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Difference in levels of groundborne noise and vibrations between the T-1300 and MX-3000 metro trains in Oslo

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The introduction of the new MX 3000 metro trains in Oslo led to complaints about increased vibrations. Measurements of groundborne noise and vibrations in three sites during the transition period confirm that these spectra had indeed changed. The values measured at the three sites in question were as follows:
Site A: Vertical vibrations in two separate points on the ground outside the house
Site B: Vertical vibrations on a floor inside the house, groundborne noise in a bedroom
Site C: Vertical vibrations on the ground. In all the points there was a significant difference between the T-1300 and the MX 3000 trains. The difference in the weighted overall levels given as A-weighted sound level and vibrations given as weighted vibration velocity showed a clear increase in all cases. However, the spectra also exhibit a clear change in spectral content. The peak frequencies show a shift. The three cases clearly show that change of train type may introduce new sound and vibration problems in urban transport. These changes in perceived noise and vibration may not be obvious from the quoted noise and vibration data for new types of trains.

1 Introduction

Oslo has had a regular metro service since the 1960's. Many of the original "red" trains in slightly varying editions had been in service for 40 years when the new Siemens MX-3000 trains were introduced in 2006. The measurements of the noise and vibrations from the older types presented in this paper are from the T-1300 series, the last type of the "red" trains. Shortly after the introduction of the new MX 3000 trains complaints were heard about increased noise and vibrations from the new trains. Some measurements were made along lines where both types of metro trains were in use during the transition period. The main purpose of this paper is to show the potential consequences in terms of increased noise and vibrations, even though one of the intentions of introducing a new type of metro train was to achieve a reduced environmental impact on the surroundings of the line. Fortunately the airborne noise contribution from the new metro trains appears to be reduced [1,2].

Figure 1 MX 3000 train

Figure 2 – T1300 series metro train

Taken from Wikipedia

2 Measurement sites

There were three sites which have been designated A, B and C. The vibration levels shown are RMS velocities, averaged and weighted according to NS 8176 [3]. Sound levels are presented as A-weighted 1/3-octave levels measured with the time constant FAST. The terms inbound and outbound are customarily used for Oslo's metros and trams. Inbound simply means the direction toward the city centre, outbound means the direction away from the city centre. Measurements on all the sites were made due to inhabitants being annoyed by groundborne noise or vibrations from the metro lines.

2.1 Site A

Site A

Site A is a detached house on flat ground, 20 meters away from the outbound track, 24 meters away from the inbound track. The maximal vibration levels arise as the outbound tracks cross a track exchange. The measurements have been made in the vertical direction using an accelerometer mounted on the ground. Acceleration was measured in two points. The measured values were converted into weighted vibration velocities in 1/3-octave bands according to NS 8176 [3].

