MTR Corporation Limited

Shatin to Central Link –
Mong Kok East to Hung Hom Section

Operational Ground-borne Noise Mitigation Measures Plan

(June 2017)

Verified by: Fredrick Leong

Position: Independent Environmental Checker

Date: 27 Jun 17

MTR Corporation Limited

Shatin to Central Link –
Mong Kok East to Hung Hom Section

Operational Ground-borne Noise
Mitigation Measures Plan

(June 2017)

Certified by: Felice Wong

Position: Environmental Team Leader

Date: 27 June 2017

AECOM

MTR Corporation Limited

Consultancy Agreement No. C11033B

Shatin to Central Link– Mong Kok East to Hung Hom [SCL (MKK-HUH)]

Operational Ground-borne Noise Mitigation Measures Plan

June 2017

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Version:	C	Date:	15 June 2017

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1 INTRODUCTION

1.1 Background

1.1.1 The Shatin to Central Link (SCL) is a 17km extension of the existing Ma On Shan Line (MOL) and East Rail Line (EAL) comprising (i) The East-West Corridor which extends the MOL from Tai Wai to Hung Hom via East Kowloon to connect with the West Rail Line (WRL) at Hung Hom Station (HUH) and Stabling Sidings at Hung Hom Freight Yard (HHS); and (ii) The North-South Corridor which is an extension of the EAL at Hung Hom across the harbour to Admiralty Station (ADM).

1.1.2 EIA Reports for SCL – Mong Kok East to Hung Hom (MKK-HUH) Section (Register No.: AEIAR - 165/2012) and SCL – Stabling Sidings at Hung Hom Freight Yard (Register No.: AEIAR – 164/2012) were approved on 17 Februrary 2012 under the *Environmental Impact Assessment Ordinance (*EIAO). Following the approval of the EIA Reports, the Environmental Permit (EP) (EP No: EP-437/2012), covering the construction and operation of SCL (MKK-HUH), was granted on 22 March 2012.

1.1.3 Pursuant to EP Condition 2.16, the Permit Holder, MTR Corporation Ltd (MTRCL), shall deposit with the Director of Environmental Protection (DEP), no later than one month after completion of corresponding parts of the tunnel excavation of the SCL(MKK-HUH) Section (hereinafter referred to as "the Project"), an Operational Ground-borne Noise Mitigation Measures Plan (OGNMMP) to justify the need of any ground-borne noise mitigation measures for that part of the tunnel in the SCL(MKK-HUH) EIA Report. The OGNMMP shall include the review and verification of the assumptions adopted in the approved SCL(MKK-HUH) EIA Report (Register No.: AEIAR-165/2012) and SCL(HHS) EIA Report (Register No.: AEIAR-164/2012), such as line source response (LSR) and ground vibration conditions, and shall also include justifications and recommendations for any noise mitigation measures found necessary, including but not limited to medium attenuation baseplates (Type 1), high attenuation baseplate or booted dual sleepers (Type 2); or floating mini slab trackform (Type 3).

1.1.4 The prediction methodology recommended by the FTA Manual[1] was adopted in the EIA studies and most of correction factors are based on the international guideline except LSR of which values are site specific and are subject to the ground materials, depth of the tunnel and the rock head. During the EIA stage, in situ line source response measurement was not conducted. As part of the review and verification of the assumptions adopted in the ground-borne railway noise impact assessment, it is proposed that line source response and ground vibration conditions will be reviewed and verified by the on-site measurement.

1.1.5 AECOM Asia Co. Ltd has been commissioned by the MTRCL to conduct the LSR test according to the Testing and Review Methodology Plan (T&RMP) (**Appendix A**). According to the T&RMP, the LSR test was conducted at the footpath adjoining International Funeral Parlour on 26 January 2017.

1.2 Purpose of This OGNMMP

1.2.1 This OGNMMP presents the LSR analysis based on the results of the impact test conducted at the footpath adjoining International Funeral Parlour and the operational ground-borne noise prediction based on the measurement results.

1.3 Report Structure

1.3.1 This plan comprises the following sections:

- Section 1 presents the background information.
- Section 2 describes the details of impact test and the prediction of LSR based on the measurement results.

[(1)] Federal Transit Administration of U.S. Department of Transportation "Transit Noise and Vibration Impact Assessment ", 2006

- Section 3 presents the LSR analysis and operational ground-borne noise prediction results.
- Section 4 presents the conclusion.

2 IMPACT TESTING AND PREDICTION OF LSR

2.1 Testing Location

2.1.1 The impact test was conducted at the footpath adjoining International Funeral Parlour on 26 January 2017. The information of the measurement location is summarised in **Table 2.1** and the testing location is shown in **Figure No. C11033B/C/SCL/ACM/M53/012**.

Table 2.1 Measurement and Testing Location

NSR		Predicted Night-time Ground-borne Noise Levels in the EIA Report, dB(A)	Measurement Location(1)		Ground Type	Location of Hammer Impact Test (Approx. Tunnel Depth)	Testing Date
ID	Description		Approx. Hori. Distance from the Tunnel, m	Approx. Slant Distance (From Ground Level to Track Level), m			
N/A	Footpath adjoining International Funeral Parlour	N/A	18 (southbound) [24m (northbound)]	22m	Soil	Impact level -8.7mPD; Ground level 4.5mPD	26 Jan 2017

Notes:
(1) Measurement location is shown in **Figure No. C11033/C/SCL/ACM/M53/012**.

2.2 Testing Instrumentations

2.2.1 The impact force levels applied within the tunnel were measured using a SINUS Harmonie connected to a laptop computer and vibration velocity levels on the ground were measured using a Brüel & Kjær PULSE connected to a laptop computer. Wilcoxon seismic accelerometers were used on the ground surface. Details of the instruments used are provided in **Table 2.2** and the calibration records of the instruments are provided in **Appendix B**.

Table 2.2 Instrumentation of the Hammer Impact Test

Instrument	Manufacturer / Model No.	Purpose
Pneumatic Hammer and Air Compressor	WM model S	Connection to air compressor to induce force (impact)
Impact Controller	WM type 1	Connection to pneumatic hammer to control impact on/ off
Analyzer Platform	Brüel & Kjær PULSE; Sinus Harmonie	Spectrum analyzers for data acquisition
Accelerometer	Wilcoxon Research 731-207 and 731A-P31	Vibration transducers to measure vibration
Force transducer	Lorenz K-18	Fitted to pneumatic hammer to measure impact force

2.3 Testing and Measurement Procedures

2.3.1 The testing and measurement procedures are summarised below:

- The test was carried out during night time when background vibration levels were relative low. All construction works inside tunnel and the adjacent tunnel were suspended during the testing. To avoid influence by existing railway vibration, the test was carried out after service hours of East Rail.

- The impact hammer hit on the centreline of tunnel invert and it applied measured impact forces within the tunnel. The measured impact forces were logged by the FFT spectrum analyzer. Each impact point was applied with 10 hits at about 100kN – 300kN on the tunnel invert.
- Meanwhile, accelerometers were mounted on the ground at the footpath adjoining International Funeral Parlour. The impact hammer in the tunnel hit on the tunnel invert at different horizontal distances (5m, 10m, 15m, 20m, 40m) from the first impact point (i.e. 0m). Site photos taken during the measurement are shown in **Appendix C**.
- The impact force in tunnel and the vibration levels on the ground were recorded by the two separated spectrum analyzers. Measurement signals were recorded in narrow band frequencies from 6.3Hz to 500Hz.
- The furthest impact point in the tunnel was made up to 40m horizontal distance from the first impact point (i.e. 0m) due to weak impact signals were identified at 40m.

2.4 Prediction of Line Source Response

2.4.1 The vibration response induced by a unit point source impact was obtained from the hammer impact test and the best fit curves were calculated to determine the LSR at the footpath adjoining International Funeral Parlour (soil type ground property referring to the geological profile) along the SCL(MKK-HUH) alignment.

