

Shatin to Central Link

A Holistic Proposal for Verification & Assurance of As-constructed Conditions and Workmanship Quality of the Hung Hom Station Extension

**(East West Line Platform Slab, North South Line Platform Slab and the
Connecting Diaphragm Walls)**

**Rev B | 4 December 2018
MTR Corporation Limited**

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Executive Summary

Background

In May 2018, there were allegations in the media about threaded steel bars being cut during the steel fixing works and engagement deficiency in the connection of threaded steel bar and couplers at the diaphragm wall (D-wall) of the East West Line (EWL) slab in the Hung Hom Station Extension works under Contract No. 1112. The Contractor had adopted an alternative design amendment with design details which are different from the design drawings accepted by the Buildings Department. In light of the above, MTRCL has proposed that a holistic study should be conducted on the Hung Hom Station Extension works.

Purpose

The purpose of the study is to verify the as-constructed conditions of the EWL platform slab to D-wall connection and investigate workmanship quality of the D-walls, the EWL and NSL (North South Line) slabs to D-wall connection, concrete and steel reinforcement, to provide assurance on the structural integrity of the Hung Hom Station Extension work.

Study Approach

The holistic study is a carefully planned staged approach exercise consisting of the following perspective:

Stage 1 (desktop exercise)

- a. Compile a set of Contractor's design amendment drawings; and
- b. Engage external engineering consultants to check design amendment drawings against construction records.

Stage 2 (physical investigation)

- a. Inspect and verify the steel bar connection details by opening up EWL slab. The current plan is to open up a minimum of 24 locations;
- b. Inspect the workmanship of steel bar/ coupler connections by opening up the EWL and NSL slabs. The current plan is to open up 56 nos. random locations on the EWL and NSL slabs viz. 28 locations at each slab, and a minimum of 168 nos. steel bar/coupler connections combined for both slabs;
- c. Conduct a detailed review of D-wall construction records. If irregularities are identified, further opening up of the D-walls will be conducted; and

- d. Conduct a suite of Non-destructive Tests (NDT) to verify condition of the concrete, steel bar spacing, steel bar/coupler connection and to inspect shear link placement.

Stage 3 (design analysis)

Based on verification findings in Stages 1 and 2, structural assessment will be conducted for EWL and NSL slabs and the station extension box. Remedial works, if required, will be designed and implemented wherever necessary to reinstate the structure to an acceptable state.

Opening –up Strategy

After consolidating and verifying all relevant drawings and records in Stage 1, random locations in the EWL and NSL slabs will be opened-up under Stage 2 for the verification of steel bar/coupler connection and investigation of workmanship quality in order to give assurance to the quality of the works. An important consideration when planning the opening-up strategy is that any opening-up in terms of location, scale and depth must be done in a manner which should not compromise the built quality, integrity and the overall structural safety of the Station structure both during and after the investigation.

MTRCL has carefully taken into account the views of relevant Government Departments and Government's experts, including the Expert Adviser Team when preparing this Proposal. MTRCL has also engaged external engineering consultants to provide advice. The objectives are to verify the following issues:

- (i) The connection details, particularly the change from the original design drawings accepted by the Buildings Department; and
- (ii) Workmanship of the coupler connections and other parts of the construction works where concerns have been raised.

The open-up locations cover both the top and bottom steel reinforcement layers of the EWL slab and they have been selected having regard to gaps in objective documentary evidence, areas with alleged problems as well as random sampling. The NSL slab is cast and constructed at formation level. It is not feasible to open-up the bottom couplers of the NSL slab for verification.

In order to provide additional assurance, MTRCL will open up these locations for testing, the number of which is more than that suggested by our external consultants. NDT will also be deployed to check the steel bar/coupler connections as well as concrete quality where necessary. MTRCL will maintain close communication with the Government and

will review any need for further testing work in the light of the findings after each stage of the holistic study.

Timelines

MTRCL has reviewed the Stage 1 interim reports and findings from the external engineering consultants to prepare this Holistic Proposal. The Stage 2 opening-up investigation and verification will commence as soon as this Proposal is agreed with the Government. It is envisaged that Stage 2 verification tests and reinstatement works will take at least 16 weeks to complete. If further sampling and testing are required, it will take more time. The timing of Stage 3 and whether any remedial works are required and their duration can only be established after the findings of the Stage 2 study are available.

1. Purpose

1.1 The purpose of this study is to:

- Verify the as-constructed conditions of East West Line (EWL) slab to diaphragm wall connection at Hung Hom Station Extension structure under Contract No. 1112;
- Verify workmanship quality of areas in the Hung Hom Station Extension with concerns, in particular the platform slab to diaphragm wall connection and quality aspects of concrete and placement of steel reinforcement detail; and
- Provide assurance on the structural integrity of the Hung Hom Station extension work by reference to the above.

1.2 The verification and investigation programme will involve physically opening-up the Station structure at specific locations to allow inspection and, where possible, testing of the existing works. This investigation will provide a direct correlation between the design and as-constructed conditions of the works and also show the workmanship quality of the structure at these locations.

1.3 It is inevitable when the opening-up below the concrete cover is done that some load-carrying capacity will be compromised. An assessment will be carried out prior to the opening-up to ensure the investigation works would not affect the overall structural safety of the Station structure.

2. Background

2.1 On 29 May 2018, MTR Corporation Limited (“MTRCL”) received an enquiry from the media raising a number of questions about steel fixing works for the East West Line (EWL) platform slab of the extended Hung Hom Station under Contract No. 1112. It was alleged that threaded steel bars had been cut during the steel fixing works and there were also reports about engagement deficiency between the threaded steel bar and couplers at the diaphragm wall (D-wall) to slab connection. Following concerns on this matter expressed by the Highways Department/Railway Development Office on 30 May 2018, an evidence gathering exercise was conducted of which the findings

were included in a report submitted to the Railway Development Office on 15 June 2018.

- 2.2 Following the evidence gathering exercise, MTRCL focused on the Contractor's alternative design amendment that had been adopted for the connection between the eastern D-wall and the EWL slab for the main station box in Area B and Area C. This design detail is different to the design accepted by the Buildings Department as shown on design drawings submitted under the Instrument of Exemption for the SCL project. Moreover, drawings for the Contractor's design amendments were only partially available during construction, and concerns have been raised regarding the construction records of the amended works for the EWL slab being readily available.
- 2.3 Recent site inspections and investigation have also revealed newly discovered workmanship issues at the EWL slab. Honeycombed concrete at the EWL slab soffit, improper installation of shear links for the steel reinforcement and incomplete infill between columns and walls against the soffit were identified.
- 2.4 In light of the above, MTRCL has proposed that a holistic study should be conducted. The purpose of the study is to verify the as-constructed conditions of the relevant parts of the EWL platform slab to D-wall connection and investigate workmanship quality in identified areas of the platform slabs to D-wall connection, concrete and steel reinforcement and to provide assurance on the structural integrity for those parts of the Hung Hom Station Extension work where concerns have been raised. This proposal sets out a staged approach methodology for the holistic study of the Hung Hom Station Extension comprising EWL platform slab, North South Line (NSL) platform slab and the D-walls.

3. Introduction

- 3.1 The Shatin to Central Link ("SCL"), with a total length of 17 kilometres (km), consists of the following two sections:
 - (a) Tai Wai to Hung Hom section:

This is an extension of the Ma On Shan Line from Tai Wai via Southeast Kowloon to Hung Hom where it will join with

the West Rail Line to form the EWL which is to be known as Tuen Ma Line (“TML”); and

(b) Hung Hom to Admiralty section:

This is an extension of the East Rail Line from Hung Hom across the Victoria Harbour to Wan Chai North and Admiralty to form the North South Line (“NSL”).

