure as this.

In addition -- and this is really why we do have the benefit of -- this enormous amount of data that's been produced from the extensive situation and surveys made on the Hung Hom Station, I wouldn't say it's without precedent but it is something which is beyond the normal, and I've taken advantage of that quantity and scope of the investigations in the evidence I will give."

43. Importantly, the two examples cited by Lau, namely that it was inappropriate to use *in-situ* concrete strength and to depart from the Government's requirement in terms of soil stiffness, are specifically regarded by Atkins to be conservative. Section 16.1 of Atkins' Stage 3 Assessment Report provides as follows[46]:-

"*16.1.1 As set out in the Final Report on Holistic Assessment Strategy for the Hung Hom Station Extension there is a requirement to achieve the safety level required in the Code of Practice for Structural Use of Concrete for meeting the requirements of the*

[46] [**OU6/4128**].

Building Ordinance ("BO") and established good practice of engineering design. The MTRCL's NWDSM should also be complied with.

16.1.2 This section of the report identifies certain areas where there is considered to be some additional conservatism remaining in the approach taken and assumptions made."

44. In relation to material strength, and contrary to Lau's suggestion, Section 16.6 of Atkins' Stage 3 Assessment Report states as follows[47]:-

"*16.6.1 The concrete cubes sampled from the concrete mixer trucks during the concreting works and tested for strength as part of the quality control and construction supervision for diaphragm walls and slabs indicate that the actual concrete strengths are typically higher than that specified for design. Typical cube strengths of above 60MPa are common as compared to the specified 40MPa (slab) and 45MPa (diaphragm wall) strengths adopted for design. Concrete cores taken from the diaphragm walls also provide an indication that the in-situ concrete strengths are likely exceed that adopted from the original design.*

16.6.2 These increased strengths can be statistically analysed and adopted for an assessment and could significantly enhance the shear strength for the reinforced concrete, however these effects have not been considered for assessment of the available strengths of the structure."

[47] [**OU6/4136**].

45. On the issue of not departing from the Government's requirement on soil stiffness, Sections 16.2.2 and 16.2.3 of Atkins' Stage 3 Assessment Report state as follows[48]:-

> "*The parameter that has a significant influence on the performance of the diaphragm walls under lateral earth loads is the stiffness of the ground, both on the active retained side, driving the wall, and on the passive supporting side within the station box, at the formation level of the excavation. A commonly adopted relationship for the ground stiffness is to correlate with the SPT-N" value, which is the number of blows required to drive a metal cone a prescribed distance down an investigative borehole. The original design and this assessment adopted the relationship of E' = 1.0 x SPT-N within the soil layers comprising the fill and sandy materials associated with the previous reclamation, and with a higher stiffness adopted within the Completely Decomposed Granite (CDG) as described under Section 6.3. <u>However, the higher stiffness of E'=1.5 x SPT-N is also commonly adopted within reclaimed soil layers for the design of deep excavations in Hong Kong, and consequently this is considered to add a degree [of] conservativism to the design</u>.*
>
> *<u>The PLAXIS analysis adopts the Mohr-Coulomb (M-C) constitutive soil model which is most commonly adopted for design in Hong Kong and is accepted for submission to government</u>… For solving deep excavations problems involving significant soil-structure interaction and unloading and reloading of soils where the soil stiffness & deformation plays a more dominant role, there are more sophisticated models available such as Hardening Soil (HS) and Hardening Soil with small strain (HSsmall). <u>The Mohr-Coulomb</u>*

[48] [**OU6/4128-4129**].

soil model tends to over-predict heave and as a consequence a better approximation of the response of the ground is possible using the HS or HSsmall models."

46. As set out at paragraph 11 above and having regard to those matters set out at paragraphs 44 and 45 above, MTRCL respectfully submits that: Lau (1) had failed to recognise the conservatism which the external consultants themselves recognised; and, (2) advocated an even higher degree of conservatism than that adopted by MTRCL's external consultants.

47. As to the other complaint that Lau has advocated an even higher degree of conservatism than that adopted by MTRCL's external consultants, it is illustrated by Lau's qualitative statements in respect of his concerns on rupture of section[49], durability and crack width, these being his only concerns following his clarification when he was cross-examined by CoI's Leading Counsel[50]. Lau's foregoing concerns are raised in the context of the three major topics (namely, coupler connections, shear links and horizontal construction joint) and they are addressed in the following sections.

V. Coupler connections

48. The Holistic Proposal consists of three stages[51]:-

(1) Stage 1 - Desktop exercise;

(2) Stage 2 - Physical Investigation (Opening-up works):-

(a) Inspect and verify the as-constructed steel bar connection details by opening-up the EWL slab to address concerns arising from gaps in the documentation or evidence

[49] §26(b) of Lau's CoI 1 Report [**ER2/Item 17.1**].
[50] Entire Inquiry [**T9/66:13-21**].
[51] **[B20/26101-26102]**.

concerning the connection between the EWL slab and the D-walls (purpose (i));

(b) Inspect the workmanship of coupler connections by opening-up the EWL and NSL slabs at random locations (purpose (ii)); and

(3) Stage 3 - Structural Assessment.

49. The purpose (ii) investigation involves the opening-up of randomly selected coupler connections at the EWL and NSL slabs for further physical inspection and/or examination using PAUT and assessment of the possible defective rate of coupler connections based on statistical principles[52].

50. For the reasons set out in Section 4 of the Holistic Report, and notwithstanding the reduction factors of 36.6% and 33.2% for the EWL and NSL slabs respectively, the Stage 3 Structural Assessment reveals that, as far as coupler connections are concerned, no Suitable Measures are required for Areas B and C for the purpose of the Holistic Report. Likewise, notwithstanding the reduction factor of 68.3% in the EWL Area A/HKC slab to D-wall connections, the Stage 3 Structural Assessment reveals that, as far as coupler connections at the slab to D-wall connections are concerned, only Area A requires Suitable Measures for the purpose of the Holistic Report[53].

51. The reduction factor was based on the Acceptance Criteria set out in paragraph 3.3.13 of the Holistic Report:

> "*For the purpose of this study, the proper installation requirement for the couplers are considered to be (i) there shall be a maximum*

[52] §8 of the Executive Summary of the Holistic Report **[OU5/3234]**; §13 of the CoI 1 Stat Report **[ER1/11.1]**.
[53] §§45 to 46 of the CoI 1 Stat Report **[ER1/11.1]**.

of two full threads exposed (which is stated in the manufacturer's installation requirements); and (ii) the engagement length of the threaded steel rebar inside the coupler should be at least 40mm. As the allowable measurement tolerance of the test equipment is 3mm, equipment readings below 37mm are regarded as defective."

