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NOISE AND VIBRATION CONTROL AT THE NEW KL SENTRAL MAIN STATION DEVELOPMENT

Tim M Marks, Marshall Day Acoustics, 6 Gipps Street, Collingwood, Victoria 3103, Australia
Telephone (613) 94161855, Fax (613) 9416 1231
e-mail: timmarks@marshallday.com.au

ABSTRACT

Noise and vibration from three train types were assessed to determine their impact upon occupied areas of the new KL Sentral railway project in Kuala Lumpur, Malaysia. Diesel goods, diesel InterCity passenger and electric commuter trains were all considered. The primary goal was to accurately determine the coupling loss from the ground to the building column caps at deck level.

1. INTRODUCTION

The KL Sentral main station is a major multi level development with an impressive form and a grand facade. Located on a deck approximately 190m x 330m in plan, the four levels of the station occupy an area approximately 150m by 200m. The station is located between a condominium precinct to the south-west, an auditorium to the north-east and a hotel precinct to the north-west.

The arrangement of the station is Level 1 (Deck): departure hall, baggage claim, operational control centre and various administration offices; Level 2: main concourse, retail, ticket hall, baggage, storage and baggage claim; Level 3: VIP lounge, assorted retail and first class lounge; Level 4: rail company offices, retail and speculative offices.

Within the 200,000m^3 main hall and concourse of the station, a light rail service (LRT) acts as a transport node enabling connection of the elevated LRT to the station for access to inter-city and local commuter trains.

Beneath the station there will be 21 railway lines with four commuter tracks, two through tracks for diesel goods trains and two tracks for diesel InterCity passenger trains . The electric commuter trains, used for local rail services within the Kuala Lumpur area, generally consist of an electric motor unit (EMU) and two or three carriages.

2. VIBRATION SURVEY

Separate vibration measurements were conducted on goods, inter-city and commuter trains to establish the vibration levels produced by these trains when travelling on different existing tracks, rail types, sleepers and at turnouts. The new tracks are continuous rail.

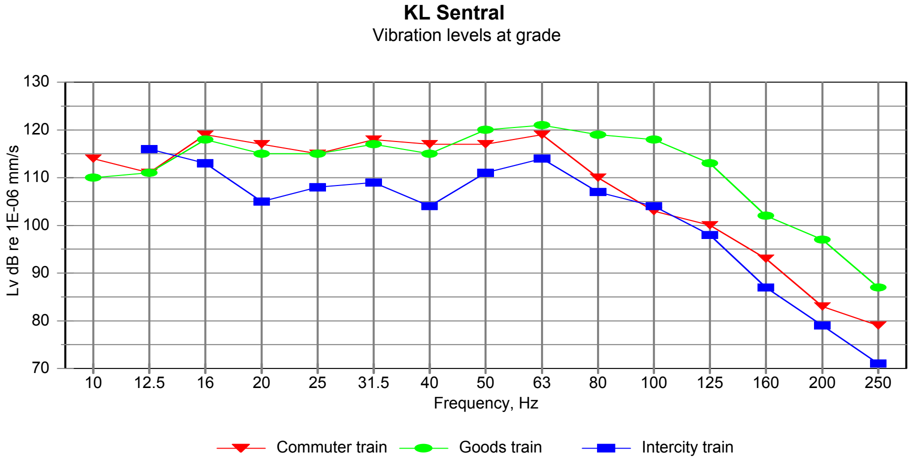
At all locations, measurements were conducted at a distance of 4m-7m from the nearest track at grade and simultaneously on the cap of the nearest column adjacent to the ground measurement position and the track.

The linear vibration measurements (2-1kHz) were carried out simultaneously at two positions using a measurement system comprising accelerometers, FFT analysers, digital tape recorders and calibration equipment. The vibration levels from each pass-by were recorded on DAT tape.

All measurements were then subsequently analysed to provide a third octave band frequency spectrum for each pass-by. The analysis was undertaken using the maximum hold function, whereby each third octave band represents the maximum RMS level occurring within that band during the pass-by.

