Analysis of Footbridge Comfort Vibrations

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Footbridges are usually statically designed to be slender, lightweight, and flexible structures. This means however that when pedestrians use the bridge, their footsteps may induce resonance. If the bridge is not designed for these phenomena in early stages, costly measures must be used afterwards to secure the criteria of pedestrian comfort. Knowing in the project stage what bridges are sensitive to vibrations will make early adjustments possible. This way material inefficiency can be reduced, which is not only cost efficient, but also makes bridge construction more sustainable.

Many steel beam footbridges (bridges carrying pedestrians, bicycles, and other foot traffic) are prone to comfort vibration issues due to their light weight and flexible structures. Comfort vibrations are not threatening to the structural stability of the bridge, but rather cause discomfort in the users.

These dynamic issues are usually not considered in the early stages. If the comfort vibration criteria are not met later in the design phase, this usually forces the designers to increase dimensions to counteract these issues, at great environmental and financial cost. Thus, it is crucial to be able to predict these issues early to avoid them. The aim of this master's thesis was to better understand how several parameters affect the dynamic behaviour of footbridges to potentially reduce the amount of excessive material use.

This understanding was accomplished by studying parameters like length, width, and number of main beams. This way it was examined what bridge geometries were safe and which were at risk of comfort vibrations. The figure shows a typical design of a steel beam footbridge, the model for which the parameters were varied. The method used was based on a guide on footbridge dynamics by the French government agency Sétra.

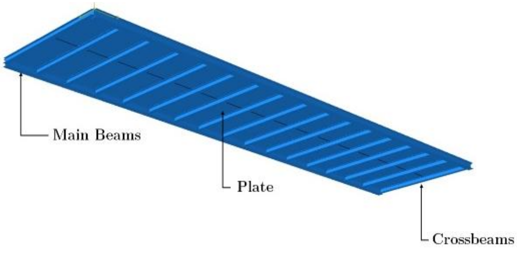

Figure 1: Bridge Model

Analyses Steel beam footbridges were analyzed using the computer program Abaqus to create models that were made to be realistic but unideal. The simulated models were then put into resonance where the accelerations were evaluated. These dynamic results were then compared to the static criteria, the requirements that are specified by law in the Eurocodes.

Results It was shown that the most crucial factor was how busy the bridge was going to be. In the cases with the most densely trafficked bridges it was safest to ensure that the bridge natural frequency was above the 5 Hz limit. Natural frequencies are the rate with which the bridge is swinging back and forth, when set in motion. These are dependent on how stiff and heavy the bridge is, but also the geometrical proportions.

For the normally trafficked class, a clear majority of the bridges achieved acceptable comfort while having lower natural frequencies. This allowed for more slender structures that more efficiently used the static bearing capacity of the bridges. Material could in other words be saved in these common bridges by investigating the accelerations.

It was found that bridges with smaller areas, will in the Sétra guide get unrealistically large dynamic loads. This means that the guide might not be ideal when analyzing these smaller footbridges. It was also concluded that a Single Degree of Freedom system (a simpler system with just a weight and spring) was quite apt at safely predicting the maximum accelerations from pedestrian footsteps.

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