52. McQuillan, Glover and Southward all agree that[54]:-

(1) on the basis of all the testing carried out to-date, a partially-engaged coupler assembly with a minimum engagement of 7 threads (32mm) satisfies the strength criteria;

(2) anything less than a full butt-to-butt will not pass the permanent elongation test e.g. 2 threads exposed will not pass the test; and

(3) HyD's Acceptance Criteria, based on BOSA's criteria, therefore unwittingly sanction the use of partially engaged coupler assemblies because anything less than locked, full butt-to-butt coupler assemblies will fail the permanent elongation test.

53. Lau, however, is of the view that "*only full engaged couplers i.e. full butt-to-butt and locked should be used in the structural assessment*"[55], the purported significance of which was expressed by Lau in the following terms[56]:-

"*According to the results of the tests commissioned by MTRCL, the permanent elongation of the partially engaged coupler connections could be up to 0.51mm [OW1/240]. Adding the said permanent elongation to the out-of-slip movement, the total deformation of the coupler connection would be a lot more than the 0.3mm maximum crack width allowed by the Concrete Code under the serviceability*

[54] [**ER2/18.3**].
[55] [**ER2/18.3**].
[56] §56 of Lau's CoI 1 Report [**ER2/Item 17.1**].

limit state [H8/2928]. Hence partially engaged coupler connection with a possible total deformation of more than 0.51 mm is unacceptable. I therefore have no confidence in the coupler assembly if it is only partially engaged. It is also difficult to come up with reliable methods to meaningfully calculate and ascertain crack widths or deflections in the structural element if the reinforcements are connected by partially engaged couplers."

54. In slide 13 of his presentation[57], Lau further explained that the problem was cracking should be considered under the SLS and on the premise that the exposure condition of the as-built structures should not be considered as "mild".

55. Lau's reliance on the permanent elongation test represents an added level of conservatism, which is unwarranted as will be demonstrated below.

V(i) <u>The Acceptance Criteria in the Holistic Report are only a deemed acceptance criteria</u>

56. On 24 December 2018, the Government stated its position in a Press Release that[58]:

(1) According to the information from BOSA the proper installation requirements of a coupler were: (i) there should be a maximum of two full threads exposed; and, (ii) the embedded length of the thread of the threaded steel bar inside the coupler should be at least 40 mm in length;

(2) As the allowable measurement tolerance of the PAUT method is 3 mm, readings below 37 mm (i.e. 40mm less the 3 mm tolerance) are regarded as failing to meet the installation requirements.

[57] [**ER2/17.11**].
[58] [**B21/26690**].

57. While noting MTRCL's position that the engagement of six full threads could provide the design strength, the Government considered that when conducting the structural analysis under Stage 3 Structural Assessment MTRCL should take into account the technical data provided by BOSA[59].

58. Between December 2018 and January 2019, a number of meetings were held and attended by representatives of the Government and MTRCL to discuss the acceptance criteria. On 10 January 2019[60], BD issued a letter to MTRCL setting out the clarifications on coupler engagement that BD had apparently received from BOSA on 7 January 2019[61], including that the couplers would require around 10 full threads engagement for a correct engagement. After discussions between the Government and MTRCL, MTRCL adopted the Government's advice that an engagement length of no less than 40 mm by direct measurement and no less than 37 mm by PAUT was required to ensure acceptance by the approval authorities. Such approval was essential to enable the station to be put into operation[62].

59. The Government's adoption of the Acceptance Criteria was explained as follows in its first Closing Submissions for the Original Inquiry[63]:-

"*61. …The benchmark adopted by the Government was based on the information provided by BOSA (i.e. the coupler manufacturer) and it decided to take 37mm instead of 40mm in order to give MTRCL and Leighton the benefit of the doubt (arising from the level of tolerance gathered from experts). This issue will be fully discussed in Section D of these submissions.*

[59] [**B21/26690**].
[60] [**H26/45853-45861**].
[61] [**H26/45858-45861**].
[62] §22 of Neil Ng's witness statement [**BB16/10088-10089**].
[63] [**CS/Item 1.1**].

162. The present deemed compliance benchmark of 37mm measured engagement/embedded length (by PAUT) was set on the basis of the requirement of a full engagement of 10 threads (40mm) for proper installation of the couplers supplied by BOSA [H26/45640]; which was adopted and accepted by MTRCL and Leighton in its QSP dated 12 August 2013 [H9/4280]. Because of the measurement tolerance of +/-3mm by PAUT, for the purpose of the present investigation, the acceptance criterion was set at 37 mm (with a view to fairly giving MTRCL and Leighton the benefit of the doubt)."

60. Therefore, the Acceptance Criteria is a deemed compliance benchmark adopted by the Government, which does not mandate a "butt-to-butt" connection as Lau now appears to contend. Under the Acceptance Criteria[64], and as noted at paragraph 51 above, the requirement is for a "proper installation" and not a "butt-to-butt" connection. Further, as previously submitted during the Original Inquiry a "butt-to-butt" connection was also not required during the construction process[65].

V(ii) <u>Permanent elongation test taken into account in Stage 3 Structural Assessment</u>

61. Lau's concern was premised on the worst permanent elongation test result. As explained by Glover[66], Lau's approach is an incorrect and speculative extrapolation of a solitary laboratory test into the performance of groups of couplers in a massive concrete structure.

62. Indeed, Lau's speculative extrapolation of a solitary laboratory result is one of the clearest instances of his adoption of a level of conservatism which is

[64] §22 of Neil Ng's witness statement **[BB16/10088-10089]**.
[65] §§87-92 of MTRCL's Closing Submissions for the Original Inquiry dated 22 January 2019 **[CS/Item 2]**.
[66] Glover's Presentation Slide No 22 [**ER2/Item 16.2]**.

simply unwarranted. The issues of elongation and cracks were in fact considered in Section 16 of Atkin's Stage 3 Assessment Report[67]:-