2.4.2 The post-processing of measurement data was taken to determine the best fit curves of PSR with respect to the setback distances, and the depth between the impact source and the receivers. The LSR [TM_{line}] is then determined by numerical integration with the formula[(2)] as shown below, of the Point Source Response (PSR, TM_{pi}) along the length of the train centred on the receiver, while PSR is determined from impacting within the tunnel.

$$TM_{\text{line}} = 10 \times \log_{10}\left[h \times \left(\frac{10^{\frac{TMp1}{10}}}{2} + 10^{\frac{TMp2}{10}} + \cdots + 10^{\frac{TMpn-1}{10}} + \frac{10^{\frac{TMpn}{10}}}{2} \right) \right]$$

Where

h	=	Impact interval (m) (interval varying from 5m to 40m)
TMpi	=	Point source transfer mobility for ith receiver location
n	=	Last Impact location

2.4.3 The calculation of LSR follows the calculation outlined in paragraph 11.3.2 Analysis of Transfer Mobility Data in FTA Manual[(3)]. The measured PSR and the determined LSR are presented in **Appendices D** and **E** respectively.

2.4.4 A total of two measurement points including Point A and Point B (for contingency purpose) were set up. Measurement results at Point A were adopted to determine the LSR as the vibration response.

[(2)] Federal Railroad Administration of U.S. Department of Transportation "High-Speed Ground Transportation Noise and Vibration Impact Assessment", 2012
[(3)] Federal Transit Administration of U.S. Department of Transportation "Transit Noise and Vibration Impact Assessment ", 2006

3 Review of Operational Ground-Borne Noise PREDICTION

3.1 LSR Adopted in the Approved EIA Report

3.1.1 The LSR determines the vibration levels or attenuation in the ground as a function of distance caused by an incoherent line source of unit force point impacts.

3.1.2 The LSR values adopted in ground-borne noise assessment of SCL (MKK-HUH) EIA Report were referenced from the data of the West Island Line (WIL) EIA Study (EIA Register No. AEIAR-126/2008). The LSR for WIL EIA Study was determined based on the results of borehole impact tests performed in rock, soil and close to the rock head both on the soil side and the rock side, with receiver vibration data taken on surface at various setback distances.

3.2 Review of LSR Values

3.2.1 The test carried out at the footpath adjoining International Funeral Parlour was specifically aimed at determining the LSR values for vibration propagating through the ground of soil type.

3.2.2 The LSR values determined at the footpath adjoining International Funeral Parlour are compared with those used in the SCL EIA study for the area of same ground type conditions (i.e. WIL D095 Rockhead Depth = 23m, Hole Depth = 10.4m). The EIA PSR values are shown in **Appendix F**. To allow a better comparison, **Appendix G** shows the LSR values determined at measurement locations at a distance similar to EIA study. A summary of observation is presented in **Table 3.1**.

Table 3.1 Comparison between Measurement Data and WIL Data

ID	Location	LSR data adopted in EIA Study	Observation
N/A	Footpath adjoining International Funeral Parlour	WIL D095 Rockhead Depth=23m Hole Depth=10.4m	Measured LSR values at both 42m & 46m are about 15dB lower than the EIA LSR values at most frequency bands.

3.2.3 It should be noted that the WIL EIA LSR was measured in the borehole while the current test was measured inside the tunnel. The decoupling effect of vibration propagation between the media of tunnel structure and the ground soil, i.e. the tunnel coupling loss (TCL), would be different to that between the media of borehole casing and the ground soil. Thus the LSR result measured in the impact test should comprise the loss due to decoupling of the actual tunnel structure. The factor of tunnel coupling loss applied in the EIA prediction for the structure at the NSR HH2 was -3dB. Therefore, apart from different testing method and geological profile at WIL D095 and this measurement, such 3dB tunnel coupling loss also accounts for difference between the LSR adopted in the EIA Report and measured LSR.

3.3 Operational Ground-borne Noise Prediction

3.3.1 Ground-borne noise assessment has been updated at HH2, at which the highest noise levels (i.e. $L_{eq,30min}$ 19.6dB(A) as shown in Appendix 7.6 of SCL(MKK-HUH) EIA Report) were predicted in the EIA stage, according to the LSR measurement results at the footpath adjoining International Funeral Parlour. Assessment methodology follows the prediction methodology recommended by the FTA Manual, which was adopted in the EIA Reports. The prediction results are summarised in **Table 3.2**. Sample calculation is given in **Appendix H**.

Table 3.2 Ground-borne Noise Prediction Results (Night-time Period)

GBNSR	Descrip-tion	EIA Prediction (unmitigated scenario), $L_{eq,30min}$ dB(A)	Updated Prediction(1) (unmitigated scenario , based on measured LSR data), $L_{eq,30min}$ dB(A)	Difference Between EIA and Updated Prediction, $L_{eq,30min}$ dB(A)	Ground-borne Noise Levels, $L_{eq,30min}$ dB(A)	Night-time Noise Criterion, $L_{eq,30min}$ dB(A)
HH2	Wing Fung Building	20	7	-13	38(2)	45

Note:
(1) Prediction results are based on the LSR results obtained at the footpath adjoining International Funeral Parlour.
(2) According to Table 4.7 of Supporting Document for Application of VEP (Application No. VEP-370/2012) (June 2012), the predicted cumulative ground-borne noise level at HH2 (i.e. HUH-1-3) is 38dB(A). The update of ground-borne noise level at HH2 due to the Project from 20dB(A) to 7dB(A) remains to be insignificant and would not have contribution to the cumulative noise level (i.e. 38dB(A)), and thus the cumulative ground-borne noise level at HH2 as shown in Table 4.7 of Supporting Document for Application of VEP (Application No. VEP-370/2012) (June 2012) remains valid.

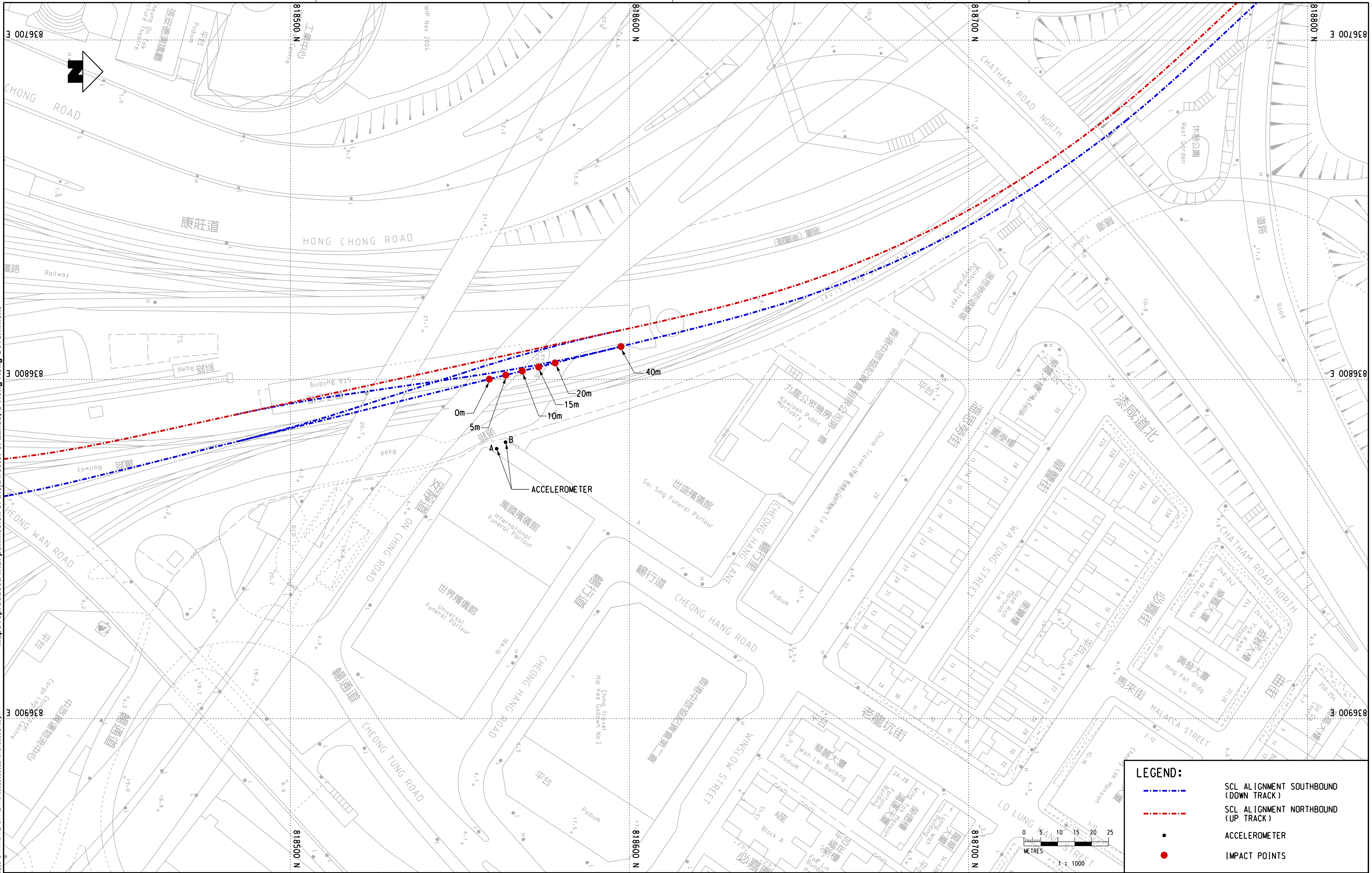
3.3.2 As mentioned in **Section 3.2.3**, the measured LSR comprises of tunnel couple loss which is about 3dB as adopted in the EIA prediction. The updated calculation therefore excluded the tunnel coupling loss in the calculation to avoid double count of the effect.

