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LOWER NOISE AND VIBRATION FROM CONCRETE TRACK-BEDS

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SUMMARY

Different methods for resilient support and isolation of rails are discussed, which can be used to reduce the noise and vibration generated by wheel-rail interaction and limit their transmission to the passengers and the environment. Methods used in the design and analysis of such systems are described. Applications for high-speed trains (Channel tunnel), metros and stations are illustrated.

1 INTRODUCTION

In the current construction of permanent way for railways, concrete track-beds are increasingly being used.

There are several engineering and operational reasons in favour of such construction:

- Although initial capital costs may be higher than for ballasted track, maintenance costs are usually reduced.
- Continuous track-bed can simplify the construction of elevated track.
- Since the track-bed depth is much reduced, height can be gained, which may be valuable in tunnels, at bridges and in stations. Height gain in tunnels is probably the most common reason for selecting such construction, since the consequent effects of a reduced tunnel bore on total costs can be very great.

However, wheel-rail generated noise and vibration from tracks with concrete track-beds are generally high when rigid rail fastenings are used. As well as increased direct airborne noise, structure-borne noise and vibration paths can be serious as regards neighbourhood environmental effects, and the noise level in enclosed areas such as tunnels can lead to difficulty in adequately isolating vehicle interiors.

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In recent years, attention has been given to means to reduce noise generation at the wheel-rail interface, noise radiation from the rails, and vibration transmission into the surroundings, by mounting the rail and track-bed resiliently. Various means to do this, and the methods used in analysing or applying them, will be discussed.

(Possibilities for reduced radiation by novel wheel designs, or secondary isolation by barriers or vehicle interior or exterior acoustic treatments, will not be covered here).

2 REQUIREMENTS FOR NOISE REDUCTION

When approaching the acoustic/vibration design of a new track, or a retro-fitting treatment, we have to assess:

- the type of traffic (high-speed, metro, freight, ...)
- the location (in station, tunnel, ...)
- the noise and vibration reduction needs (interior passenger environment only, rail users and staff at stations, non-users in adjacent properties, ...)
- the length of track (and consequences for project costs) access for maintenance and life-cycle cost aspects.

Based on these parameters, as well as the basic engineering of the permanent way, loads, &c, we can determine the most effective treatment.

For a tunnel on a high-speed line, such as the Channel tunnel, only passenger environment is of concern, hence acoustic radiation must be reduced but vibration output to the surroundings is of little consequence. (Certain aspects of ground stability may need to be checked).

In stations, in tunnels such as metro systems or other track adjacent to or beneath buildings, reducing vibration transmission and structure-borne noise can be of equal or greater importance.

3 METHODS FOR TRACK-BED SUPPORT

3.1 Flexible Ballastless Track

The conventional approach uses discrete concrete sleepers, separated from the continuous concrete track-bed by elastomeric pads ('boots') - see Figure 1.

Correct specification of the pad can give a reduction of noise emission of 10 dBA. The frequency of the first wheel-rail bending resonance is reduced from about 100 Hz to about 45 Hz, and static loads are also better distributed (see Figure 2).

Such a method is appropriate where rail-radiated noise must be reduced, but vibration isolation is of no concern, as for example in the Channel tunnel (see Figure 3).

3.2 'DS-ISO-RAIL'

This system initially appears similar to the use of discrete sleepers with boots, but has alternating flexible and stiff pads (see Figure 4).

The stiff supports reduce the amplitude and wavelength of rail deflections, whereas the flexible, highly-damped, supports introduce damping and reduce amplitudes.

A low and less-disturbing first resonance frequency of about 45 Hz is achieved, similarly to conventional flexible ballastless track, but dynamic rail displacements are lower. This gives a further reduction of emitted noise of about 3 dBA. The reduced static deflections also reduce the required tractive effort and rail wear, giving an energy saving of about 5%: the system may be termed 'environment-friendly'.

This system was first introduced on the Antwerp pre-metro tracks (Blancefloerlaan).

3.3 Floating Track-bed

Placing a continuous isolation layer under the full track-bed is a standard method to obtain vibration isolation of the track from its surroundings. When combined with a system such as DS-ISO-RAIL, it gives optimum vibration isolation (see Figure 5).

When designing such a combined system, attention must be paid to avoiding coincidences of resonance of the primary (rail) and secondary (track-bed) isolation.

This combination of floating track-bed and iso-rail is planned for the new Brussels Midi station, where a maximum noise level of 60 dBA is allowed in the station concourse, which lies under the tracks. It is already in use in certain parts of the Antwerp pre-metro.