> "*16.8.9 The small preload induced by the butt to butt connection may be sufficient to tighten the coupler against the threads, eliminating the initial slack and reducing the permanent elongation to less than 0.1mm over the gauge length. The out working of this is that any coupler which is not tightened "butt to butt" will have additional slack and this slack will be mobilised on first loading. This is irrespective of engagement length.*
>
> *16.8.10 Therefore, for the SLS condition we have the additional permanent elongation to account for in the assessment of the coupler performance under serviceability load. It also raises the question about the comparative performance between the partially engaged couplers and those that have been tightened correctly. Some couplers would be properly tightened (approx. 50% have 40mm or better thread engagement). These would pick up load preferentially until the slack in the incorrectly installed couplers was absorbed.*
>
> *16.8.11 <u>The average permanent elongation from the test results is 0.27mm.</u> The specification requires <0.1mm and the average from the original tests is 0.05mm. The difference between the original tests (i.e. taken as correctly installed) and the partially engaged coupler tests is 0.22mm over a 200mm gauge. This equates to a stress on 220N/mm2 in the correctly installed bars before the partially engaged bars become effective…*
>
> *16.8.14 <u>To assess this effect on the station the number of effective bars needs to be evaluated. A rigorous approach would be a non-</u>*

[67] [**OU6/4137-4138**].

linear assessment to account for the fully engaged bars first up to 0.27mm movement then add the partially engaged bars. Alternatively, and conservatively, the excess initial permanent elongation can be added to the crack width calculated for all bars. 0.1mm is the permitted permanent elongation, so the excess to add to the crack width calculation is 0.27mm (tested) – 0.1mm (permitted) = 0.17mm.

16.8.15 The partially engaged coupler test results show that all the tested bars have similar performance at SLS stresses at first yield and they are all still effective to nearly 5% strain. Indeed, the best test results for permanent elongation came from a coupler with 28mm engagement. This is logical, as general tests on threaded bars show that most of the anchorage comes from the first few threads. Therefore, the results would indicate that the couplers with an engagement length of 28mm and above could be considered as effective at SLS. (The 28mm bars are not be consider effective at ULS).

16.8.16 It would therefore be possible to include the coupled bars with minimum 28mm engagement for the SLS condition, and with minimum 32mm engagement at ULS, in the capacity checks for the structures."

63. In summary, Atkins was cognisant of the samples which failed the permanent elongation tests and had already considered the consequential risk of cracks under SLS. Atkins' conclusion was that even taking into account the risk of cracks it was possible to include couplers with 28mm engagement for the SLS condition.

64. Indeed, McQuillan, Glover and Southward have all considered the relevance of the permanent elongation test and they all concluded that the

samples that failed the permanent elongation test would not cause any concern under SLS.

65. The lack of credence in Lau's speculative approach is further highlighted by the fact that there is absolutely no evidence of any cracking of the kind which concerns him in the as-constructed structure despite the fact that the structure is currently sustaining about 90% of its total expected loading and has been subjected to severe vibration from the very intrusive Stage 2 opening-up works[68].

V(iii) <u>The as-built structures are in a benign environment</u>

66. Under the HKCoP, the exposure condition is classified into 5 categories[69]. It is Lau's view that the as-built works are exposed to a "moderate" or "severe" condition.

67. A "moderate" exposure condition is defined as:

> *"Internal concrete surfaces exposed to high humidity e.g. bathrooms and kitchens.*
>
> *External concrete surfaces exposed to the effects of severe rain or <u>cyclic wetting and drying</u> e.g. fair faced concrete, concrete with cladding secured by dry or mechanical fixing, curtain walling."*

68. It appears that the Government's case was focused on the fact that the D-wall was subject to tidal variation but this was only seriously explored with Glover. When cross-examined by Counsel for the Government, Glover explained that there was no wetting and drying[70]:-

[68] Glover's Presentation Slide No. 23 [**ER2/Item 16.2**].
[69] [**H8/2857**].
[70] Entire Inquiry [**T11/43:5-44:23**].

"Q. And given the tidal variation can go up to plus 2.8, with that tidal variation am I right in understanding that the top part of the EWL slab is subject to wet and dry conditions?

A. The external face of the diaphragm wall?

Q. Yes.

A. Yes. The external face of the diaphragm wall could be, yes. But, I mean, you've got to remember, wetting and drying -- what wetting and drying means is something is wet, you know, you take a bucket of water and you throw it on it, and then you allow it to dry in oxygen, so it's got lots of oxygen coming into it, and then you dry it, and then in a short period after that you throw another bucket of water over it and you get more oxygen in it.

In the ground, it's not like that. You see, the fact -- an interesting thing that people don't realise about waves, for example, the water doesn't move. All a wave is is a circular motion of a particle of water moving round and round. So because the tide actually moves up and down, we've got this thinking that there's huge in-flush of water, but it's not, it's a pressure, and the water locally just rises up and goes down. The level of oxygen in that water is not substantially

changed.

This is not the same as my bucket of water, drying it out with a hairdryer and then putting another -- it's not like that. So I'm not sure where you are going.

Q. The short point I'm suggesting --

A. We are talking about the outside wall of the diaphragm wall. I thought we were talking about cracks local to the couplers which

are inside the structure, away from the wetting and drying. So can you get the connection between the two?

Q. As I understand --

A. Otherwise we are going to waste our time, aren't we, talking about the diaphragm wall?

COMMISSIONER HANSFORD: Sorry, just pause there. You said "away from the wetting and the drying". It's just wetting.

A. It's just wetting, and the ground is very humid. I really don't know. This is not --

COMMISSIONER HANSFORD: Because it's not drying, is it?

A. No."

69. There is therefore no cyclic wetting and drying as contended by Lau making the structures fall into the moderate or severe category.

V(iv) <u>Coupler connections safe and fit for purpose</u>

70. As stated in Section I above, MTRCL does not regard it as necessary to state the differences between McQuillan, Glover and Southward in terms of how they each came to the conclusion that the as-constructed works are safe and fit for purpose – the important point is that they *all* regard the as-constructed works as safe and fit for purpose.

71. However, in relation to Southward, in so far as there is any remaining[71] suggestion that the as-constructed couplers achieve Compliance[72], during cross-examination by MTRCL's Leading Counsel in the context of shear links, Southward agreed with the proposition that the CoI is not concerned with Compliance[73] – which is obviously correct.

[71] §6.12 of Southward CoI 1 Report has been directed to be redacted [**ER2/14.1**].
[72] §6.9.4 of Southward CoI 1 Report [**ER2/14.1**].
[73] Entire Inquiry [**T8/87:18-88:18**].

