Research Report

Floor Vibrations
Causes and Control Methods

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Introduction:

Metal plate connected wood truss floor systems are subject to vibrations from many sources. While many of these vibrations are considered negligible from a structural standpoint, they can prove to be a point of contention between designers and customers. Perceived movements and vibrations in a truss system, although innocuous, can reduce the comfort to the occupants and can lead to customer dissatisfaction.

Perceptions:

Occupant comfort can be compromised by vibrations and movements in a floor system, although it is often difficult to prevent all causes. The perception of excessive vibrations in a floor is based on human interpretations. Figure 1 shows a graph from a Finnish research paper "Classification of Human Induced Floor Vibrations". While the floor system studied in the report are not trussed floors, similar concepts apply. The vertical axis provides the acceleration of the floors studied as vibrations were applied and the horizontal axis shows the frequency of the vibrations. Each marker shown is a floor system and the markers are differentiated with "[]" for acceptable floor performance and an "X" for un-acceptable. As you can see in the graph, while systems which exhibited less acceleration were perceived as more acceptable, there are many instances where a floor system was perceived as being "unacceptable" while performing better than another which was perceived as acceptable.

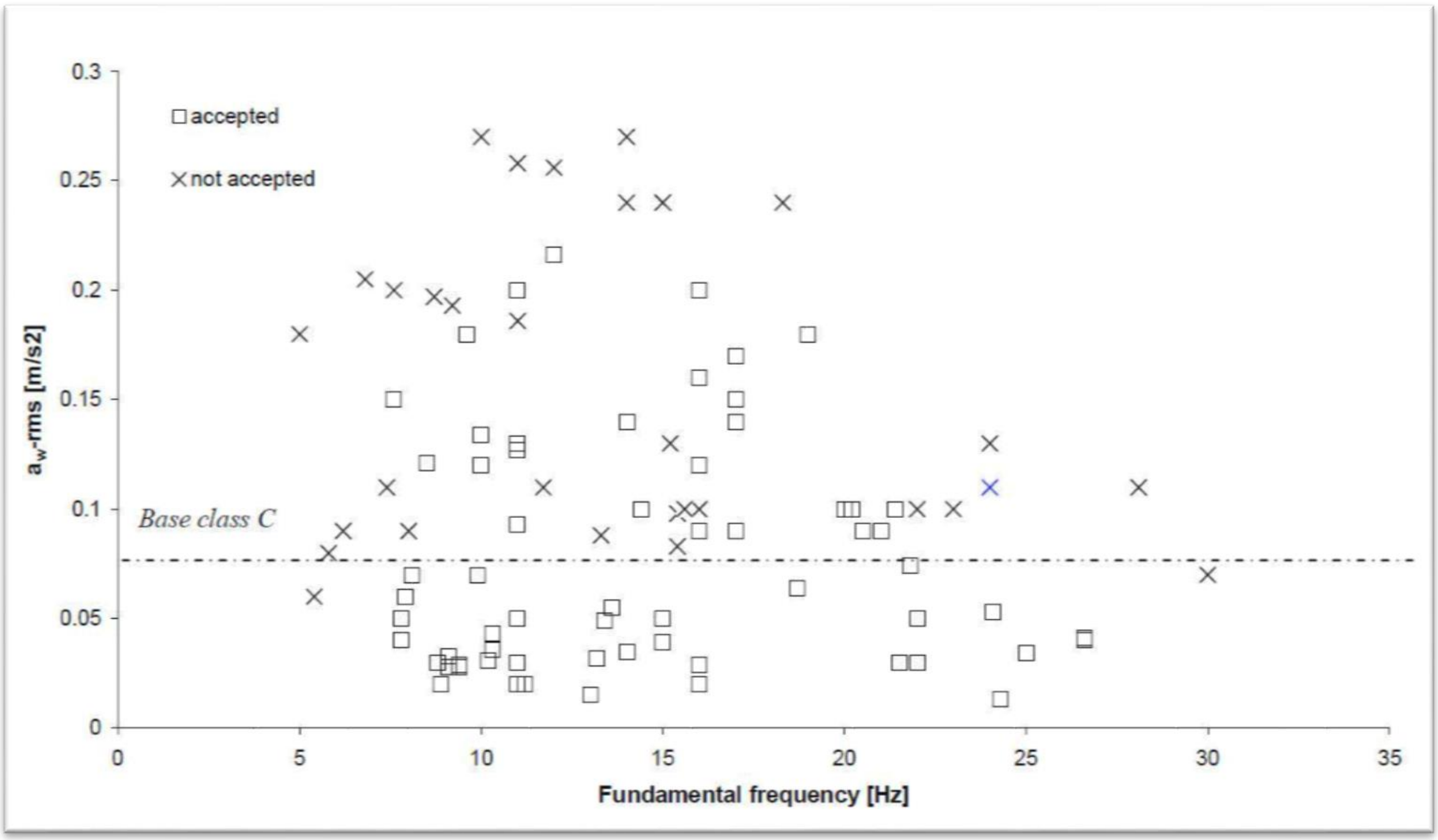

Figure 1: Weighted acceleration compared to acceptability. (Graph from Classification of Human Induced Floor Vibrations. In Building Acoustics. Tomi Toratti & Asko Talja. SAGE Publishing, 2006, 217)

The study also showed that pecieved performance of the floor was also heavily correlated with the deflection seen in the floor when vibrations were induced as shown in graph Figure 2. The horizontal axis reflects the frequency of vibrations while the vertical axis represents the peak floor deflections. Again, while the trend for better percieved performance was a lower deflection, there were many instances where the floor systems were considered un-acceptable (marked with an "X") while performing better than some which were considered acceptable (marked with "[]").