3.2 The SCL has ten stations. Apart from the improvements to the existing Tai Wai Station, the SCL project involves construction of new stations and expansion of existing stations at Hin Keng, Diamond Hill, Kai Tak, Sung Wong Toi, To Kwa Wan, Ho Man Tin, Hung Hom, Exhibition Centre and Admiralty. Construction of the Ho Man Tin Station and expansion of Admiralty Station were included as part of the Kwun Tong Line Extension project and South Island Line (East) project respectively.

3.3 Hung Hom Station Extension

3.3.1 The Hung Hom Station Extension is made up of a new station box, formed of diaphragm walls to the west and east with a 3m thick slab at ground level spanning between and forming the EWL platform in the main station area. Below the EWL platform is a 2m thick slab cast at formation level of the excavation forming the NSL slab.

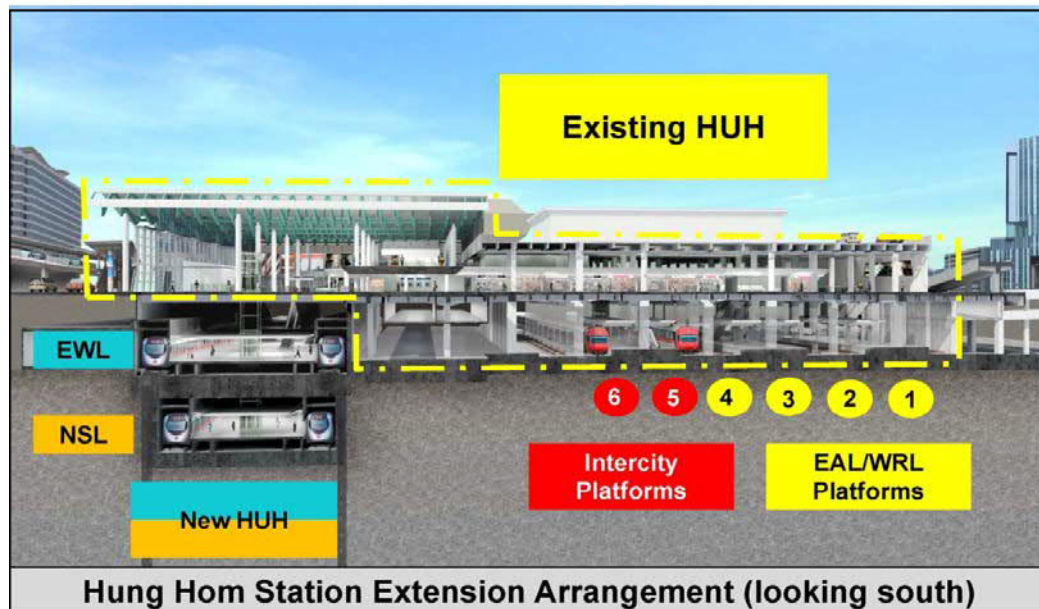


Figure 1 Hung Hom Station Extension Arrangement

3.3.2 With reference to the concerns raised regarding the quality of steel bar/coupler connections and the changes in connection detail in the EWL slab as highlighted above, this proposal sets out a strategy to verify the as-constructed conditions and workmanship quality in the Hung Hom Station Extension. The strategy generally comprises the following 3 stage approach to consolidate evidence finding and verification, staged checks, site tests, analyses and possible remedial works to assure the as-constructed conditions and structural integrity of the station structure:

- i. Consolidation of construction records and checking Contractor's design amendment drawings (as-constructed);
- ii. Physically examine and verify as-constructed works between platform slab and diaphragm wall, integrity of the connection and coupler by opening-up selected areas and supplementing by implementation of a non-destructive testing (NDT) programme; and
- iii. Conduct detailed structural analysis of the Hung Hom Station Extension structure taking into consideration the as-constructed conditions and workmanship of works identified upon physical examination.

3.3.3 Details of the various stages of the study are described in Section 6 of this Proposal.

3.3.4 As the details of the later stages are dependent on the findings of the earlier stages, only detail of Stages 1 and 2 will be outlined within this proposal. The details of the subsequent Stage 3 study will be proposed after the preceding Stages 1 and 2 have been completed.

4. New Hung Hom Station Structure

4.1 The SCL project at the Hung Hom Station Extension includes the construction of new platforms for the EWL and NSL. The extension works to the station structures are demarcated as Area A, HKC (Hong Kong Coliseum), Area B and Area C. The demarcated areas are shown in a layout plan in **Appendix A**. The EWL is essentially at ground level and the NSL is located immediately underneath.

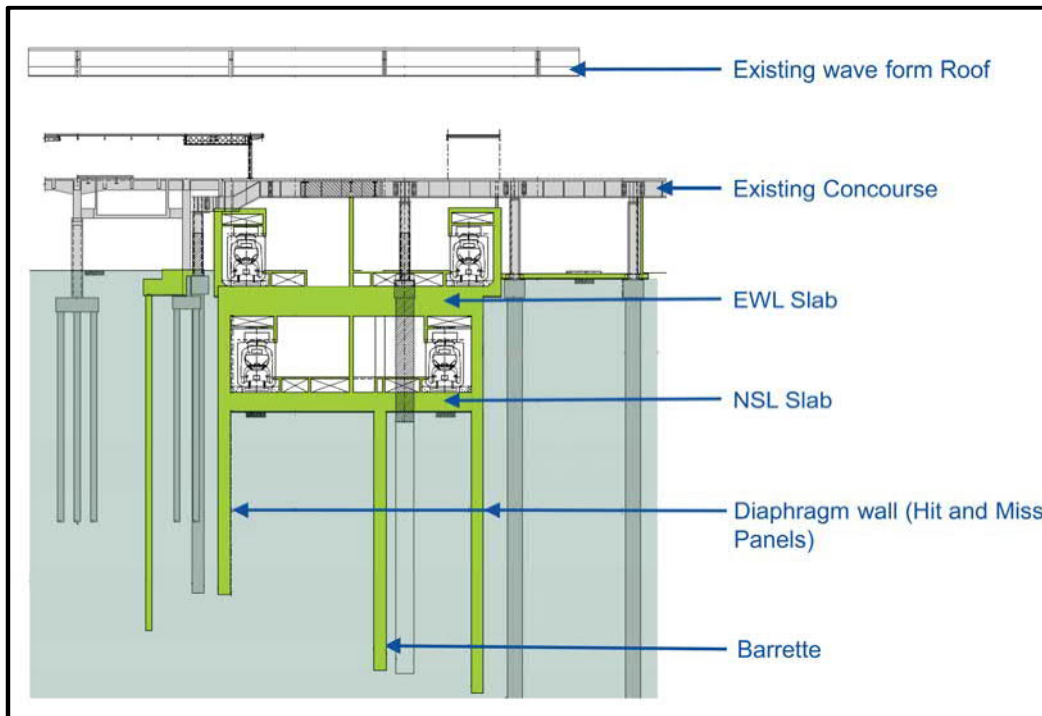


Figure 2 Typical Cross Section of Hung Hom Station Extension (looking north)

4.2 Primary Station Box Structure

4.2.1 The major constraint on the construction of the primary station box structure has been the limitations placed upon it by retention of the existing station concourse and the podium deck which formed a low-headroom roof to the construction of the new structure; the concourse had to be kept operational throughout construction of the new station. These limitations have had a major impact on construction necessitating the use of low headroom plant and craneage, severe limitation on ground movement and extensive underpinning of existing foundations.

4.2.2 The station structure within the main station box in Area B and Area C was constructed by top-down construction method. Diaphragm walls of 1.2m thick were constructed along the perimeter of the station footprint using low headroom plant below the existing Hung Hom Station. The EWL and NSL platform slabs were constructed in phases with the excavation sequence. Intermediate strut support for the diaphragm wall, excavation and lateral support (ELS) system for the excavation and in-situ support to existing structures and services were provided prior to excavating to the formation level to construct the NSL slab.