VI. Shear Links

72. The issue concerning shear links has been explained in the Holistic Report[74]:

(1) Defects in the shear link placement were first discovered when the shear links at the EWL slab soffit were exposed during the investigations into the honeycombing in the concrete. Atkins conducted inspections at the EWL slab soffit and identified 22 locations, in the areas inspected for honeycombing, with defects in the shear link placement;

(2) 18 additional locations at the EWL slab soffit were opened up for further investigation of the as-constructed condition of the shear link placement, which revealed shear link irregularities at all 18 locations. These included missing shear links, smaller bar sizes than specified and insufficient anchorage lengths. These irregularities did not conform to the design and also reflected construction and supervision issues;

(3) A structural analysis has been conducted with the Updated Design considerations. It has been concluded that for the purposes of the ongoing construction activities, the station is structurally safe;

(4) For the permanent case, in order to avoid damaging the structure by extensive opening up, a conservative approach has been adopted by ignoring any shear links at platform slabs that may have been installed in the Stage 3 Structural Assessment. The Stage 3 Structural Assessment shows that Suitable Measures will need to be taken to restore the shear capacity of the slabs; and

[74] §§3.5.24 to 3.5.30, 4.2.14 of the Holistic Report **[OU5/3264-3265, 3278]**.

(5) Although the installed shear links have not been included in the Stage 3 Structural Assessment, it is considered that the installed shear links will provide some strength and, hence, an additional safety margin to the slab.

73. Putting aside the issue of Compliance, McQuillan, Glover and Southward are all agreed that the as-built CoI 1 Structures, including the shear links, are safe and fit for purpose[75]. In particular, the three experts agreed that[76]:

(1) In the areas where nominal/minimum shear reinforcement is required, there is some 25% over-provision, or more, in the shear links installed;

(2) The shear links provided should not be disregarded in their entirety;

(3) The actual proven concrete cube strengths should be used in the structural shear assessment and, furthermore, concrete strength gain with time is a legitimate consideration;

(4) There are other beneficial factors which could be considered, e.g. compressive action and arch action; and

(5) Codes allow, when retro-analysing (forensically) a structure, the safety factors to be reviewed, e.g. to use actual loads and actual material properties.

74. However, Lau disagreed with the other experts generally. In particular, he raised the concern that there may not be any shear links in areas where shear reinforcement is required and that without the implementation of Suitable Measures the as-built CoI 1 Structures are neither safe nor fit for purpose[77]. As will be demonstrated below, none of Lau's so-called

[75] Supplemental Memorandum of Agreement dated 2 January 2020 **[ER2/Item 19.2].**
[76] §2 of Memorandum of Agreement dated 20 December 2019 **[ER2/Item 18.3].**
[77] §2 of Memorandum of Agreement dated 20 December 2019 **[ER2/18.3]**; Supplemental Memorandum of Agreement dated 2 January 2020 **[ER2/19.2].**

concerns detract from the conclusion that the as-constructed shear links are safe and fit for purpose.

75. It is also noted that Southward in his Expert Report challenged the legitimacy of shear links investigation under the Holistic Report on the basis of the opening up of the 18 additional locations at the EWL Slab soffit[78]. MTRCL will first deal with Southward's challenge before moving on to deal with Lau's disagreements with the other three structural engineering experts that the as-built CoI 1 Structures are safe and fit for purpose.

VI(i) Shear links investigation

76. Southward raised the issue that all of the 18 additional locations were opened up with an "L" shape. With reference to location HZ01, Southward disagreed with the finding of MTRCL that as no shear links are visible no shear links are present at this location on the basis that the location of the right-angle slots are not positioned correctly in order to pick up shear links[79]. Southward then referred to a photo showing a 1m by 1m square opening up by LCAL in Area A of the EWL slab soffit and contended that if a 150mm x 1m right angle slot is superimposed on the photo, it is possible to see that the right angle slot can be positioned so that no exposed shear links are visible, even though they are present. Southward expressed the opinion that he does not believe there is any legitimacy in MTRCL's findings that at locations HZ01, HZ05, HZ08 and HZ10 there are in fact no shear links present[80].

77. However, as Glover explained:

[78] §§7.1-7.2 of Southward's Expert Report **[ER2/14.1]**.
[79] §7.1 of Southward's Expert Report **[ER2/14.1].**
[80] §7.2 of Southward's Expert Report **[ER2/14.1].**

(1) The opening up investigation to expose the share links by creating an “L" "-shaped excavation in the slab soffit is not an unreasonable approach as it has the advantage that it limits the area of concrete that has to be removed and thus also reduces the nature and extent of the damage to the structure. In Glover’s view, it is also likely that such a method of opening up the structure would expose the shear links that were anchored around the bottom slab rebar, albeit that exposure of all the potential shear link locations is not guaranteed;

(2) By comparison, removing a square area of concrete is unnecessarily invasive of the structure and results in more damage, albeit that it will confirm with certainty the provision (or otherwise) of shear link reinforcement anchored around the bottom slab rebar;

(3) In the circumstances, the “L“-shaped opening up approach was appropriate, albeit that the width of the strips could in hindsight have been marginally wider to cover the extremes of link spacing;

(4) Glover also considers that the investigation which was carried out was adequate in terms of providing an overview of the nature and extent of the shear link installation and revealed the range of non-conformities present for those shear links which were anchored around the bottom slab rebar; and

(5) The investigation could not be expected to expose those shear links that were anchored around the rebar at a higher level in the many layers of bottom slab rebar, which were up to 9 layers deep. Notwithstanding, the nature and extent of the investigation adopted was not, in Glover’s view, in any way unusual having regard to the massive concentrations of rebar which existed in the structure, both in terms of its spacing (nominally T40 rebar at 150mm centres in both directions) and the number of layers (up to 9 layers) which

would have made breaking into the upper layer of rebar totally impractical on any meaningful scale[81].

78. In fact, the adequacy of the shear links investigation carried out is even supported by Lau[82].

79. It is worth noting that Southward's criticism on the shear links investigation is confined to the opening up methodology for the 18 additional locations (i.e. the "L"-shaped opening up), which for the reasons set out above are adequate in terms of providing an overview of the nature and extent of the shear link installation. It is telling that Southward did not question the validity of the remaining investigation results, namely the 22 locations with defects in the shear links which were identified when they were exposed during the honeycombing investigation.

80. In the circumstances, there is no reason to question the shear links investigation conducted under the Holistic Report.

81. Nevertheless, the treatment of the investigation results from a Compliance perspective and from a safe and fitness for purpose perspective may be different, which will be dealt with in the next sub-section.

VI(ii) <u>Overprovision of as-constructed shear links and the as-constructed shear links should not be disregarded</u>

82. The shear links investigation under the Holistic Report revealed shear link irregularities at all 40 locations, which included missing shear links, smaller bar sizes than specified and insufficient anchorage lengths[83].

