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LIGHTWEIGHT TIMBER FLOOR DESIGN TO ACHIEVE HIGH SOUND INSULATION AND IMPACT ISOLATION WITHOUT CARPET

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ABSTRACT
A new timber floor/ceiling design with a hard floor finish has been developed to meet the acoustical requirements of the New Zealand Building Code. The floor/ceiling is lightweight, structurally sound, of reasonable cost, and meets aesthetic requirements. A series of experiments were used to refine and improve an initial design.

1 - INTRODUCTION
In a recent 14 storey apartment building in Auckland, New Zealand the building was constructed using a structural steel frame, with a lightweight timber floor 65 mm thick. The timber floor was left bare for aesthetic reasons and so posed a potential problem with impact noise on the hard surface transmitting into adjacent apartments.

2 - DESIGN REQUIREMENTS
The New Zealand Building Code currently requires floor/ceiling constructions to achieve an airborne sound insulation of STC 55 or better and an impact insulation of IIC 55 or better. These ratings are for the construction when measured in a laboratory and there is a 5 dB allowance for installation factors such as flanking and workmanship so that constructions when measured on site must achieve at least FSTC 50 and FIIC 50.

3 - DESIGN CONSIDERATIONS
The architectural designers had chosen a 65 mm thick timber floor that was able to span distances of up to 4 m between steel beams, resulting in a very light and simple structure. To the architect it seemed desirable to show off the natural beauty of the wooden floor by simply polishing the top surface. However it was obvious that impact noise was a potential problem and because this type of floor/ceiling had not been used previously in apartment building and so it was necessary to develop a construction that could meet the acoustical requirements of the building code, while being structurally and financially viable.
Now it should be possible to design such a construction by calculating the noise energy generated by a standard tapping machine and calculating the noise transmission and radiation of various designs. However no suitable deign methods were known to the author that were sufficiently accurate. It was therefore decided to design a prototype system using educated guesswork and to then refine the system by carrying out laboratory tests of the prototype.
No data could be found for the impact insulation of thick timber floors, however from measurements on 18 mm wood fibre board it was estimated that the impact insulation would be only about IIC 23. Thus a ceiling was required to achieve an improvement of at least 32 points.
Structure borne transmission from the floor to ceiling below was ignored as it was assumed that the ceiling would be structurally isolated from the floor. Therefore it was only airborne sound radiated off the underside of the timber floor that need to be controlled. Conventional techniques [1] were used to estimate the airborne sound transmission of the extra ceiling.

Preliminary calculations suggested that a single practical ceiling would not be sufficient to reduce the noise radiated off the timber floor to achieve IIC 55, but that a double ceiling would be just capable of reducing the transmission to achieve IIC 55. The prototype ceiling is shown in figure 1, and consists of a 65 mm thick glue laminated timber floor, an airspace with a 75 mm thick fibreglass blanket, 2 layers of 12 mm thick gypsum plaster board, another airspace with a 75 mm thick fibreglass blanket and a finished ceiling consisting of a single layer of 12 mm gypsum plasterboard. The overall thickness of the floor ceiling system was 500 mm.