4 COMPUTER-AIDED ANALYSIS AND TESTING TECHNIQUES

4.1 Conventional Methods

The rail-pad-sleeper-bed-ground system can be considered as a series of springs, and so combined with the (dynamic) mass of the wheel-set into a single-degree-of-freedom system. This is then amenable to calculation 'by hand', giving simple, basic results. Simple test methods can also be applied on prototypes or test track, to determine actual material properties and validate calculations.

4.2 Multi-degree-of-freedom Systems

For more complex cases, multi-degree-of-freedom (mdof) models must be used. For example, for the iso-rail system the correct stiffnesses must be determined for the stiff and flexible supports.

Finite element (FE) analysis then offers a proven technique for predictive modelling. Both resonant and forced response behaviour can be calculated (see Figure 6). The length of rail which has significant vibration amplitude due to the passage of one wheel-set can be shown, and hence the possible amplification of vibrations due to the positions of the different wheel-sets passing at a particular speed. The model illustrated was used to show that the length of rail vibrating (and hence radiating noise) was reduced compared to other support systems, and also that there was little reinforcement of the response by adjacent wheel-sets.

Mdof measurements can also be used: experimental modal analysis enables correlation and validation of FE predictions (see Figure 7); multiple (parallel) time histories for the same test event enable interaction between wheel-sets and similar effects to be checked (see Figure 8). Although such methods require more complex and costly test equipment, they repay this investment with enhanced knowledge of the track dynamics.

4.3 Noise Modelling

Numerical techniques are now available which enable detailed studies of noise radiation from wheels, rails and other items, reverberation in tunnels, and vehicle interior noise fields resulting from structure-borne and airborne noise paths. Both boundary element and finite element models may be used (usually, for exterior and interior fields respectively). Since these models are usually related to the design of vehicles and components (engines, wheels, ...) they will not be discussed further here (eg, see Reference 1).

5 CONCLUSIONS

Continuous concrete track-bed offers several functional and cost advantages in many permanent way locations.

A major disadvantage is that noise and vibration levels can be substantially higher than for conventional ballasted track. Proper attention has to be given to this at the design stage, and the noise control engineer has a more difficult task.

Technical solutions exist which enable the generated and emitted wheel-rail noise and the transmitted vibrations to be minimised. Using appropriate methods for assessment, design and analysis, an effective solution can be chosen for each case.

As national and local regulations are tightened and the demand for lower environmental noise levels increases, there will be mounting pressure on rail and metro operators, from the public as well as their own customers, to use the engineering techniques described here to improve the human environment.

REFERENCES

1 J-P Coyette, K R Fyfe & C F McCulloch 'Modelling interior and exterior acoustics using finite element and boundary element methods' IMechE Autotech congress C399/21 Birmingham, UK, 1989