- 4.2.3 The 3m thick EWL platform slab in the main station area provides support to the excavation as well as additional counter weight to resist flotation of the station box.

4.3 East West Line (EWL) Slab

- 4.3.1 The 3m thick EWL slab in the main station area (Areas B and C), reducing to 1m thick outside the station (Areas A and HKC), is a suspended slab and located approximately at ground level. The slab within the main station box has an additional design provision to be “keyed” into the eastern diaphragm wall with a shear key. The slab is also designed to span between the diaphragm walls during the construction phase up to completion of the NSL slab. After the NSL slab is constructed, support to the EWL slab is supplemented by loadbearing walls and columns from the NSL level.
- 4.3.2 The slab has many openings for escalators and stairs, services, risers and pre-existing concourse columns and foundations which constrain the spanning capability of the structure.

4.4 North South Line (NSL) Slab

- 4.4.1 The NSL slab is supported by intermediate barrettes and diaphragm walls with shear key formed at the eastern and western sides. The structural action of the NSL slab (generally 2m thick in the main station area and 1m thick outside the station area) differs from the EWL slab with respect to its interaction with the diaphragm walls as it is subject to both vertical gravity loads and hydrostatic uplift conditions.
- 4.4.2 The construction of a shear key into the diaphragm wall is an additional feature of the NSL construction in transferring the uplift forces into the diaphragm walls.

4.5 Diaphragm Walls

- 4.5.1 In many respects, the diaphragm walls are a structural element which has the multi-purpose of providing vertical support to the EWL and NSL slabs and the structure above, supporting the sides of the excavated box and a barrier to water flow into the excavation during construction and the station in its permanent

state. The walls would limit water ingress into the station to comply with the MTRCL's specification requirements which limit water ingress to only localised damp patches.

5. Detailed Design Consultancy and External Engineering Consultants

5.1 MTRCL's Detailed Design Consultant for the Hung Hom Station Extension is Atkins China Ltd. As a result of the concerns raised regarding the as-constructed conditions and workmanship quality in the Hung Hom Station Extension and the state of construction records available to date, a staged holistic study to verify the integrity of the station structure has been commissioned. To ensure that independent third party professional assessment is provided, MTRCL has engaged external engineering consultants with no prior involvement in Contract No. 1112 to contribute to the staged holistic study. The key mandate for the external engineering consultants is to conduct an independent review of the design changes and construction details, and to provide professional opinions on the structural integrity and structural performance of the works in respect of which concerns have been identified.

5.2 Relevant project information, design data and construction records have been made available to the external engineering consultants to conduct their specific assessments which are currently on-going. MTRCL has reviewed the interim reports and findings from the external engineering consultants and prepared this Holistic Proposal in order to conduct the study with the best possible information and recommendations.

5.3 Mott MacDonald

5.3.1 MTRCL have engaged Mott MacDonald in September 2018 to examine available known design change data with respect to the latest Contractor's design amendment drawings (as-constructed) and site record photographs for the EWL and NSL platform slab connection to the diaphragm walls (Area B and Area C) to establish whether there was direct correlation between the sources of data. In particular for the EWL slab, the main source of design change data examined has been the handwritten bar bending/cutting schedules (BBS) used by the sub-contractor who

prepared the rebar for construction on site. Examination of the design change information is an iterative process based on updates of available design drawings. This exercise would provide an indication on the coverage and certainty of the evidence and confidence levels for the as-constructed works.

- 5.3.2 This examination exercise was subsequently extended to cover the review of the EWL and NSL slab connection to the diaphragm walls in Areas A and HKC.

5.4 Siu Yin Wai & Associates Ltd.

- 5.4.1 MTRCL have engaged the service of Siu Yin Wai & Associates Ltd. (“SYW”) since June 2018. SYW have been providing independent professional advice and review on the project works which included a 3rd party review of the Contractor’s design amendments on EWL slab and requirements for the BD design amendment submission currently under preparation.

- 5.4.2 SYW also advised on the holistic study to the Hung Hom Station Extension and their scope of services included a study of available project information similar to those available to other external engineering consultants viz. latest Contractor’s design amendment drawings (as-constructed) and working drawings current at the time of construction, site record photographs and inspection records. Based on experiences and knowledge of Hong Kong construction site practices, SYW was asked to propose an opening-up strategy for the EWL platform slab in order to verify and establish confidence on the as-constructed conditions and workmanship quality of the EWL slab – diaphragm wall connections.

5.5 Ove Arup & Partners Hong Kong Ltd

- 5.5.1 Ove Arup & Partners Hong Kong Ltd has been appointed to conduct an independent assessment and review of the structural integrity of the as-constructed works. More specifically, their scope includes the following services:

- Providing a verification programme to a statistical confidence level for the as-constructed connection workmanship quality between the EWL platform slab and Eastern D-wall;

- Providing a verification programme on the as-built records of the Eastern and Western D-walls at both the EWL and NSL levels;
- Assessing structural integrity of the works for which concerns have been raised taking into account the as-constructed conditions and remedial works for defective workmanship. Up to this point, the structural integrity assessment has only been design checks only. It is expected that Ove Arup & Partners will be involved in a full structural analysis to be conducted in Stage 3 of this proposal; and
- Providing an Expert Engineer's review on the structural integrity assessment of the works having regard to the above factors. This work will continue into Stage 3 of this proposal.

6. Stages of Verification and Assurance

6.1 A holistic study adopting a staged approach will be conducted to verify the as-constructed conditions, investigate workmanship quality and assure the structural integrity of the relevant Hung Hom Station Extension structures. Design changes and as-constructed details are first correlated and verified. Where there are gaps identified in the objective evidence or review process, site examinations and tests would be conducted as a supplement to verify the structure and integrity. Where defective works are found they will be rectified.

6.2 The staged approach is proposed from the following perspectives:

Stage 1a: Consolidating all available construction records (and findings from Stage 1b) to form a set of Contractor's design amendment drawings (as-constructed) for Stage 2 verification and assessment.

Stage 1b: Checking the latest Contractor's design amendment drawings (as-constructed) with reference to available evidence, by external consultants, with an emphasis on objective evidence.

Stage 2a: Purpose (i) Verify the as-constructed conditions against design amendment drawings (as-constructed) to address concerns on gaps in the documentation or evidence on the connection between EWL slab and D-

walls; and
Purpose (ii) Verify workmanship quality for coupler connections by opening-up at random locations and check connections using Non Destructive Testing (NDT) to address concerns on workmanship of coupler conditions between EWL slab and D-walls.

Stage 2b: Verify the workmanship of coupler installation for connection between NSL slab with D-walls by opening-up at random locations and check connections using NDT.

Stage 2c: Review of D-wall construction records. If irregularities are identified, opening-up of the D-walls will be conducted.

Stage 2d: Conduct Non Destructive Testing (NDT) of concrete quality and steel bar/coupler connection at selected locations and inspection of shear link placement.

Stage 3: Based on findings of Stages 1 and 2 above, a detailed structural analysis of the station structure would be conducted to assure structural integrity and performance. Options of remedial works, if necessary, would also be formulated.

6.3 Stage 1

Stage 1a: Consolidating Latest Contractor's Design Amendment Drawings (As-constructed)

6.3.1 The latest design amendment drawings (as-constructed) with the Contractor's alternative design changes for the as-constructed EWL slab and NSL slab have been obtained from the Registered Contractor in November 2018. The drawings were prepared by the Contractor as part of the contract requirement. MTRCL has carried out checking based on available information as described in Stage 1b below. In view of the concerns raised on the consistency between the design amendments and as-constructed works, further verifications are recommended.

