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Development of passive viscoelastic damper to attenuate excessive floor vibrations

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ABSTRACT

Recent changes in the construction of building floors have included the use of light material composite systems and long span floor systems. Although these changes have many advantages, such floor systems can suffer from excessive vibration due to human activities. This problem is exacerbated in office buildings due to the reduction in inherent damping associated with modern fit outs. Excessive floor vibrations are often realised after the completion of construction or following structural modifications and normally arise due to inadequate knowledge of the damping values in the design process. Thus rectification measures are normally required to reduce floor accelerations. This paper proposes a new innovative passive viscoelastic damper to reduce floor vibrations. This damper can be easily tuned to the fundamental frequency of the floor and can be designed to achieve various damping values. The paper discusses the analytical development of the damper with experimental results presented on a prototype to demonstrate its effectiveness.

1. Introduction

Building floors are subjected to dynamic loads from people when they walk, run, dance or engage in aerobics activities. Such excitation forces cannot be easily isolated from the structure and they occur frequently [1]. Typical pacing rates for walking are between 1.6 and 2.4 Hz (slow to fast walk) whilst for jogging the rate is about 2.5 Hz and running occurs at rates up to about 3 Hz.

Although the excitation from pedestrians is dominated by the pacing rate, it also includes higher harmonic components with frequencies corresponding to an integer multiple of the pacing rate. Since annoying vibration amplitudes are caused by a coincidence of the natural frequency of the floor (f_1) with one of the harmonics of the walking excitation, the problem may be avoided by keeping these frequencies away from each other. For this reason, engineers may aim to design floor systems to have a fundamental frequency greater than three times the walking frequency (i.e. above about 6 Hz) [2]. This is a simple and effective approach for design but it does not necessarily guarantee acceptable floor performance since it does not take account of damping. Indeed composite floors with very low damping ($\leq$2%), can experience high levels of vibration even if their fundamental natural frequency is above 7.5 Hz [3].

The reaction of people who experience floor vibration depends on the activity they are engaged in, as reflected in the commonly used acceptance criteria as illustrated in Fig. 1. For example, offices and residences are normally designed to have a maximum peak acceleration of about 0.5% gravity (g) whereas pedestrian bridges can be designed for acceleration levels 10 times greater (5% g) [4]. In addition to acceleration amplitude, people's perception is also affected by the characteristics of the vibration response including frequency and duration [1]. Comfort studies for automobiles and aircraft have found that humans are especially sensitive to vibration in the frequency range of 4–8 Hz. This is explained by the fact that many organs in the human body resonate at these frequencies [5] whilst outside this frequency range, people accept higher vibration acceleration levels [4] as shown in Fig. 1.

There are several design models for predicting the maximum response of a floor due to walking excitation. One of the most commonly used method is that documented in the American Institute of Steel Construction Design Guide 11 (AISC DG11) [5,4]. This is the most popular method used by Australian designers. This method is based on reducing the floor structure to a Single Degree of Freedom (SDOF) system. The peak acceleration response is calculated using Eq. (1) (the full derivation of this expression can be found in [4]).

$$\frac{a_p}{g} = \frac{P_0 \mathrm{Exp}(-0.35 f_1)}{\zeta_1 W} \tag{1}$$

where a_p/g is estimated peak acceleration in units of gravity acceleration (g), f_1 is the fundamental frequency of the floor

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