RESEARCH REPORT


# Sound Transmission Through Floors

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# SOUND TRANSMISSION THROUGH FLOORS

Prepared for

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NOTE: **DISPONIBLE AUSSI EN FRANÇAIS SOUS LE TIRE:**

TRANSMISSION DES SONS À TRAVERS LES PLANCHERS

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# CLIENT REPORT

for

## Canada Mortgage and Housing Corporation
## Housing Innovation Division
## 700 Montreal Road
## Ottawa, Ontario K1A 0P7

# Sound Transmission Through Floors
# Phase III - Summary Report

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## INTRODUCTION AND SUMMARY OF REPORT

Footstep noise and other impact sounds are common sources of annoyance in multi-family dwellings. Standard tests [ASTM E492, ASTM E1007, ISO 140] are available to measure impact sound transmission through floors. Research has shown, however, that the ratings provided [ASTM E989, ISO 717] do not rank floors as would human subjects listening to walkers on the floors. Some floors may be acceptable according to these tests yet apartment occupants find them unacceptable because of low-frequency thumping noises. This is especially true for wood-joist and similar lightweight constructions with carpeted floors; the carpet ensures a good rating in the standard test, but does little to attenuate low-frequency impact sound. Occupant dissatisfaction can be very high and may lead to litigation and costly repair work, if repair is even possible.

The data in this report is taken from a research project [NRCC CR6132.2] that investigated a possible new test for evaluating the transmission of low-frequency impact sounds through lightweight floor constructions. Measurements were made of sound transmission through 75 different floor structures. Analysis of the data showed that the best compromise for testing impact sound transmission through floors is to continue using the ASTM/ISO tapping machine with the frequency range for measurement extended to 50 Hz. As well, a new single number rating should be introduced to replace impact insulation class [ASTM E989] and the weighted impact sound index, $L'_{n,w}$.

The data available from the research project form a consistent set and for the purposes of this summary report, a rating is introduced and called the tapping machine rating (TMR). It has no official standing as yet and its derivation is described in Appendix A. The tables in this report give values of the single number ratings sound transmission class (STC) [ASTM E413], impact insulation class (IIC) [ASTM E989], and TMR. One-third octave band data for the the tests can be found in the earlier report [NRCC CR6132.2]

## USE OF TABLES

The tables that follow may be used to select constructions for use in multi-family homes. To do this, criteria for minimum acceptable values of the single number ratings are needed. They are suggested here although users are always free to set higher standards.

### Recommended Minimum Value of STC

For walls or floors between homes, the National Building Code of Canada recommends a minimum STC of 50. In practice, sound insulation is often degraded because of construction errors and design errors that introduce flanking transmission. Selecting designs with STC ratings of 55 or more provides some margin of safety to allow for this kind of degradation. Thus the minimum STC recommended here is 55.

Note: During the measurements of airborne sound transmission it was found that the laboratory seemed to have a limit to the STC that could be measured, about 60. This has been attributed to flanking transmission. Consequently, the STC ratings for some of the better floor designs may be too low.

### Recommended Minimum Values of IIC and TMR

The National Building Code does not recommend a minimum value of impact insulation class. Some other jurisdictions require a minimum IIC of 55. That is the value recommended here too. [See also Bodlund(1989)}]. To ensure that removal by tenants of soft coverings, such as carpet, does not lead to serious degradation of the impact insulation, this minimum value of IIC 55 should be obtained when the floor is tested without carpet.

Using the data collected in the present work, the criterion found for the minimum acceptable value of TMR is 50.

Of the 75 floors tested, 39 of them had IIC values of 55 or more. Of the 51 uncarpeted floors tested, only 19 of them had an IIC of 55 or more. Using the TMR rating and the criterion that it should be 50 or more, the corresponding numbers are 40 and 26.