6.3.2 From the EWL slab drawings showing the Contractor's alternative design changes for the top layer of steel bar in the slab

and the eastern D-wall, there are 3 generic types of connection details at the slab and D-wall interface:

- Type 1 – Couplers for all layers at top mat;
- Type 2 – Only top layer of couplers at top mat replaced with half-through steel bar;
- Type 3 – All top layers of couplers at top mat replaced with through steel bar.

6.3.3 The 3 generic connection types are illustrated in **Appendix B**.

6.3.4 The Contractor's design amendment drawings (as-constructed) were prepared by the Contractor based on information and records available to it, including issued Working Drawings, Request for Inspection/Survey Check (RISC) records, Design Amendment records (DAmS), Method Statements, Request for Information (RFI), Technical Queries (TQ) documents and site photographs. The drawings have been further checked by Contractor site staff who attended the work on site. These drawings form the best available information on the as-constructed work. It should be noted that despite the best endeavours by the Contractor's project staff and checking by MTRCL, based on all available information, there still exists a degree of uncertainty on the correlation between the design amendment drawings and the as-constructed conditions. Nevertheless these drawings for the EWL and NSL platform slabs will form the basis for comparison with the site opening-up verifications at later stages of this study and will eventually be updated for submission under the Instrument of Exemption.

Stage 1b: Checking the Latest Contractor's Design Amendment Drawings (As-Constructed) with an Emphasis on Objective Evidence

6.3.5 Checking the latest Contractor's design amendment drawings (as-constructed) with all information available to MTRCL, with an emphasis on objective evidence, will be the first test of the reliability of the drawings. Given that there are doubts about some written quality records, objective evidence will be more important for this stage of checking. Objective evidence refers to materials that provide contemporaneous records of what was built on site and is unlikely to have been tampered with or prepared post construction or after allegations of problems have arisen. These would include materials such as photographs taken prior to

concrete pours and bar-bending schedules from sub-contractors. Following checks and verifications on the objective evidence, areas with gaps in evidence for design-compliant construction and quality workmanship can be identified, and the information can be used to guide the choices of site examination and verification in subsequent stages in areas with less certainty.

- 6.3.6 External engineering consultants have examined objective evidence for the EWL slab and NSL slab connecting to both the east and west D-walls.
- 6.3.7 Evidence such as photographs, although not a regulatory requirement, may provide confidence of placement of the common steel reinforcement bars. However, it is difficult if not impossible to verify the workmanship of the work such as coupler connections by relying on site photographs alone. Better and clearer photos may provide a higher level of certainty as to the main types of connection details adopted in the interface between the EWL platform slab and eastern D-wall. The external engineering consultant Mott MacDonald has developed a colour code system to illustrate levels of certainty of the as-constructed condition on the EWL slab and D-wall connection.
- 6.3.8 In order to provide a higher level of confidence on the as-constructed conditions, including both connector workmanship quality and the placement of the main reinforcement bars, parts of the structures will be opened up. However, opening-up serves two different purposes relating to two different issues, namely,

Purpose (i) Verifying the as-constructed conditions due to gaps in the objective records or concerns about the reliability of the records; and

Purpose (ii) Assessing the workmanship in the coupler connections and steel bar fixing in light of allegations raised, and workmanship in other known / suspected irregularities (e.g. honeycombed concrete and non-compliant installation of shear links).

6.4 Stage 2

6.4.1 Opening-up Strategy

The opening-up of the EWL and NSL slabs, in terms of location, scale and depth, is required to address the gaps in the objective documentary evidence and concerns on workmanship. It will be done in a manner so as not to compromise their built quality and integrity and the overall structural safety of the Station structure both during and after the investigation.

6.4.2 Based on the two purposes of opening-up, different opening strategies are proposed, however it is noted that purposes (i) and (ii) are not mutually exclusive:

- For **Purpose (i)**, as there are gaps in documentation or evidence, physical examination is needed. The extent of opening-up will be dependent on the level of certainty on the “as-constructed records”.
- For **Purpose (ii)**, the extent of opening up should be based statistically. A sample size of not less than 84 randomly selected couplers for the EWL and NSL slabs respectively will give a meaningful result with 95% confidence level using Binomial statistics.

6.4.3 In addition

Concrete defects will be further investigated with various NDT techniques to be agreed with the Government. Other known / suspected irregularities (such as shear link installation) will be further investigated with localised opening-up. These results will all be used in the Stage 3 structural analysis to assess the integrity of the slabs. Before physical removal of concrete from the slab, NDT would be carried out as far as reasonably practicable to scan and detect the rebar placement for comparison with the actual rebar placement after opening-up.

6.4.4 Opening-up Work Considerations

Prior to opening-up the selected locations at both the EWL and NSL slab, method statements will first be prepared and agreed with the Building Authority. The opening-up methods will attempt to minimise the impact on the load carrying capacity and structural stability. However, it is recognised that opening-up to layers deeper than the concrete cover will inevitably de-bond the outer layer reinforcement from the concrete. It can only be

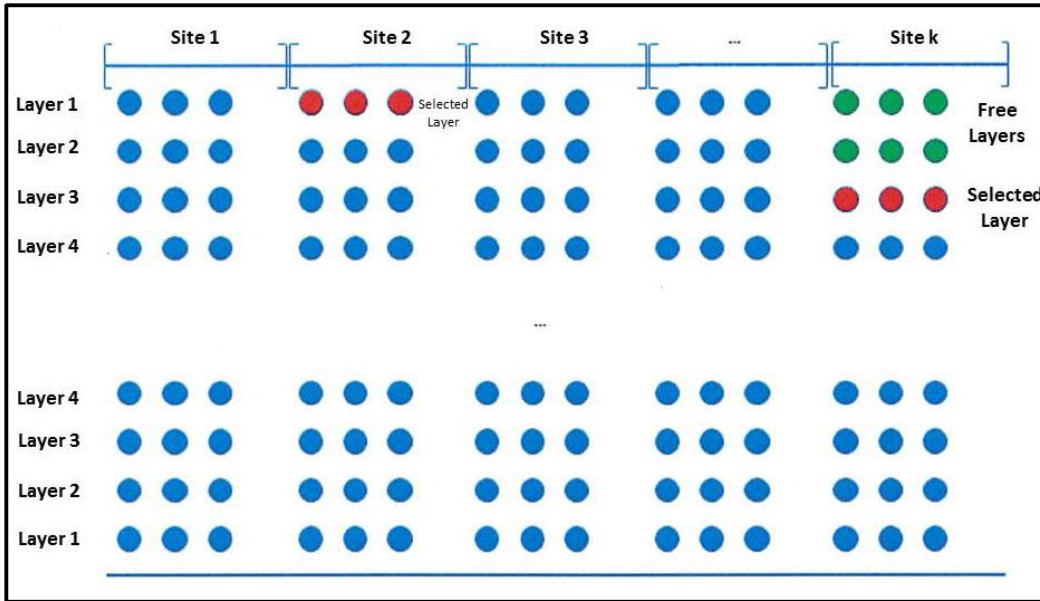
assumed that the de-bonded steel reinforcement bars, after reinstatement, will at most only be able to carry new live loads on the slabs. Nevertheless, although the original stress states cannot be fully restored at the opened up locations, the location will be repaired and made good with approved methods. The loss in the load carrying capacity due to de-bonding will be taken into account in the Stage 3 structural analysis. If necessary, remedial reinforcement structures will be designed and installed.

- 6.4.5 The loss of some load-carrying capacity will be inevitable when the opening-up is done below the concrete cover. An assessment will be carried out prior to the opening-up to ensure the investigation works would not affect the overall structural safety of the Station structure.

