Flooring Fastening Performance and Floor Squeaking

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Introduction

Squeaking and creaking floors are a continuing problem for strip and sheet flooring. Squeaking and creaking result from relative movement between components of the floor such as flooring and fastenings, one piece of flooring and another and framing members. A recent ***Forest Research*** project examined the effects of fastening systems and framing moisture content on the squeaking that arises from the interaction between the joist, flooring and flooring fasteners. Flooring fastening also affects joist stiffness through partial composite action. The study was funded by the Foundation for Research Science and Technology under its public good science fund and was restricted to particleboard flooring only. However the conclusions are probably also applicable to other less common sheet flooring materials such as plywood and MDF.

Fastener squeaking mechanisms

The problem of squeaking of flooring fasteners is likely to be related to shrinkage of joists leading to a gap between the flooring and the joists. The flooring can then move on the nails under walking loads, leading to squeaking. The gap between flooring and joists develops when the joist shrinks along the length of the nail from the top edge of the joist to the point of the nail. The longer the nail shank in the joist, the greater the potential shrinkage gap. Hence this shrinkage gap may be reduced by using a shorter fastener that develops its withdrawal resistance from its diameter or screw threads, rather than its length. The gap does not develop due to withdrawal of the nail, unless the joists are very uneven in height and the nail has poor withdrawal resistance.

Gluing the flooring to the joists keeps the flooring in contact with the joists. If there is shrinkage, this will may appear as nail popping above the floor rather than as a gap developing between the flooring and the joist. Gluing of upper floors is easy but for ground floors this is complicated by the foil insulation commonly draped over the joist. Gluing is possible for ground floors but either a strip of foil must be removed from the top edge of the joist where the glue is spread, or an alternative insulation method must be used. With glue, the nail need only maintain the board in contact with the glued joist and keep the board in position until the glue cures. The nail can therefore be of simple design, (e.g. short, plain shank, galvanised) spaced relatively widely. This reduced nailing can offset the cost of gluing.

Gluing also provides additional benefits by stiffening both the joist and the flooring between the joists. Reduced flooring and joist movement may reduce other squeaking from other sources.

Experimental programme

Trials were set up using small specimens of joist with strips of flooring fastened to each edge of the joist with different systems. The objective was to determine the effect of the fastening system on shrinkage gaps and on the shear stiffness of the joint. Specimens were assembled with both dry and green joists and the particleboard flooring was fastened with nails, screws and glue. Foil insulation was used between the joist and the flooring.

The specimens assembled green, (green specimens) were allowed to dry in the laboratory. The shrinkage of the joist was measured by measuring both the gap between the flooring and the joist, and the distance between the underside of the flooring and the centre-line of the joist.

After shrinkage measurements were complete, green and dry specimens were sawn into sections and the shear stiffness of the different joints was measured.

Test specimen design and assembly

Specimen layout is shown in Figure 1. Each joist length had 4 different pairs of fixing systems on each edge.

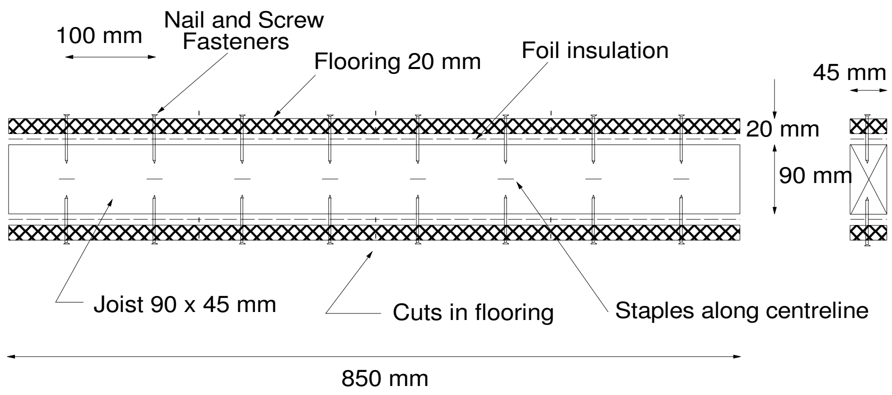
1) Standard flooring nail, 60 mm × 3.15 mm galvanised, annular grooved
2) Short galvanised nail, 40 × 3.15 mm, plain shank
3) Short galvanised nail, 40 × 3.15 mm, plain shank, combined with a construction adhesive meeting AFG-01 American standard for field glued flooring
4) Flooring screws, 45 mm

Timber was selected from dry 190 × 45 test material sawn down the centre into two 90 mm wide pieces. One half of each piece was re-wetted to saturated with clean water by pressure treatment. Thus there was a set of dry joists and a matched set of green joists.

