VELOCITY COMPUTATION FROM FLOOR VIBRATION[1]

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BACKGROUND

Each floor system has its own characteristic natural vibration. The characteristic vibration of a floor is expressed in terms of its frequencies (Hz) and the vibrating shape (mode) associated with each frequency. The characteristic vibration depends on a floor's geometry, support conditions, weight, and stiffness. Software, such as ADAPT-Floor Pro can create a realistic three dimensional model of a floor, and determine its natural vibrations in terms of frequencies and the mode shape of each.

The intensity of vibration and its perception by either humans, or its adverse impact on equipment at any point on a floor system relate to the amount of maximum displacement (amplitude) at the location of interest. Depending on whether the purpose of design is human perception and objection, or malfunction of equipment, the corollaries to the maximum displacement and frequency at the point of interest are expressed in different forms, such as peak acceleration, or maximum velocity. The larger the magnitude of impulse, the greater will be the ensuing displacement, velocity and acceleration, at the inherent natural frequencies of a floor.

Irrespective of the design objective, to evaluate the consequence of vibration, it is necessary to know its source. The source can be due to foot fall from walking individuals, pushing a trolley on an uneven floor, movement of vehicles in parking structures, or equipment with unbalanced moving/rotating parts.

If the impulse causing the vibration repeats itself at intervals that match one of the frequencies of a floor, in particular one of the lower frequencies, the consequence of impulse becomes accumulative over the matching frequency and magnifies the floor's response. The phenomenon is referred to as resonance.

Guideline to estimate the design response of a floor system to vibration is discussed next.

PARAMETERS OF DESIGN

The natural frequencies (f) and mode shapes of a given floor are generally determined using a software such as ADAPT-Floor Pro.

Next, the maximum acceleration for the frequencies calculated is estimated using one of the industry standard empirical formulas, such as the one given below (ADAPT-TN290)

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$$a = \frac{P_0 e^{-0.35fn}}{\beta W} \times g \qquad (1)$$

Where,

- a is the peak acceleration resulting from P_o
- P_o is the value of the exciting force.
- fn is the natural frequency in Hz
- B is the damping factor of the floor; and
- W is the weight of the floor that is primarily will be excited from the impulse Po
- g is the gravitational acceleration [32.2 ft/sec; 9800 mm/sec]

Having determined the frequency (f) and the peak acceleration (a), the maximum velocity (v) is given by the following relationship:

$$v = a /(2\pi f) \qquad (2)$$

APPLICATION GUIDE

The determination of maximum velocity (v) for vibration design of sensitive equipment requires engineering judgment in the selection of the exciting force (Po), damping factor of the floor system β, and the excited weight W.

Recommended values for damping factor β are given in ADAPT-TN290.

The weight W for excitations resulting from footfall is based on a strip of floor generally less that the width of common panel size and length equal to the span of the affected panel. In most cases, the weight of a single panel is used, when three dimensional analyses are performed.

For perception and objection by humans, and the impact on sensitive measuring equipment, P_0 is the force of footfall (ADAPT-TN290). Where in addition to footfall, rolling of carts or other equipment on a floor can result in vibration; the value of Po depends on the weight of the cart and the unevenness of the floor. For sensitive laboratories, floors are generally smooth and an impact factor between 0.5 to 1 percent may be appropriate. Thus, W will be the weight of the cart times the assumed impact factor. For parking structures impact factor between 4 to 6 is used (ADAPT-TN291).

Where the source of vibration is an equipment with unbalanced rotating parts, the specification of the equipment should be consulted to obtain the unbalanced force Po. The rest of the design follows the same procedure as for footfall.

EXAMPLE

The natural frequency of a floor system for excitation of the panel of interest is 5.59 Hz. The peak acceleration from the exciting force using equation 1 is 0.004g. The design maximum velocity will be:

$v = a /(2\pi f)$ = (0.004 * 9800) / (2*3.14*5.59) = 1.1 mm/sec in SI units

= (0.004*32.2*12) / (2*3.14*5.59) = 0.044 in/sec in American units

REFERENCES

ADAPT-TN 290 (2010),"Vibtration Design of Concrete Floors for Serviceability," www.adaptsoft.com, 20 pp., 2010

ADAPT-TN 409 (2011), "*Vibration Evaluation of a Parking Structure*," www.adpatsoft.com, 9 pp., 2011