FTMA TECH Talk

FEBRUARY 2020 - NO.20

Vaimiti Rigal - Multinail Structural Engineer

BOUNCY FLOORS - DON'T BLAME THE JOISTS!

As our houses become more modern, clients' requirements become more challenging. Home-owners and architects are demanding more open-plan spaces for living areas. Commercial projects tend to require wide open spaces stacked on two or three stories, with little furniture and equipment and few partition walls. This brings a typical issue in the upper floor: bounciness!

Often, upon arrival on site, very little furniture has been installed. Floor joists can be seen sitting on a tiny steel beam, doing a great job at transferring loads across a wide span. The design was carried out in accordance with the latest Australian Standards, the joists and steel beams were specified in order to have the adequate capacity by the designer/project engineer. So why does the floor bounce?

What do the Australian Standards say?

The suggested serviceability limit state criterion for floor vibration stated in the Australian Standard 1170.0 is "*1 or 2mm deflection in the static analysis under 1kN applied at mid-span*". Additional notes mention that for floors receiving rhythmic impact, the floor system's natural vibration should remain above 8Hz.

Where floor joists sit on brick walls, the floor system is limited to the joists. Where floor joists sit on beams, although this is not stipulated in any standards, the joists and the beams make the floor system. This is because, as horizontal elements, the beams participate in transferring floor loads to the vertical elements.

What is the theory?

Let's have a look at the theory. The natural frequency of a vibrating system is a combination of each element's natural frequency. It is written as:

$$\frac{1}{f_n^2} = \frac{1}{f_j^2} + \frac{1}{f_g^2}$$

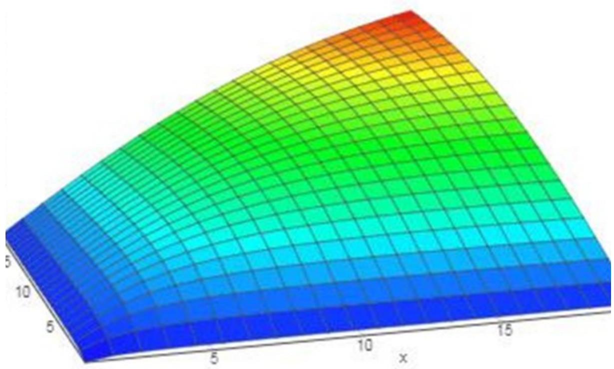
Where:

f_n is the natural frequency of the system

f_j is the natural frequency of the joist

f_g is the natural frequency of the girder, i.e. primary beam, secondary beam, etc.

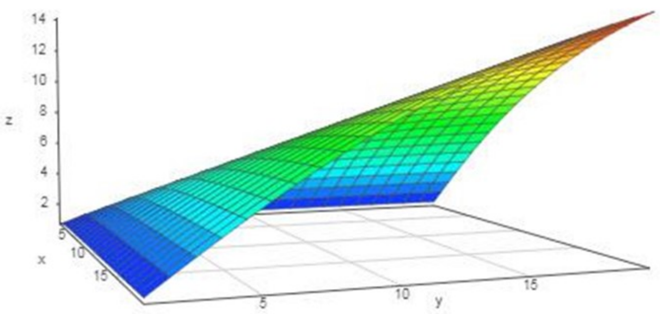
This formula tells us a lot about the theoretical behaviour of a floor system; its representation below may be helpful.



System frequency (z), as a function of joist frequency (x) and girder frequency (y). Credits – Academo.org

The natural frequency of the system will always be lower than the lesser of the joist's and the girder's natural frequency. So no matter how stiff a floor joists may be, if the support below is a tiny bouncy beam then the whole system will bounce, and vice versa.

Each element having a natural frequency above 8Hz does not imply that the system's frequency is above 8Hz! Should a joist have a natural frequency of 8.5Hz, its support should have a natural frequency of at least 23.7Hz for the system to remain above 8Hz.



The path to an optimized system frequency
Credits – Academo.org

Based on the above it can be seen, that further increasing the stiffest element's frequency will increase the system's frequency, but it is more efficient to aim for balanced frequencies. Two systems of 11.5Hz natural frequency have a combined frequency of 8.1Hz. This balance is easier to achieve than 8.5/23.7Hz.

What does experience tell us?

There is more to take into account than theoretical consideration of the floor joists and their support: damping! Damping is related to the amount of load applied to the joists, the nature of materials transferring the vibration, and how the elements get to share the vibration.

Floors may appear to be bouncy at installation stage but may behave a lot better once all loads are in place and the flooring is completed. *If you think of a trampoline, it is much harder for little Johnny to bounce on it when Grandpa and his mates are sitting in the middle!* Be careful not to exceed the design load there…

Materials used for flooring play an important role too. For example, carpet flooring will mitigate bounce better than tiles. Ceilings and partition walls also play an important role in damping; they were found to add load and spread the vibration across the floor.

Finally, the use of continuous strongbacks has also been found to improve overall floor behaviour. This could be because strongbacks share the vibration among joists and hence include neighbouring joists in the damping effort.

Flooring, ceiling and strongbacks increase the overall system's stiffness and participate in reducing the bounciness.

What should be done?

As always, vibration issues are best mitigated at design stage. Using walls and stiff elements as supports is the safest option. When this is not possible, the supporting beam should be closely examined for vibration. A small increase in cost here could save a lot further down the road, in preventing the floor system from requiring extra stiffening.

When designing floor joists, span-to-depth ratios can be used, depending on the final floor use and requirements. Finally, incorporating strongbacks and ensuring their good connection to the rest of the building will also help share the bounce and reduce its effects.

Strongbacks help to reduce bounciness

This edition of FTMA Tech Talk was written by Vaimiti Rigal, Structural Engineer of our Gold Sponsor, Multinail.

If you have any questions for Vaimiti, please don't hesitate to contact her.

PH: 07 3297 3250

E: vaimiti.rigal@multinail.com