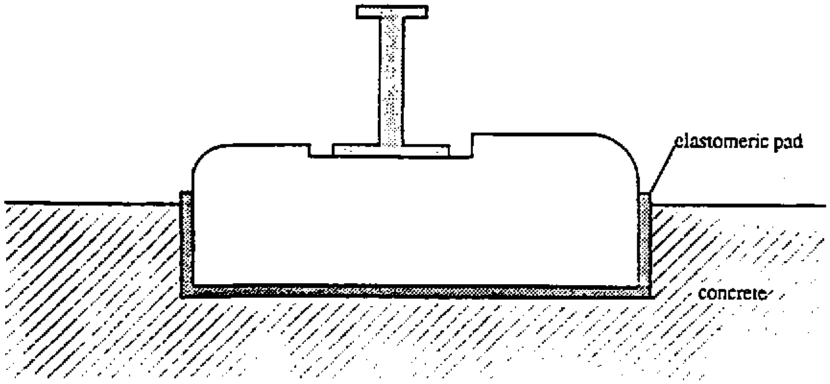

Figure 1: Flexible ballastless track

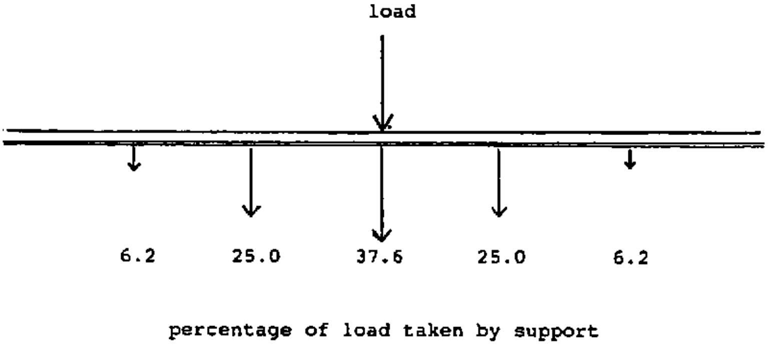

Figure 2: Typical axle load distribution with resilient support

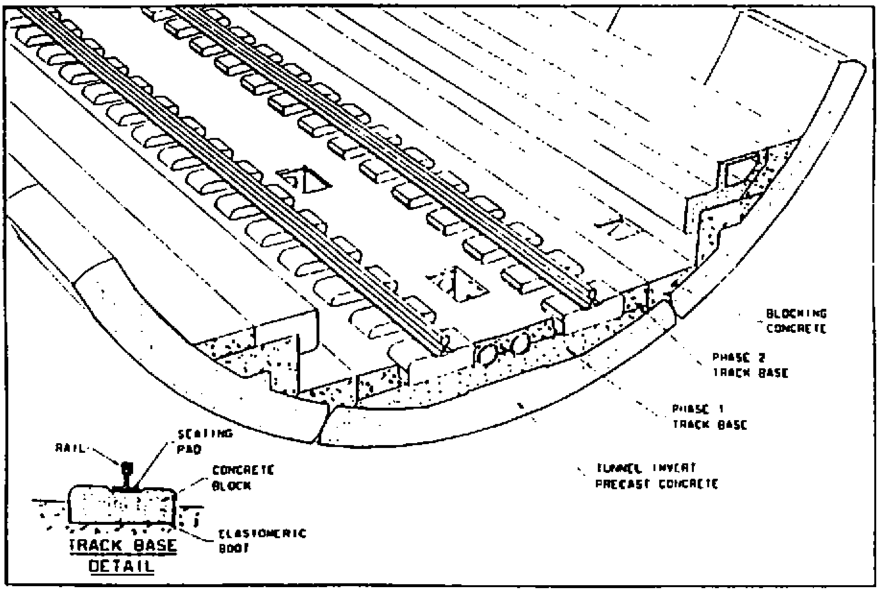

Figure 3: General arrangement for resilient supports in tunnel

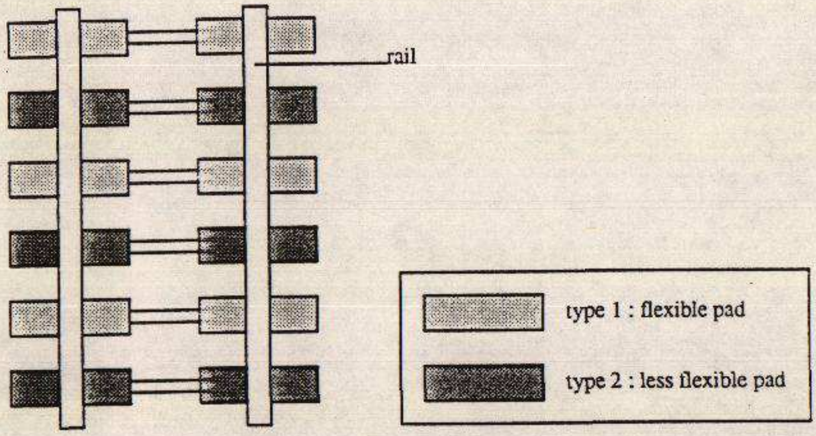

Figure 4: Arrangement of DS-ISO-RAIL

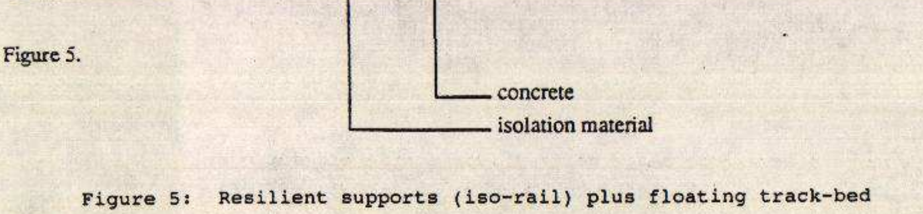

Figure 5.

