The Dynamic Shoe Rack

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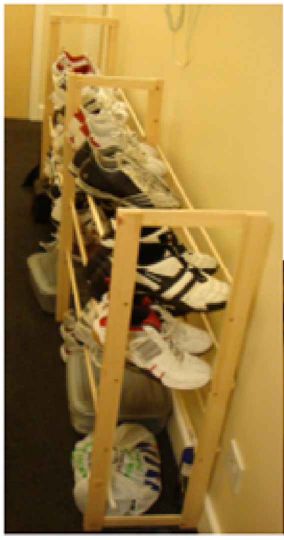
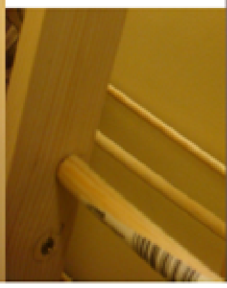
CONCEPT: The Natural Frequency of a system, ω is inversely proportional to the mass of the system and damping is inherent in real structures.

THE MODEL: A shoe rack which resembles a 2-bay portal frame, simply supported at the base with semi-rigid joints connecting the members.



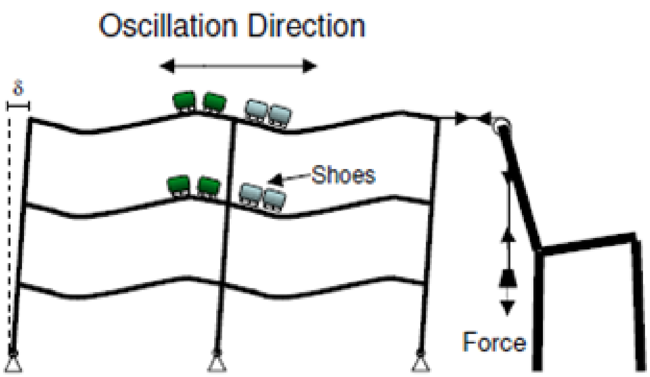
Shoe Rack



Semi-rigid joint

Measurement method

The Model



Schematic Diagram

The shoe rack was deflected by attaching the frame to a weight which was hung off a pulley system. Oscillations are induced by cutting the connecting string to remove the horizontal load. The mass of the frame is varied by changing the number of shoes placed on it. The oscillations are recorded on video and analysed frame-by-frame (0.06s intervals).

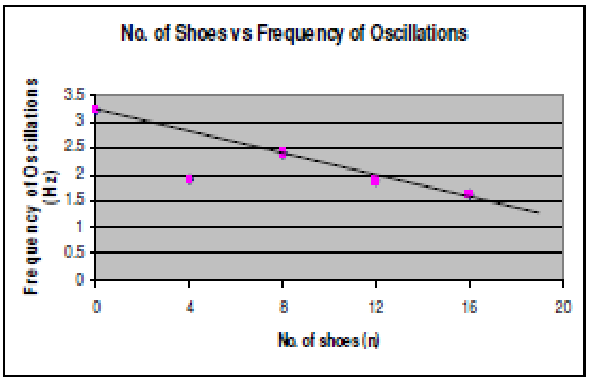
The results from this demonstration show that the oscillation frequency of the frame reduces as more shoes are loaded onto the frame (hence increasing the mass of the system). The same effect may be demonstrated by observing the oscillation frequency of the free end of a plastic ruler and subsequently observing its new frequency when an eraser (additional mass) is attached to its free end.

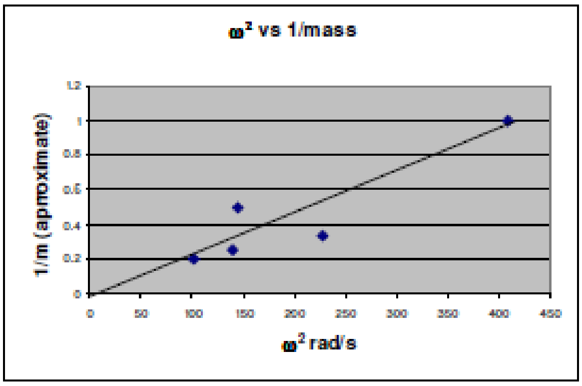
The shoe rack, a real structure, approximately obeys the relationship for an ideal system:

Natural frequency, $\omega = (\text{stiffness}/\ \text{mass})^{1/2}$

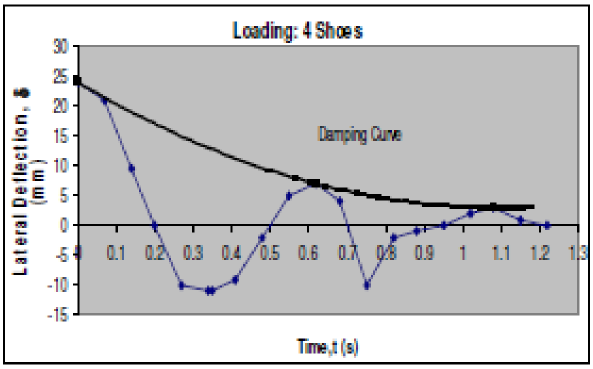
Or in other words:

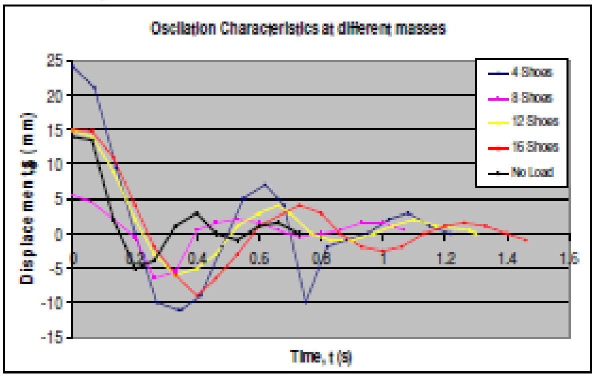
ω^2 is inversely proportional to mass.





It is also shown that some light damping naturally occurs within the frame:





Damping in real structures occurs due to the dissipation of energy through internal friction and heat. Thus changing a structure's material and structural arrangement will change its damping characteristics.

In some tall buildings, tuned mass dampers are employed to reduce lateral oscillations caused by external forces such as earthquakes and wind loads.

The natural frequency of the tuned mass damper (TMD) is designed to match the natural frequency of the structure it will be used in (Kashani). This is achieved not only by varying the stiffness of the TMD but also by varying its mass. The effectiveness of a tuned mass damper is dependent on its damping ratio and the frequency which it is tuned at. Hence knowledge of a structure's natural frequency allows an effective design of a tuned mass damper for it.

References:

GERB SCHWINGUNGSISOLIERUNGEN GMBH & CO. KG. 2009. *Tuned mass dampers.* <Available at: http://www.gerb.com/en/arbeitsgebiete/arbeitsgebiete.php?ID=140> <Last Accessed: 28 February 2009>

KASHANI, R. *Tuned Mass Dampers and Vibration Absorbers.* <Available at: