RELATIONSHIP BETWEEN RAILWAY GROUND-BORNE VIBRATION PROPAGATION AND TRACK ELEVATION - A FIELD STUDY

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1 Introduction

While railways have operated for centuries it has only been in modern history that technological advancements in instrumentation have permitted collection of railway ground-borne vibration data [1]; however, even with detailed measurement capabilities published data is relatively scarce despite industry demand in the land-use planning process for railway vibration assessments.

The disconnect between capability and existence of data is presumably attributed to a combination of both the high cost to complete field studies, and the large variations in measurements between field locations. To address the above challenges, the author of this paper has organized independent field tests under common field parameters and presented the data as a field study.

2 Methodology

2.1 FCM-RAC measurement procedure

Within Canada there are no federal or provincial guidelines for the assessment of railway induced ground-borne vibration [2]; however, the approach suggested jointly by the Federation of Canadian Municipalities (FCM) and the Railway Association of Canada (RAC) outlines specific measurement parameters to be used to assess the impact of railway ground-borne vibration on residential and sensitive commercial developments [3].

2.2 Study parameter criteria

To reduce the number of variables influencing results, the following criteria was imposed in order to provide reasonable comparisons between field locations:

- Freight train pass-bys were the only railway source assessed.
- Measurements were only considered in soil medium to remove the effects of vibration energy coupling losses between soil and other surface mediums i.e. asphalt or concrete.
- Train speeds needed to be greater than 50 kph. Speeds were estimated on site.
- Only surface track conditions were included.
- Tracks conditions needed to be continuously welded on ballast and tie construction.
- Effects of jointed rail or at source vibration mitigation controls, such as ballast mats or resilient tie fasteners, were excluded from this study.

Other influencing factors such as soil conditions, wheel/rail roughness and wheel flat conditions are acknowledged to influence vibration measurements, but were not documented in this study.

2.3 Track elevation groups

Field tests satisfying the above study parameter criteria were then grouped under the following track elevation configurations relative to the measurement locations:

- At Grade
- Embankments
- Landscape or Retaining Cuts

Tracks at grade represent source elevations equal to measurement locations while tracks on embankments represent source elevations raised relative to measurement locations. Elevated structures, which differ from embankments, are not considered in this paper. Tracks with landscape or retaining cuts represent source elevations below measurement locations.

2.4 FTA guidance

To provide a frame of reference to the results of the field study, the U.S. Federal Transit Administration (FTA) manual [4] was considered. The manual provides a reference "base curve" in RMS velocity for predicting the ground-borne vibration propagation from freight trains at various distances from tracks.

Further guidance is provided with "adjustment factors" for various parameters that may increase or decrease vibration propagation from the tracks. One adjustment factor is for site specific geological conditions resulting in "efficient propagation" of ground-borne vibration such as shallow bedrock or stiff clay soils.

3 Results

A total of 18 field locations were included in this study with measurements at various setback distances from railway track centerlines. Since multiple train pass-bys were recorded during each field test, only the maximum overall RMS vibration velocity for each setback distance was included (See Figure 1). The FCM-RAC guideline limit and the FTA base curve with and without the "efficient propagation" adjustment for freight pass-bys is also included. The shaded regions in the graph correspond to the approximate range of the measurement data sets.

As shown in Figure 1, field tests from cut track locations produced the highest overall vibration velocities while embankment tracks generally produced the lowest.

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Field tests for at grade locations are somewhere in between these two.

In the context of suggested limits from the FCM-RAC, most of the cut track data lies above the limit implying vibration mitigation is warranted for future developments at those sites. The embankment track locations, on the other hand, were consistently below the guideline limit meaning vibration mitigation would not be warranted.

In reference to the FTA freight base curve, the "at grade" locations are generally below or follow the reference curve with few exceptions. This result supports the use of the base curve as a reasonable approximation of freight traffic in at grade track settings and a conservative estimate for embankment track settings; however, cut track locations are consistently above the reference curve suggesting that adjustment factors may need to be applied for better approximation.