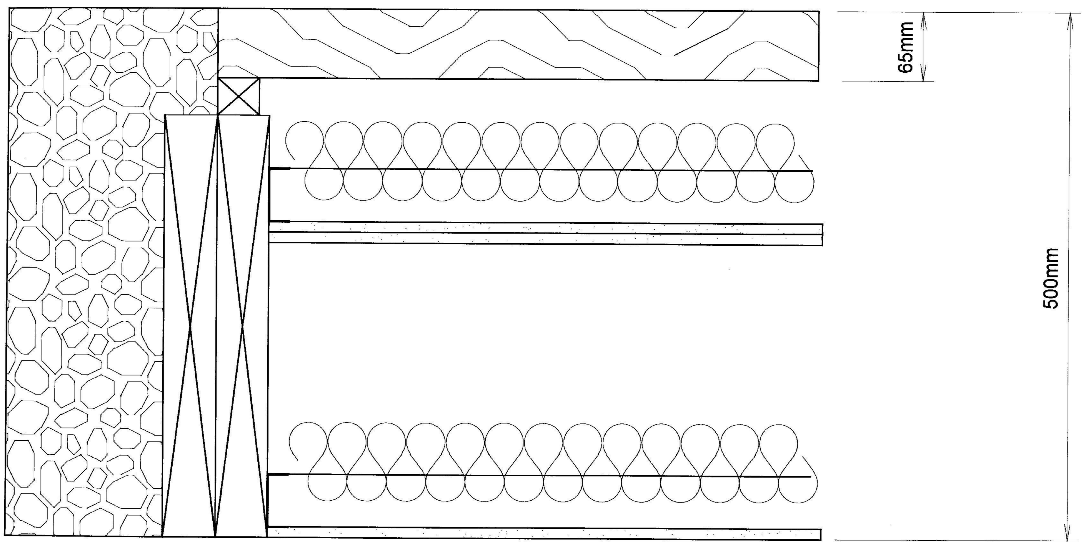

Figure 1: Prototype floor/ceiling design.

4 - TEST PROGRAMME

Instead of simply testing this design straight off it was decided to test different elements of the construction separately to gather information that would enable improvements or alterations to the design to be accurately predicted. A test programme was developed to make the best use of resources. The constructions tested are shown in figure 2.

5 - TEST RESULTS

It was found that the impact insulation of the bare 65 mm thick timber floor was only IIC 18, not IIC 23 as initially estimated, this meant that the prototype design was probably going to be inadequate. The next 2 tests showed however that simply fixing plasterboard to the underneath of the timber floor improved the impact insulation by 4 points for a single sheet of 16 mm plasterboard and 8 points for two sheets of 16 mm plasterboard. This is a much larger improvement than suggested simply by the increase in mass of the floor. It was assumed that these improvements would be approximately independent of the improvements obtained by the ceilings and so could be used to make up any shortfall in performance. The next tests showed that a single ceiling increased the impact insulation of the bare floor from IIC 18 to IIC 36, however addition of another sheet of 12 mm plasterboard only increased the performance to IIC 37.

With the addition of an extra ceiling of 12 mm gypsum plasterboard hung underneath the first ceiling the impact insulation was increased to IIC 52. This was the initial prototype ceiling which it had been hoped would achieve IIC 55. Addition of another layer of 12 mm plasterboard to the lower ceiling only increased the impact insulation by one point to IIC 53.

The effect of using higher density cavity absorption was established by replacing the 10 kg/m^3 blankets with 22 kg/m^3 blankets, this increased the IIC only one point.

The following conclusions were used to estimate the performance of the final design:

- Addition of a 16 mm gypsum plasterboard sheet screwed to the underneath of the timber floor would increase the IIC by approximately 4 points, and a second sheet by a further 4 points.
- Addition of a sheet of 12 mm gypsum plasterboard to either the inner or outer ceiling would increase the IIC by approximately 1 point.