3. MEASURED VIBRATION LEVELS

The results of these measurements are summarised in Figure 1 which shows the maximum values less 3dB for each train type at grade. This -3dB provides the 90% confidence limits of a typical spectrum used for the subsequent analysis.



The project performance specification sets the criteria for ground-borne vibration within the station as less than the curve specified in ANSI Standard S3.29/1983 (vertical axis). For critical areas such as the VIP lounge, the maximum acceptable curve was 1.4 (0.14mm/s in the range 100-250 Hz).

The ground attenuation relationship used to correct for distance was 12 log d_1/d_2 where d_1 and d_2 are relative distances in metres. The loss factor is from Ref [1] for dry sand.

To account for the various speeds of the different trains, the correction factor used was 17 log (v_1/v_2), where v_1 and v_2 are the relative speeds of the train. This relationship corresponds to the magnitude of the change due to speed as given by Ref [2].

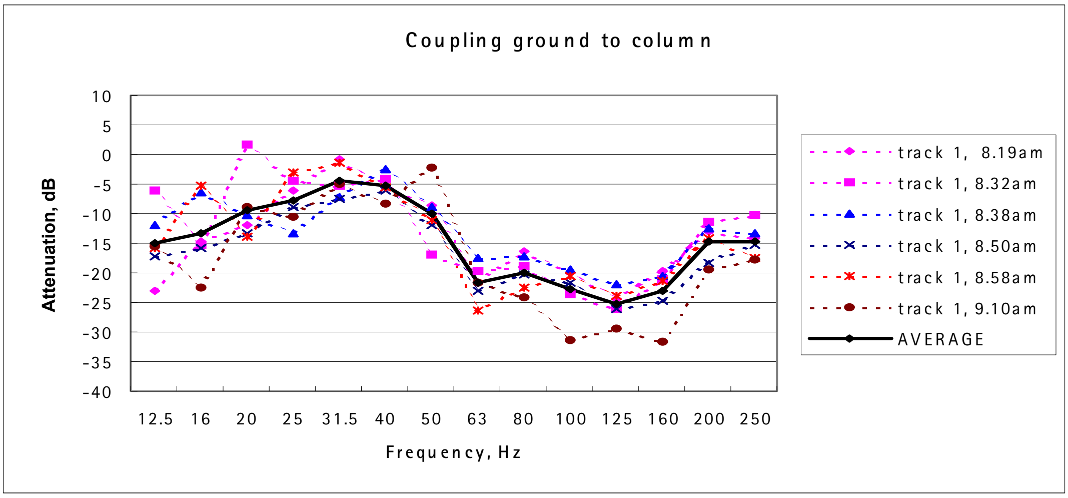
In this project, the design speed $v_{1,}$ was 50km/hr. The overall vibration levels after normalisation for distance and speed were remarkably consistent. The standard deviations ranged between 2-4dB. A standard deviation of 4dB may be regarded as typical. The results were based on the track in its existing condition, that is, with surface discontinuities and timber sleepers.

The conservative approach was to assume the ‘worst-case’ measured spectrum for design purposes throughout the site. No adjustments were made to the measured values to account for differences between discontinuous and continuously welded rail, or concrete sleepers (For details see Ref [6]).

4. COUPLING LOSS

The nature of the coupling between the ground and the structure was unknown. Ref [2] presents the coupling loss for several foundation types, namely: slab on grade, spread footings, piles in earth and piles on rock. At KL Sentral we had 8m piles into soft earth. Ref [2] gives empirical curves taken from Ref [3], but the KL Sentral project gave us the opportunity to compare the at grade and on column vibration levels for the same event. This was because the new structure was built around existing rail lines, and we could measure on the column caps immediately adjacent to these lines.

The attenuation given by Ref [3] for large masonry buildings on piles is from –5dB at 4Hz to –15dB at 250Hz. For the commuter trains at KL Sentral , the attenuation from ground to column cap (5m high above ground) is presented in Figure 2.



5. BUILDING VIBRATION

Building floors, walls and ceilings are subject to significant amplification of vibration relative to the foundation vibrations. The amplification of walls, ceiling and floors is difficult to predict but is typically in the range of 5-15dB, over a frequency range of 16-80Hz (Ref [2]).