3.3.3 Results indicate that the measured LSR values at actual ground condition would give lower ground-borne noise levels than EIA predictions which are well below the noise criteria. In addition, other assumptions such as Building Coupling loss, Speed and Turnout Adjustment as adopted in the EIA Report have been reviewed and there are no changes in these assumptions. It is therefore expected that the ground-borne noise levels at other NSRs would also be subject to the noise levels as predicted in the EIA and thus are well below the noise criteria, and noise mitigation measures are not required.

4 Conclusion

4.1.1 The measurement of ground LSR values has been conducted at the footpath adjoining International Funeral Parlour to check the suitability of the LSR assumptions adopted in the EIA stage for soil ground type.

4.1.2 The measured LSR values have been adopted to predict the ground-borne noise levels at the NSR. The predicted ground-borne noise levels would be much lower than the EIA predictions and are well within the noise criteria, it is therefore concluded that no noise mitigation measures are required.



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SHATIN TO CENTRAL LINK

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TITLE

C11033B

SCL (MKK-HUH)

LOCATIONS OF MEASUREMENT POINTS AT THE FOOTPATH ADJOINING INTERNATION FUNERAL PARLOUR

SCALE 1 : 1000 (A3)

FIGURE NO. C11033B/C/SCL/ACM/M53/012

REV. A

Appendix A

Operational Ground-Borne Noise Mitigation Measures Plan – Testing and Review Methodology Plan (Revision A)

AECOM

MTR Corporation Limited

Consultancy Agreement No. C11033B

Shatin to Central Link– Mong Kok East to Hung Hom [SCL (MKK-HUH)]

Operational Ground-borne Noise Mitigation Measures Plan – Testing and Review Methodology Plan

January 2017

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Reviewed & Approved:	Josh Lam	

Version:	A	Date:	12 January 2017

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1 INTRODUCTION

1.1 Background

1.1.1 The Shatin to Central Link (SCL) is a 17km extension of the existing Ma On Shan Line (MOL) and East Rail Line (EAL) comprising (i) The East-West Corridor which extends the MOL from Tai Wai to Hung Hom via East Kowloon to connect with the West Rail Line (WRL) at Hung Hom Station (HUH) and Stabling Sidings at Hung Hom Freight Yard (HHS); and (ii) The North-South Corridor which is an extension of the EAL at Hung Hom across the harbour to Admiralty Station (ADM).

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1.1.4 The prediction methodology recommended by the FTA Manual[1] was adopted in the EIA studies and most of correction factors are based on the international guideline except LSR of which values are site specific and are subject to the ground materials, depth of the tunnel and the rock head. During the EIA stage, in situ line source response measurement was not conducted. As part of the review and verification of the assumptions adopted in the ground-borne railway noise impact assessment, it is proposed that line source response and ground vibration conditions will be reviewed and verified by the on-site measurement.

1.1.5 AECOM Asia Co. Ltd has been commissioned by the MTR to prepare this Testing and Review Methodology Plan (T&RMP) and to conduct the LSR test according to the agreed T&RMP. The testing results and calculation, together with the approved T&RMP, will be included in the OGNMMP which will be submitted under EP Condition 2.16.

1.2 Purpose of This T&RMP

1.2.1 This T&RMP is prepared to seek the DEP's agreement on the testing and review methodology prior to the review of the assumptions adopted in the approved SCL (MKK-HUH) and SCL(HHS) EIA Reports.

[1] Federal Transit Administration of U.S. Department of Transportation "Transit Noise and Vibration Impact Assessment ", 2006

1.3 Report Structure

1.3.1 This Test Proposal comprises the following sections:

- Section 1 presents the background information.
- Section 2 describes selection criteria for impact test and proposed testing locations.
- Section 3 presents the testing methodology.
- Section 4 presents the method of LSR prediction.
- Section 5 presents the review methodology of the operational ground-borne noise.

2 SELECTION OF TESTING AND MEASUREMENT LOCATIONS

2.1 Selection Criteria

2.1.1 The selection of testing location is based on the following considerations:

- Ground Type – LSR values at different ground types (soil, rock and mixed rock) is proposed to be obtained for review in OGNMMP.
- Accessibility – The testing receiver location should be accessible for conducting the test on building structure or foundation.
- Ambient vibration – The measurement results will be affected by the ambient vibration from existing traffic. As such the measurement location should be located away from roads with heavy traffic.
- Building Pile – Type and depth of building foundation and building pile arrangement are considered. High rise building with pile down to rock head would give high noise level from tunnel and will have higher priority for selection.
- Predicted Ground-borne Noise Levels – LSR test is proposed to be conducted at the more sensitive locations in close proximity to the SCL tunnel, i.e. the ground-borne noise sensitive receivers (NSRs) predicted with relatively higher operational ground borne noise levels. The NSRs identified in the EIA Reports will be reviewed for selection of appropriate testing location(s).
- Tunnel Depth – The measurement signal would be weak if the tunnel is too deep in vertical depth and too far in horizontal distance. The slant distance between ground level of the testing location and the track level of the tunnel is preferable to be within 20m and should not be greater than 40m.

2.1.2 There is only one type of geological characteristic (i.e. soil) along the tunnel alignment (Table 7.8 of SCL(MKK-HUH) EIA Report refers), and thus only this type of representative LSR values will be required to be adopted in the review in the upcoming OGNMMP.

2.1.3 During the consideration of appropriate measurement location for determination of line source response, it is important to obtain a measureable vibration impact at the NSR with minimal influences from the existing surrounding environment. Existing ambient vibration environment at the NSRs is considered as an important factor because the vibration impact source for the testing is relatively low and would be easily affected by the vibration induced from surrounding road traffic. It is expected that ambient vibration would be comparatively high in masking the impact signal and thus it would be difficult to obtain the signal even with the use of very sensitive seismic accelerometer.

2.1.4 In addition, slant distance to the tunnel is also a key factor for consideration as the larger the separation distance between tunnel and NSR, the weaker the vibration signal to be recorded at the NSR. The NSRs are located at a slant distance of more than 40m away from the tunnel and the vibration signal would be insignificant to measure and therefore not suitable for the test. Based on previous substantial experience in LSR test, the response signal from the hammer impact located at greater than 40m would be weak and cannot be measurable in any ground type.

2.1.5 Furthermore, NSRs with predicted $L_{eq\ 30min(dB(A))}$ lower than 30 dB(A) in the EIA ground-borne noise prediction results would not be considered as a representative location for testing and measurement as the vibration signal is predicted to be insignificant to measure.

2.2 Review of Testing and measurement Location

2.2.1 All NSRs in the EIA Reports as shown in **Figure C11033B/C/SCL/ACM/M53/011** have been reviewed according to the criteria in **Section 2.1.1**. A summary of review findings is provided in **Table 2.1** and the detailed information is presented in **Appendix 2.1**.