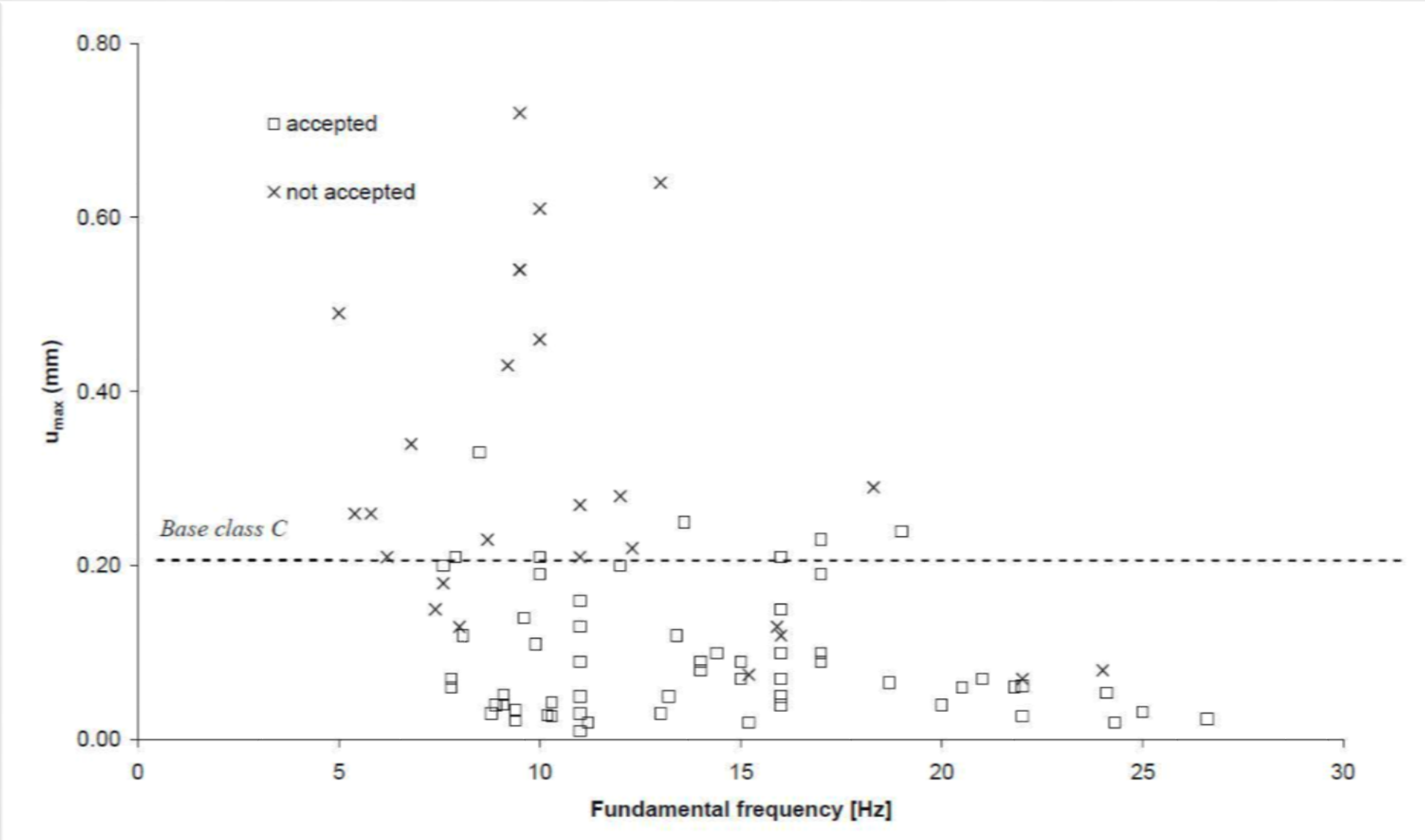

Figure 2: Maximum Dynamic deformation uMAX compared to acceptability (Graph from Classification of Human Induced Floor Vibrations. In Building Acoustics. Tomi Toratti & Asko Talja. SAGE Publishing, 2006, 217)

<u>Sources of Vibrations</u>:

While there are many sources of vibrations in wood truss floor systems, movement along the floor system is a common cause of vibrations. One of the most prominent sources of movement along the floor system is simply people walking throughout the system. The application of weight from each footstep causes accelerations and deflections in the supporting trusses. Depending on the intensity of each footstep, two different frequencies may be created: A low frequency vibration from the truss deflecting under the weight and if the step is "sharp" enough a higher frequency will be generated by the impact between the person's foot and the floor. The same effects are seen when moving relatively heavy objects across a floor system.

Another common source of vibrations is from seismic activity in the area of the floor. Earthquakes are a common source of vibrations in some areas, however, there are other causes of localized seismic activity. A floor system's proximity of a railroad line or roadway can allow vibrations to be passed into the floor. Also, areas in close proximity to high sound volumes such as airports and factories are subject to induced vibrations in the floor system.