83. The Holistic Report, which was prepared for the purpose of achieving Compliance adopted a conservative approach by ignoring in the Stage 3

[81] §§8.1-8.5 of Glover's Expert Report **[ER2/16.1]**; Entire Inquiry **[T11/73:7-22].**
[82] §117 of Lau's Expert Report **[ER2/17.1].**
[83] §§3.5.24 to 3.5.30 and Appendix B8 of the Holistic Report **[OU5/3264-3265, 3331-3332].**

Structural Assessment any shear links that may have been installed at the platform slabs [84].

84. However, from a safety and fitness for purpose perspective, McQuillan, Glover and Southward all agreed that the shear links which had been provided should not be disregarded in their entirety and in the areas where nominal/minimum shear reinforcement is required, there is some 25% over-provision, or more, in the shear links installed[85].

85. Lau's only concern here is the possible absence of shear links at the critical locations[86].

86. There is no dispute between the experts that it is unnecessary for the shear links to extend all the way to the bottom mat of the reinforcement[87]. In locations where shear links were not observed to be visible in the exposed bottom layers, both Southward and Glover were of the view that this may have been because the shear link was stopped in the upper layers of the bottom mat of the reinforcement[88]. Lau accepted this as a possible reason for not discovering the shear links during the investigation[89].

87. Moreover, 24 of the 40 openings showed the presence of shear links, albeit that the shear links may have been defective or irregular for other reasons[90], as acknowledged by Lau. Importantly, Lau also agreed that there will be strength in the shear links that are present[91].

88. Therefore, from a safety and fitness for purpose perspective, the shear links which were actually provided should not be totally disregarded.

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[84] §4.2.17 of the Holistic Report **[OU5/3278].**
[85] §2 of the Memorandum of Agreement **[ER2/18.3].**
[86] §§122, 124, 126, 128, 133, 135, 137 of Lau's Expert Report **[ER2/17.1].**
[87] §7.4 of Southward's Expert Report **[ER2/14.1]**; §121 of Lau's Expert Report **[ER2/17.1]**; §140 of McQuillan's Expert Report **[ER2/15]**; Entire Inquiry **[T11/75:8-15].**
[88] §7.4 of Southward's Expert Report **[ER2/14.1]**; Entire Inquiry **[T11/80:19-81:13].**
[89] Entire Inquiry **[T9/175:3-176:21].**
[90] Appendix B8 of the Holistic Report **[OU5/3331-3332].**
[91] Entire Inquiry **[T9/168:1-16].**

89. Further, Atkins' Stage 3 Assessment Report noted that where shear reinforcement has been installed which does not satisfy the detailing rules for the anchorage of the links around the main horizontal reinforcement bars of the slabs, such a configuration would not achieve the full shear strength allowed by the HKCoP, albeit that the residual strength can be assessed and the contribution of the partially installed links included in the capacity of the slab[92].

90. As explained by Glover, the for-construction drawings show a very substantial provision of shear link reinforcement throughout the structure which very comfortably exceeds the future demands of the structure when in use. This means that there is a substantial reserve of strength which can be utilised to compensate for any failings in terms of workmanship[93].

91. The above is supported and elaborated upon by Southward in his Expert Report[94]. In this regard, it is noted that Southward clarified during his cross-examination by Leading Counsel for MTRCL that he accepted that the as-constructed shear links do not comply with the detailing rules of the HKCoP and that his calculations and justifications as contained in his Expert Report were done on the basis of safety, namely can the shear links withstand the load, and not Compliance[95]. Therefore, Southward's opinion as set out below, including references to the HKCoP, only goes to the issue of safety and not Compliance.

92. Insofar as the over-provision of shear links is concerned, Southward explained that the HKCoP requires a minimum area of shear links to be provided. This is typically 300 mm^2/m and the original design satisfies this by providing T12 bars at 300 centres in both directions. The area provided

[92] §16.7.3 of Atkins' Stage 3 Assessment Report Vol. 1 **[OU6/4136].**
[93] §8.9 of Glover's Expert Report **[ER2/16].**
[94] §§7.5-7.8 **[ER2/14.1].**
[95] Entire Inquiry **[T8/86:25-88:16].**

is therefore 113/ 0.3 = 377mm^2/m. There is, therefore, an over-provision of the shear link reinforcement of 377/300 -1 = 25.6%[96].

93. Southward explained and calculated that based on the specifications under the HKCoP there is a 13% reduction in the anchorage capacity of the as-constructed shear links, which only extend 70mm as opposed to 120mm beyond the end of the bend. However, as the design of the shear links over-provides by around 26% (or 25.6%), Southward concluded that the as-constructed shear links are adequate for the design[97]. Lau has no disagreement with Southward in this regard[98].

94. Southward also demonstrated that the as-constructed shear links are safe and fit for purpose on the basis of the Eurocode and the AASHTO codes[99], the conclusion of which Glover supports[100]. Lau is silent on this and has not raised any objections.

VI(iii) <u>The actual proven concrete cube strengths should be used in the structural shear assessment</u>

95. It is the unanimous view of McQuillan, Glover and Southward that the actual proven concrete cube strengths should be used in the structural shear assessment and, furthermore, concrete strength gain with time is a legitimate consideration[101].

96. As highlighted in Atkins' Stage 3 Assessment Report:

    (1) The concrete cubes sampled from the concrete mixer trucks during the concreting works and tested for strength as part of the quality control and construction supervision for the D-walls and slabs

[96] §7.5 of Southward's Expert Report **[ER2/14.1].**
[97] §§7.5.1-7.5.4 of Southward's Expert Report **[ER2/14.1]**; see also §8.8 of Glover's Expert Report **[ER2/16.1].**
[98] §126 of Lau's Expert Report **[ER2/17.1].**
[99] §§7.6.1 to 7.6.2 of Southward's Expert Report **[ER2/14.1].**
[100] §8.7 of Glover's Expert Report **[ER2/16.1].**
[101] §2 of the Memorandum of Agreement **[ER2/18.3]**; see also Glover's explanation: Entire Inquiry **[T10:67:10-76:21].**

indicate that the actual concrete strengths are typically higher than specified for the design. Typical cube strengths of above 60 MPa are common as compared to the specified 60 MPa (slab) and 45 MPa (D-wall) strengths adopted for the design. Furthermore, concrete cores taken from the D-wall also provide an indication that the in-situ concrete strengths are likely to exceed that adopted for the original design; and

(2) These increased strengths can be statistically analysed and adopted for an assessment and could significantly enhance the shear strength for the reinforced concrete[102].

