COMMISSION OF INQUIRY INTO THE DIAPHRAGM WALL AND PLATFORM SLAB CONSTRUCTION WORKS AT THE HUNG HUM STATION EXTENSION UNDER THE SHATIN TO CENTRAL LINK PROJECT

CLOSING SUBMISSIONS FOR LEIGHTON

A. Introduction

1. It is important to put the matter in perspective.

2. This Original Inquiry ("**COI-1**") started against the background of sensational allegations of misconduct capable of endangering the integrity and safety of the HUH Extension.

3. Now after the dust had settled following COI-1 and the Holistic Report, it transpired that:-

   (1) Any cutting of the threaded ends of rebar is not extensive or systematic,[1] and was not performed by Leighton.[2]

   (2) In light of the massive redundancy factor in the structure, any partially engaged coupler connections have not resulted in the need for any suitable measures, even on the basis of the exceedingly conservative statistical and technical approach adopted in the Holistic Report.

[1] COI-1 Interim Report §249(a).
[2] COI-1 Interim Report §248.

(3) The ONLY suitable measures referable to partially engaged coupler connections were in an area which had NOT been part of MTRCL's opening up investigation, namely Area A of the EWL slab, and only by applying a wholly unrealistic extrapolation of the strength reduction factor from a nearby area which was constructed a year after the works had been completed in Area A by different subcontractors.

(4) Of the other suitable measures:-

(a) Those relating to shear links are based on unwarranted wholesale disregard of the shear links in the relevant areas (which have been conclusively proved to exist by photographic records), and in any event the extent of the suitable measures was not more than 1%.

(b) Those relating to the construction joint related to the existence of a gap within the construction joint which all experts agree has no structural implications.

4. Therefore, any insinuation that the HUH Extension constitutes a public hazard is entirely misguided.

B. <u>Suitable measures</u>

5. The Commission in its COI-1 Interim Report concluded at §383:-

> On a consideration of all the evidence, especially that of the independent structural engineering experts, the Commission is confident that the station

box structure (that is, the Hung Hom Station Extension diaphragm wall and platform slab construction works) are safe.

6. On 18 July 2019, MTRCL published the Holistic Report verifying the as-built conditions and workmanship and structural integrity of the HUH Extension. The Holistic Report concluded at §4.1.7:-[3]

> Based on the Updated Design, and after consideration of the as-constructed conditions and the inspections carried out, MTRCL considers that for the purpose of the ongoing construction activities, the station is structurally safe.

7. Nevertheless, the Holistic Report proposed suitable measures to be carried out in parts of the HUH Extension (§4.1.8):-[4]

> to cater for the poor workmanship issues and to achieve the safety level required in the [Code of Practice for Structural Use of Concrete] for meeting the requirements of the [Buildings Ordinance] and the established good practice of engineering design.

8. The Holistic Report was carefully worded. It did **not** state that without the suitable measures the HUH Extension is structurally unsafe. Rather, they were **only** proposed for the purpose of so-called **"code compliance"**:-

> "Suitable measures" means actions which are **deemed necessary** to address the issues identified in this Report and **achieve the safety level required in the Code** for meeting established good practice of engineering design.

9. However, whether the HUH Extension is structurally safe is not to be determined by whether it complies with the relevant codes or regulations in all aspects.

[3] [OU5/3274].
[4] [OU5/3274].

10. As the Chairman put to Mr Southward:-[5]

> CHAIRMAN: Sorry, could I just put it this way: would you agree that **whether a particular structure is safe or not is an objective fact determined by scientific methodology**?
>
> A. Yes.
>
> CHAIRMAN: Whether a building code in any different country or, as against that, building codes in different countries set out requirements that those countries, for whatever reason, determine must be met?
>
> A. Yes.
>
> CHAIRMAN: And **the two aren't necessarily synonymous on all occasions**?
>
> A. Correct, yes.
>
> CHAIRMAN: Even though, obviously, by way of a general rule, they are both aiming -- or the two should meet, should but not necessarily?
>
> A. Yes.

11. This point was further explained by Mr Southward in an exchange with the Chairman and Commissioner Hansford:-[6]

> 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.

[5] [COI-1+2] Day 8:3(16)-4(7).
[6] [COI-1+2] Day 7:122(7)-123(8).

> 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 a 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.

12. We are in agreement with Professor McQuillan who criticised the approach taken by the Holistic Report as follows:-[7]

> What the Report does, in essence, is to conflate the prime issues of "safety" and "contractual compliance" under the umbrella of "code compliance". As will be explained later, elements of a structure or even an entire structure can be "safe" even though not 100% "code compliant".

13. The distinction between safety and code compliance is also in accordance with common sense. Codes (in the sense of contracts, guidelines, codes of practice or statutes) potentially deal with a wide array of matters **other than** safety; and even for provisions concerning safety, the draftsmen could (e.g. for administrative convenience, the need to provide for "redundancy", or some other reasons) provide for standards in excess of what is strictly required to achieve structural safety.