A 50 mm wide strip of double-sided foil insulation was placed between the joist and flooring before fixing. Along the section that was glued, a strip of foil 20 mm wide was removed over a 150 mm length, using a wooden block with two craft knife blades inserted in it.

The fasteners were driven fully home by hand-hammering the nails and power-driving the screws. After assembly, the flooring was cut through to the joist between each group of two fasteners so that there was no interaction between the groups. A row of staples were placed with a staple gun along the centre-line of the joist specimens at each fastener position so that the depths of the joists could be measured between the underside surface of the particleboard strips to the centre-line. The green specimens were then stored in the laboratory to dry alongside the dry specimens.

Figure 1. Test Specimen Layout



Measurements

Moisture contents of the joists were measured before test with a moisture meter and after test by oven drying. Joist density was also measured.

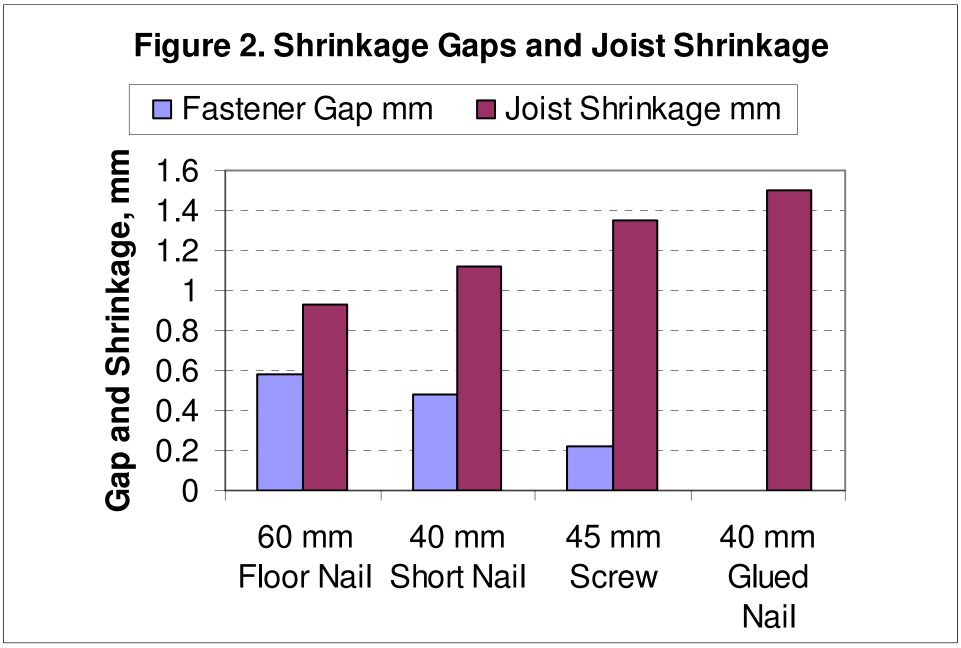
Gaps between the flooring and the green assembled joists at the nail positions were measured with a feeler gauge. Shrinkage of the green joists was measured between the underside of the flooring strips and the centre-line staples at nail positions on both sides of the joist. From these measurements the total shrinkage of the joists was calculated.

Measurements of the shear stiffness of both green assembled and dry assembled joints were made by sawing them right through at the cuts made in the flooring and measuring deflections whilst loading the joist sections on end in a testing machine and supporting the flooring strips on either edge.

