Spatial variation of the point mobility of a timber joist floor

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Introduction

In wood framed buildings, floors are formed by fastening wood sheathing to joists spaced at a regular interval. The sheathing is typically fastened to the joist using screws so the resulting system is a complicated periodic point-connected plate-rib structure. The point mobility will be expected to vary significantly with location. This paper presents measured and predicted mobilities for a point-excited timber joist floor where a single layer of chipboard forms the sheathing. The spatial variation in point mobility is bounded. The characteristic plate mobility defines the upper bound while the characteristic beam mobility defines the lower bound. Experimental and predicted results indicate a general behaviour with respect to the distance to the nearest screw position, normalised with the governing bending wavelength. A master mobility curve is proposed, based on infinite beam and infinite plate behaviour, which is useful for simple prediction of floor response.

Experimental Set-up

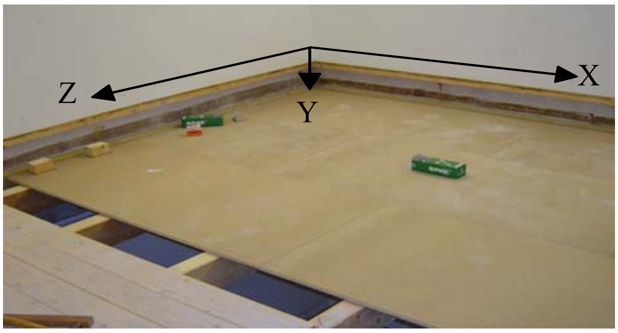

Figure 1: Wood joist floor, built in HfT-laboratory, used to evaluate the spatial dependence of drive point mobility

The wood joist floor, Figure 1, was of dimensions 4.55 m x 4.95 m, with 21 mm chipboard sheathing supported by seven Norwegian spruce joists of dimensions 0.096 m x 0.192 m x 4.55 m, at 0.78 m spacing. The chipboard sheathing, consisted of panels of dimension 0.9 m x 2.05 m, joined by tongue and grooves, and were secured to the joists using screws; no glue was used. A massive concrete test frame supported the ends of each joist without additional fixing and intermediate layer. Therefore, the boundary conditions for this floor construction were not obvious. The mobilities were measured with a calibrated impulse hammer. The dynamic condition corresponded with many practical situations where mechanical sources rest on receiver structures without fixing. Even if the sources are rigidly mounted through to the joists at some points, there might be many more contact points which are not.

Experimental Results

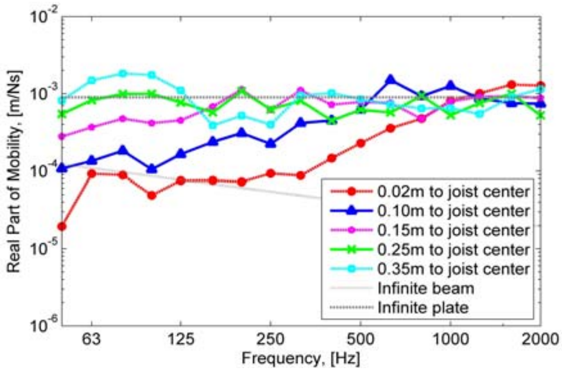

Figure 2: Measured real part of point mobility with parameter, distance from a joist.

Figure 2 indicates that the mobility at points near the centre of a bay (more than 0.15 m from a joist) is reasonably approximated by that of an uncoupled infinite plate of the same material and thickness. Further, the mobility, at low frequencies, decreases with decrease in distance to an adjacent joist. The mobility on a joist, in the low frequencies, is reasonably approximated by that of an uncoupled infinitely long beam with the same depth and width.

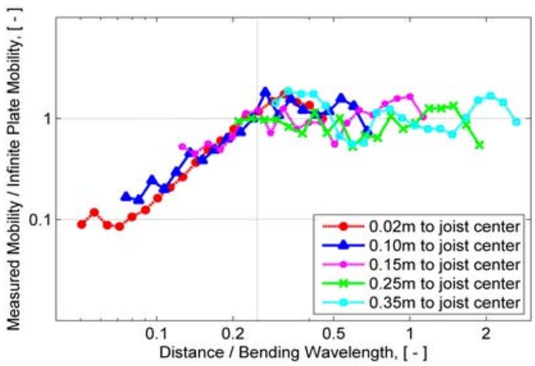

Figure 3: Mobilities as a function of the non-dimensional distance between drive point and nearest joist.

Figure 3 shows the measured mobilities normalized to that of an infinite plate and plotted as a function of distance normalized to the bending wavelength on the chipboard. The results indicate that when the ratio of the distance to the bending wavelength is less than one-quarter the joist behaviour dominates and the mobility is considerably less than that of an uncoupled infinite plate. Whereas when this ratio is greater than one-quarter, the joists have minimal effect and the chipboard panel can be considered as an uncoupled infinite plate.