14. Mr Southward pertinently observed as follows:-[8]

> As the COI have already heard, the [Code of Practice for the Structured Use of Concrete] is not a statutory document, but **just provides a set of requirements that if followed will ensure that the resulting design and as built structure will be "deemed to comply" with Statute**. As such, these "deemed to comply" requirements must be **extensive** and **cover every possible scenario** so that a

[7] Prof McQuillan's COI-1 Supplemental Expert Report §30 (p.20) [ER2/Item 15].
[8] Mr Southward's COI-1 Report §6.9.2 (p.20) [ER2/Item 14.1].

> "deemed to comply" approach can be guaranteed. This does not however mean that the requirements are mandatory and must be followed. **Every engineer in the course of design work must use engineering judgment** to best interpret design code rules and guidelines to achieve the optimum solutions for the benefit of the projects that are worked on.

15. It bears emphasis that the Code of Practice for the Structured Use of Concrete ("**Code**") expressly states that it is NOT a "statutory" document and confirms that compliances with its requirements is merely "deemed" by BD to satisfy the Buildings Ordinance and regulations. That is, the Code confirms Mr Southward's point that its requirements are not mandatory and represent a standard applicable to all building for "deemed acceptance" purposes. It follows that BD does not need to insist upon rigid compliance with the Code and can approve individual structures even if they do not meet every aspect of the Code.

16. In this context, it is Leighton's position that the HUH Extension complies with all applicable statutory, regulatory and legal requirements. While the Commission has indicated that it is not concerned with such matters (i.e. so-called "code compliance"), Leighton denies any allegation that it has not satisfied its legal and regulatory obligations. Leighton will defend itself against any such allegations in the appropriate forum. In light of Leighton's position, the Commission is invited to leave such allegations to the parties to resolve in subsequent proceedings.

17. Similarly, Leighton maintains that the HUH Extension structure complies with Contract 1112. This reflects the fact that Leighton has diligently and promptly rectified any defects that were identified. On

that basis, the Commission is respectfully invited to withdraw its interim finding that the structure does not satisfy all aspects of the Contract 1112.[9] Ultimately, the question of contractual liability (if any) is a matter for Leighton and MTRCL to resolve in another forum. Indeed, it would be unfair to Leighton if the Commission ruled on contractual issues given that no specific allegations of breach have been pleaded against Leighton and the Commission has not invited Leighton to address any allegations of non-compliance with any specific clauses of Contract 1112.

18. In the following sections we focus on the following three suitable measures proposed in the Holistic Report:-

    (1) Coupler assemblies in some locations in Area A of the EWL slab;

    (2) Shear reinforcement at Areas A, HKC, B and C of the EWL slab; and

    (3) Construction joint between EWL slab and D-walls in Areas B and C.

19. We will demonstrate to the Commission that none of these suitable measures are justified and necessary for the purposes of structural safety, and accordingly the Commission can conclude beyond any shadow of a doubt that the whole of the HUH Extension structure is safe and fit for purpose.

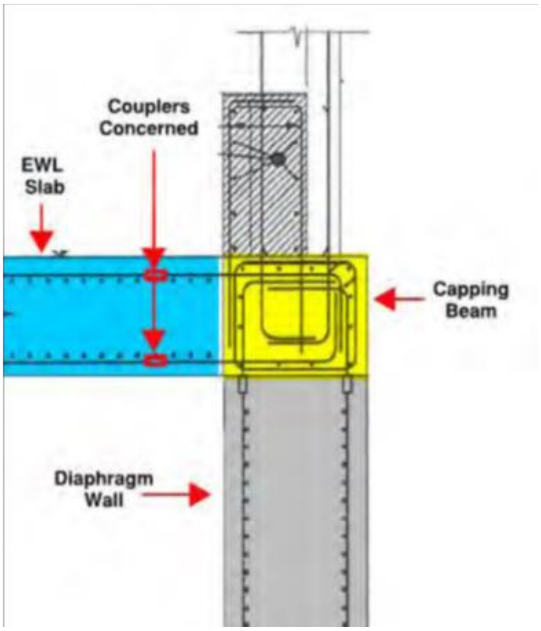
[9] COI-1 Interim Report §481(1).

20. That the Government and MTRCL seemed determined, for so-called "code compliance" or other reasons, to carry out those measures (and have indeed already commenced work) is a matter entirely for them, and does not preclude a conclusion by this Commission as suggested above.

C. <u>Alleged defective coupler connections in Area A of EWL slab</u>

C1. Overview

21. The only suitable measures proposed to be carried out in the HUH Extension with respect to coupler connections is in a section of the Area A of the EWL slab approximately 500mm away from the east D-wall into the EWL slab, illustrated as follows:-



22. As a result of the opening up investigation and statistical analysis in the Holistic Report and Appendix II of MTRCL's Statistical Report

for COI-1,[10] a strength reduction factor of 68.3% was adopted for the coupler connections in Area A of the EWL slab.[11] According to Atkins' calculation, this means that the section is understrength and therefore needs to be strengthened.