Table 2.1 Justifications for NSR selection for LSR measurement

Ground Type	NSR No.	Justification(s)	Suitable for LSR Measurement? (Y/N)
Soil[1]	HH2 / HUH-1-3 – Wing Fung Building	• Very high ambient vibration near Chatham Road North; and • slant distance from tunnel is more than 40m	N
	HH3 - Cheung On Tak Lecture Theatre	• Very high ambient vibration near Hong Chong Road; and • Slant distance from tunnel is more than 40m	N
	HH5 - HK Poly U Block V - Jockey Club Innovation Tower[2]	• Very high ambient vibration near Chatham Road South; and • Slant distance from tunnel is more than 40m	N
	HH7 - The Metropolis Residence	• Very high ambient vibration on podium of transportation interchange ; and • Slant distance from tunnel is more than 40m	N

Note:
(1) Table 7.8 of SCL(MKK-HUH) EIA Report refers.
(2) Planned Poly U Phase 8 as defined in SCL(MKK-HUH) EIA Report is currently named as HK Poly U Block V - Jockey Club Innovation Tower.

2.2.2 Based on the review findings, the tunnel of this Project is running under the urban area with busy roads, and all NSRs as identified in the EIA Reports are subject to high ambient vibration environment. Furthermore, all NSRs are located more than 40m slant distance from the tunnel and with predicted $L_{eq\ 30min(dB(A))}$ lower than 30 dB(A) in the EIA ground-borne noise prediction results (**Appendix 2.1** refers). It is therefore concluded that the NSRs as identified in the EIA Reports are considered not suitable for the test.

2.2.3 For reviewing on the line source response (LSR) in soil type, a measurement and testing location other than NSR is proposed for the measurement of LSR in soil type. Site investigation has been conducted to identify feasible location for LSR measurement. Based on the selection criteria discussed in **Section 2.1**, it is proposed to conduct LSR measurement at the footpath adjoining International Funeral Parlour. Location of proposed LSR measurement is shown in **Figure C11033B/C/SCL/ACM/M53/011** with details of information provided in **Table 2.2**.

Table 2.2 Proposed Measurement and Testing Location

Proposed Measurement Location	Predicted Night-time Ground-borne Noise Levels in the EIA Report, dB(A)	Latest Approx. Hori. Distance from the Tunnel Impact Point, m	Slant Distance (From Ground Level to Track Level)	Ground Type	Location of Hammer Impact Test (Approx. Tunnel Depth)	Anticipated Testing Schedule
Footpath adjoining International Funeral Parlour	N/A	18m (down track) [24m (up track)]	22m	Soil	Impact level -8.7mPD; Ground level 4.5mPD	Q1 2017

3 TESTING METHODOLOGY

3.1 Instrumentations

3.1.1 The impact force levels applied within the tunnel would be measured using a SINUS Harmonie connected to a laptop computer and vibration levels would be measured using a Bruel & Kjaer PULSE also connected to a laptop computer. Bruel & Kjaer and Wilcoxon accelerometers would be used on the surface. Details of the instruments are provided in **Table 3.1**.

Table 3.1 Instruments to be Used in the Hammer Impact Test

Instrument	Manufacturer / Model No.	Purpose
Pneumatic Hammer and Air Compressor	WM model S	Connection to air compressor to induce force (impact) at about 200kN(1)
Impact Controller	WM type 1	Connection to pneumatic hammer to control impact on/ off
Analyzer Platform	Bruel & Kjaer PULSE; Sinus Harmonie	Spectrum analyzers for data acquisition
Accelerometer	Bruel & Kjaer type 4370V; Wilcoxon Research 731-207	Vibration transducers to measure vibration
Force transducer	PCB 207C	Fitted to pneumatic hammer to measure impact force

Note:
(1) 200kN is only the design force of the impact machine and the actual output force in fact depends on the machine status and on-site condition.

3.2 Testing and Measurement Procedures

3.2.1 The testing would be carried out after the completion of tunnel excavation. The testing and measurement procedures are summarised below:

- The test will be carried out during night time when background vibration levels are relative low. All construction works inside tunnel and the adjacent tunnel shall be suspended during the testing.
- The impact hammer will hit on the centreline of tunnel invert. The hammer will apply measurable impact forces within the tunnel upto 8 impact points to represent the length of about half a train (i.e. about 100m) but subject to on-site condition during the measurement. The measured impact forces will be logged by the spectrum analyzer. Each impact point will have 10 hits at about 100kN – 200kN on the tunnel invert. The locations of impact points for selected measurement location are illustrated in **Figure Nos. C11033B/C/SCL/ACM/M53/ 011.**
- The impact force in tunnel and the vibration levels on the ground will be recorded by the two separated spectrum analyzers. Measurement will be conducted in narrow frequency bands from 6.3Hz to 500Hz.
- Impact force and vibration measurements will be repeated for all impact location points along the tunnel upto a distance of about half train length (i.e. about 100m) but subject to on-site condition during measurement. Due to symmetry of the train, the point source response of transfer mobility for another half train length can be obtained by calculation by multiplying two to the measured results. At each impact point, 10 hits will be sufficient for prediction of LSR.

4 METHOD OF LINE SOURCE RESPONSE PREDICTION

4.1 Introduction

4.1.1 The vibration response caused by a unit point source impact can be obtained from the hammer impact test and the best fit curves can be calculated to determine the LSR at the selected measurement location along the SCL alignment. The prediction of LSR is presented in this section.

4.2 Prediction Method of Line Source Response

4.2.1 The measurement data will be processed so that the specific geological conditions at selected measurement location along the alignment, namely, the setback of the measurement location from the alignment, the depth of the tunnel, and the depth of the measurement location can be input. For the given input conditions, the best fit curves of PSR are determined from the impact database with respect to the setback, and source and receiver depth. The LSR (TM_{line}) will then be determined by numerical integration with the formula[2] as shown below, of the Point Source Response (PSR, TM_{pi}) along the length of the train centred on the receiver, while PSR will be determined from impacting within the tunnel.

$$TM_{\text{line}} = 10 \times \log 10 \left[h \times \left(\frac{10^{\frac{TMpi}{10}}}{2} + 10^{\frac{TMp2}{10}} + \cdots + 10^{\frac{TMpn-1}{10}} + \frac{10^{\frac{TMpn}{10}}}{2} \right) \right]$$

Where

h	=	Impact interval (m) (interval varying from 5m to 40m)
TMpi	=	Point source transfer mobility for i-th impact location (dB re 1e-9 (m/s)/N)
n	=	Last impact location

4.2.2 The calculation of LSR will follow the calculation outlined in paragraph 11.3.2 Analysis of Transfer Mobility Data in FTA Manual[3].

4.2.3 The measured LSR will be compared with those adopted in the EIA Reports for equivalent ground types to allow verification of the ground-borne noise calculation in the EIA Reports.

2 Federal Railroad Administration of U.S. Department of Transportation “High-Speed Ground Transportation Noise and Vibration Impact Assessment”, 2012

3 Federal Transit Administration of U.S. Department of Transportation “Transit Noise and Vibration Impact Assessment ”, 2006