Contributing Factors:

There are many contributing factors to vibrations in a floor system. The first contributing factor is the materials used in the construction of the floor, including joists or trusses, the upper sheathing and the bottom sheathing (if there is any) absorb and transmit vibrations differently. Also, the materials used in the construction of the floor system will affect the stiffness of the system. Another contributing factor is the floor span between supports. Floor systems with large spans between supports tend to display more vibrations than those with shorter spans, usually as a result of larger deflections. The depth of joist/trusses used in the floor system affects vibrations. Shallow joist/trusses tend to deflect more and exhibit more vibrations than those with more depth. How stiff a support is will affect the vibrations of the floor. If a support is a beam or girder truss that will exhibit deflection this too can cause an increase in the vibrations of the floor. One more thing to consider is the placement of furniture relative to floor joist/trusses. When furniture is placed between two or more joist/trusses which are deflecting at different rates, the furniture may increase perceived vibrations to the occupants (see Figure 3)

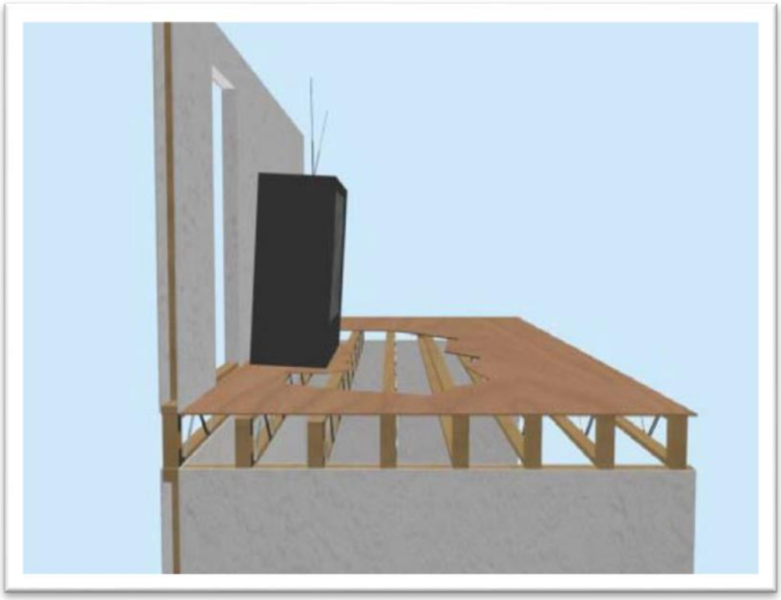

Figure 3: Furniture as a contributing factor

Solutions:

