STEEL INDUSTRY GUIDANCE NOTES

Floor Vibrations

Floor vibrations can be a critical serviceability condition for modern building structures. Specifiers are more frequently facing the need to consider the vibration response of floors and this article summarises some of the key issues.

1. All Structures Vibrate

All structures vibrate if subjected to cyclic or sudden loading. In most cases, the vibrations are imperceptible, and can be neglected in building design. However, in some circumstances, the response of the structure to a reoccurring load (e.g. walking activities) is sufficient to produce a response that is perceptible to the occupants of the building. The most common example of such small, but perceptible, vibrations occurs in floor structures. This is not a new phenomenon, but can be more noticeable within the working environment of some modern offices and residential dwellings.

2. Predicting Vibration Acceptability

Two approaches can be used to assess the serviceability vibrations of floors. These are the frequency tuning method and the response calculation method. The frequency tuning method requires the floor to be constructed of elements each with a minimum natural frequency (typically 4Hz for beams). This method is by far the most popular and well known amongst engineers but it does not guarantee the response of the complete flooring system. The method sets only the frequency of the floor but does nothing to estimate or control the value or the amount of vibration that will occur at that frequency.

The response calculation method is increasingly being used by engineers. This method predicts a value for the amount of vibration and as such is directly scaleable against base levels to determine the likely acceptability of the floor. This method addresses directly the issue of amplitude and as such is a more realistic model of how vibration is perceived. It is also significantly more accurate than the frequency tuning method. Current advanced design guidance is based on this method including SCI P331 and Advisory Desk Notes AD253, AD254 & AD 256.

3. Practical Considerations

It is not possible to guarantee that a given floor will exhibit an acceptable response by considering geometry alone. For example, although long span structures are generally more likely to have lower frequencies due to higher deflections, this is not always a limiting criterion. Long span members often enable the mobilisation of a greater mass of floor which is helpful in reducing vibrations. Despite this complexity, practical guidance is available to assist designers in producing an acceptable design with minimum effort.

Designers are advised to detail steel layouts with continuous lines of secondary/floor beams where possible to take advantage of this mobilisation of mass. Walking paths should be carefully considered to isolate as much as possible long walking paths from the vicinity of sensitive floor areas.

Damping is variable across structures but is linearly proportional to the response of an individual structure. It should also be remembered that fully finished floors perform better than newly constructed floors as the final finishing and furniture increase the natural damping of the floor and hence reduce response. Full height partitions have the effect of increasing the structure's natural damping.

4. Advanced Methods of vibration analysis

Because the simple design guidance available for hand calculation methods was developed for general application it will not always give a realistic value of the floor response, however the calculation will be conservative. It is possible to use numerical analysis techniques to reduce conservatism. Such techniques include the use of Finite Element modelling which may be used at the pre- and post-design stage to demonstrate acceptability with regard to human-induced vibrations. The SCI has provided such a service for sensitive floors, office floors and also floors in very active environments, such as those that are subject to synchronised crowd loads (e.g., gymnasia, dance-floors, etc.).

5. Special cases

While the issue of vibrations is normally considered to be a serviceability criteria it is very important for designers to understand that on some occasions the phenomenon can be an ultimate state consideration. Vibrations must be considered in the ultimate limit state calculations in cases of high dynamic forces such as gymnasiums, dance halls, and other areas of aerobic activity. In such circumstances the requirements of BS6399-1 must be met which state that the floor system should have a minimum frequency of 8.4Hz or be designed to withstand the additional load imposed due to the aerobic activity. Consequently, special attention must be made to the intended use of the structure.

Special consideration must also be given to critical working areas. These are defined in BS6472 and require a very low level of vibration response. Frequently occurring instances of such floors are hospital operating theatres and precision laboratories. Generally increasing mass (by using deeper slabs) or increasing the stiffness of the floor is the common way of achieving the specified response factor for these areas. Isolation of an important or sensitive area from walking paths, or local treatments of the floor properties (such as thickening of the slab) may also be considered to prevent nearby walking activities inducing an unfavourable response locally

6. Steel Solutions

Normal construction in steel can generally be shown to be acceptable to BS 6472 criteria for offices and other non- critical environments. Environments such as hospitals have more onerous requirements, but properly designed composite steel construction is perfectly suitable for hospital and other buildings where low vibration environments are required.

Key Points

1. Steel solutions meet vibration criteria
    - For offices and residential buildings, normal construction will generally be entirely satisfactory. Sensitive structures, such as operating theatres, have more onerous limits on vibration, but properly designed composite construction can meet these limits.
2. Design Approaches
    - Two approaches are available for the assessment of the serviceability vibration of floors; the simple frequency method and the response calculation method
3. The response calculation method
    - The response calculation method is recommended, giving a more accurate and realistic assessment of the vibration response.
4. Utilise long span members
    - Long span members often enable the mobilisation of a greater mass of floor which is helpful in reducing vibrations.
5. Utilise multiple secondary beam arrangements
    - Designers are advised to detail steel layouts with continuous lines of secondary/floor beams where possible, as this will allow mobilisation of a greater effective area in response to footfall action.
6. Damping is increased by fit-out
    - Fully finished floors perform better than newly constructed floors, due to increased levels of damping.
7. Take care with areas of rhythmic activity
    - Vibrations must be considered in the ultimate limit state calculations in cases of high dynamic forces such as gymnasiums, dance halls, and other areas of aerobic activity.
8. Take care with operating theatres and critical working environments
    - Special consideration must be given to critical working areas, such as Operating theatres (limits specified in HTM2045).
9. Local structural and architectural treatments can be used to eliminate vibration response
    - Isolation of critical areas from walking paths, or local treatments of the floor properties can be used to prevent walking activities causing excessive vibration in an important location.

Further sources of Information

1. **National Structural Steelwork Specification, 4th Edition (Published by BCSA and SCI)**
2. **Commentary on the National Structural Steelwork Specification (Published by BCSA and SCI)**
3. **Steel Designer's Manual – Chapter 31 (Published by Blackwells)**
4. **Design for Construction – Section 8 (Published by SCI)**

Sources 1, 3 and 4 are available on both **www.steelconstruction.org** and **www.steelbiz.org**