23. This was despite NO physical investigation work being carried out in Area A,[12] nor any evidence being obtained to show there are any defective coupler connections in that area.

24. The figure was derived from a very small sample size, **all derived from Area HKC of the EWL slab**: specifically, 11 samples on the capping beam side (2 failed), and 7 samples on the platform slab side (2 failed).[13]

25. There is no justification to rely on the very limited evidence of coupler defects found in Area HKC of the EWL slab and to extrapolate them to infer that Area A has similar defects, particularly when Area A was built in May to July 2015, almost one year before Area HKC was built in July to August 2016, and by different subcontractors.[14]

26. Further, the 68.3% strength reduction factor was adopted on the assumption that the rebar could be partially engaged on both sides of the coupler such that either or both sides could fail:-

[10] [ER1/Item 11.3].
[11] Atkins Stage 3 Assessment Report, Appendix B3 [OU6/4504-4514].
[12] The layout plan in Appendix B2 to the Holistic Report [OU5/3306] showed that there was no opening up in the EWL slab in Area A.
[13] Prof Yin's Report §4.1.2 (p.18) [ER1/Item 12].
[14] Prof McQuillan's COI-1 Supplemental Expert Report §48 (p.25) [ER2/Item 15].

> While a coupler connection could only perform as intended when the rebars on both sides of the coupler are properly screwed in, it is necessary to consider the workmanship of the coupler connection of both sides. **Only in the situation where the connections on both sides are proper can a coupler connection be considered as satisfactory for this type of configuration**. Failure in either side or both sides of the coupler connection will result in a defective coupler connection as a whole. **It is therefore necessary to find a way to take into account the failure rates on both sides of the coupler connections for those EWL panels with capping beam**.[15]

27. Such an assumption is fundamentally flawed from an engineering perspective because only the bar end with the least engagement can fail as the "weakest link" of the coupler connection.[16]

28. We agree with Professor McQuillan that the adoption of a 68.3% strength reduction factor was totally unjustified and conservative in the extreme.[17] Notably, Dr Glover and Mr Southward also agree with this position and do not agree with the approach adopted in the Holistic Report nor its proposed strength reduction.[18]

C2. The appropriate strength reduction

29. From an engineering perspective, the maximum strength reduction should be the same as that applied to the rest of the EWL slab.[19]

30. A 36.6% strength reduction was proposed in the Holistic Report for the rest of the EWL slab.[20] This figure is itself exceedingly

[15] Prof Yin's Report §4.1.2 (pp.18-19) [ER1/Item 12].
[16] Prof McQuillan's COI-1 Supplemental Expert Report §38 (p.22) [ER2/Item 15].
[17] Prof McQuillan's COI-1 Supplemental Expert Report §103 (p.36) [ER2/Item 15].
[18] Dr Glover's COI-1 Report §7.11(xi) to (xiii) and Annex 1, Section A2 and Table 1 [ER2/Item 16]; Mr Southward's COI-1 Report §6.11 (p.23) [ER2/Item 14.1].
[19] Prof McQuillan's COI-1 Supplemental Expert Report §39 (p.22) [ER2/Item 15].
[20] Holistic Report §3.3.24 [OU5/3255].

conservative, completely unjustified and does not reflect the as-built condition, for two main reasons:-

(1) The high minimum requirement of thread engagement:-

(a) was based on a mis-interpretation of the requirement of proper installation by the coupler supplier; and

(b) was not justified from an engineering perspective.

(2) The binomial statistical analysis unjustifiably discarded the strength contribution of all coupler connections:-

(a) that do not meet the purported minimum requirement of thread engagement even though they are proven to carry the necessary load; and

(b) where no measurement of thread engagement length could be taken by PAUT.

C2.1 Mis-interpretation of BOSA requirements

31. The 36.6% strength reduction factor was based on the adoption of a minimum requirement for thread engagement of 37mm measured by PAUT, or 40mm by direct measurement:-[21]

> … engagement lengths found to be less than 37mm by PAUT or 40mm by direct measurement are treated as **not complying with the manufacturer's installation requirements** and **are considered as defective**. 25 out of 90

[21] Holistic Report §10 [OU5/3235].

samples at the EWL slab … were defective … Based on the binomial analysis, it is estimated that, with a 95% confidence level, not more than 36.6% … of couplers at the EWL … slab … are considered defective.

32. This, in turn, was premised upon BOSA allegedly imposing a "butt to butt" connection installation requirement for its couplers:-[22]

To comply with the requirement of the supplier/manufacturer, BOSA, the threaded bars **must be connected "butt to butt" insider the coupler**. Only fully engaged coupler connection (i.e. with "butt-to-butt" connection) can satisfy all the requirements of various tests specified in the Concrete Code.