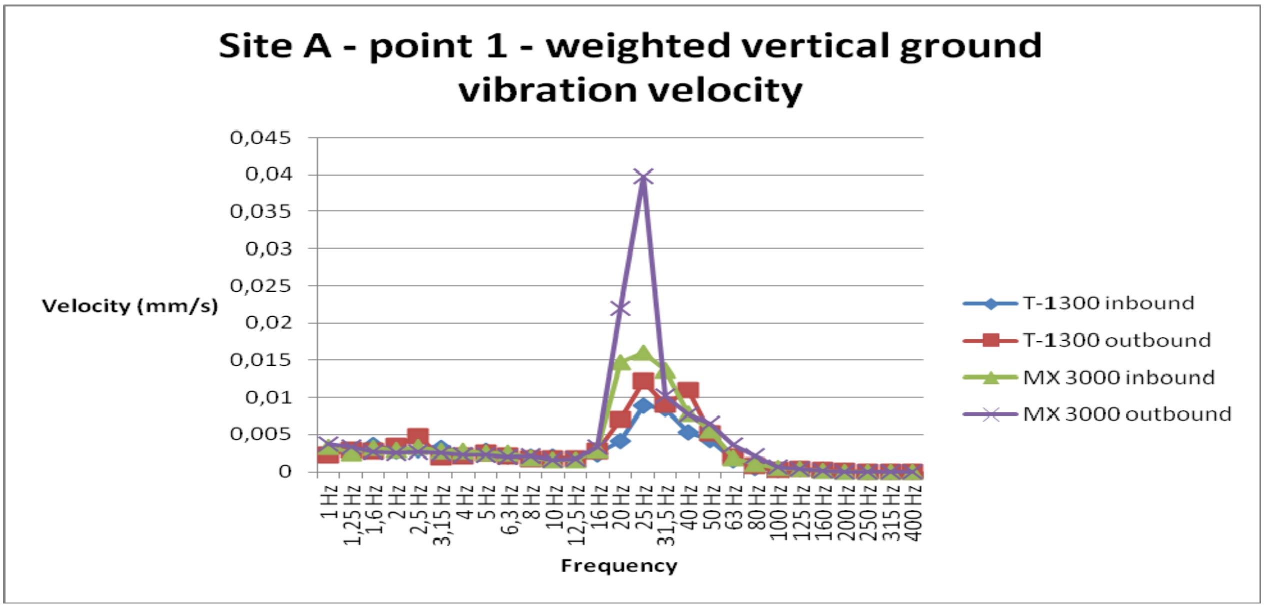

Figure 3 Site A point 1 vertical ground vibrations

Figure 3 shows the vibration spectrum from point 1 on site A. In this measurement a marked increase in vibration levels from outbound trains is clearly visible. In this case the highest levels occur at the same frequency, 25Hz. Thus it would be reasonable to assume that the same excitation mechanism is present. In this measurement point the change is an amplification of a similar phenomenon.

In the figure 4, a different point on the same site, a somewhat different picture emerges. The earlier T-1300 trains give the highest contribution to the vibration velocity at 40 Hz outbound, 31,5 Hz inbound. The recent MX-3000 trains give the highest vibration level at 25 Hz outbound, 20 Hz inbound. In addition to a higher vibration level, a downward shift of the dominant frequency can also be observed.

It should be noted that all the measured values at site A were made on the same day with the same accelerometers mounted in the same position. At that time, there was mixed traffic with both types of trains. So the explanation for the change should be sought in the dynamics of the trains or in the interaction between the train and the ground.

A track interchange is the suspected reason for the difference between outbound and inbound trains.