Results

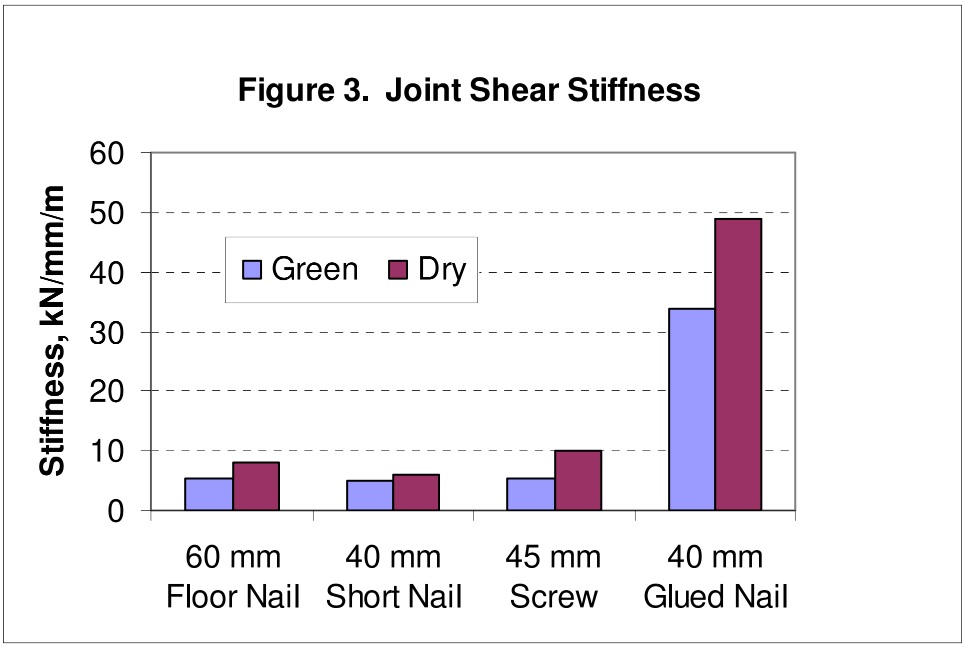
Shrinkage gaps and joist shrinkage

The average shrinkage gaps and joist shrinkage in the green assembled joists for each fastener type is shown in Figure 2.



Joint shear stiffness

The particleboard to joist joint shear stiffness (kN per mm of joint displacement) for each fastener type is shown in Figure 3. The fasteners are assumed to be spaced at 150 mm.



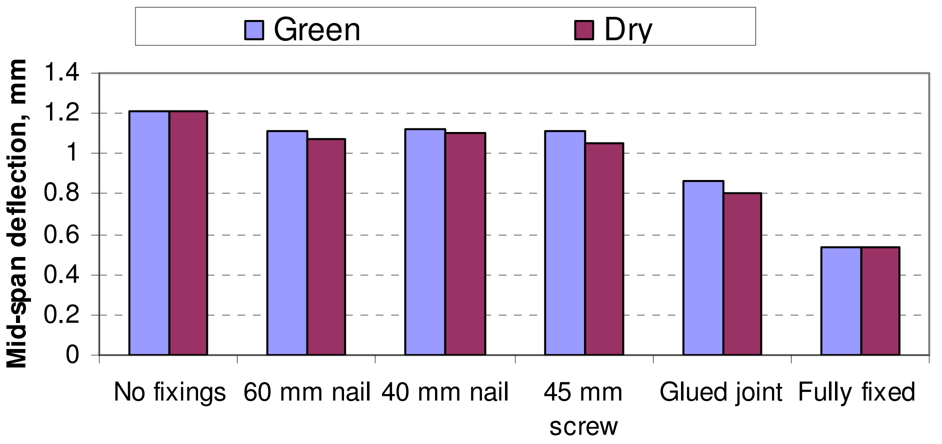
Effect of joint stiffness on joist stiffness

Using a method due to McCutcheon, 1986, the floor joist stiffness taking into account the flooring attached to the joist with non-rigid fastenings, is calculated. These estimates are then used to calculate the deflections of a typical floor system. Results are given in Figure 4.

It is assumed that the floor comprises 190 × 45 mm joists at 600 centres spanning 2.0 mm and carrying a 2.0 kPa uniform load. The joist material has an MoE (stiffness) of 8.0 GPa (average No 1F grade radiata pine) and the particleboard flooring has an MoE of 3.0 GPa in tension.

To indicate the relative effectiveness of each fixing system, the first bars in the graph show deflections which would be expected with no fixings between the flooring and the joist. The last columns show deflections if the joint were fully fixed with a rigid glue.

Figure 4. Deflections of composite joist floor, mm



Discussion

Shrinkage gaps and joist shrinkage

From Fig 2. It can be seen that the screw was the most effective mechanical fastener in reducing shrinkage gaps between the flooring and the joist. The short nail without annular grooves was next most effective, but the gaps were still twice as large as the screw. The long annular grooved nail was least effective. This supports the proposition that the gaps appear as a result of the timber shrinking away from the flooring towards the point of the fastener. A short fastener would be expected to reduce the shrinkage gaps, and it does. Large threads on the shank should restrain shrinkage along the shank and this also appears to occur. The good performance of the screw is probably a result of both its short length and the deep threads restricting the amount of shrinkage along the shank.