33. BOSA's guideline for workers in the field (as shown below) does not refer to a "butt-to-butt" requirement, and focuses on a visual inspection to ensure a maximum of two full threads exposed:-[23]

SUMMARY:

1. After connection has been fully tightened, one should see a maximum of TWO FULL THREADS to ensure a proper installation.
2. Please refer to our SEISPLICE Technical and Quality Assurance Manual Dimensions table for our thread length tolerance. Appendix 4 of our Coupler Specifications.
3. Under normal circumstances, we provide a positive tolerance of half a thread.
4. As illustrated in the above scenario, the exposed thread, if any, always occurs at the top of the continuation bar.

[22] Dr Lau's COI-1 Report §55 (p.21) [ER2/Item 17.1].
[23] BOSA Visual Inspection – Acceptance Thread Tolerance **[C10/7016]**.

34. This was also how BOSA trained site inspectors:-

(1) Edward Mok, Site Inspector of Leighton:-[24]

> … when I first joined in 2013, BOSA, the supplier of couplers, provided training. I attended the training. So that's why I know what the criteria were for acceptance. Now, it was mostly visual inspection, that **we were told there could be an allowance of one to two threads that may be exposed**.

(2) Kobe Wong, Site Inspector of MTRCL:-[25]

> … I had seen the installation of the couplers in that area, because **for the training given by BOSA to us** for -- under the QSP, when inspectors went to see -- went to check whether the coupler installation passed or not, **we would check whether there was a maximum tolerance of 1 to 1.5 pitch of the thread**.

35. As a matter of common sense, the number of exposed threads is the only possible external visual guide that site inspectors could use to check whether a rebar has been properly screwed into a coupler. As the Chairman pointed out:-[26]

> If I am screwing this in as one of the workmen, I can't be certain that the parent that I'm screwing into necessarily set absolutely at right angle, and therefore, when I'm screwing in, I might well be pushing it in at a slight mis-angle and then I will get to a certain stage which I can't see myself, because it's all covered, where it suddenly stops and I can't go any further. So **I need something external as an indicator, okay? And external as an indicator is two threads**. Now, that was what I understood that to be, so that your ordinary guy down there has a foreman saying to him, "You put in. Obviously if it's at completely wrong angles you are going to have to get some assistance, but otherwise look for two threads. **If it's two threads and no more than two threads, you are going to be okay", and there is nothing in the documentation that came before me at the earlier stage to suggest anything contrary to that understanding on my part**.

[24] [COI-1] Day 21:17(25)-18(5).
[25] [COI-1] Day 30:20(18)-(23).
[26] [COI-1+2] Day 8:20(14)-21(7).

36. The Chairman also pertinently observed:-[27]

> Now, have you got some magical means of knowing that it's butt-to-butt? No. Do threads sometimes become soiled? Are there perhaps some nicks in the threads, or is it not at the exact right, 90-degree angle, full angle? Yes, all of these things arise. You are working away, you're doing the best job you can, and clunk, it's not going any further, you look, you've got two threads showing, and you say "Thank you very much", and you move on to the next job. That's empathy, that's understanding how workmen do it, and I would hate to have a situation where this Commission, through its own ignorance, puts out documents which effectively act as condemnation of the quality of workmen in Hong Kong when they don't deserve it.

37. The Government's acceptance criteria of 37mm (PAUT) / 40mm (direct measurement) embedment AND up to two exposed threads could not result in a "butt to butt" connection unless the rebar on **both** sides have a threaded length of 48mm. The evidence however clearly showed that there were very few 48mm threaded rebar on site and, in fact, the threaded ends of rebar were much shorter.[28] Professor McQuillan remarked that he had NEVER yet seen a Type A rebar with 48mm on site.[29]

38. Indeed, as the Chairman noted, it is unrealistic to expect workers to know whether a rebar has a threaded length of 44mm or 48mm to gauge whether a butt-to-butt connection has been achieved:-

> … **how does the workman know if he's got rifling, if I might call it that, that's 48 or 44**? Does each rebar come out with a little sign on it saying, "This is 48"? Because **if he doesn't, he's just got another rebar and he screws it in and he sees two threads and he says, "Well, that's fine."**

[27] [COI-1+2] Day 8:34(9)-(23).
[28] Holistic Report Appendix B3 [OU5/3309-3319].
[29] [COI-1+2] Day 11:136(18)-(20).

39. By accepting a thread engagement length of 37mm and exposure of two threads – which will not result in a "butt to butt" connection (see below) – the Government must necessarily accept that "butt to butt" connection is not required for structural safety purposes. This is so, as a matter of simple arithmetic, and is confirmed by photographic evidence of what goes inside a coupler:-

Slide 15 of Mr Southward's presentation which shows two rebar with 44mm threads, with one fully engaged and two threads exposed on the other

C2.2 Alleged butt-to-butt requirement is unjustified

40. The alleged "butt to butt" requirement is neither apparent from the manual and training provided by BOSA (as explained above), nor justifiable from a structural safety perspective.