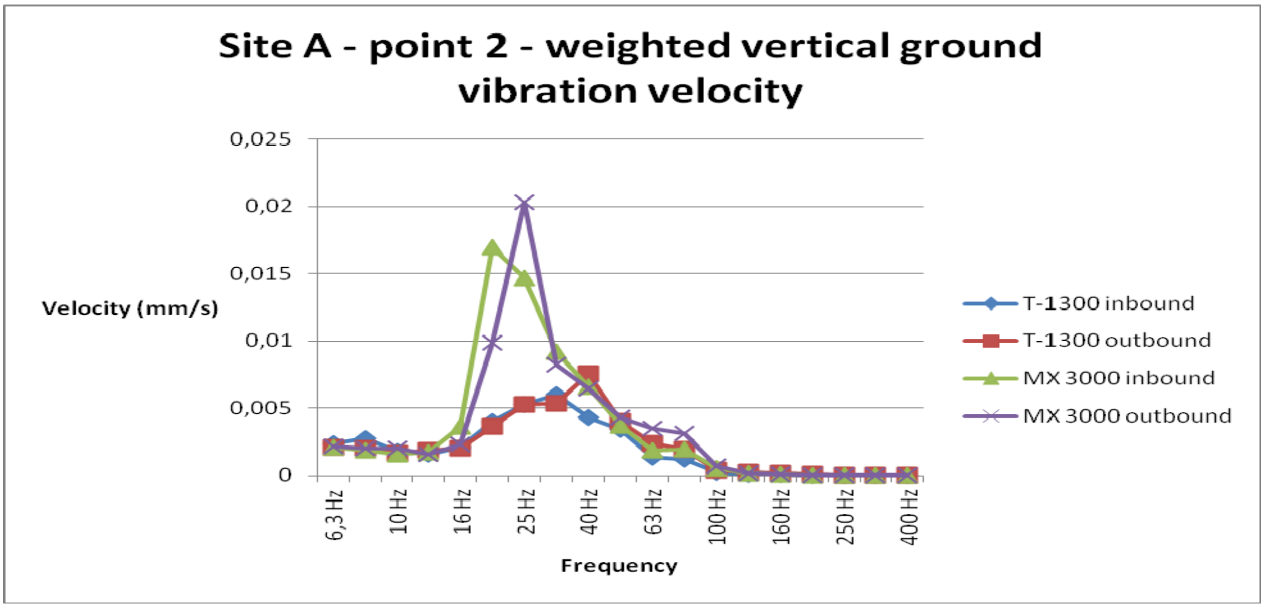

Figure 4 Site A point 2 vertical ground vibrations

2.2 Site B

Site B is a detached house situated 10 meters away from the inbound track, 14 meters away from the outbound track. It was a new house which was actually built on an insulated foundation due to the proximity to the metro line. There was a high noise barrier close to the metro line. In combination with a modern, well insulated house, this virtually eliminated airborne noise inside the house. The house had been designed to comply with applicable Norwegian regulations [4] that permit indoor maximal levels (L_{PAmax},FAST) of up to 45 dB from groundborne noise as long as the sound source is above ground. Figure 5 shows two peaks in the vibration spectrum, one at 16 Hz and one at 50-80 Hz. In this case it is no longer obvious that the MX-3000 gives a higher vibration level than the T-1300. The MX-3000 gives lower vibrations than T-1300 at 16 Hz, but higher at 50-80 Hz.

The groundborne noise measurements in figure 6 shows a slight increase in the noise level at 50 – 80 Hz from the MX-3000 as compared to the T-1300. For this site, there is clearly a change in the noise and vibration pattern from the new metro trains. For site B, this change in pattern is more important than the increase in overall level.

In this case residents perceived the noise and vibrations from the MX-3000 as more annoying than those from the T-1300.