The fact that the chipboard is fastened to joists using a series of screws leads to the chipboard being effectively point-connected to the joists at the high frequencies and line-connected at the low frequencies. Hence, the location relative to the nearest fixing point (where the chipboard panel is screwed to the joist) is an important factor when the drive point is above a joist. To examine this effect, the mobility for positions above and along a joist were measured at various distances from a screw, see Figure 5. Results indicate that the point mobility is a function of distance to the nearest fastener. At low frequencies and at small distances from the fastener, infinite beam behaviour is evident. With increasing distance and/or frequency the mobility tends towards the characteristic plate mobility. In Figure 4 the measured mobilities again are normalized to that of an infinite plate and plotted as a function of the distance to the nearest screw normalized by the bending wavelength. The behaviour is similar to that was observed in Figure 3 for the distance from a joist.

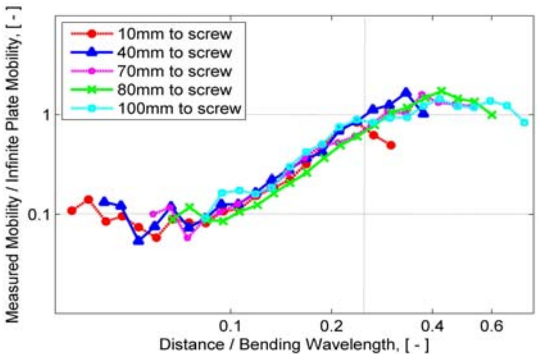

Figure 4: Point mobility as a function of the non-dimensional distance between the drive point and adjacent fixing point.

The similarities between Figure 3 and Figure 4 allow generalization. Since the distance between the observation point and the nearest fastener is the determining factor, it can be assumed that when the ratio of this distance to the bending wavelength is less than one-quarter the joist dominates the floor response and the mobility is considerably less than that of an uncoupled infinite plate. When the ratio is greater than one-quarter, the joists have minimal effect and the chipboard panel can be considered as an uncoupled infinite plate. From Figures 3 and 4 a master curve can be constructed for predictions to engineering accuracy based on simple infinite beam and plate mobilities. In terms of the distance/bending wavelength axis, the infinite beam assumption could be used below 0.1, the infinite plate above 0.25, with straight-line interpolation between.

Modelling

The plate-rib structure is modelled using the analytical formulation for an assembly of finite-sized plate strips coupled at a series of parallel junctions [1]. Since the model used assumes that the plate(s) and rib are line-connected it is not possible to account for point-connected behaviour analytically. A pragmatic solution is necessary to more accurately predict the mobility of points located above a joist. Based on the results of Figure 3 and 4 it is assumed the mobility is determined by the nearest point at which the plate and rib are rigidly coupled, that is the nearest screw. If the measurement point is a distance ξ to the nearest screw, the mobility at the measurement point above the joist can be approximated by the mobility of an “equivalent” point offset a distance ξ from the screw in the direction normal to the axis of the joist [1].

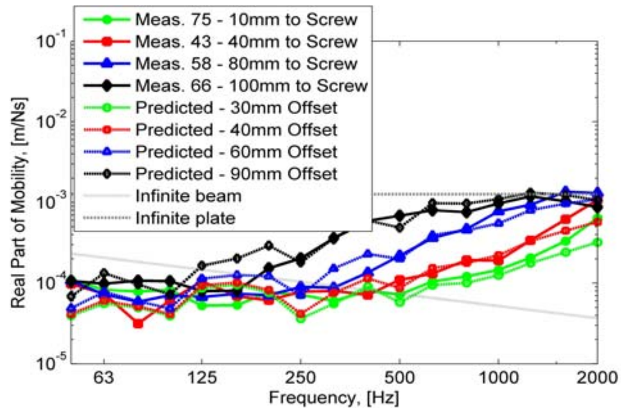

Figure 5: Measured and predicted real part of the drive point mobility for points located above a joist as a function of distance from a screw.

Figure 5 shows predictions for several positions located above a joist for various distances from a screw, when the approximate method described above is used. Here the positions are far removed from an edge of the floor. An agreement with measurement is indicated. With the exception of Position 75 the offset used in the prediction was smaller than the measured distance. This might be explained by recognizing that the distance that really matters is the distance between the measurement point and the nearest point on the chipboard where the chipboard and joist move together in phase. The presence of a finite contact area around the fastener will tend to reduce this distance

Conclusion

When the distance between the measurement point and nearest fastener (screw) is less than one-quarter bending wavelength, the mobility will be strongly affected by the presence of the joist below. A practical implication is that when the fastener spacing is at least one-half wavelength there will be some points above the joist for which the quarter wavelength condition is not satisfied and the joist will have minimal effect on the mobility. This half wavelength criterion marks the transition between line and point-connected behaviour.

Reference

[1] Mayr, A.R., Nightingale T.R.T.: On the mobility of joist floors and periodic rib-stiffened plates. Internoise 2007, Istanbul, Turkey

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