Living (Comfortably) with VIBRATION

Vibration due to human activity is a major design consideration. But it doesn't have to be a problem.

BY THOMAS M. MURRAY, PE, PHD

VIBRATION HAPPENS.

In all building types and materials, vibration due to human activity has become an increasingly significant serviceability concern. Modern design specifications, coupled with today's stronger materials, allow for lighter sections when strength considerations govern. Monumental stairs and pedestrian bridges are longer and more slender than ever before. Balconies and grandstands in stadiums have increasingly longer cantilevers and lighter seating areas. There are a lot of opportunities for vibration, to be sure!

But don't fret. The second edition of AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity* provides the design engineer with the resources necessary to solve these vibration concerns in steel structures.

The first edition of Design Guide 11 was published in 1997 and revised in 2003. Since that time, a large amount of new information has become available, and much new literature now exists on the response of steel-framed structural systems, including floors, monumental stairs and balconies. In addition, some human tolerance and sensitive equipment tolerance limits have been modified, and updated methods to evaluate high-frequency systems have been proposed. Finally, the use of the finite element method for analysis of structural systems has been refined, and new techniques for evaluating problem floors have been proposed. This second edition of the guide updates design practice in all of these areas. It is organized to move from basic principles of occupant-caused vibration and the associated terminology in Chapter 1, to serviceability criteria for evaluation and design in Chapter 2, to estimation of natural frequency in Chapter 3, to applications of the criteria in Chapters 4, 5, 6 and 7 and finally to possible remedial measures in Chapter 8. A brief overview of each chapter follows.

Chapter 1 includes a greatly expanded list of basic terminology. Terminology required to understand sensitive equipment manufacturer's tolerance limits is provided, as well as terminology associated with finite element analysis techniques. A section on structural response principles related to human activity has been expanded from the first edition of the guide to help the reader understand basic concepts. Resonant response due to walking is illustrated using measured data from an actual floor. Walking, running and rhythmic forcing functions taken from a number of publications are presented. The chapter ends with a brief discussion of the use of finite element analysis to assess structural systems supporting human activity.

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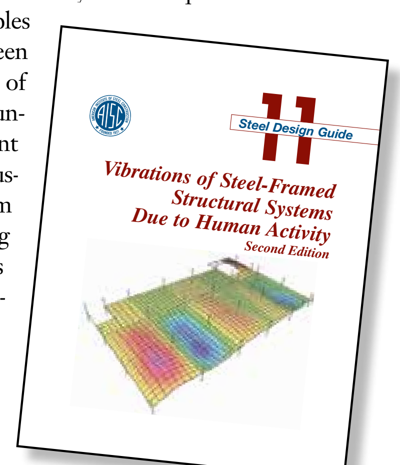

Chapter 2 describes the development of the evaluation criteria for human comfort that are implemented in Chapter 4 (Design for Walking Excitation) and Chapter 5 (Design for Rhythmic Excitation). It includes evaluation criteria for walking on high-frequency floors and running on a level surface and describes the development of criteria for monumental stairs and rhythmic excitation.

Chapter 3 gives guidance for estimating the natural frequency (the most important vibration property) of steel beam- and steel joist-supported floors and pedestrian bridges, including the effects of continuity and shear deformation of trusses and open web joists.

Chapter 4 presents a criterion for the evaluation of concrete slab/steel framed structural systems supporting offices, residences, churches, schools and other quiet spaces, as well as shopping malls, pedestrian bridges and (in a modified form) monumental stairs. Six design examples demonstrate application of the criterion.

Chapter 5 provides design guidance for floors supporting dancing, lively crowd movement and aerobics. The primary concern is the tolerance of occupants to floor motion near rhythmic activities. The recommended criterion is based on acceleration limits and is more direct and easier to apply than in the first edition.

Chapter 6 provides guidance for evaluation of vibrations of floors supporting sensitive equipment such as precision imaging, measurement and manufacturing instruments, and also of floors supporting sensitive occupancies such as hospital patient rooms and operating rooms. New assessment procedures developed at the University of Kentucky through an AISC-sponsored research project are presented. Assessments can be made in relation to widely used generic tolerance limits or equipment manufacturers' tolerance limits stated in terms of peak velocity or acceleration, narrow-band spectral velocity or acceleration or one-third-octave-band spectral velocity or acceleration.

Chapter 7 is entirely new and presents recommendations for finite element analysis of floors, pedestrian bridges and stairs subject to walking or running, floors and balconies subject to rhythmic activities and floors supporting sensitive equipment, based on research by Brad Davis. Design examples are included of the analysis of structural systems that are outside the scope of the methods presented in Chapters 4, 5 and 6.

Chapter 8 provides guidance on experimental evaluation and on remedial measures to resolve floor vibration problems that can arise in existing buildings. The recommended vibration measurement approach requires minimal equipment.

Vibration happens, and the second edition of Design Guide 11 provides an abundance of practical knowledge from the experts that can eliminate it as a design concern. AISC members can download the guide for free at **www.aisc.org/dg**. ■

About the Authors

The second edition of AISC Design Guide 11 is dedicated to David Allen, PhD, who made seminal contributions to the first edition but was unable to contribute to the second edition because of health issues. Brad Davis, SE, PhD, an assistant professor with the University of Kentucky's College of Engineering, is a new coauthor, and Eric E. Ungar, PhD, Acentech's chief engineering scientist, and Professor Davis provided significant new information regarding floor systems supporting sensitive equipment.