As rail vibration passes upwards from floor to floor in the station there will be a reduction in the vibration level. In multi-storey buildings, the common value for the attenuation of vibration from floor to floor is approximately 3dB. Data presented in Ref [4] shows approximately 1dB floor to floor attenuation in the upper floor regions at low frequency and more than 3dB attenuation per floor at lower floors.

6. VIBRATION CONTROL MEASURES

Vibration generated by trains passing under the station propagates through the ground or intervening soil to the building structure, where it can be felt or heard by people in the station as a rumbling sound. The problem is commonly addressed by the installation of ballast mat or undersleeper pads.

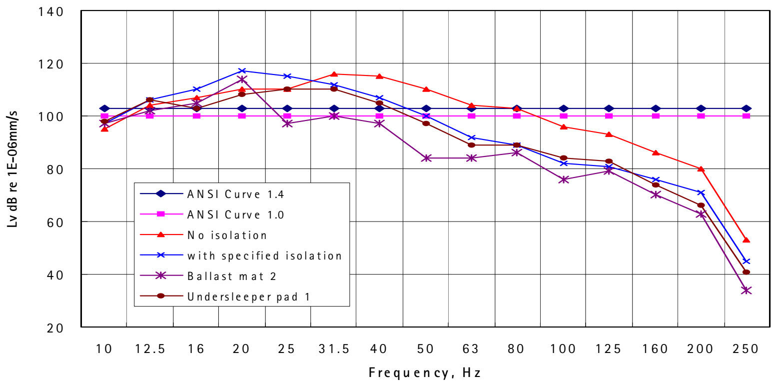
Ballast mat and undersleeper pads are well known products used for decoupling rail and associated elements from the ground to prevent the transmission of vibration. In most circumstances, ballast mats must be supported by a concrete sub-structure to ensure optimum effectiveness. Data from several manufacturers and test results conducted on actual installations have resulted in a wide range of information being available in relation to the insertion loss performance of these products (Ref [5]).

Undersleeper pads do not require a special concrete base and are fixed to individual sleepers, rather than being laid down beneath the track. At low frequencies, around 16-30Hz, vibration amplification due to material internal resonance is common in ballast mats and undersleeper pads. The degree of amplification depends on the stiffness and the dynamic loss factor of the specific product, but it can be as high as 8-10dB at 20Hz.

At KL Sentral, the structure-borne noise level criteria were in compliance, even with no vibration isolation treatments. Hence the introduction of any treatment (ballast mat or undersleeper pads) will further lower radiated noise levels, and compliance was assured.

The selection of the most appropriate isolator was ultimately controlled solely by vibration considerations. Except for the VIP lounge, either the ballast mat with the concrete substrate or the undersleeper met the project vibration criteria in all areas. The expected vibration in this area of the station is presented in Figure 3.

Figure 3 - VIP Lounge Vibration



7. CONCLUSIONS

We decided that a ballast mat or undersleeper pad isolation system with at least 10dB insertion loss at 20-25Hz would be adequate to control vibration to most sensitive areas.

As the more effective of the two ballast mat systems considered required a concrete base to achieve the performance, the undersleeper pad system was chosen because it was considered the most cost-effective option.

Vibration can enter the station via other paths and not only through shear walls and structural columns. Vibration in adjacent, connected, buildings which have inadequate isolation from rail track vibration, may propagate into the station. In particular physical or structural connections by building elements or services such as cables, piping or ductwork can transmit significant vibration.

Much care needs to be taken in this regard.

8. REFERENCES

[1] Propagation of Ground Vibration; A Review by T G Gutowski and C L Dym, JSV 1976, [2] P. Nelson, Transportation Noise Reference Book, Butterworth (1987), [3] Nelson, G and Saurenman, T (US D of T Report UNTA/06/0049/03/4), [4] Ishii and Tachibana (Reprint L10, JASA meeting Honolulu 1978), [5] Getzner Werkstoffe, technical literature, [6] Office for Research and Experiments for the International Union of Railways (ORE), (1986).