5 REVIEW OF OPERATIONAL GROUND-BORNE NOISE METHODOLOGY

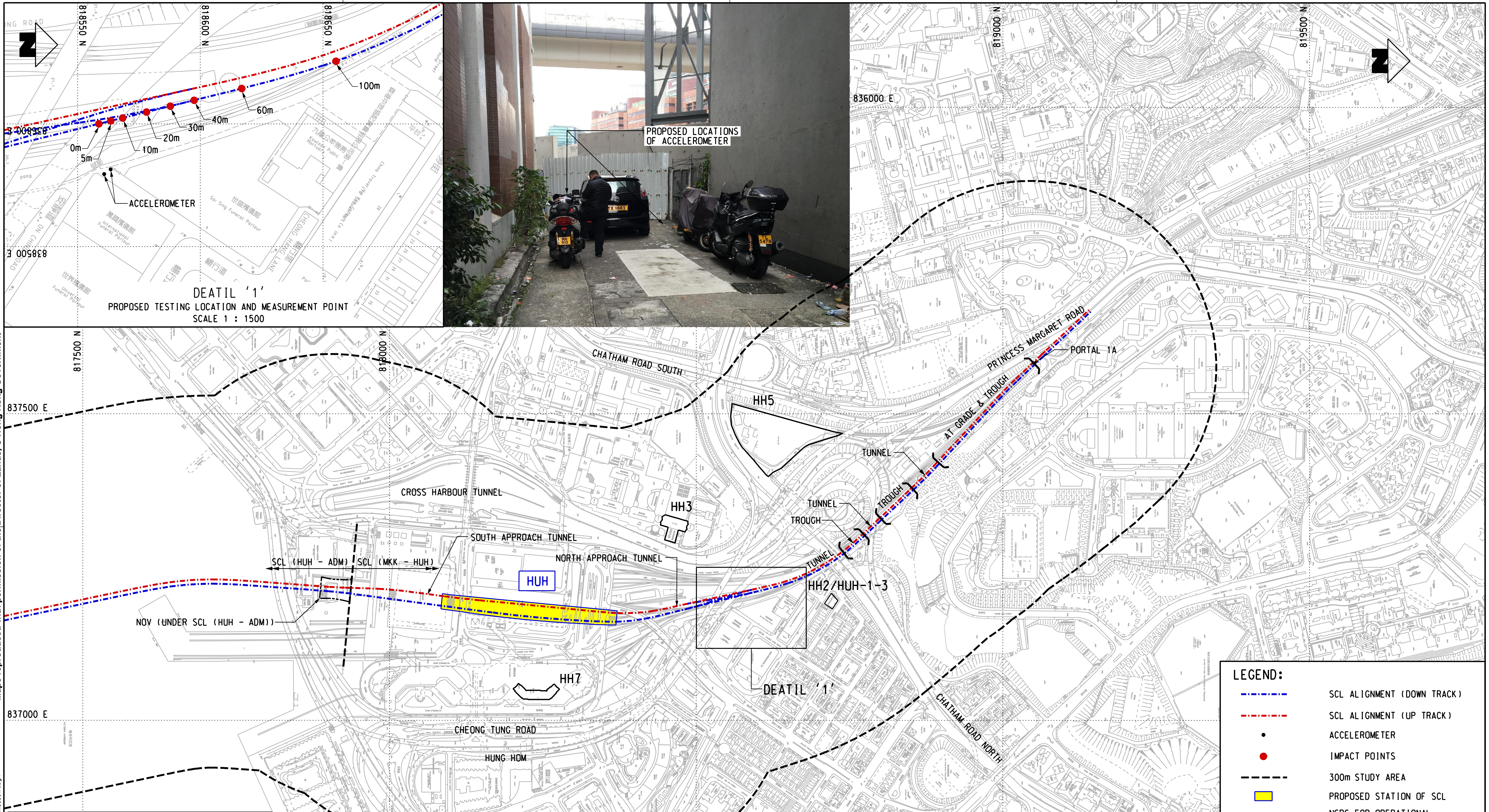
5.1 Review of Other Assumptions

5.1.1 Other assumptions adopted in the EIA Reports will be reviewed and updated based on the latest available information, where necessary, in the upcoming Operational Ground-borne Noise Mitigation Measures Plan.

- Tunnel Coupling Loss (TCL) and Building Coupling Loss (BCL) – these factors depend on whether the tunnel and building (or building piles) are in rock or soft ground. Updated building information, if any, will be reviewed.
- Geological Profile – updated geological profile along the alignment, if any, will be reviewed.
- Speed – updated speed profile along the alignment, if any, will be reviewed.
- Turnout Adjustment – updated information, if any, on the type of turnouts to be used and the adjustment corresponding to corresponding type of turnouts will be reviewed.

5.2 Update of Ground-borne Noise Assessment

5.2.1 Ground-borne noise assessment at the selected NSRs will be updated according to the review findings of the assumptions as discussed in **Section 5.1** and the measurement results of LSR. Assessment methodology will follow the prediction methodology recommended by the FTA Manual, which was adopted in the EIA Reports.



REPRESENTATIVE NSRS FOR OPERATIONAL GROUNDBORNE NOISE ASSESSMENT	
HH2/HUH-1-3[1]	WING FUNG BUILDING
HH3	THE HONG KONG POLYTECHNIC UNIVERSITY (POLYU) CHEUNG ON TAK LECTURE THEATER
HH5	POLYU PHASE 8
HH7	THE METROPOLIS RESIDENCE

REMARK: [1] NSR ID NO. IN SCL(HHS) EIA REPORT

LEGEND:

- SCL ALIGNMENT (DOWN TRACK)
- SCL ALIGNMENT (UP TRACK)
- ACCELEROMETER
- IMPACT POINTS
- 300m STUDY AREA
- PROPOSED STATION OF SCL
- HH7 — NSRS FOR OPERATIONAL GROUNDBORNE NOISE ASSESSMENT

ABBREVIATIONS:

NOV	NORTH VENTILATION BUILDING, PLANT ROOMS AND EMERGENCY ACCESS
SCL (MKK - HUH)	SHATIN TO CENTRAL LINK - MONG KOK EAST TO HUNG HOM SECTION
SCL (HUH - ADM)	SHATIN TO CENTRAL LINK - HUNG HOM TO ADMIRALTY SECTION

REV	DESCRIPTION	BY	DATE	APPROVED	REV	DESCRIPTION	BY	DATE	APPROVED

DRAWN	ZFX
DESIGNED	---
CHECKED	LCR
APPROVED	---
DATE	30/NOV/2016

DO NOT SCALE DRAWINGS. ALL DIMENSIONS SHALL BE VERIFIED ON SITE.

MTR

SHATIN TO CENTRAL LINK

ORIGINATOR

AECOM

CADD REF. C11033B_C_SCL_ACM_M53_011A.dgn

TITLE

C11033B
SCL (MKK-HUH)
LOCATIONS OF NOISE SENSITIVE RECEIVERS (GROUNDBORNE) AND PROPOSED LSR MEASUREMENT LOCATION

SCALE 1 : 6000 (A3)

FIGURE NO. C11033B/C/SCL/ACM/M53/011

REV. A

PLOT DRV: v:\ustnset\MTR\PLOTDRIVER\WINDOWS\A3 COLOUR.plt 16:46:26
MODELNAME: Default PRINTED BY: ZENGFX 2017/1/3
FILENAME: P:\projects\60280233\DRAWING\REPORT\ENV\C11033B_C_SCL_ACM_M53_011A.dgn

Appendix 2.1

Review of Suitable Locations for Impact Test

Appendix 2.1 Review of Suitable Location for Impact Test Measurement

NSR ID	NSR Description	Ground Type [1]	Worst case Scenario[2]		Building Piles (Y/N/NA) [3]	The Nearest Slant Distance to Tunnel (m) [4]	Ambient Vibration		Suitable location for measurement?
			Predicted $L_{eq,30min}$ (dB(A))	Criterion $L_{eq,30min}$ (dB(A))			Ambient Vibration Factor	Ambient Vibration (High /Low) [5]	
HH2 / HUH-1-3[(6)]	Wing Fung Building	Soil	<20	45	Y	41	Chatham Road North	High	No
HH3	Cheung On Tak Lecture Theatre	Soil	<20	55	Y	101	Hong Chong Road	High	No
HH5	HK Poly U Block V - Jockey Club Innovation Tower[(7)]	Soil	<20	55	Y	101	Chatham Road South	High	No
HH7	The Metropolis Residence	Soil	<20	45	Y	91	Transport interchange under Podium	High	No

Notes:

[1] The Ground Type is categorized into 3 groups which are Rock, Mixed rock and Soil. Tunnel on or under rockhead is defined as Rock; Tunnel above rockhead and below soil is defined as Mixed rock, and Tunnel in the soil is defined as Soil. For this Project, the tunnel is located in soil type only.

[2] Worst case Scenario represents either Nighttime noise criteria or Daytime noise criteria adopted in EIA reports for NSRs depending on its land use.

[3] Y: Building pile of the NSR founded on rock head; N: Building pile of the NSR not founded on rock head; NA: No existing piles and information of future piles is not available yet.

[4] The nearest distance to tunnel is determined between the boundary of respective NSR and tunnel (i.e. the slant distance from ground level to track level.)

[5] Low: For the nearest road(s) with traffic flow AADT less than 30,000, relative low ambient vibration anticipated at NSRs; High: For the nearest road(s) with traffic flow AADT equal or greater than 30,000, or nearest roads with busy traffic such as transport interchange, relative high ambient vibration anticipated at NSRs.

[6] NSR ID No. in SCL(HHS) EIA Report

[7] Planned Poly U Phase 8 as defined in SCL(MKK-HUH) EIA Report is currently named as HK Poly U Block V - Jockey Club Innovation Tower.