Gluing the flooring to the joists however, eliminates the shrinkage gap completely.

Fig. 2 shows that the fasteners which were most effective in reducing the shrinkage gaps, had least effect on restricting the joist shrinkage in the vicinity of the fastener. The long flooring nail probably restrained joist shrinkage along its length. Away from the nail the joist shrinkage would be unrestrained. Thus the surface of the joist would be humped in the vicinity of the nail leaving an even greater gap between the flooring and the joist between the fasteners.

Joint shear stiffness

From Fig. 3 it can be seen that the glued joint was much stiffer than the mechanical joints. However the stiffness of the nailed or screwed joints depends on the spacing of the fasteners. For a 150 mm spacing, the joint stiffness for the glued joint was 6 to 7 times greater than for the mechanical fasteners with green assembled joints, and 5 to 8 times greater for the dry assembled joints.

The reduced shrinkage gaps, in the dry assembled specimens could explain their greater joint stiffness but this argument does not apply to the glued joints. It seems likely that the green assembled glued joints are not as stiff as the dry assembled glued joints, because the quality of the glued joint was affected by the water present in the green joist when it was glued. Also as the joist shrunk in the vicinity of the nail, the glued joint would be strained by the nail attempting to form a shrinkage gap. The elastomeric glue would creep to accommodate this movement leading to a thicker and less stiff glue line. If this is the case, it implies that fewer nails in a glued floor system, would give a stiffer joint.

Effect of joint shear stiffness on joist stiffness

For the floor joist example given in Fig. 4, deflections reduced by 7% or 8% for the green assembled mechanically fastened joints and by between 9% and 13% for the dry assembled joints. For the glued joint the deflection reduction was 29% for the green assembled joint and 33% for the dry assembled joint. If the joint were rigidly assembled, the deflection in this example would be reduced by about 66% or two thirds. Hence the construction adhesive glued joint achieved about half of the potential deflection reduction.

Practical considerations

Upper floors, without the metal foil insulation are straightforward to glue. The sheets are stood up on edge as the glue is applied to the joists and then laid down accurately on the glued joist, rather than slid across the joists into position as is usual.

For joists with foil insulation, strips of foil must be removed from the joist to allow the adhesive bond to form between the joist and the flooring. The gaps left by removing the strips need not be continuous. Bridges, say 30 mm long every 300 mm may be left to connect the foil on either side of the joist. In addition, staples could be placed at intervals along the top edge of the joist, in these bridges, before cutting the foil, to stop the foil from moving across the joist and displacing the glue gap.

If glue is used, the number of fasteners can be reduced as their main job is simply to hold the flooring in position until the glue sets. Doubling nail spacing to 300 mm around the edges and 600 mm along intermediate joists may be satisfactory with straight joists. The reduction in labour required to drive, punch and stop the nails can be offset against the cost of gluing. It also seems likely that in a glued system with green timber, reduced nailing may lead to a stiffer joint due to the shrinkage effects in the vicinity of the nail as discussed above. This effect would not apply to flooring glued to dry joists.

Conclusions

Of the fastening systems evaluated, the usual 60 mm particleboard flooring nail is the worst in terms of shrinkage gaps and only slightly better than the short nail in terms of joint stiffness. The screw is the best mechanical fastener but is inferior to the glued joint in terms of shrinkage gaps and joint stiffness.

There are worthwhile benefits of squeak reduction and increased joist stiffness to be obtained by gluing sheet flooring to floor joists with construction adhesive. There is an additional cost for gluing but this may be partially offset by reduced nailing requirements. Foil insulation can be used between the flooring and the joist provided that a strip of foil is removed from the top of the joist.

In Australia, gluing of particleboard to joists is required in their residential timber-framed construction code, AS 1684.2 – 1999. New Zealand should also adopt this practice more widely.

References

McCutcheon William J, 1986. Stiffness of framing members with partial composite action. J of Structural Engineering 112 (7) July 1986.

Standards Australia, 1999. Residential timber-framed construction. Part 2 Non-cyclonic areas. AS 1684.2 – 1999.