Stage 2a: Opening-up Selected Areas at EWL Slab

- 6.4.6 The study of the EWL slab will include both of the above purposes. Information gaps in Contractor's alternative design changes adopted for the connection between the EWL slab and D-walls in Area B and Area C requires opening-up under purpose (i).
- 6.4.7 Considering the concerns about evidence and records for the top steel bars of the EWL slab and its connection to the eastern D-wall in Area B and Area C, opening-up would verify whether the as-constructed steel bar arrangement is consistent with the current design amendment drawings (purpose (i)). Samples would be selected from locations with gaps in objective evidence to verify the accuracy of the as-constructed condition.
- 6.4.8 As for verification of the workmanship quality of the couplers (purpose (ii)), a statistically meaningful number of random samples should be selected for verifications. A two-stage cluster sampling scheme will be adopted by first randomly sampling the locations/site (stage 1) and then randomly sampling the layer of the selected location/site (stage 2). A sampling frame by dividing all possible area into locations/sites of similar size will be developed. A statistical meaningful number of locations/sites will first be chosen at random, and a layer will then be sampled from each selected site. It is expected that each layer will yield 3 couplers. For example, if layer 3 is selected, the 6 couplers in layers 1 and 2 will also be examined and included as extra samples (see Figure 3). Details will be further elaborated in the

detailed method statement to be submitted to the Building Authority. The implementation of the sampling strategy should follow a “best-compliant” rule. That is, every endeavour should be made to obtain the data chosen by the random selection scheme. If it is impossible to reach certain layer e.g. layer 4, the data from the nearest layer should be collected. These random samples can be taken from EWL slab connection to the east and the west D-walls.



Note: Couplers above the selected layer will be exposed and included as extra samples for verification of workmanship quality.

Figure 3 An illustration of the proposed Sampling Scheme with layer 1 of site 2 and layer 3 of site K being selected

6.4.9 Connection of the EWL slab to the west D-wall has been built based on design which has been accepted by the Buildings Department, and no allegation has been reported in this regard. There is also no suggestion of any similar irregularity of steel bars being cut or tempered in Areas A and HKC. However, these areas are also available for random verification under purpose (ii). The available photographic and other relevant records will be reviewed to ascertain if there are any irregularities in the as-constructed structures. The alleged cutting of threaded steel bars for the as-constructed steel bar/coupler connections in Areas C and other known/suspected irregularities will require opening-up under purpose (ii).

- 6.4.10 Once the couplers are exposed, a non-destructive testing (NDT) methodology called Phased Array Ultrasonic testing, has been developed and tested for measuring the depth of engagement of couplers. This methodology allows the integrity of the couplers to be checked without needing to remove them because such removal will affect the integrity of the slab. This ultrasonic testing method will be further verified with an on-site validation programme. Further detail can be found in Stage 2d on NDT methods.
- 6.4.11 On the opening-up strategy for the EWL slab, both of the external engineering consultants have developed a staged verification programme for slab to D-wall connection for the EWL slab as described below.

Views by Siu Yin Wai & Associates Ltd.

- 6.4.12 Considering the limited quantitative reference of such verification programme in the industry, SYW have proposed a percentage of opening-up the track slab based on established testing frequency for pile foundations and laboratory testing for steel bars and couplers. A 5% sample rate of the 75 nos. eastern D-wall panels is proposed which represent test locations at 4 nos. panels (each location of 600mm wide will expose 5 steel bars or coupler connections) at the top of the EWL slab and an additional 2 nos. locations (each location will expose 5 coupler connectors) at the bottom of the EWL slab. A 90% confidence level of the as-constructed conditions could be established if the connection detail is found as per the design details at all 6 nos. locations.

Views by Ove Arup Hong Kong Ltd

- 6.4.13 Similarly, Ove Arup's have proposed sampling rates based on the design details but at a higher sampling rate with test locations at 6 nos. panels at the top of the EWL slab and 4 locations at the bottom of the EWL slab (each location of 1m wide will expose 7 steel bars or coupler connections). In the process of exposing the steel bar connections, it is expected to expose a population of about 50 nos. couplers for inspection. Based on Binomial Statistics, if all exposed couplers are found to be properly connected, there is a 95% confidence that no more than 5.67% of coupler population will be defective.

Proposal by MTRCL

6.4.14 Having considered the external engineering consultants' advice and views resulting from their study, it is found there exists gaps in the objective evidence. The Government has commented and MTRCL proposes to increase their number of sampling locations for purpose (i) and purpose (ii) investigations in order to provide further assurance of the as-constructed conditions from the opening-up work.

6.4.15 Purpose (i) is to verify the as-constructed conditions against amendment drawings. Considering the gaps identified in the objective evidence checking process, opening-ups of approximately 250mm by 250mm will be conducted at locations where there are gaps in the objective evidence on the contractor's alternative design shown in their amendment drawings. This stage of the study will therefore fill the gap of information and verify the accuracy of the contractor's design amendment drawings (as-constructed). Subject to the results of Stage 1 investigation, additional locations of opening-up could be required for further study.

6.4.16 MTRCL will submit a detailed method statement ("MS") for Purpose (i) to the Building Authority for scrutiny. The MS would include the following details:

- (a) Selection criteria of areas to be investigated;
- (b) Opening-up procedures including size and depth;
- (c) Proper site record system;
- (d) Independent supervision arrangement;
- (e) Reinstatement proposal for areas to be opened-up;
- (f) Assessment of structural safety and connection with the opening-up works.

6.4.17 Concrete core, where possible, may also be taken at the opening-up locations to determine the concrete interface between the platform slab and D-wall to verify the horizontal construction joint.

Area	Reason	No. of locations
Top of EWL slab	To verify generic types of connection	24 at D-wall Panels (subject to consultation with the Government)

Note: Study area to include Areas A and HKC outside the main station box.

Table 6.1 – Verification of As-Constructed Condition (Purpose (i))

- 6.4.18 In the process, couplers in the row below the top layer of through bar are also expected to be exposed. These couplers could be added to the sample size for purpose (ii) study.
- 6.4.19 Purpose (ii) is to verify the workmanship quality for coupler connections with opening-ups of approximately 400mm wide. Sampling will be primarily done on random basis except for the locations where allegation was raised on steel bar cutting. The population for sampling will include all the couplers-only connections in the top and bottom mat along the east D-wall and the bottom mat along the west D-wall. MTRCL will submit a detailed method statement (“MS”) for Purpose (ii) to the Building Authority for scrutiny. The MS would include the following details:
- (a) Random selection methodology of couplers to be investigated;
 - (b) Opening-up procedures including sequence, size, depth, hold-points that requires consultation with the Government and design assessment to ensure structural safety;
 - (c) Proper site record system;
 - (d) Independent supervision arrangement; and
 - (e) Reinstatement proposal for areas to be opened-up.

Area	Reason	No. of locations	No. of couplers
EWL slab	To verify couplers at random locations	28	84

Table 6.2 – Verification of Steel Bar / Coupler Connection Workmanship (Purpose (ii))

- 6.4.20 By increasing the number of couplers examined to 84 numbers and maintaining the same 95% confidence level, no more than approximately 3.5% of coupler population could potentially be defective (in a worst case scenario) if all the exposed couplers are found to be properly connected.

Total sample number = 84	
Total number of failures in the samples	Maximum failure rate in the population
0	3.5%
1	5.5%
2	7.3%
3	9.0%
4	10.6%
5	12.1%

Table 6.3 Statistical Implication of Sampling Test Results

- 6.4.21 For example, if all 84 numbers of couplers were found to be properly connected (i.e. zero failure rate), it can be estimated with 95% confidence that no more than 3.5% of the couplers in the population will be defective. Similarly, one failure in the samples means that no more than 5.5% of the couplers in the population will be defective. These percentages will change with different total sample numbers.
- 6.4.22 Depending on the initial investigation results and if defective coupler connections are found, a greater sample size may be considered.
- 6.4.23 Investigation at locations where there were allegations of threaded steel bars having been cut during the steel fixing works and where there were reports about engagement deficiency between the threaded steel bar and coupler at the D-wall to slab connection at the main station box, will also be conducted.

