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Publisher's version / Version de l'éditeur:

Solplan Review, May 98, pp. 18-19, 2001-05-01

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NRCC-44987

A version of this paper is published in / Une version de ce document se trouve dans :
Solplan Review, no. 98, May 2001, pp. 18-19

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Traffic Vibrations in Houses

by Osama Hunaidi and Jim Gallagher

Vibrations induced in buildings by road traffic are a common concern in cities in Canada and worldwide. Vehicle contact with irregularities in the road surface (e.g., potholes, cracks and uneven manhole covers) induces dynamic loads on the pavement. These loads generate stress waves, which propagate in the soil, eventually reaching the foundations of adjacent buildings and causing them to vibrate. Traffic vibrations are mainly caused by heavy vehicles such as buses and trucks. Passenger cars and light trucks rarely induce perceptible vibrations.

When a bus or a truck strikes an irregularity in the road surface, it generates an impact load and an oscillating load due to the subsequent "axle hop" of the vehicle. The impact load generates ground vibrations that are predominant at the natural vibration frequencies of the soil whereas the axle hop generates vibrations at the hop frequency (a characteristic of the vehicle's suspension system). If the natural frequencies of the soil coincide with any of the natural frequencies of the building structure or its components, resonance occurs and vibrations will be amplified.

Factors Influencing Vibration Level and Frequency

The predominant frequencies and amplitude of the vibrations depend on many interdependent factors including the condition of the road; vehicle weight, speed and suspension system; soil type and stratification; season of the year; distance from the road; and the type of building. Generally, the rougher the road, the more speed affects the vibration amplitude. The effect of the suspension system type also depends on vehicle speed and road roughness. For low speed and smooth road conditions, the effect of the type of suspension system is not significant. But for high speeds and rough roads, the type of suspension system becomes important. An IRC study showed that vibration levels induced by a transit bus and a truck of the same weight category travelling on a rough road were similar at 25 km/h. At 50 km/h, however, vibration levels induced by the bus were at least twice those induced by the truck.

Also important are soil type and stratification. The lower the stiffness and damping of the soil, the higher the vibration. For impact loads, ground vibrations are highest at the natural frequencies of the site. At these frequencies, the soil and other similar structural systems offer the least resistance and hence the greatest response to loads. For soils, the natural frequencies depend on stiffness and stratification. Typically, traffic vibrations are worst in areas underlain by a soft clay soil layer that is between 7 and 15 m deep. In these areas, the natural frequencies of the soil can coincide with those of houses and their floors, leading to resonance or amplified vibration.

Where the topsoil normally freezes in winter, vibration levels in winter can be less than half those of other seasons. The number of complaints is usually highest during the spring thaw, when people notice the higher vibration levels after the relative quiet of winter.

Effects of Vibrations on People and Houses

Building vibrations caused by road traffic are not a health and safety concern; they are more an annoyance. Vibrations may be unacceptable to occupants because of annoying physical sensations produced in the human body, interference with activities such as sleep and conversation, rattling of window panes and loose objects, and fear of damage to the building and its contents. Experience has shown that people living in houses are likely to complain if vibration levels are only slightly above the perception threshold, the major concern being fear of damage to the building or its contents.

Vibration levels are rarely high enough to be the direct cause of damage such as cracks in walls and ceilings or foundation cracks, though they could contribute to the process of deterioration from other causes. Building components usually have residual strains as a result of uneven soil movement, moisture and temperature cycles, poor maintenance or past renovations and repairs. Therefore small vibration levels induced by road traffic could trigger damage by "topping up" residual strains.

The most stringent vibration guide value specified in published standards for damage to houses is more than 30 times the human perception level. In the IRC study mentioned above, vibration levels were found to be significantly lower than this value.

Suggested Solutions and Preventive Strategies

Maintenance of the road surface (for example, levelling manhole covers, patching potholes and applying a new pavement overlay) is the most economical and effective remedial method. However, it is usually a short-term measure; for example, cracks and defects in the original pavement reappear in the overlay. Reducing speed limits and restricting heavy vehicles, while effective, are usually difficult to enforce.

Improving the thickness and stiffness of the road is not effective for reducing vibration levels in the predominant frequency range of traffic-induced vibration. On the other hand, improvement of the soil structure under roads using deep mixing techniques could reduce vibration levels.

Increasing the distance between roads and houses might be a practical strategy for planned developments. Where vibrations result from impacts with a pothole or crack in the road, vibration levels could decrease by at least one-third for each doubling of the distance if the soil is homogeneous.

This article is adapted from Construction Technology Update No. 39, published by the Institute for Research in Construction. To order a copy of this Update, please access the following web site: http://www.nrc.ca/irc/catalogue/ctu.html

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