

steel quiz

THIS MONTH'S STEEL QUIZ is on walking vibrations and the AISC/CISC Design Guide 11, *Floor Vibrations Due to Human Activity*. It was submitted by Brad Davis, University of Kentucky, and Tom Murray, Virginia Tech.

- 1 How are floor width and length determined for walking vibration analysis? (a) based upon the average bay size (b) based upon the largest bay size (c) based upon the overall floor plate dimensions, openings, and deck orientations (d) both b and c
- 2 What is a sub-harmonic of the fundamental frequency? (a) an integer multiple of the fundamental frequency (b) an integer divisor of the fundamental frequency (c) a frequency within 1 Hz of the fundamental frequency (d) none of the above
- 3 Which of the following statements is true about resonant floor vibrations? (a) the forcing frequency is a sub-harmonic of the fundamental frequency (b) the activities can cause large accelerations (c) human walking and rhythmic activities can create resonance (d) all of the above
- 4 True/False: The range of typical human step frequencies is 1.6 Hz (96 bpm) to 2.2 Hz (132 bpm) when walking on a flat surface?
- 5 True/False: Fast dancing and aerobics fall in the same frequency range as for walking on a flat surface.
- 6 Why does AISC Design Guide 11 recommend that floors and footbridges should have a fundamental frequency greater than 3 Hz? (a) to prevent the first harmonic of the walking force from causing resonance (b) This eliminates any tendency to vibrate (c) to control deflections under load and limit stresses in the members (d) all of the above
- 7 True/False: Walking and jumping have similar severity as occupant loadings for floor vibration design.
- 8 When should column axial deformation be considered when determining fundamental frequency? (a) in all cases (b) only when the columns are moment-connected to the beams (c) when the columns have four or more stories below the loaded floor (d) when the columns are more flexible than the girders
- 9 If a proposed framing layout does not satisfy the walking criterion, which of the following is the best approach that can be used to improve the design? (a) Increase the girder moment of inertia (b) Increase the beam moment of inertia (c) Increase the moment of inertia of the beam or girder, whichever has the higher natural frequency (d) Increase the moment of inertia of the beam or girder, whichever has the lower natural frequency
- 10 Which of the following are methods that can be used to retrofit vibration-related problem floors? (a) structural stiffening (b) addition of tuned-mass dampers (c) addition of active control systems (d) all of the above

- 1 (c) The floor width is the floor plan dimension perpendicular to the joists or beams. It is bounded by the edge of slab or a significant change in the framing, such as a deck direction change or large opening. The floor length is the floor plan dimension perpendicular to the girders and is also bounded by slab edges or significant changes in the framing. See AISC Design Guide 11 Section 4.2 for further information.
- 2 (b) A sub-harmonic of a frequency is an integer divisor of that frequency. For example, the third sub-harmonic of a 6 Hz natural frequency is 2 Hz. This is significant because resonance occurs if an integer multiple (harmonic) of a forcing frequency matches a natural frequency. Thus, if the natural frequency is 8 Hz, walking at 2 Hz causes resonance with the fourth harmonic of the walking force.
- 3 (d) Resonance is a phenomenon that occurs when a repetitive force is applied at a sub-harmonic of the fundamental frequency of the structure. It is possible for humans to walk or move rhythmically (dance, sway, bounce, etc.) at frequencies that cause resonance, and this can result in large accelerations. See AISC Design Guide 11 Sections 1.4 and 1.5 for further information.
- 4 True. See AISC Design Guide 11 Table 2.1.
- 5 False. Fast dancing has a frequency range of 1.5 Hz (90 bpm) to 3.0 Hz (180 bpm); Aerobics has 2 Hz (120 bpm) to 2.75 Hz (165 bpm). See AISC Design Guide 11 Table 5.2.
- 6 (a) A fundamental frequency greater than 3 Hz helps to prevent the first harmonic of the walking force from causing resonance. The first harmonic has much more energy (see AISC Design Guide 11 Table 2.1) than the higher harmonics, so very high accelerations may result if the first harmonic matches the natural frequency and causes resonance.
- 7 False. Rhythmic loading, such as jumping exercises, is the most severe occupant loading. The first three harmonics for jumping exercises have a ratio of harmonic force amplitude to bodyweight of approximately 1.5, 0.6, and 0.1, whereas the first three harmonics of walking have ratios of 0.5, 0.2, and 0.1 (see AISC Design Guide 11 Table 2.1).
- 8 (c) To evaluate a bay for aerobic (jumping exercises) excitation if the bay is located more than about four stories high. See AISC Design Guide 11 Chapter 5.
- 9 (d) The bay natural frequency will be increased by increasing the beam moment of inertia, girder moment of inertia, or both. However, it is best to increase the member with the lowest natural frequency first. If the beam and girder have the same natural frequency, then increase them together.
- 10 (d) Three methods in common use include: stiffening the structure (to increase the natural frequency) by creating a queen post truss or adding partitions or columns below; passive control via tuned-mass dampers (TMD); and active control (see AISC Design Guide 11 Section 7.3).

Anyone is welcome to submit questions and answers for Steel Quiz. If you are interested in submitting one question or an entire quiz, contact AISC's Steel Solutions Center at 866.ASK.AISC or at solutions@aisc.org.



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