41. Professor McQuillan, Dr Glover and Mr Southward agreed that 7 threads (32mm) engagement would definitely satisfy the strength criteria.[30] Indeed, they all indicated that even 6-thread engagement would be sufficient for all practical purposes.[31]

[30] Joint Expert Memorandum p.1 [ER2/Item 18.3].
[31] Mr Southward's COI-1 Report §6.8.1 (p.19) [ER2/Item 14.1]; Prof McQuillan [COI-1+2] Day 12:5(13)-(15); Dr Glover [COI-1+2] Day 11:113(13)-114(24).

42. Initially, Dr Lau contended that partially engaged couplers could not satisfy the static tension test, permanent elongation test and cyclic test.[32] However, he later admitted in his testimony that he was not concerned with the static tension test or cyclic test.[33]

43. These tests arise from the Code and are only relevant to so-called "code-compliance". They are not to be equated as an assessment of structural safety.

44. In respect of the static tension test:-

    (1) According to the drawings, none of the couplers within the EWL slab is subject to a ductility requirement.[34]

    (2) Similarly, it was generally agreed by Professor McQuillan, Dr Glover and Mr Southward that ductility was not relevant to the structure (i.e. there was no need for ductile couplers to be used).[35]

    (3) Therefore, according to BD's requirements, the couplers are only required to carry a load strength of 529MPa.[36]

    (4) A coupler with 6 threads engaged would already satisfy such a strength requirement.[37]

[32] Dr Lau's COI-1 Report §§92-97 [ER2/Item 17.1].
[33] [COI-1+2] Day 9:167(16)-(21).
[34] Mr Southward's COI-1 Report §6.5.3 (pp 16-17) [ER2/Item 14.1].
[35] Joint Expert Memorandum §1, Appendix XI to Prof McQuillan's Expert Report [ER1/Item 3.0]; Prof McQuillan's Supplemental Expert Report §85 [ER1/Item15.1] and [COI-1+2] Day 11:138(21)-140(2); Mr Southward [COI-1] Day 42:114(18)-115(2); Dr Glover [COI-1] Day 43:97(1)-(14).
[36] BD acceptance letter for couplers without ductility requirement §4(a) [H9/4045].
[37] MTR tests in February 2019 [OW1/93]; GCE tests in February 2019 [OW1/97-100].

(5) Dr Glover accepted this to be the case, although he preferred 7 threads just to demonstrate beyond any doubt that the strength criteria and the difference in failure rates between 6 and 7 threads was insignificant.[38]

(6) Professor McQuillan agreed that 6 threads will pass the basic strength requirement. He noted BD had imposed a threshold of 575MPa for couplers with a ductility requirement, but he confirmed there is no ductility requirement for the couplers in Area A of the EWL slab (i.e. the only area where suitable measures have been proposed in the Holistic Report). In any event, he decided to suggest that 7.5 threads should be engaged in order to "play safe".[39]

45. In respect of the permanent elongation test:-

(1) This test is irrelevant. As Professor McQuillan explained in Part One of COI-1, the rebar would never be subject to such high level of stress to strain to 0.1mm.[40]

> The point I'm simply making is that to perform that test, you stress the bar to a fairly high level, and because of the utilisation values in this job, the bars will never be subjected to that level of stress, so they are never going to strain to 0.1 of a millimetre … Then even if such cracking were to take place on site due to elongation, Dr Glover has explained that the tests are done in the open. When the couplers are encapsulated in concrete, they don't actually behave that way.

[38] [COI-1+2] Day 11:113(12)-114(24).
[39] [COI-1+2] Day 11:138(10)-(20).
[40] Prof McQuillan [Day 44:106(22)-107(20)].

(2) Any cracking would have been observed by now.[41]

(3) The environment within the EWL slab is dry,[42] protected by a diaphragm wall and a soil barrier, and over 2.8m above ground water level,[43] such that there is no risk of water ingress to cause corrosion to the coupler assemblies.

(4) Dr Lau's concerns about water seepage should be rejected as fanciful and unrealistic.

(5) The Government's own acceptance criteria of 37mm thread engagement and two threads exposed would not result in "butt to butt" connections. As such, even those coupler connections which the Government itself accepts as satisfactory are likely to fail the permanent elongation tests. It follows that even the Government has disregarded the permanent elongation test in practice, by its own acceptance criteria. This goes to show the unlikelihood and improbability that "butt to butt" is somehow essential to ensure structural safety **for this structure**.

46. In respect of the cyclic tension test:-

(1) As Professor McQuillan explained in Part One of COI-1, the slab given its thickness would never bend upwards against its self-weight and be subject to cycles of load reversal.[44]

[41] [COI-1+2] Prof McQuillan [Day 11:141(24)-142(6).
[42] [COI-1+2] Mr Southward [Day 8:44(13)-(24)]; Dr Glover [Day 11:37(12)-(23)] (the interior of the station being a "benign" environment); Prof McQuillan [Day 12:45(1)-(8)].
[43] See Figure 3.4 in Arup Stage 3 Assessment Report [OU6/8590].
[44] [COI-1] Prof McQuillan [Day 44:107(21)-109(5)].