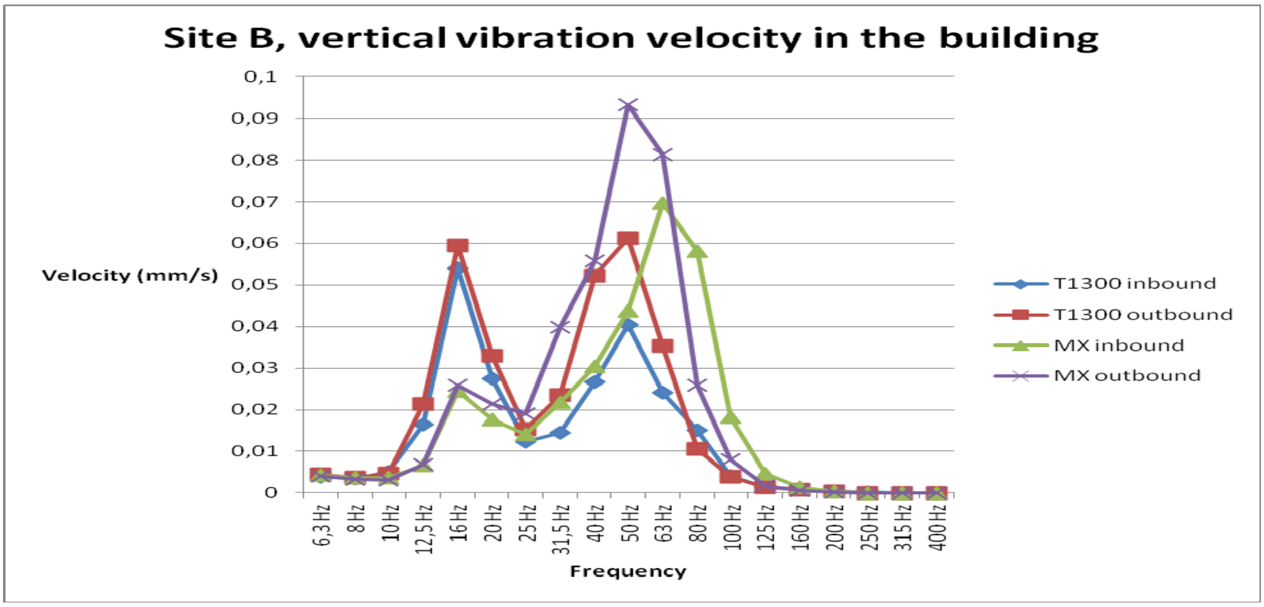

Figure 5, vertical vibrations on a floor in the building, site B

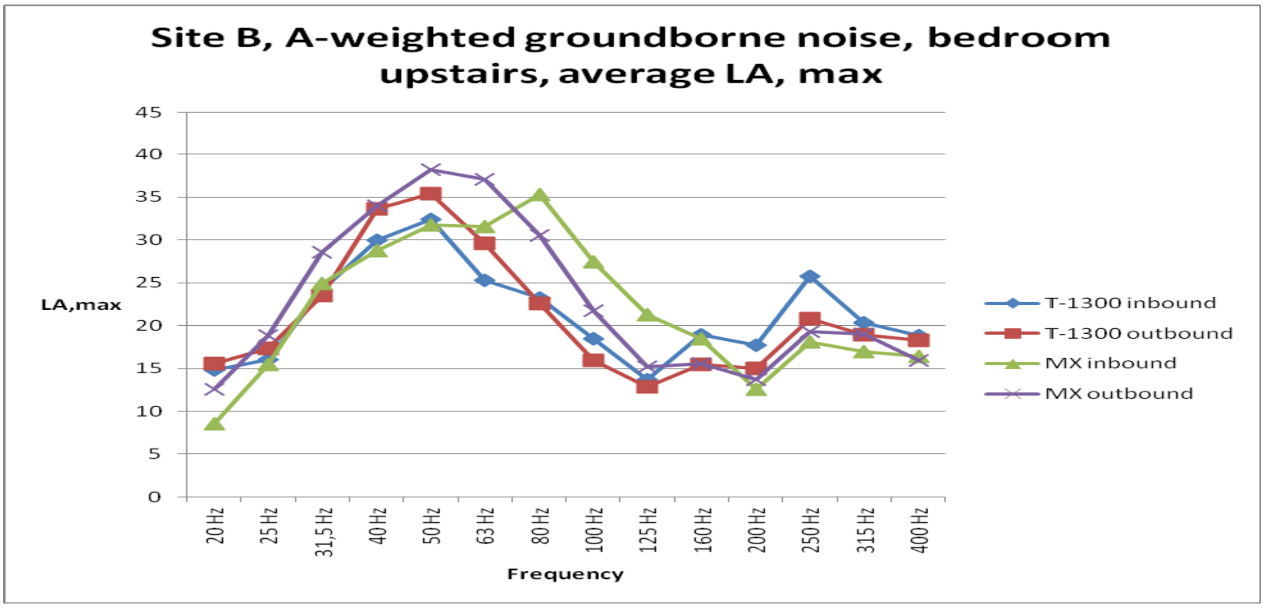

Figure 6, site B, groundborne noise in an upstairs bedroom.

2.3 Site C

Site C is a four-story multifamily block 25 meters away from the metro line. The vibration measurements were made on the ground outside the house. The measured values are shown in figure 7 below.

In this case, there are three spectrum peaks, at 16 Hz, 25 Hz and 63 Hz. The peak at 16 Hz is clearly lower with the new MX 3000 trains than with the older T 1300 type. At 25 Hz the picture is different; the inbound trains give more vibrations, it seems the difference is more due to some difference between the tracks than between the train types. The peak at 63 Hz only shows up with MX trains outbound.