Appendix B

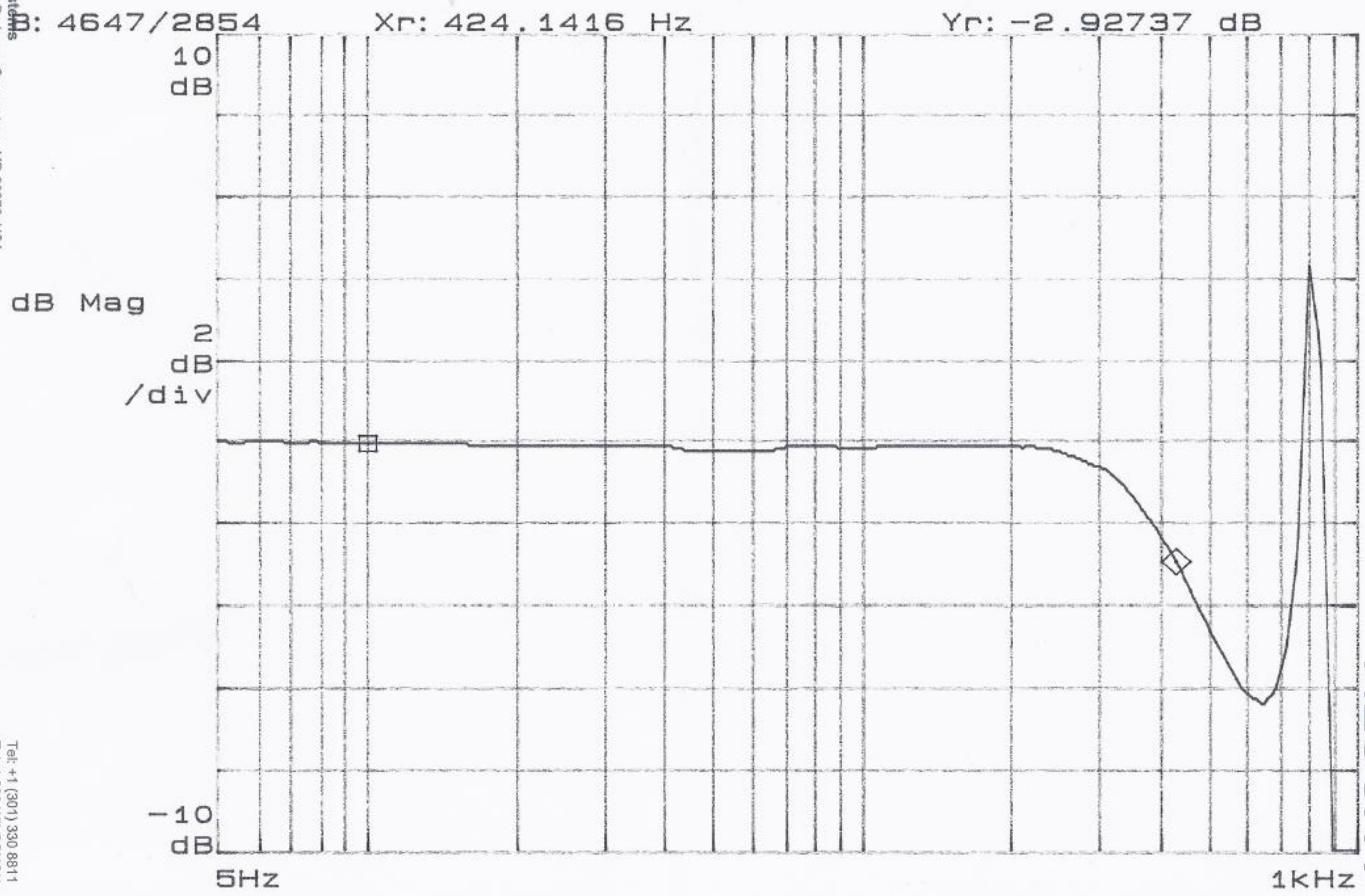
Calibration Records of Measurement Equipment

Accelerometer System, Models 731A/P31, Calibration Data

Serial Numbers, 731A/P31 4647/2854
Voltage Sensitivity 10.29 V/g*
Transverse Sensitivity <1 % of axial
P31 Settings: Gain...x1 Filter...450 Hz

Nominal Low End Frequency Response:
-1dB 0.10 Hz
-3dB 0.05 Hz

Mounted Resonance 809 Hz
Maximum Amplitude Range 0.5 g Peak
Calibrated By Thep Phanbandit Date 2-20-2014



Meggitt Sensing Systems
20511 Seneca Meadows Parkway, Germantown MD 20876, USA

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Fax: +1 (301) 330 8873
www.meggittsensingsystems.com
www.meggitt.com

* *Reference Sensitivity at 10 Hz, 25℃. This calibration is traceable to the National Institute of Standards and Technology, Gaithersburg, MD.*

F94152 REV A

MEGGITT

Calibration Data

Low Frequency Accelerometer

Model **731-207**

Serial Number **3511**

Sensitivity **9.8 V/g**

Bias Voltage **11.1 Vdc**

Resonance **2.4 kHz**

Maximum Amplitude Range **0.5 g peak**

Frequency Response			
±5%	**0.60 Hz**	to	**660 Hz**
±10%	**0.50 Hz**	to	**850 Hz**
±3dB	**0.20 Hz**	to	**1400 Hz**

Calibrated by: **S.HONGMANIVAN** Date: **01/24/2014**

This calibration is traceable to the National Institute of Standards and Technology, Gaithersburg, MD 20899.
Frequency Response is traceable 5 Hz to 10 kHz.
Low end frequency response and amplitude range are nominal values.
Sensitivity measured at 100 Hz, 25°C.

Meggitt (Maryland), Inc. is an ISO 9001:2008 and EN/JISQ/AS9100:2004 Registered Company.

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LORENZ MESSTECHNIK GmbH Obere Schloßstr.131 73553 Alfdorf ☎ 07172 /93730-0 Fax 07172 /93730-22

Prüfzertifikat

Test Certificate

Kraftsensor / *Force Sensor*

Druckkraftsensor / *Compression Force Sensor*

Kunde / *Customer*:	**Bestech Australia Pty Ltd (TSE Equipment Co Pty Ltd)**		
Auftrags-Nr. / *Order no*:	**162839**	**Nennkraft /*Nominal force* F_{nom}:**	**1000 kN**
Sensor Typ / *Type*:	**K-18**	**Ser. Nr. / *Ser. no*:**	**152466**

Kalibrieraufbau / *Calibration Configuration*

Referenz / *Reference*

Kalibriereinrichtung / *Calibration device:*	E0766	Messgerät / *Measuring device:*	E0953
Referenzsensor / *Reference sensor:*	E0679		

Prüfling / *Specimen*

Messgerät / *Measuring device:*	E0327	Speisegerät / *Supply unit:*	E0966
Kabellänge / *Cable length:*	----		

Prüfergebnisse / *Test Results*

Lastrichtung / *Load direction:*	Druck / *Compression*
Speisespannung / *Excitation voltage:*	10 V
Brückenwiderstand / *Bridge resistance:*	350 Ω
Isolationswiderstand / *Isolation resistance:*	> 2000 MΩ
Kennwert / *Sensitivity:*	1,000 mV/V
Nullsignal / *Zero signal:*	0,001 mV/V

Technische Daten des Sensors / *Technical Data of the Sensor*

Genauigkeitsklasse für eine Lastrichtung / *Accuracy class for one load direction:*	0,5 %
Nenntemp. Bereich / *Nominal temp. range:*	-10 ... +70 °C
Gebrauchstemp. Bereich / *Service temp. range:*	-30 ... +80 °C
Grenzkraft / *Limit force:*	150 % F_{nom}
Bruchkraft / *Ultimate force:*	> 300 % F_{nom}
Speisespannung / *Excitation voltage:*	2 ... 12 V

Anschlussbelegung / *Pin Assignment*

Stecker Typ:	6-polig	*Connector Type:*	*6 pin*
Funktion	**Pin**	***Function***	***Pin***
Versorgung (-)	1	*Supply (-)*	*1*
Versorgung (+)	2	*Supply (+)*	*2*
Schirmung	3	*Shield*	*3*
Signal (+)	4	*Signal (+)*	*4*
Signal (-)	5	*Signal (-)*	*5*
NC	6	*NC*	*6*

Bemerkungen / *Remarks:*

Prüfer / *Tester:* Kämmler Datum / *Date:* 13.06.2016

Die oben ausgewiesenen Messwerte wurden auf einer Prüfeinrichtung ermittelt, deren jedes einzelne Messmittel einer regelmässigen Prüfung unterliegt.
Es ist somit die Rückführbarkeit nach ISO 9000 ff gewährleistet.
The above stated measurand values were determined on testing equipment, where each single measuring device is subject to regulary inspections.
Thus, traceability accroding ISO 9000ff is guaranteed.