The designer of a wood truss floor system has several options on how to reduce vibrations. If permissible, the designer can reduce truss spans with additional bearing walls or supports. The designer may also increase the depth of a truss. The truss design can also be altered to assist in the reduction of vibrations by either use of higher strength members, increased webbing, or a combination of the two. The goal of the truss design should be to increase stiffness and reduce deflections.

Once trusses are designed and installed, there are still several other methods one could use to reduce vibrations. The most common method is to install stongbacks (see Figure 4) into the truss system. Stongbacks tie multiple trusses together, allowing forces, deflections and vibrations to be shared among adjacent trusses. BCSI-B7 provides information regarding the requirements for and installation of stongbacks in metal plate connected wood truss floor systems. The next method to reduce vibrations is the use of a rigid ceiling on the bottom chord of the floor trusses. The connection provided by the ceiling helps reduce the “twisting” of the truss and enhances truss stiffness. Another method to reduce vibrations is to use adhesive when installing the floor sheathing to the top chord of the truss. The adhesive connection between the floor sheathing and the top chord of the truss helps prevent slippage between the two surfaces and fills gaps creating a solid vertical connection for loads applied to the sheathing. Finally, floor sheathing can be selected with a higher stiffness to aid in the overall perceived vibrations of a floor system. Even when trusses installed in the floor system are properly designed, sheathing which allows too much deflection between trusses will hinder floor performance.

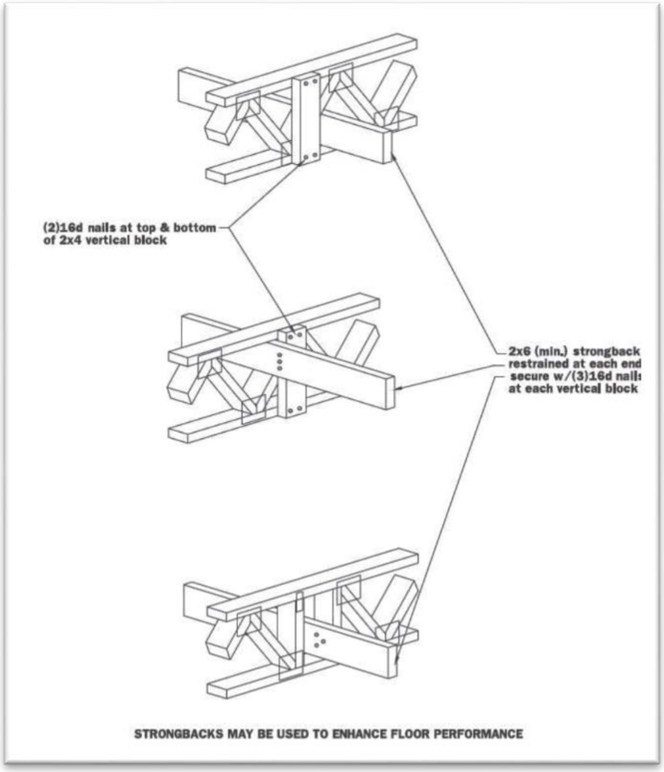

Figure 4: Strongbacks used with truss

Conclusion:

While the perception of floor vibrations is subjective from one person to the next, overall floor systems which exhibit lower deflections and less acceleration from vibration sources tend to be perceived better than other designs. To accomplish this, the designer may elect to do one or a combination of things such as change the bearing conditions to decrease spans, increase depth, re-configure/increase webbing or use higher strength materials. It is also heavily recommended that floor trusses be installed with strongbacks as shown in BCSI-B7. Finally, the truss can also be installed with stiffer sheathing designed to reduce vibrations. Although vibrations in floor systems cannot be completely removed, the designer has several options to improve the overall perceived performance of the floor.

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