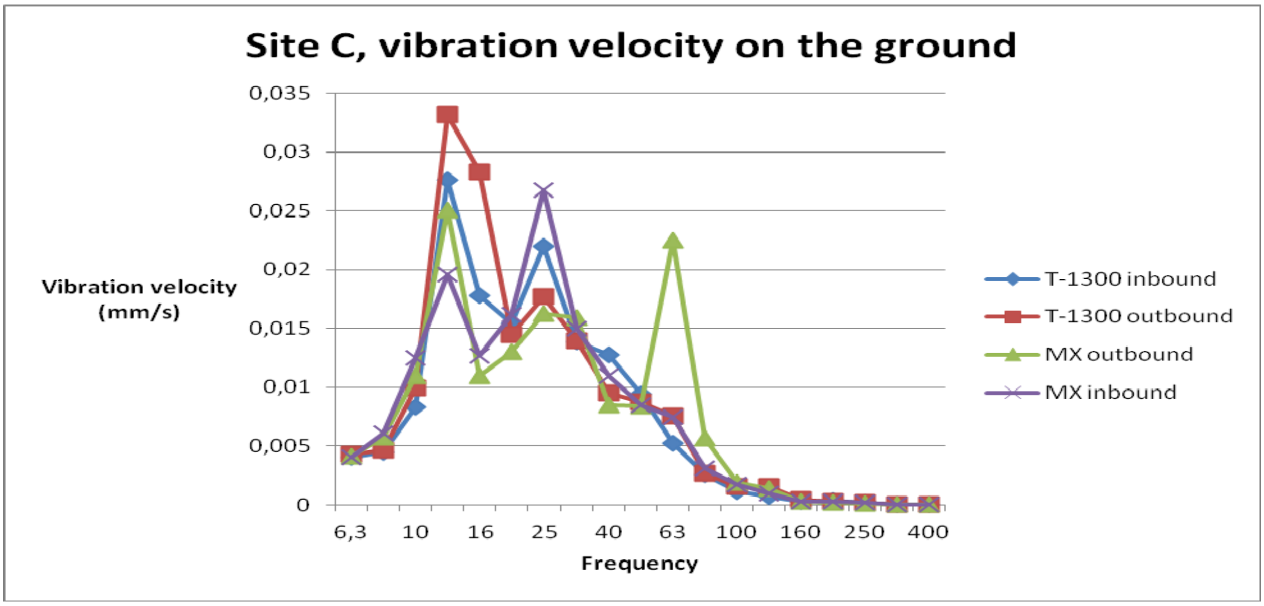

Figure 7 Vertical vibrations on the ground, site C

3 Discussion of results

The clearest result is that the new MX 3000 trains give a different spectrum of vibration and groundborne noise than the earlier T-1300 trains. It would seem that there are two or three distinct peaks in the spectrum. There are one or two peaks at 16 Hz to 25 Hz and a peak at 50 – 80 Hz.

At site A, there was clearly an increase in vibrations with the introduction of the MX 3000 trains. At site B, there was an increase at some frequencies and a reduction at other frequencies which significantly alters the perception of annoyance from vibrations. At site C, the MX 3000 clearly gives lower vibration levels at 16 Hz, there's a mixed picture at 25 Hz, and there's a marked increase in vibration levels from one of the tracks with the MX 3000 train as compared to the T 1300.

The only consistent result is that the MX 3000 trains give different patterns of vibrations and groundborne noise than the T1300 trains.

4 Further research

Urban railbound transport lines are often located very close to residences. Our results show that it is very difficult to predict the consequences for nearby residences when a change of train or tram type is considered. This situation needs to be improved. Railbound vehicles are a very energy efficient means of transport, and lack of space will force residences to be located close to transport lines.

This means that reliable methods to predict vibration transmission at very short distances will be required. A deeper understanding of how to predict vibrations from trains to the ground at the design stage seems to be important. Hopefully it will be possible to investigate the dynamic properties of the bogies and wheels of the MX 3000.

Another challenge that needs to be investigated further, is that the metro lines often run very close to residences. In these cases a traditional model of a vibration source, a transmission path and a receiver is not always applicable. A substantial number of measurements of vibration along three axes in several points on the ground, on the building foundation and on the floors or rooms in residences should be made. This could possibly provide a database of transmission into the building. Different types of ground conditions have different transmission properties, and so a train that gives modest vibrations in one city or on a test track could give more severe vibration problems at another site. The same applies for buildings. Different construction practices could give rise to different vibration problems.

5 Acknowledgements

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6 Conclusions

The transition from the old T1300 type trains to the new MX 3000 trains on Oslo's metro lines gave rise to a changed pattern of vibrations and groundborne noise. Further research into vibration generation and transmission is recommended.

References

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