97. In addition to Atkins' approach on the permissibility of using in-situ concrete strength for the purpose of structural analysis as stated in paragraph 44 above, in its Final Independent Structural Assessment Report, AECOM also assessed the in-situ material strengths of the relevant reinforced concrete structures at the CoI 1 Structures by reference to the available testing results provided by MTRCL for materials used on the Project. As explained by AECOM:

(1) The structural design capacity was based on the characteristic strength for the materials. At the design stage, the structural design strengths were 40 MPa and 45 MPa respectively for the concrete used for the majority of station structures and for D-walls in compression;

(2) Paragraph 3.1.2 of the HKCoP provides that the characteristic strength of concrete is that value of the cube strength at 28 days below which 5% of all compressive test results would be expected to fail;

[102] §§16.6.1 to 16.6.2 of Atkins' Stage 3 Assessment Report **[OU6/4136]**.

(3) For the Grade 40 concrete used on the Project, 8,640 cube test results were available. The average strength for these cubes was approximately 73 MPa and the characteristic strength was approximately 59 MPa;

(4) For the Grade 45 concrete used in the D-walls, 7,761 cube test results were available. The average strength for these cubes was approximately 73 MPa and the characteristic strength was approximately 62 MPa;

(5) In addition to the cube strength results, a total of 39 core test results were also available in relation to the D-walls. The core samples were obtained from the top of the D-walls in a vertical orientation and an assessment of the compressive strength test results in accordance with Construction Standard CS1 Testing Concrete Section allowed an estimation of the in-situ cube strength; and

(6) The average estimated in-situ cube strength from the 39 samples was 79 MPa and using the same 5% criteria from the HKCoP, the characteristic strength would be 64.5 MPa. The core test results are consistent with the cube test results and substantiate the use of 62 MPa as the characteristic strength of the Grade 45 concrete used in the D-wall based on the cube results[103].

98. In this context, Glover noted that the mix design for the D-wall is slightly different from that which has been used in the EWL slab, but the fact is that they are very similar. Glover is *"more than satisfied that the strength in the structure is at least 60 MPa and with an age factor applied to it now of about three of four year which is quite considerable"*[104].

[103] §6.5 of AECOM's Final Structural Assessment Report **[OU6/199/6-4 – 6-5]**.
[104] Entire Inquiry **[T10/74:22-76:21]**.

99. In fact, the following core samples were taken from the EWL slab between 2017 and 2018:

(1) Three random concrete core samples were taken from the EWL slab in October 2017 and tested in November 2017. According to the concrete core test report, the measured compressive strength in MPa of the three core samples ranged between 74.4 and 80.8[105]; and

(2) Six further random core samples were taken from the EWL slab and tested in July 2018. According to the six test reports on static modulus of elasticity in compression, the compressive strength in MPa of the six core samples ranged between 55 and 71.5[106].

100. Glover was shown these results during his re-examination. He told the CoI that the results are very consistent with the strength in the works being substantially larger than the design strength of 40 MPa. Importantly, Glover considered that it has reached the point where it is almost beyond doubt that the concrete in the works is, indeed, substantially stronger than the design strength that was achieved, or was set out in the design of 40 MPa[107].

101. Further, it was put to Glover by counsel for the Government during his cross-examination that it would be prudent not to adopt the higher strength of the concrete in view of the extensiveness of the honeycombing and the location of the honeycombing:

(1) This proposition was rejected by Glover. Glover explained that there is no relationship between strength and honeycombing;

[105] **[B17/14220]**.
[106] **[B17/14238-14243]**.
[107] Entire Inquiry **[T11/116:6-122:17]**.

(2) In this regard, Lau does not suggest that the concrete strength itself is inadequate. His doubt lies with the quality of the concrete on the basis of the honeycombing and workmanship;

(3) As Glover noted, honeycombing is a workmanship issue which can and has in fact been repaired. Once it has been repaired, it remediates the situation to that expected in the required standard; and

(4) Therefore, it is inappropriate to extrapolate from the honeycombing at the soffit of the EWL slab that the concrete is inadequate in strength[108].

102. In the circumstances, Lau's objection that one can only use the concrete strength of the Grade 40 in design checks from a safety and fitness for purpose perspective because the concrete cube test results do not represent the actual concrete strength in the structure[109] is devoid of any substance.

103. Lau also said that he has a lot of data on the strength of cores of old buildings, and because of the age of the buildings which are all over 50 years old, the core strengths of this concrete are normally much lower than the design strengths. On this basis, Lau opines that the strength of concrete after it has been cast will continue to rise because of chemical reaction, but after two to three years the chemical reaction stops, and because of the creation of micro-cracks during the use of the building, the strength starts to fall, so with the age of the building the strength of the concrete can decrease[110].

104. However, contrary to Lau's contention and as Glover noted, the concrete technology 50 years ago is very different from what it is now. Since the turn of the century MTRCL has led the way in concrete mix design in Hong

[108] Entire Inquiry **[T11/14:16-26:18]**.
[109] §79 of Lau's Expert Report **[ER2/17.1]**.
[110] Entire Inquiry **[T8/98:15-99:8, T9/5:4-15]**.

Kong, and together with other organisations and Government, has gone a long way in changing the mix designs that existed 50 years ago. One of the major ingredients in a modern concrete is the addition of a pozzolanic material, a Roman concrete, which has a totally different chemical composition. A minimum of 25% of modern concretes in Hong Kong contain this material. It is referred to as a pulverised fuel ash. The pozzolanic materials have a slow gain of strength with time and they plateau with no decline[111].

105. Southward also explained that concrete gets stronger as it ages. When it is first created, it is a liquid and therefore has no strength. When it is one day old, it is set but is very weak. When it is seven days old, it is a bit stronger. Engineers' design is based on a 28-day strength, which is even stronger. In his presentation, Southward referred to an extract from the Hong Kong Structures Design Manual, which he considered as the best reference for the effect of age on Hong Kong concrete strength[112]. He explained that when concrete is 360 days old, it is typically 20% stronger than its 28-day strength[113].

VI(iv) <u>Other beneficial factors which could be considered, e.g. compressive action and arch action</u>

106. McQuillan, Glover and Southward all agreed that there are other beneficial factors which could be considered, e.g. compressive action and arch action[114].

107. The principles of compressive action and arching action were explained by Southward with reference to the calculations conducted by Arup in their Stage 3 Structural Assessment:

[111] Entire Inquiry **[T10/69:18-71:5; T11/12:3-13:16]**.
[112] Southward Presentation Slide No. 34 **[ER2/14.9]**.
[113] Entire Inquiry **[T7/76:6-23]**.
[114] §2 of the Memorandum of Agreement **[ER2/18.3]**.