Figure 5: Resilient supports (iso-rail) plus floating track-bed

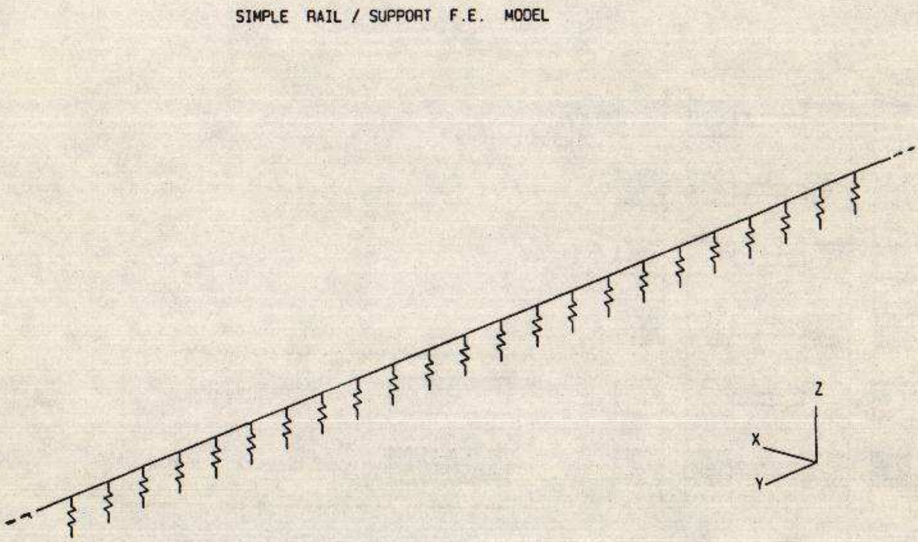

Figure 6(a): Finite element model of rail and supports

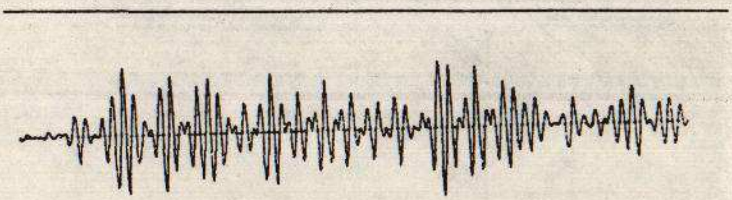

Figure 6(b): Mode shape derived from finite element model
(ie, waves along length of rail: 289 Hz)

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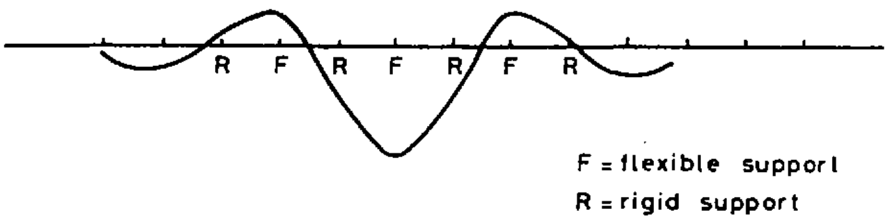

Figure 7: Experimentally-derived mode shape (303 Hz)

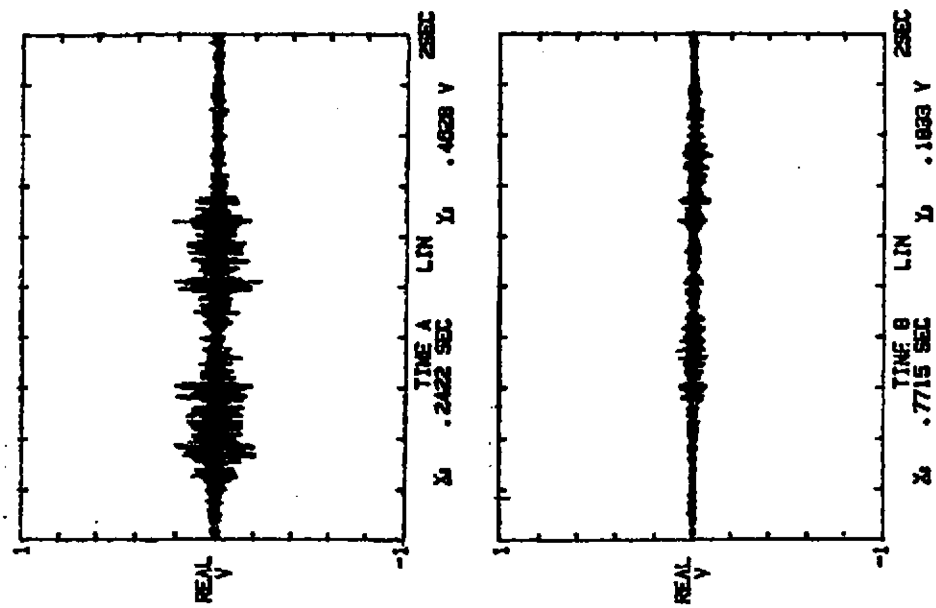

Figure 8: Acceleration time signals at flexible/rigid supports (left/right): vibrations are localised, succeeding wheel-sets do not cause reinforcement

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