Appendix C

Photo records of Measurement at the Footpath adjoining International Funeral Parlour

Appendix C - Photo records of Hammer Impact test near International Funeral Parlour

Near International Funeral Parlour

Measurement Date: 26 Jan 2017
Measurement Time: 1:00am to 5:00am 26 Jan 2017

Point A

Point B

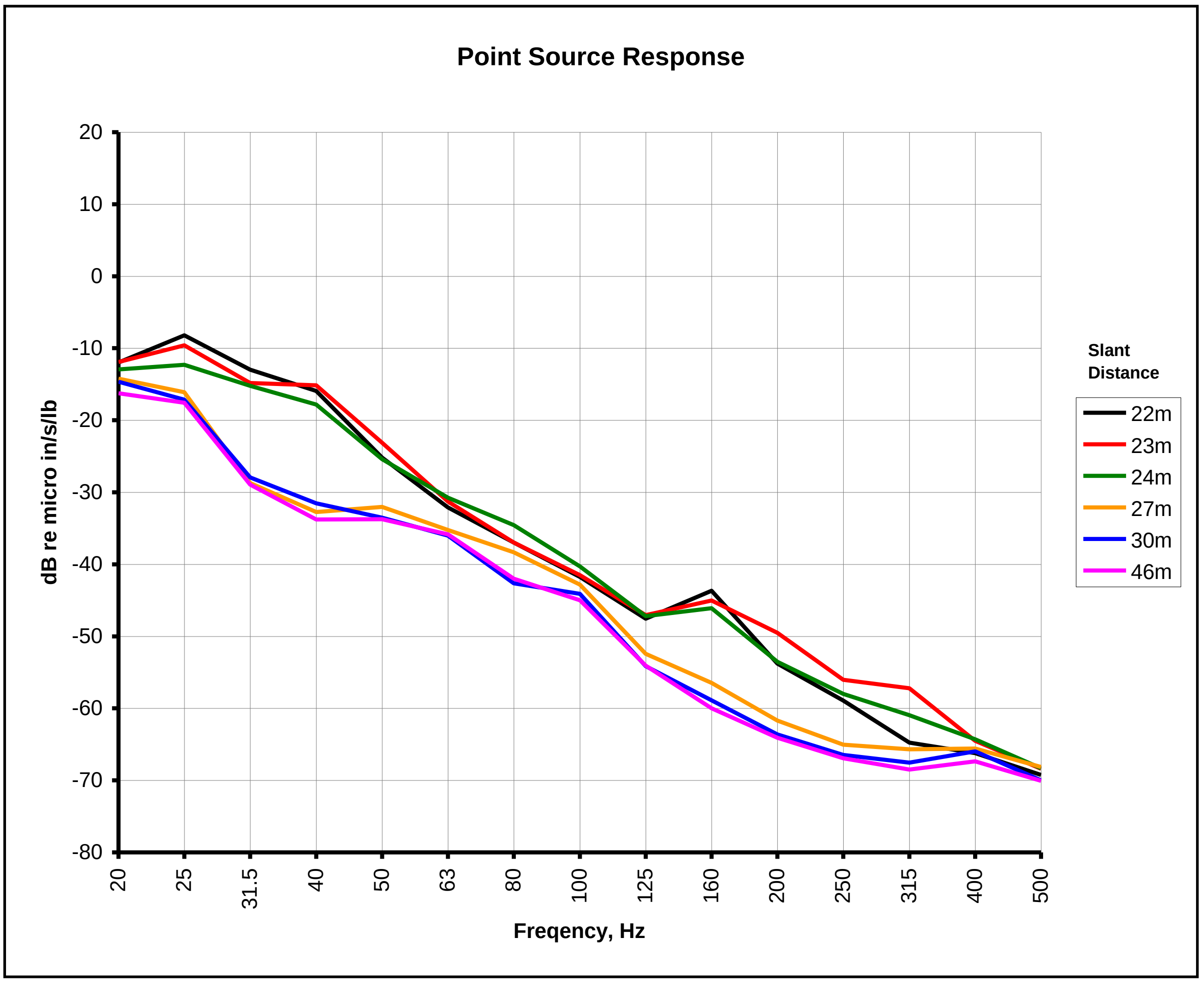
Hammer Impact Point in the Tunnel	**Accelerometer on ground level**

Appendix D

Measured Point Source Responses at the Footpath adjoining International Funeral Parlour

The footpath adjoining International Funeral Parlour

Point A

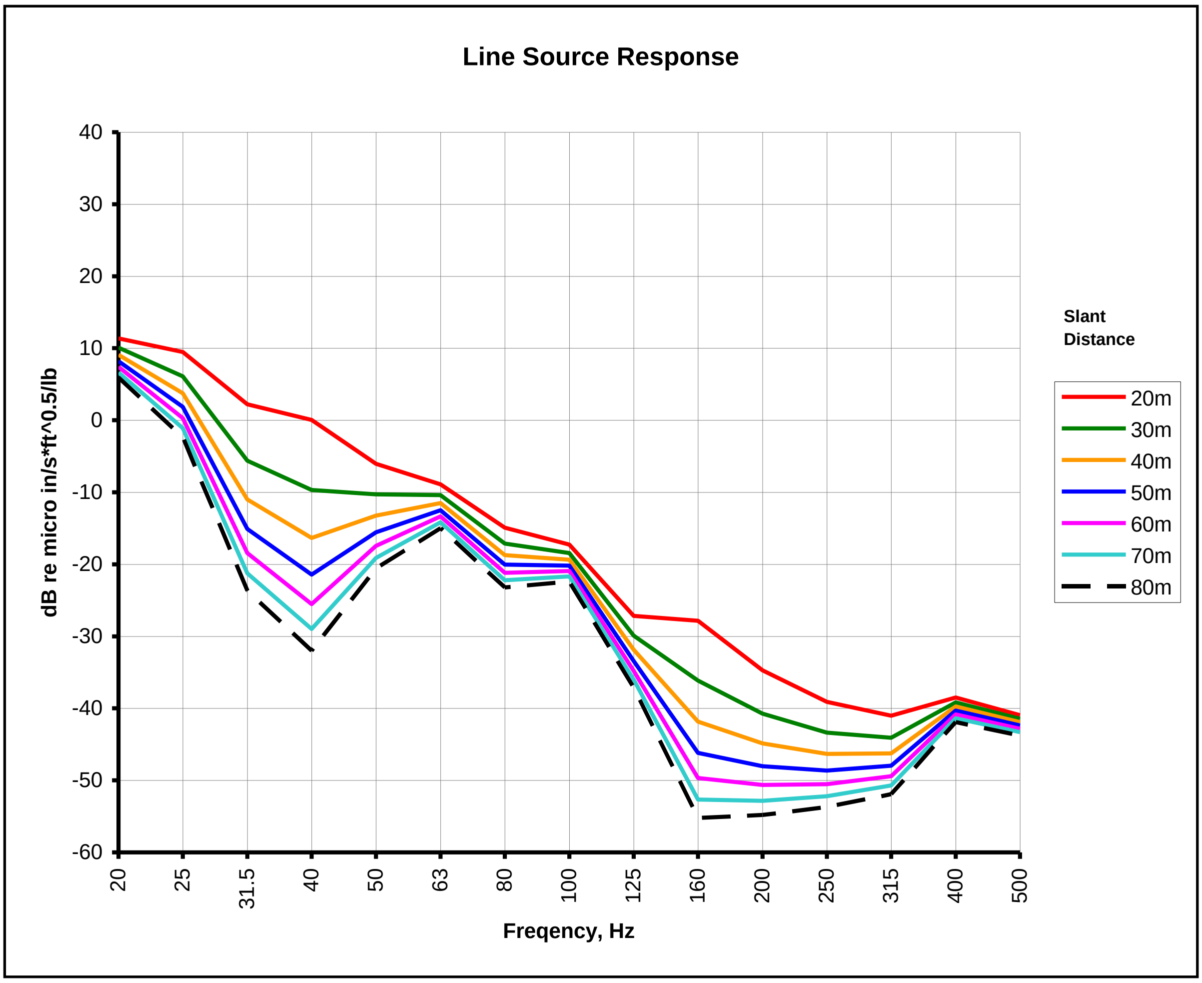


Appendix E

Determined Line Source Responses at the Footpath adjoining International Funeral Parlour

