

# 1 FDL Measurements and the Results

## 1.1 Measurement Methodology

- 1.1.1.1** The measurements consist of 2 parts: measurement of vibration levels during train passage of a test train, and Line Source Response (LSR) measurements at the same location by hammer impact test.
- 1.1.1.2** For the test train vibration measurement, accelerometers are placed at the rail and on ground surface at various setbacks from the alignment. Vibration levels during train passby  $L_v$  in 1/3-octave bands (3.15Hz to 500Hz) are continuously logged for further analysis.
- 1.1.1.3** The soil mobility of the test site is determined by hammer impact test. The impacts conducted consecutively give the Point Source Response (PSR) at individual setback locations. LSR is calculated from numerical integration of the PSR along the length of the train for each individual 1/3-octave band.
- 1.1.1.4** FDL is determined by subtracting train induced vibration by LSR in logarithmic scale according to the equation below (reference: U.S. Department of Transportation “Transit Noise and Vibration Impact Assessment Manual”, 2018):

$$\mathbf{FDL}(f) = L_v(f, x, y, z) - \mathbf{LSR}(f, x, y, z)$$

where

- FDL**( $f$ ) : FDL in dB re 1 lb/in<sup>0.5</sup>, as a function of frequency  $f$ . FDL depends on the geology and train operating conditions.
- $L_v(f, x, y, z)$  : Vibration level at ground surface outside building structure in dB re 1  $\mu$ in/s, as a function of vibration frequency  $f$  and the sensor coordinate  $x, y, z$ .
- LSR**( $f, x, y, z$ ) : LSR from track to ground in dB, re 1  $\mu$ in/s/(lb/in<sup>0.5</sup>), as a function of vibration frequency  $f$  and the sensor coordinate  $x, y, z$ .

## 1.2 Train Types Measured

- 1.2.1.1** FDL measurements were only conducted for TCL. The current TCL train fleet comprises both the Adtranz-CAF trains and the K-stock trains. A test train of each train types was arranged for the FDL measurements.

## 1.3 Measurement Location and Procedure

- 1.3.1.1** The FDL measurements were conducted at a ballast section of the test track of Siu Ho Wan Depot (SHD) as shown in **Annex Figure 4.7.1**. Photos of setback and hammer impact test

locations are given in **Annex 4.7.1**. The FDL measurements comprises train passby vibration measurement and LSR measurement by hammer impact test at the same locations.

- 1.3.1.2** The train speeds at 30km/h, 40km/h and 60km/h were tested. For each train type, a test train was arranged to pass the track section at constant speed as far as practicable.
- 1.3.1.3** The vibration levels under rails, on sleeper, and at various setback distances at 5m, 15.5m, 20.5m, 30.5m and 40.5m were measured simultaneously by accelerometers.
- 1.3.1.4** Hammer impact test was conducted at 3 impact points along track alignment with the same setback locations of accelerometers for determining the soil mobility of the test site.
- 1.3.1.5** Rail roughness condition at the test site was taken record using a Corrugation Analysis Trolley (CAT). Rail roughness measurement was conducted in accordance with BS EN 15610: 2019 “*Railway applications. Acoustics. Rail and wheel roughness measurement related to noise generation*” over a track section of 200m at both rails.

## 1.4 Testing Conditions of Test Trains and Track

- 1.4.1.1** The test trains were controlled at constant speed specified when passing the measurement location. At least 3 – 5 runs were conducted for each train speed.
- 1.4.1.2** The timing of each test train passby was controlled to avoid overlapping with operational train passbys along AEL and TCL (Note: The operational tracks in both eastbound and westbound directions near the measurement location are shared by AEL and TCL, and are located at approximately 22m and 26m respectively from the test track inside SHD).
- 1.4.1.3** Wheels are preferably to be in normal operation conditions, without audible wheel flats or any other unusual noise associated with the running of the test trains. During train passby vibration measurement of Adtranz-CAF test train, wheel flat noise from one of the wheelsets was noted, hence the FDL result of Adtranz-CAF test train represented that of a slightly deteriorated wheel condition, which adds conservativeness to groundborne noise prediction.
- 1.4.1.4** The rails of the test section were continuously welded. The measurement locations were at least 50m away from any rail expansion joints or insulation joints, where any vibration impact induced by the joints should be minimized.
- 1.4.1.5** The rails should not have corrugation or fresh lateral grinding groove. A visual check was conducted prior to the measurement to verify the rail condition. Rail roughness measurement was conducted to keep record of the rail surface conditions.

## 1.5 Data Analysis

- 1.5.1.1** PSR from hammer impact point at track to accelerometer locations is determined by adopting the standard signal-processing techniques of frequency response function of the measured groundborne vibration velocities reference to the excitation force, averaged for 5 to 10 hammer impacts.