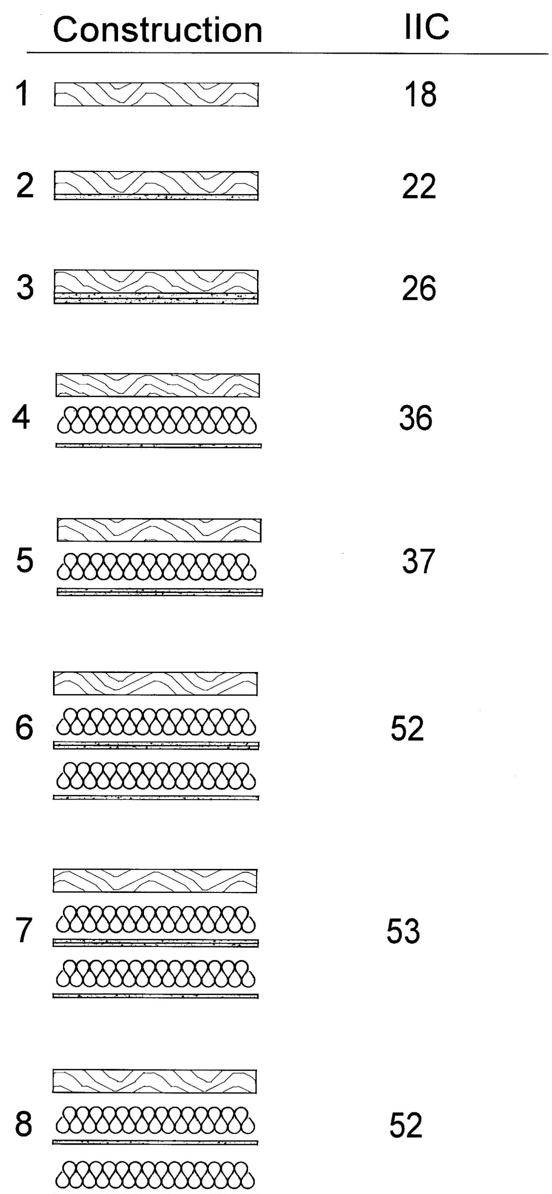

Figure 2: Floor/ceiling constructions tested.

- A pour on polyester finish will increase the IIC by approximately 1 point.
- Replacing the 10 kg/m^3 fibreglass with 22 kg/m^3 fibreglass blankets would increase the IIC by 1 point.

The final design chosen is shown in figure 3, this was estimated from the intermediate results to achieve IIC 55.
Note that the final design uses the same amount of material as the prototype design and is estimated to cost the same to construct, but achieves a higher performance by fixing the second sheet of plasterboard directly under the timber floor instead of to the inner ceiling.
The airborne sound insulation of construction 9 was STC 61. The estimated sound insulation of the final design was STC 64.
Measurements have been carried out in the completed building. A sample of 3 floor/ceiling were selected and measured in-situ. The airborne sound insulation results were FSTC 58, 66 and 54. The impact insulations were IIC 55, 62 and 52. In all cases the results were comfortably in excess of the Building Code minimum requirements.

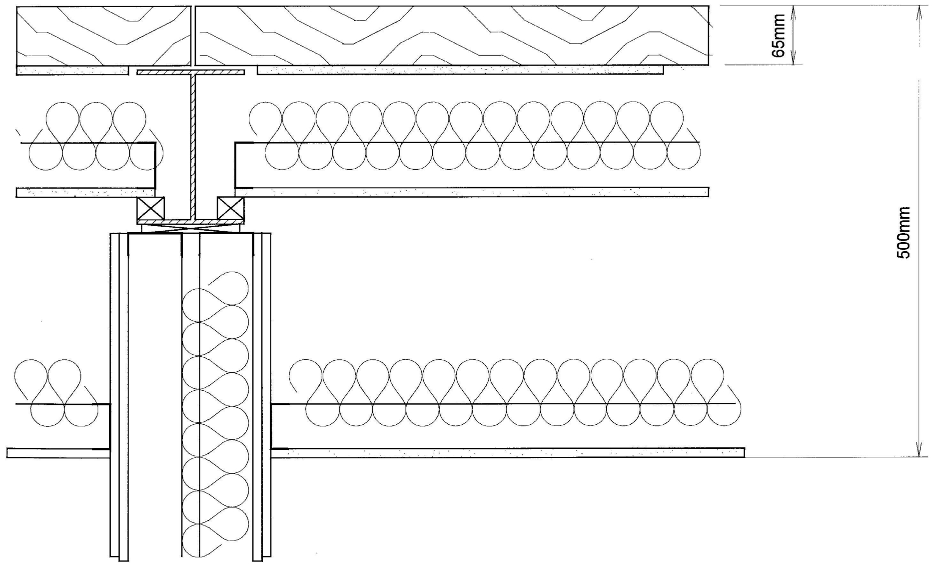

Figure 3: Final floor/ceiling design.

6 - CONCLUSIONS

A lightweight floor using a 65 mm thick timber structural floor has been designed that will achieve in excess of STC 60 and IIC 55 with a hard floor finish.

REFERENCES

1. **B.H. Sharp**, Prediction Methods for the Sound Transmission of Building Elements, *Noise Control Engineering*, Vol. 11 (2), pp. 53, 1978