Stage 2b: Opening-up Selected Areas at NSL Slab

- 6.4.24 The investigation of NSL slab will be mainly for purpose (ii), that is to assess the workmanship quality in the coupler connections and reinforcement bars fixing. A random sample of 84 numbers couplers is proposed for the coupler connections of the NSL slab randomly selected in Areas A, HKC, B and C, from both the east and west D-wall connections.
- 6.4.25 As the NSL slab is cast and constructed at formation level, it will be infeasible and cause significant implication to the slab's integrity to open-up for verification of the workmanship of the bottom couplers since there is a very high risk to damage the

waterproofing membrane at the soffit of the slab. For the purpose of Stage 3 structural assessment, the findings from the opening-up of the EWL slab couplers and the NSL slab top couplers will also be taken into consideration in the assessment of the NSL slab integrity and bottom coupler connections.

Stage 2c: Review of Diaphragm Walls

- 6.4.26 A detailed review is being conducted for all available photographic and other relevant records to ascertain if there are any irregularities in the as-constructed structures. If irregularities are identified, opening-up of the D-walls will be conducted.

Stage 2d: Non-Destructive Testing of Concrete Quality, Steel Bar Spacing, Steel Bar/Coupler Connection and to Inspection of Shear Link Placement

- 6.4.27 Concrete defects, e.g. honeycombing, on the soffit of the EWL slab have recently been identified during the course of the station investigation works. In some of the slab soffit areas that have been exposed, some shear links reinforcement has also been found to have been improperly installed. The defective works also include isolated incomplete filling up of the gaps between the soffit and some of the columns, walls and hanger walls. This stage of work will include a thorough study of the extent, severity and causes of the honeycombing in the EWL soffit. Furthermore, the severity and structural implications of the improper placement of shear links will be investigated, especially at critical areas with shear stress concentration by opening-up the soffit. Remedial works for any defects found will be proposed under Stage 3 study for agreement with the Building Authority. Investigation of the general conditions of the NSL slab will also be conducted with these NDT methods.
- 6.4.28 Having inspected over 90% of the EWL slab soffit at the main station box, investigation has identified 13% of the area with relatively minor defect i.e. <50mm and 6% of the area with deeper honeycombing i.e. >50mm.
- 6.4.29 A suite of non-destructive testing (NDT) would be conducted to verify condition of the concrete, steel bar spacing and steel bar/coupler connections as tabulated in Table 6.4.

<u>Location</u>	<u>NDT Method</u>	<u>Purpose</u>
EWL slab soffit	Automatic hammer ¹	Checking of extent and severity of concrete honeycombing near the surface
EWL slab soffit and NSL slab	Video Rigid Scope (VR Scope) ¹	Checking of extent and severity of concrete honeycombing at localized testing location
EWL and NSL slab	Ultrasonic (Phased Array) survey ²	Detect the degree of engagement in a coupler connection
EWL and NSL slab	Ground Penetration Radar ³	Detect the location of the outer layer of main reinforcement bars, and to confirm their placement (spacing)

Notes: 1. Testing commenced; 2. Trial and validation proposal will be consulted with the Government; 3. Not yet commenced.

Table 6.4 Non-destructive Testing (NDT) Methods and Application

6.4.30 The scope of concrete inspection will cover the whole area of the EWL slab soffit (bottom of the slab). In light of the honeycombing found in the EWL slab, it is prudent to also investigate the NSL slab for any defects. The method of investigation, to be agreed with the Government, would only be possible from the top of the slab as the NSL slab has been cast against formation surface. In addition, steel bar placement surveys will be conducted in selected areas on the EWL slab soffit and, where accessible, on the top of the EWL and NSL slabs.

6.4.31 During investigation for concrete defects, some reinforcements and couplers have been exposed at EWL slab soffit and can also be examined. This would provide additional information on both the as-constructed conditions accuracy as well as integrity of couplers. These exposed couplers will be examined by Ultrasonic (Phased Array) method. Further tests including a destructive test will be used as site-based validation programme for the Phased Array ultrasonic method.

6.4.32 In general, any defects and deficiencies discovered in the course of the opening-up tests from the earlier stages will be taken into

account in the final structural assessment of the structure. The structural assessment will identify whether or not and to what extent remedial work is needed.

6.5 Stage 3

Structural Assessment (and Implementing Remedial Works if necessary)

6.5.1 Based on the verification findings in Stages 1 and 2, structural assessment will be conducted for the EWL and NSL slabs and the station extension box. Any defects and deficiencies identified from the above stages will be incorporated into the analyses to verify structural integrity. The defects to be included in the final structural assessment will include the honeycombed concrete in the EWL slab soffit, incomplete infill of gaps between the soffit and some of the columns and walls and the improper placement of shear links. The structural assessment will include an examination on the structural capacity and stability of the structure.

6.5.2 Remedial works, if required, will be designed and implemented wherever necessary to reinstate the structure to an acceptable state. It is not possible to predict the scale and types of remedial measures before the Stage 2 examinations have been completed and the structural assessment is concluded. A scheme for such remedial works will be prepared after the completion of Stage 2 examinations and during the Stage 3 assessment.

7. Safety Loading Test

7.1 A safety test on the Hung Hom Station structure using a static load to proof load the structure to demonstrate the loading capacity has been developed. However, the need for such a test would be considered after the completion of Stage 3 analysis and whether such loading test will provide any further additional assurance.

8. Long-Term Structural Performance

- 8.1 The EWL slab is currently being monitored for any sign of movement by an Automatic Deformation Monitoring System (ADMS). As part of the holistic study for the EWL and NSL slabs and the D-walls, a long-term instrumentation & monitoring programme of the structure would be proposed based on the results of the above staged investigation. Attention will be paid to the measurement of small structural strains and deformation.

9. Verification and Investigation Testing Programme

- 9.1 The Stage 2 work involves extensive opening-up work on both of the EWL and NSL slabs. As much of the railway systems, trackwork and building services work have to be removed before the tests, it is envisaged that the tests will take at least 16 weeks to complete and repair/make good. Detailed programme for the Stage 2a and 2b and associated resource requirements are shown in **Appendix C**. If further tests and analyses are identified during the opening-up work, the programme will be further extended.
- 9.2 The scope and programme for the Stage 3 work would depend on the finding of the previous stages. The loading test, if considered necessary, will take about 8 additional weeks to complete. Depending on the nature of the potential remedial work, it may need to be implemented before the loading test. The re-instatement of the railway systems, trackwork, and building services will take some time and will likely be carried out after the remedial works are completed.
- 9.3 At this point, it is premature to determine how long the verification study will take and be fully completed. It is recommended that the Stage 2 opening-up work is to be conducted as soon as possible to commence the stage verification.

10. Reports

- 10.1 In order to report interim findings in time and to help to optimise the planning of the subsequent stages of work, “Stage Reports” will be submitted as works progress. The Contractor’s latest design amendment drawings (as-constructed) for the EWL and NSL slab to D-wall connection have been submitted.

- 10.2 The report submissions for each stage of the study will be made upon the completion of the work in the respective stages. This will allow the Government Expert Adviser Team, the Buildings Department and Highways Department to keep track of the progress and the latest findings, in order to adjust the directions of investigations if and when necessary.