The Footpath adjoining International Funeral Parlour

Point A

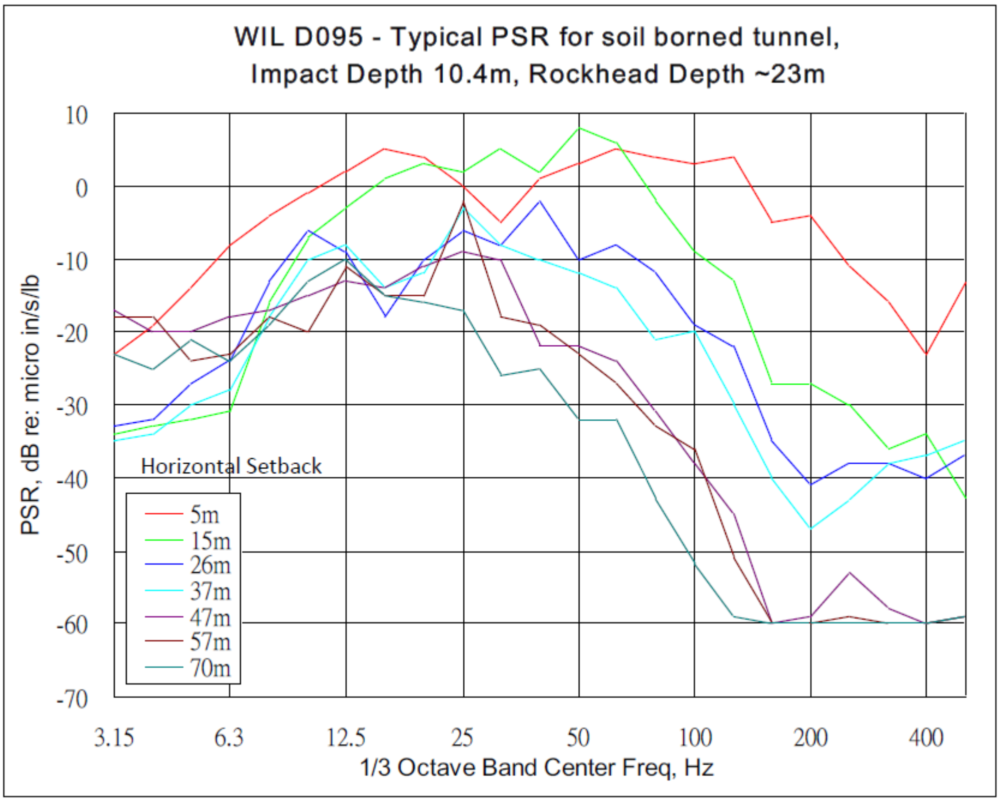


Appendix F

Point Source Responses Adopted in SCL EIA (Appendix 7.3 of SCL(MKK-HUH) EIA Report

Appendix 7.3

Typical Point Source Response (PSR)



Appendix G

Comparison of Measured and EIA Line Source Responses

Comparison between the LSR adopted in the EIA and Measured LSR at the Footpath adjoining International Funeral Parlour

Northbound (Up track) Calculation

Southbound (Down Track) Calculation

Appendix H

Updated Calculations of Ground-borne Noise Prediction

The footpath adjoining International Funeral Parlour Updated EIA Calculation by Measured LSR

Project:	SCL Operational Rail Noise Assessment	**Southbound Speed:**	63 kph	**Northbound Speed:**	63 kph
NSR No.:	HH2	**Passby in 30min per Direction (night):**	12		
NSR Usage:	Residential	**Head-Tail Effect:**	3 dB		
NSR Location:	Wing Fung Bldg榮豐大樓				
No. of Basement Floors:	0				
NSR Floor:	1				

	Horizontal Dist, m	Track Depth, m
Southbound	40	11
Northbound	45	11

Inferred Rockhead
30-40m

Descriptions	Unit			20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Southbound Calculation																		
FDL	dB re 1 lb/ft0.5			34.4	38.4	37.4	35.4	34.4	38.4	41.4	42.4	42.4	38.4	37.4	36.4	33.4	34.4	31.4
TOC	dB	N/1/2																
TIL	dB	Type	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TCF	dB	Type	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSR	dB re micro-in/s * ft0.5/lb			8.6	3.3	-11.7	-17.2	-13.7	-12.0	-19.2	-19.9	-32.3	-42.5	-45.4	-46.8	-46.7	-40.2	-42.3
Southbound Vibration Level	dB re 1 micro-in/sec			43.0	41.7	25.7	18.2	20.7	26.4	22.2	22.5	10.1	-4.1	-8.0	-10.4	-13.3	-5.8	-10.9
Northbound Calculation																		
FDL	dB re 1 lb/ft0.5			34.4	38.4	37.4	35.4	34.4	38.4	41.4	42.4	42.4	38.4	37.4	36.4	33.4	34.4	31.4
TOC	dB	N/1/2																
TIL	dB	Type	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TCF	dB	Type	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSR	dB re micro-in/s * ft0.5/lb			8.3	2.5	-13.4	-19.3	-14.7	-12.3	-19.7	-20.1	-33.0	-44.4	-46.8	-47.8	-47.4	-40.3	-42.4
Northbound Vibration Level	dB re 1 micro-in/sec			42.7	40.9	24.0	16.1	19.7	26.1	21.7	22.3	9.4	-6.0	-9.4	-11.4	-14.0	-5.9	-11.0
Total of Soutbound and Northbound Calculation																		
Total Vibration Level Outside Building				45.9	44.3	28.0	20.3	23.2	29.2	25.0	25.4	12.8	-1.9	-5.6	-7.9	-10.6	-2.8	-8.0
BCF	dB	Type	4	-7.0	-7.5	-8.0	-9.0	-10.0	-11.0	-12.0	-13.0	-14.0	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5
BVR - Floor to Floor	dB	Floor	1	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
BVR - Resonance	dB			6.0	6.0	6.0	6.0	5.8	5.6	5.4	5.2	5.0	4.0	3.0	2.0	1.3	0.7	0.0
CTN	dB			2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
SAF	dB			10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Predicted Noise Level		1/3 Oct (Linear), dB		54.9	52.8	36.0	27.3	29.0	33.8	28.4	27.6	13.8	-2.4	-7.1	-10.4	-13.8	-6.6	-12.5
Predicted Noise Level		Oct (Linear), dB				52.9			35.9			27.8			-4.8			-5.6
Predicted Noise Level		1/3 Oct (A-weighted), dB		**4.4**	**8.1**	**-3.4**	**-7.3**	**-1.2**	**7.6**	**5.9**	**8.5**	**-2.3**	**-15.8**	**-18.0**	**-19.0**	**-20.4**	**-11.4**	**-15.7**
Predicted Leq(Double PassBy)	dB(A)			**14.5**														
Predicted Lmax,slow	dB(A)			**15.0**														
Predicted Leq(24Hr)	dB(A)			**5.5**														
Predicted Leq(30min)	dB(A)			**6.8**														

Note:
Southbound refers to down track and northbound refers to up track.

The following abbreviations are used in the above calculation:

FDL	force density level, in dB re 1 lb/in$^{1/2}$
TIL	trackform attenuation or insertion loss, relative level
TOC	turnout and crossover factor
TCF	vibration coupling between the tunnel and the ground for soil based tunnels, relative level
LSR	line source transfer mobility, in dB re 1 (uin/s)/(lb/ft^0.5)
BCF	adjustment to account for building coupling loss, in dB
BVR	building vibration amplification within the structure, in dB
CTN	conversion from vibration to noise within the building, in dB
SAF	safety factor to account for wheel/rail condition and uncertainties in ground conditions, in dB