(2) Dr Lau accepted that this test is of no concern.[45]

C2.3 Binomial statistical analysis unjustified

47. In addition, the 36.6% strength reduction factor was derived from a binomial statistical analysis, treating all coupler connections that do not meet the minimum thread engagement of 37mm by PAUT and 40mm by direct measurement as not contributing to **any** load bearing [46] even if they only fall short of the acceptance criteria marginally, or were conclusively proven to have sufficient load-bearing capacity (in particular those with 6 and 7 threads engaged which satisfy the static tension test).

48. The binomial statistical analysis also discarded coupler connections where PAUT measurements could not be taken.[47]

49. Professor Yin was engaged by the Government in the preliminary stages of the opening up investigation to comment on the statistical approach and methodology proposed by MTRCL when conducting the proposed sample testing of coupler assemblies installed in the EWL and NSL.[48] He was instructed to analyse the results of the opening up investigation based on the pass/fail criteria given to him for coupler assemblies.[49] He was provided with data already determined as "defective" or "non-defective" [50] and did not seek to question or challenge the instructions given to him.

[45] [COI-1+2] Dr Lau [Day 9:167(19)].
[46] Prof Yin's COI-1 Report §1.3.2 (p.5) [ER1/Item 12].
[47] Holistic Report §3.3.15 [OU5/3252].
[48] Prof Yin's COI-1 Report §1.1.6 (p.4) [ER1/Item 12].
[49] [Part Two] Day 5/72:18-21.
[50] [Part Two] Day 5/43:22-23.

50. In contrast, Dr Wells had the benefit of approaching this matter independently and without any need to defend the approach taken by MTRCL and the Government in the study.

51. Dr Wells is of the view that the binomial approach adopted by MTRCL and Professor Yin is not appropriate for this study. It results in a specimen that fails the criteria by only a small amount (e.g. a few millimetres short of 37mm) being classified as "defective" and having no contribution at all to the competence and integrity of the structure. This contradicts the structural engineering evidence that the load bearing capacity of the coupler assemblies diminishes gradually as the embedded length of the bar decreases.[51]

52. Dr Wells also considers that the results shown in the Holistic Report for the coupler assemblies that were sampled as part of the opening up investigation were biased towards a higher number of defectives than should be expected in the structure:-[52]

> … something is only discarded in this sense: if it has already passed the first part of the test, it has already been classified as "not defective" on the first part of the test, which is the visual test. So **the discards only come from that "not defective" pile**. They don't come from the "defective" pile. So we are discarding some of the "not defectives" or, rather, discarding what, under the testing regime has at this stage decided is not defective, because it is a multi-stage process; it's not simply binary. **So obviously if you are only discarding from one pile and not from the other pile, I think it should be fairly obvious that that will lead to a bias in results, a bias towards a higher number of deficiencies.**

[51] Dr Well's COI-1 Report §4.20 (p.7) [ER1/Item 10].
[52] [COI-1+2] Day 3:44(23)-45(12).

53. Instead, the correct approach would be to adopt a "Missing Values Approach" and replace the discarded specimens with the "mean" value (being a representative or expected value) of the remainder of the specimens, rather than to discard them altogether.[53]

C2.4 Conclusion

54. If the test results are re-analysed using a 28mm engagement length, the strength reduction factor reduces from 36.6% to 16.3% (for EWL) and from 33.2% to 6.9% (for NSL). The strength reduction factor for the combined EWL and NSL sample is 10.2%.[54]

55. If, in addition to adopting a 28mm engagement length, a "Missing Values Approach" is adopted, then the strength reduction factor is reduced further to 14.5% (for EWL), 6.5% (for NSL) and 9.4% (for the EWL and NSL combined).[55]

56. Incidentally, Dr Wells' revised statistical calculation of the strength reduction factor tallies with Professor McQuillan's "sanity check" analysis based on an engineering perspective.[56]

57. This is far below the spare capacity of coupler connections in the EWL and NSL slabs,[57] and renders the suitable measures wholly unjustified and unnecessary for the purposes of structural safety. It

[53] Dr Wells' COI-1 Report §4.12 (p.5) [ER1/Item 10].
[54] Dr Well's COI-1 Report §4.29 (pp.8-9) [ER1/Item 10].
[55] Dr Well's COI-1 Report §4.29 (p.9) [ER1/Item 10].
[56] Prof McQuillan's COI-1 Supplemental Expert Report §44 (p.23) [ER2/Item 10].
[57] 40% for the top mat, 50% for the bottom mat: see COI-1 Interim Report §363 and §365.

follows that the as-constructed coupler connections in the structure are safe and fit for purpose.

D. Shear reinforcement

58. Suitable measures were proposed to not more than 1% [58] of the total floor area of Areas A, B, C and HKC by reason of the fact that Atkins had disregarded all the shear link reinforcement throughout the EWL and NSL slabs, on the basis that shear links were allegedly not found in some of the opening up locations.[59]

59. However, the shear inspections **in fact exposed** shear links in the opened up areas.[60] It is therefore nonsensical to extrapolate from this that there are no shear links at all.