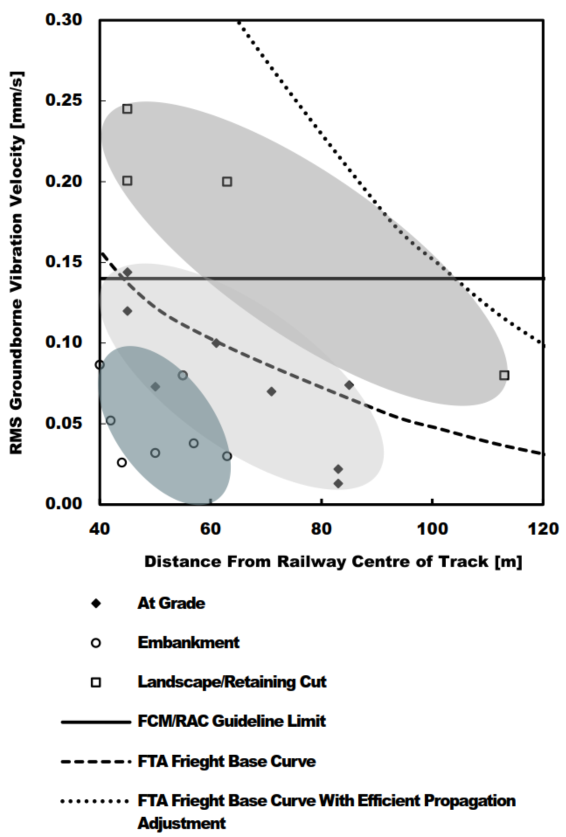

Figure 1: Results for various track elevation configurations.

For context, the efficient propagation adjustment factor significantly over estimated all results but does represent an extreme worst case upper limit for the geological effects on vibration propagation.

4 Discussion

It is not recommended to simply conclude from the data in Figure 1 that cut track locations produce overall higher vibration velocities due to track elevation alone. As noted in the FTA manual, the proximity of the bedrock layer to the surface track can significant increase vibration propagation magnitude and distance (See Figure 2 for the concept).

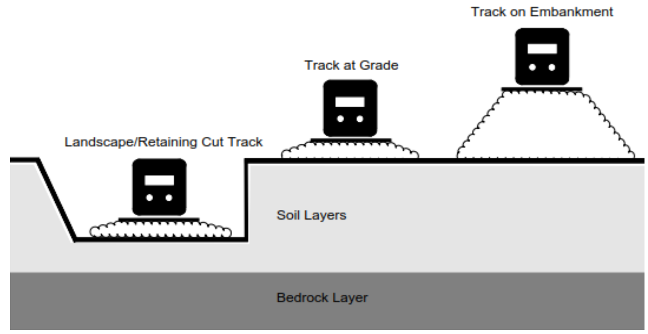

Figure 2: Concept of track elevation comparison to bedrock layer

Therefore the data shown in Figure 1 from at grade/embankment track settings may have been from locations with deep bedrock layers compared to cut track locations with shallow bedrock layers; however, embankment track data presented in Figure 1 does support a previous study [5] which concluded increasing embankment height produced reduced vibration magnitudes at locations adjacent to the railway. This suggests embankment track configurations provide additional vibration attenuation from the material used to construct the embankment.

5 Conclusion and next steps

More measurement data is needed before a relationship between track elevation and ground-borne vibration propagation can be defined; however, data provided in this field study is promising and warrants additional research in this subject.

Further research should investigate the relationship of bedrock elevation in the context of the track configurations presented in this paper. Future field tests should also consider frequency specific data for understanding the influence of soil attenuation.

Acknowledgments

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References

[1] Katsiroumpas & Matthew. The Evolution of Environmental Ground Borne Vibration Measurement, Assessment and Reporting Over the Last 50 Years. Canadian Acoustics. Vol 44, No. 3, 2016.

[2] Matthew & Lightstone. Guidelines for New Development in Proximity to Railway Operations. Canadian Acoustics, Vol 43, No. 3, 2016.

[3] DIALOG & J.E. Coulter Associates Ltd. Guidelines for New Development in Proximity to Railway Operations, Prepared for The Federation of Canadian Municipalities and the Railway Association of Canada, May 2013.

[4] U.S. Department of Transportation, Federal Transit Administration, Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, May 2006.

[5] Wilson, Ihrig & Associates Inc, Handbook of Urban Rail Noise and Vibration Control, February 1982.