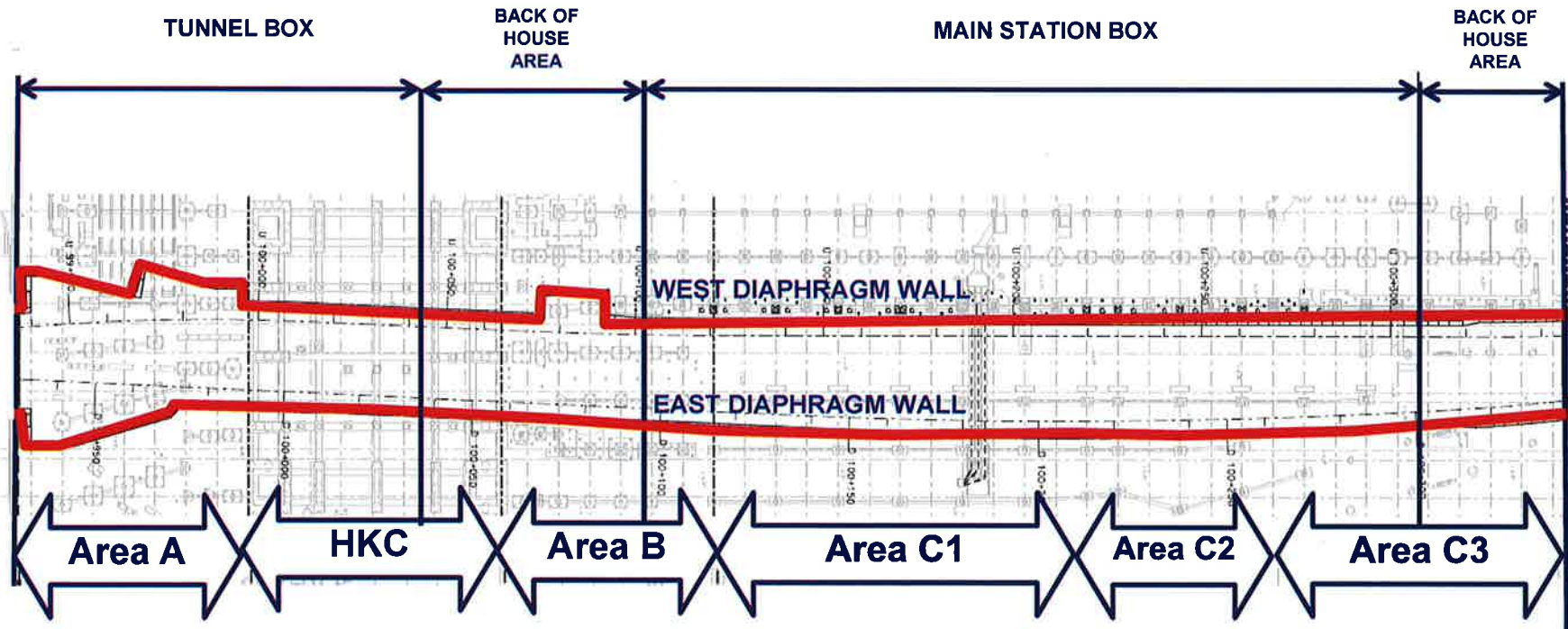
Appendices

- A Layout Plan of Hung Hom Station Extension
- B Generic Types of EWL Slab / East Diaphragm Wall Connection
- C Detailed Programme for Stages 2a and 2b and Associated Resource Requirements

Appendix A

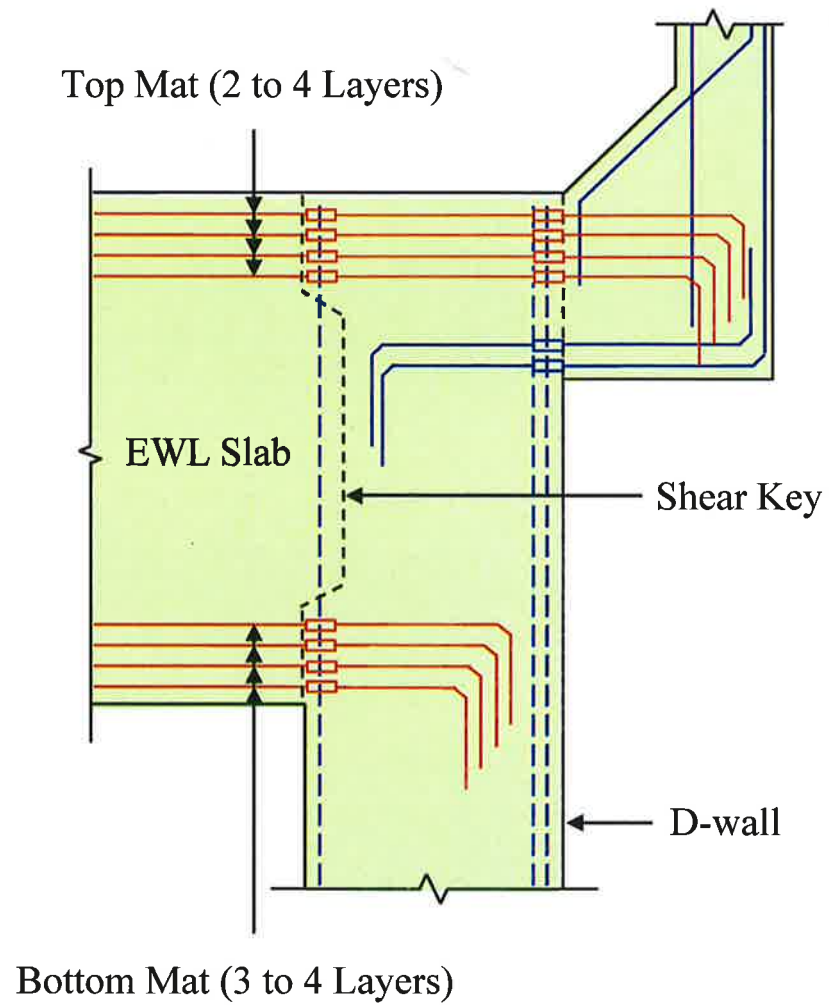
Layout Plan of Hung Hom Station Extension