60. In addition, shear links were clearly visible in the site photos taken prior to concreting in various areas where MTRCL claimed not to find shear links in the opening up.[61] Professor McQuillan, Dr Glover and Mr Southward confirmed that the photos produced by Leighton prove that shear links were installed in the relevant areas.[62]

61. The 300mm x 300mm L-shape opening up may fail to expose the shear links depending on its positioning given the rebar may not be spaced uniformly at 300mm apart.[63] It may also miss out on the shear

[58] [COI-1+2] Dr Lau [Day 9:64(6)-(11)].
[59] Holistic Report §4.2.17 [OU5/3278].
[60] Holistic Report, Appendix B8 [OU5/3332].
[61] Mr Southward's Presentation, Slides 21-24 [ER2/Item 14.9].
[62] Prof McQuillan [COI-1+2] Day 12:16(10)-(15); Dr Glover [COI-1+2] Day 10:112(8)-(15); Mr Southward [COI-1+2] Day 7:72(1)-73(1).
[63] Mr Southward's COI-1 Report, Figure 6 (p.26) [ER2/Item 14.1].

links attached to the upper layers of the exposed bottom mat of the reinforcement.[64]

62. Professor McQuillan, Dr Glover and Mr Southward agreed that the opening up did not expose a wide enough or deep enough (as the vertical shear links could be hooked on to a layer of horizontal bars which are not the ones closest to the concrete cover) opening to confirm if shear links were present.[65] Similarly, Dr Glover explained that the inspection of the honeycomb concrete would not have identified the shear links that were present because the honeycombing was in narrow vertical chasms.[66] It follows that neither the opening up investigation nor the rectification of honeycombing could prove that shear links were not installed.

63. Mr Southward remarked:-[67]

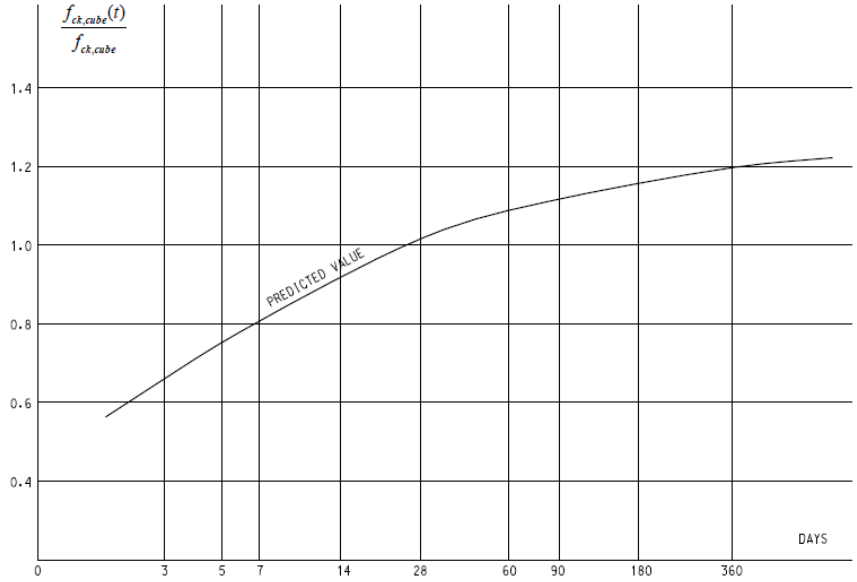
> So I think the evidence shows me that there are shear links there, and the evidence that there is to disprove that shear links are not there is not sufficient to demonstrate that they are not there.
>
> COMMISSIONER HANSFORD: So are you saying that your view is the shear links are there but the opening-up just hasn't exposed them?
>
> A. Yes. And that example at HZ01 was one example I've just shown you here as to why the shear links -- why the opening-up has not shown shear links to be there.[68]

[64] Mr Southward's COI-1 Report §7.4 (p.27) [ER2/Item 14.1].
[65] Prof McQuillan [COI-1+2] Day 12:15(18)-16(5); Dr Glover [COI-1+2] Day 11:73(16)-(22); Mr Southward [COI-1+2] Day 8:61(16)-62(2).
[66] [COI-1+2] Day 11:81(3)-(13)/
[67] [COI-1+2] Day 8:64(24)-65(8).
[68] The opening-up photo for HZ01 referred to by Mr Southward can be found in Appendix JL1-E to Dr Lau's COI-1 Report (p.JL1-E4) [ER2/17.6], and Mr Southward explained why the narrow opening as shown in the photo may not have picked up the shear links on the two sides of the vertical slot opened up or those in the second layer: [COI-1+2] Day 8:61(4)-62(5).

64. Professor McQuillan concurred:-[69]

> … the preponderance of evidence that we've seen to date, including the massive amount of photographic records, show that it's impossible for shear links not to be present … I would say it is highly improbable that no shear links were installed at those locations. I would think most likely they were installed but we have been unable to see them.