- 1.5.1.2** LSR is then evaluated by interpolation of the measured PSR and numerical integration along the train length.

$$\mathbf{LSR}(s, d, f) = 10 \log \left\{ \int_{-\frac{L}{2}}^{\frac{L}{2}} \left[ 10^{\mathbf{PSR}(\sqrt{d^2+s^2+y^2}, f)/20} \right]^2 dy \right\}$$

where  $s$ ,  $d$  and  $L$  represents the perpendicular setback distance, the depth of track level and the train length respectively.

- 1.5.1.3** FDL for each train type is determined by subtracting the LSR from the measured train passby vibration levels of the respective test train. The average values and standard deviations are derived from the obtained FDL at various setback locations.

## **1.6 FDL Measurement Results**

- 1.6.1.1** The FDL measurement results with averaged spectra and the averaged spectra plus two standard deviations of the FDL results at train speed 60km/h are presented in **Annex 4.7.2**.

## Annex Figure





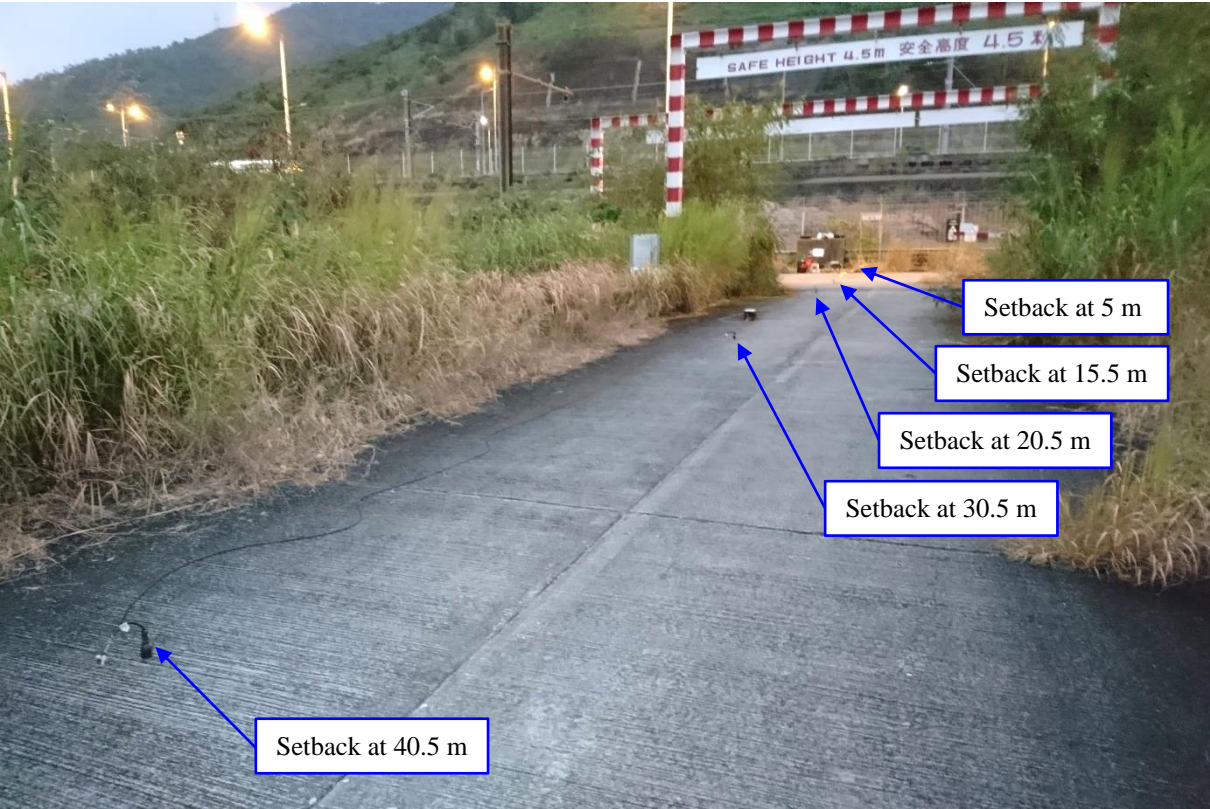


## Annex 4.7.1

Photos of setback and  
hammer impact test location

Photos of Setback and Hammer Impact Test Locations

a) Photo of the Setback Locations at SHD



b) Photo of the Impact Hammer Setup at SHD Test Track



## Annex 4.7.2

### FDL measurement result

**Force Density Level**

Force Density Level Results of TCL Adtranz-CAF and K-stock Trains