(1) Arching is a real effect in structures with a low span-to-depth elements. Arching is the action whereby load that is applied to the slab is transferred to its ends (i.e. the D-walls) by the establishment of a line of thrust within the depth of the slab; in a pure arch, as say a flying buttress, there is no "shear" since the structure acts in direct compression, as in an axially loaded building column;

(2) Arup's non-linear computer analysis modelled the effect of the establishment of the arch by applying load to the concrete slab until such time that the model showed the slab had failed. The results showed that the slab is able to withstand two to three times the amount of load that the slab had been designed for using the methods in the HKCoP. In other words, the actual shear capacity of the slab is at least twice the shear capacity of the slab when calculated using the shear capacity calculation methods specified in the HKCoP;

(3) The analysis did not include the beneficial effect of the shear links in the slab. The only reinforcement considered was the top and bottom longitudinal steel, which shows that there is two to three times the reserve of shear strength in the slab when compared to what is achieved when a design is computed using the methods in the HKCoP; and

(4) This inherent reserve of strength provides an additional safety factor, providing further re-assurance that the structure is safe for use[115].

108. Lau suggested, without any substantiation whatsoever, that the arching action depends on the depth span ratio. He said that because there are a lot

[115] §5.6.1 of Southward's Expert Report **[ER2/14.1]**; see also McQuillan's analogy of a short row of clay bricks: §132 of McQuillan's Expert Report **[ER2/15.1];** and Entire Inquiry **[T11/82:3-83:8]**.

of openings in the slab, there may not be any arching action in the slab for the shear calculation[116].

109. Lau's suggestion constitutes an overly simplistic proposition and does not reflect the situation of the CoI 1 Structures. As explained by Glover:

(1) If one looked at it in two dimensions, the proposition of openings disrupting the arch is correct. However, the CoI 1 Structures are not two dimensional. If there is a hole then there will be a rib on either side of it. The fact that there is a hole does not change the arching principle because the arching principle occurs where there is no hole and then in between these are counter-arches onto those main ones. It all depends on the geometry; and

(2) There should be no dispute that the arching effect happens, particularly when one is talking about a 3 m deep slab[117]. Arching should be viewed as a three dimensional action with primary arches spanning between supports with secondary arches spanning between the primary arches; in this structural system openings can be accommodated in the secondary arching system.

VI(v) <u>Codes allow, when retro-analysing (forensically) a structure, the safety factors to be reviewed</u>

110. McQuillan, Glover and Southward all agreed that the codes allow, when retro-analysing (forensically) a structure, the safety factors to be reviewed, e.g. to use actual loads and actual material properties[118].

111. As explained by Southward during his cross-examination by Counsel for the CoI, at the time of design there is not even a contractor on board. One has no idea what type of concrete the contractor will use, or where he

[116] Entire Inquiry **[T9/5:16-20]**.
[117] Entire Inquiry **[T11/82:3-83:8]**.
[118] §2 of the Memorandum of Agreement **[ER2/18.3]**.

sources it from, and where he is going to get his reinforcement from. As a practising engineer, one just uses the rules in design codes which are unified to consider every possible scenario. There are a lot of conservatisms included in design codes to account for what the contractor might do when he comes to build the structure. Design codes are really for pre-construction work[119].

112. Indeed, it is expressly stated in the Foreword of the HKCoP that:

> "*This Code of Practice is based on the limit state design philosophy, which provides a more realistic assessment on uncertainties associated with different loading conditions, material properties, workmanship etc. The drafting of this Code of Practice has taken into account the local conditions, work practice and development of new technologies in analysis, design and strength of materials*"[120]

113. In this regard, Glover explained that:

(1) At the inception and design stages of a project, much is unknown as to the actual future construction loadings and sequence, material strengths and geometric accuracy. For this reason, the international codes and standards contain partial safety factors which include for the extremes of the variations in the applied loads and "ignorance" factors, which are intended to reflect the level of uncertainties in the assumptions made in the design and the sophistication of the analysis methods to be adopted, to mitigate these unknowns;

(2) The logical consequence of the substantial reduction in risk between inception and post-construction of a project is that the basis of assessment of the structure should recognise and take account of the fact that many of the safeguards and conservative assumptions

[119] Entire Inquiry **[T7/95:13-96:11]**.
[120] **[H8/2821]**.

included in the original design and construction no longer apply and should be relaxed. The reality of the situation is that the level of "*ignorance*" has greatly reduced and hence so should the partial safety and "*ignorance*" factors; and

(3) It is inappropriate to apply the same loading and material strength assumptions used at the inception of a project to its surveyed and tested post-construction condition[121].

114. Lau's objection to Glover's position is that he does not agree that once the construction phase is over the nature and extent of any unknowns and uncertainties that existed at the design stage are reduced. His position is that after the construction, there would be *more* uncertainties during the long life of the building[122].

115. This, however, is contradicted by Lau's own evidence that the safety factors under the HKCoP "*cater for all sorts of conditions, including the design stage, the construction stage, and* ***the long life of the building***."[123] In other words, uncertainties during the long life of the building, according to Lau, would have already been taken into account during the design stages under the HKCoP. Accordingly, there would not be *more* uncertainties, which had not been catered for at the design stages, after the construction had been completed.

116. Importantly, and as Glover explained, at the start of a project there is a list of risks that one has to consider, including design, construction, operations and all the way through to the final demolition of the building. Therefore, all of these issues are considered. Once the construction stage is over, the risks associated with the construction stage have been removed or

[121] §§5.5-5.7 of Glover's Expert Report **[ER2/16.1]**.
[122] Entire Inquiry **[T10/38:4-20]**.
[123] Entire Inquiry **[T10/34:20-36:18]**.

mitigated. Therefore, it is wrong to suggest that there are more unknowns after the constructions stage[124]. It is submitted that not only must this be correct from a structural engineering perspective but that it also accords sound, with common sense.