65. Atkins have assessed the shear using the concrete strength originally specified in the design. This ignored the fact that the 28-day cube concrete strength is proved by many tests to be considerably higher than the 28-day strength assumed by Atkins and that such strength would have increased over time (see diagram below).[70] Thus the shear strength of the slabs was underestimated by Atkins.



66. Where relevant, partial utilisation of the shear links should have been considered by Atkins.

[69] [COI-1+2] Day 12:16(10)-(25).
[70] Mr Southward's Presentation, Slide 34 [ER2/Item 14.9] referring to Figure 5.1 in the Hong Kong Structures Design Manual [C35/26932]; Joint Expert Memorandum p.2 (item 2) [ER2/Item 18.3].

67. The shear calculations by all the consultants involved demonstrate that the shear capacity of the slabs is more than adequate.[71] The as-constructed shear links are therefore safe and fit for purpose.

E. Construction joint between EWL slab and D-walls

68. As part of MTRCL's investigations, four core holes were made at the top of EWL slab in Areas C1 and C2.

69. A gap was observed at the concrete interface between the slab and D-wall at one of the core holes, and the remnants of a hessian sheet were observed at another core hole.[72]

70. All experts agree that this is solely a workmanship issue.[73]

71. Further, Professor McQuillan, Dr Glover and Mr Southward agreed that it did not affect their conclusion that the structure was safe and fit for purpose.[74] They further agreed that nothing needs to be done, but it would be prudent from a public perspective to remediate the two locations where workmanship issues had been identified.[75]

72. Mr Southward remarked that the suitable measures only provided additional shear reinforcement of 2.2% and were thus negligible.[76]

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[71] Mr Southward's COI-1 Report §7.9 [ER2/Item 14.1]; Prof McQuillan's COI-1 Supplemental Expert Report §154 [ER2/Item 15].
[72] Holistic Report §§3.5.33-3.5.34 [OU5/3265-3266].
[73] Joint Expert Memorandum p.2 (item 3) [ER2/Item 18.3].
[74] Prof McQuillan's COI-1 Supplemental Expert Report §179 (p.57) [ER2/Item 10] and [COI-1+2] Day 11:163(12)-(14); Dr Glover's COI-1 Report §9.6 (p.29) [ER2/Item 16.1] and [COI-1+2] Day 10:114(1)-(7); Mr Southward's COI-1 Report §9 [ER2/Item 14.1] and [COI-1+2] Day 7:86(15)-(22).
[75] Joint Expert Memorandum p.2 [ER2/Item 18.3].
[76] Mr Southward's COI-1 Report §8.6 [ER2/14.1].

73. Both Mr Southward and Professor McQuillan warned of the danger that rebar may be damaged during the coring process.[77] Since the work is not required at all, the risk is reduced by not doing it.

74. Leighton warned MTRCL of the risk as early as in August 2019,[78] but were instructed to proceed regardless.[79]

F. Conclusion

75. In respect of the work performed in the HUH Extension (including that of Leighton), Professor McQuillan relevantly remarked:-

> … and I repeat what I've just said, just to make sure that everybody understands why that is: the diaphragm wall has been designed in accordance with all of the standards required. It's been constructed in accordance with all the standards. It has all of the quality assurance tests. It has been passed by the approval authorities. It's undergone the highest level of inspection. If you start to question that, Mr Chow, then you should question every single diaphragm wall in Hong Kong.[80]
>
> I don't believe the general workmanship on this site in terms of the operatives, whatever, in terms of forming the connections, was substantially substandard. I don't think there was anything where the workers were of a lower quality. There is no doubt that sometimes people didn't fix it as well as they possibly could, but I think, if you take it as an average across Hong Kong, it would probably be reasonably representative.[81]

76. None of the suitable measures as analysed in Sections C, D and E above are necessary for the purposes of structural safety.

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[77] Mr Southward's COI-1 Report §8.7 (2nd bullet point) (p.47) [ER2/14.1] and oral evidence at [COI-1+2] Day 8:77(13)-80(10); Prof McQuillan's COI-1 Supplemental Expert Report §164 (pp.164-165) [ER2/Item 15] and oral evidence at [COI-1+2] Day 12:25(21)-26(4).
[78] [OU5/3393ff].
[79] [OU5/3393ff].
[80] [COI-1+2] Day 11:47(11)-(22).
[81] [COI-1+2] Day 11:123(13)-(25).

77. The Commission is respectfully invited not to draw conclusions on so-called "code compliance" or any allegations that Leighton has not complied with any statutory, regulatory or legal obligations. Such matters should be left for the parties to resolve in the appropriate forums.

78. The Commission is invited to maintain its conclusion in the COI-1 Interim Report that the HUH Extension is safe and fit for purpose, as agreed by Professor McQuillan, Dr Glover and Mr Southward in their Supplemental Memorandum of Agreement.[82]

Dated 17 January 2020

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[82] [ER2/Item 19.1].