Hung Hom Station Extension Layout Plan

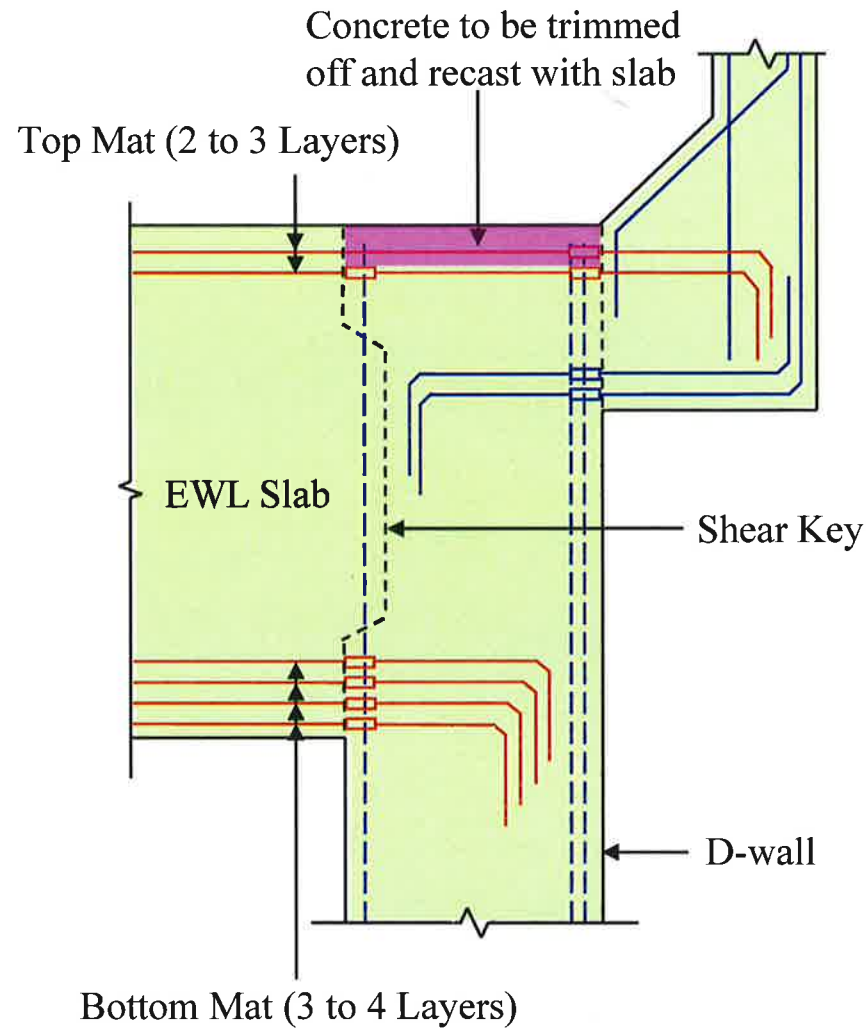


Appendix B

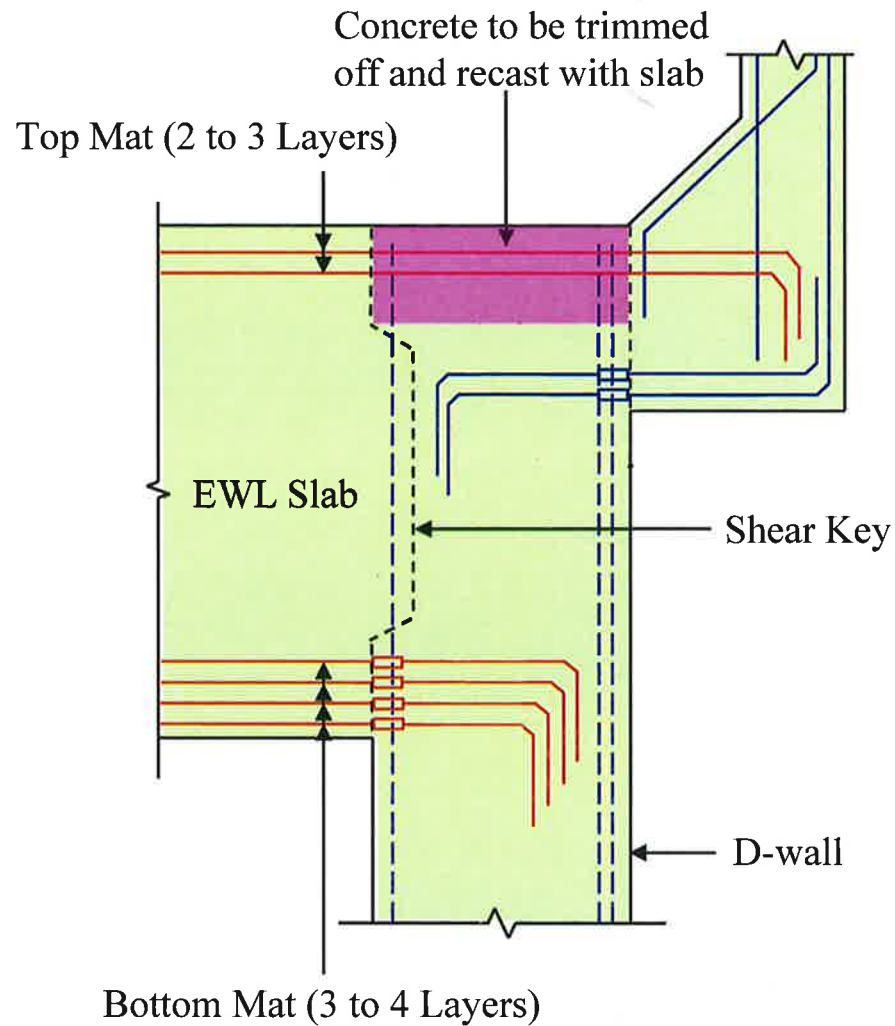
Generic Types of EWL Slab / East Diaphragm Wall Connection



Type 1 - Couplers for all layers at top mat
(Simplified version for clarity)



Type 2 - Only top layer of couplers at top mat replaced with half through steel bar
 (Simplified version for clarity)

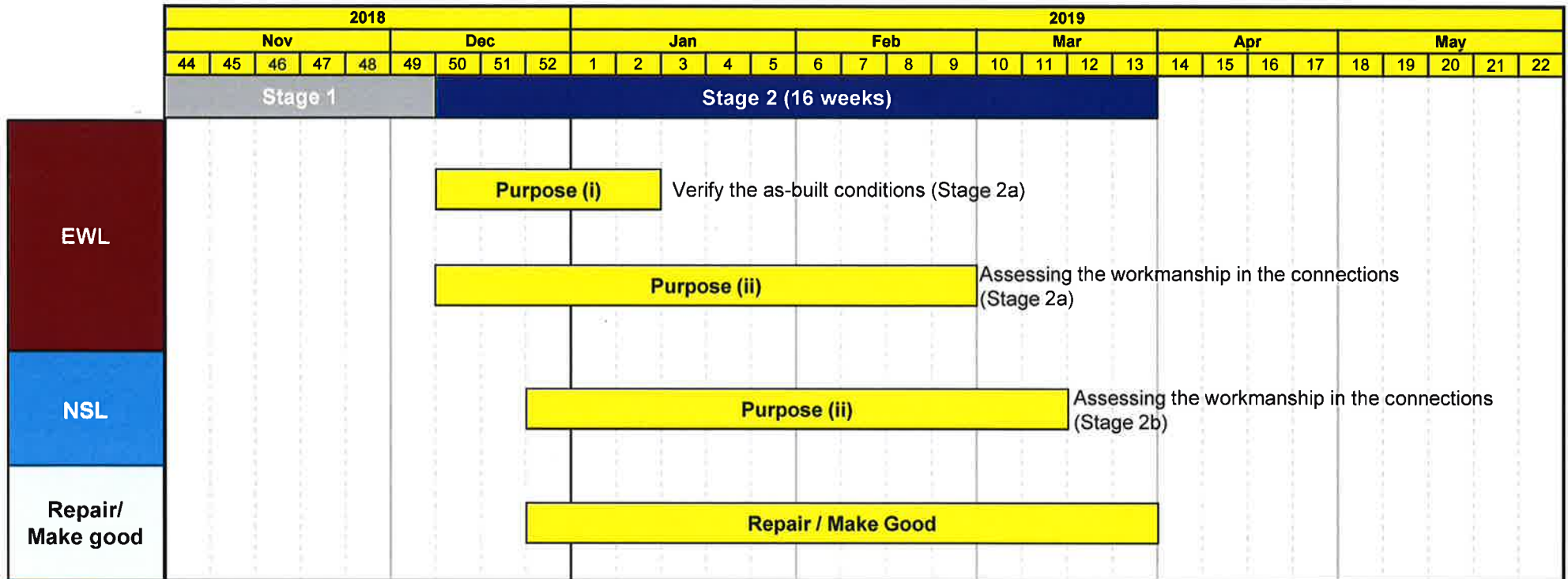


Type 3 - All top layers of couplers at top mat replaced with through steel bar
(Simplified version for clarity)

Appendix C

**Detailed Programme for Stages 2a and 2b
and Associated Resource Requirement**

HUH Verification & Investigation Testing Programme (Stage 2a and Stage 2b)



Remarks:

Assume 9 workfronts for EWL & NSL Works