VII. Horizontal Construction Joint

117. The issue concerning the horizontal construction joint in the EWL slab to D-wall connection has been explained in the Holistic Report[125]:

(1) With reference to the contractor's amendment drawings (as-constructed), 56 D-wall panels in Areas B and C were trimmed down by LCAL in order to replace the cast-in coupler connections with through bars and/or semi-through bar details during the construction of the EWL slab. The concrete pouring of the EWL slab in Areas B and C involved 20 bays and created a horizontal construction joint at each pour as a result of the trimming works;

(2) Concrete core samples were taken at D-wall panels EH69 (one core hole) and EM94 (three core holes). VR Scope was conducted at the four holes to inspect the horizontal construction joints through the holes created by the concrete core;

(3) A gap was observed at the concrete interface between the slab and D-wall at one of the core holes at D-wall panel EM94 and remnants of a hessian sheet were observed at another core hole in D-wall panel EM94;

(4) External consultants were engaged to review the core samples and results from the VR Scope. It was concluded that there were no signs of movement, slippage or distress of the horizontal construction

[124] Entire Inquiry **[T10/57:16-60:21]**.
[125] §§3.5.31 to 3.5.36, 4.3.9 of the Holistic Report **[OU5/3265-3266, 3283]**.

joints. The gap and the presence of hessian material were considered as workmanship issues; and

(5) To cope with the workmanship issues at the horizontal construction joints, additional dowel bars were proposed to be installed in the areas of high utilisation.

118. All four experts agree that this is solely a workmanship issue and not a structural issue[126].

119. As explained by Glover:

(1) The structural integrity of the EWL slab to D-wall connection was controlled by the strength of the D-wall and not by the strength of the horizontal construction joint;

(2) The integrity of the construction joint has been demonstrated beyond any reasonable doubt through calculations using simple models illustrating that dowel action or OTE thrust block action separately were capable of ensuring structural integrity across the construction joint. In addition, sophisticated non-linear finite element models have been used assuming a frictionless interface across the joint (in simple terms a gap) to demonstrate, again beyond any reasonable doubt, that the construction joint has an insignificant influence on the structural engineering performance of the EWL slab to D-wall connection. Similar analyses have been conducted by Atkins, who have arrived at the same conclusion;

(3) These analyses also confirmed that the failure mechanism of the EWL slab to D-wall joint zone is at the D-wall connection with the soffit of the EWL slab. It is also important to note that the D-wall failure load is substantially greater than the maximum ultimate loads

[126] §3 of the Memorandum of Agreement **[ER2/18.3]**; Entire Inquiry **[T9/5:21-6:5]**.

predicted for the EWL slab to D-wall connection by structural analyses of the as-constructed structure as set out in the Stage 3 Structural Assessment. This provides yet further assurance of the large reserve of strength in the structure; and

(4) It follows indubitably that the structure is safe[127].

120. McQuillan, Glover and Southward all agreed that nothing needs to be done but that it would be prudent, from a public perspective, to remediate the two locations where poor workmanship has been identified. Lau disagreed and considered the workmanship defects must be rectified by retro-installing vertical steel dowel bars[128].

121. Insofar as the proposed dowel bars as Suitable Measures are concerned, Southward and McQuillan both raised the concern that if vertical bars are to be drilled into the top surface of the EWL slab and then downwards into the D-wall, there is a danger that the horizontal shear link bars might be cut by the action of drilling[129].

122. In this connection, it is noted that the risk perceived by Southward and McQuillan has been addressed in the latest Method Statement for Suitable Measure Works for Area B & C EWL level. For instance, under section 6.2 "*Typical procedure for 200 thk. RC Slab of Suitable Measures (Details 1)*" it is provided, *inter alia*, that:

(1) Step 6: "*Trim the concrete cover to expose the T1 layer rebar*";

(2) Step 7: "*Identify and agree the drill hole locations with the MTR engineer*";

[127] §§9.3 to 9.6 of Glover's Expert Report **[ER2/16.1]**.
[128] §3 of the Memorandum of Agreement **[ER2/18.3]**.
[129] §8.7 of Southward's Expert Report **[ER2/14.1]**; §§164, 180 of McQuillan's Expert Report **[ER2/15.1]**; Entire Inquiry **[T11/164:10-165:14]**.

(3) Step 8: "*Drilling will be commenced with M12 drill bit (max. length 900mm) and then with M16 drill bit (max. length 900mm)*";

(4) Step 9: "*Concrete coring will be carried out at same location of step 8. In case the drilling/coring crashed with the existing rebar, it will be stopped immediately, and we will agree another drill hole location with MTRC*"[130].

123. Having been shown the latest Method Statement with the procedure set out above, Southward accepted that the risk is reduced[131]. McQuillan accepted during his exchanges with Commissioner Hansford that "*if it is only cutting a shear link, it will not have a hugely detrimental effect on the structural integrity*". Glover is of the view that with the revised method statement, the risk of hitting anything important is much reduced[132]. By analogy, he opines that the carrying out of the Suitable Measures will not affect the structural safety of the works[133].

VIII. Need for long-term monitoring

124. In Chapter 11 of the Interim Report, the CoI recommended that the as-constructed works should be instrumented to detect movement during the operational phase of the station and that instrumentation should be by means of fibre optics or other approved measures[134].

125. As explained by Glover[135] following the Stage 2 and Stage 3 work the movements in the structure will be extremely small and within the "noise/accuracy" of the monitoring system, any monitoring system (such as fibre-optics or the like) would have the disadvantage that because of its highly sensitive nature there would be many false alarms and his

[130] **[OU9/11402]**.
[131] Entire Inquiry **[T8/76:15-79:25]**.
[132] Entire Inquiry **[T10/115:2-7]**.
[133] Entire Inquiry **[T10/123:7-17]**.
[134] [**A2/843**].
[135] Glover's Presentation Slide No. 35 [**ER2/16.2**].

considered advice is not to install such a system but to rely on regular visual inspections of those areas with high stress levels to assuage any residual public concerns. These inspections will focus on any signs of distress.

126. McQuillan agrees with Glover's suggested scope of monitoring[136]. Indeed, McQuillan in his report has stated that there would be no justification at all for monitoring if the Suitable Measures were successfully carried out[137]. MTRCL submits that the CoI should adopt the views of McQuillan and Glover on the issues of monitoring and that there is no need for any monitoring system (such as fibre-optics or the like). Instead, MTRCL should carry out regular visual inspections of those areas with high stress levels, which will be sufficient.

IX. Conclusion

127. MTRCL invites the CoI to determine that the CoI 1 Structures are safe and fit for purpose. MTRCL welcomes and looks forward to receiving the recommendations which the CoI sees fit to make in its Final Report and takes this opportunity to reiterate and emphasise that its top priority is public safety, an objective that it will do its absolute upmost to achieve and, in the context of the Hung Hom Station *has* achieved.

Dated 17 January 2020

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[136] Entire Inquiry [**T10/138:8-10**].
[137] §§187-188 of McQuillan's CoI 1 Report [**ER2/14.1**] and Entire Inquiry [**T12/49:5-50:2**].