## BASIC FLOOR CONSTRUCTIONS TESTED

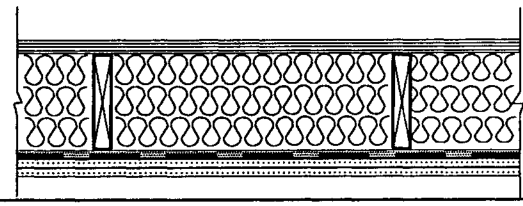
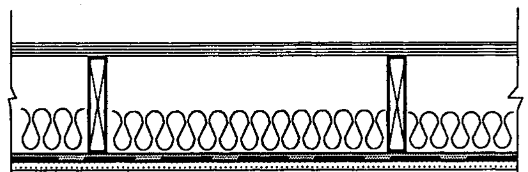
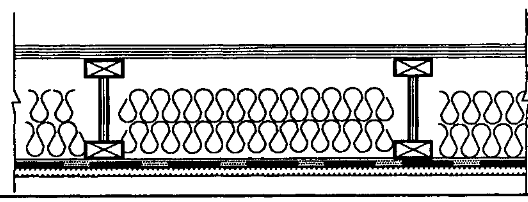
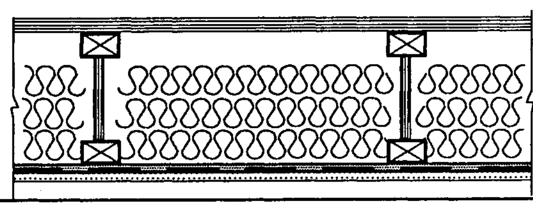
Two types of wood joist floors, three types of wood truss floors and one solid concrete floor were tested. As well as testing the basic floor with the top surface unfinished (Bare), five different floor toppings were placed on the floors. These were a carpet, a carpet and underpad and three types of floating floor. Combinations of the five basic floors with the five toppings formed the specimens for the main measurement series. Other toppings were tested in some cases. Details are in the complete table of ratings.

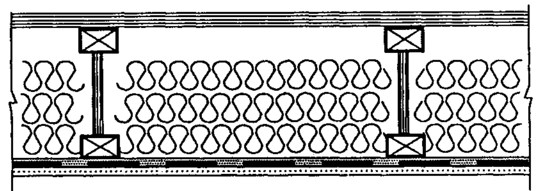
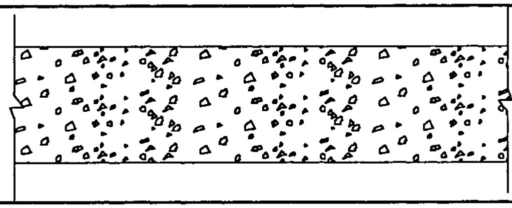
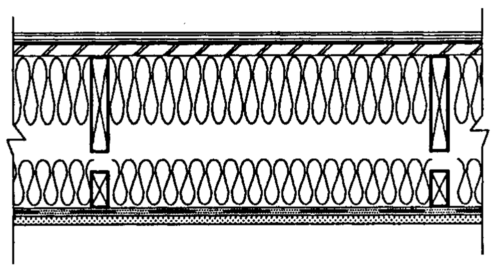
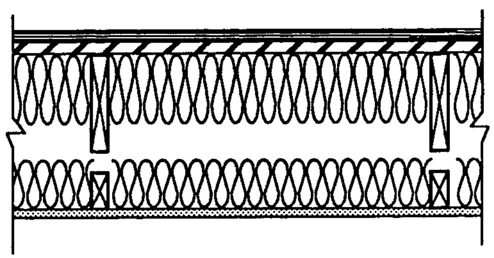
In the tables that follow, floor systems are identified by names such as Joist1, Joist2 and so on. The floor coverings are identified as C and CU for carpet and carpet and underpad. The floating floors are identified as F1, F2, and F3 for Float1, Float2, and Float3. These identifiers are also used for conciseness in the summary tables.

The construction of the basic floors is given in Table 1. The descriptions of the floating floors are given in Table 2. The physical characteristics of the materials used are given in Appendix B.

The floor Joist1 is essentially the same construction that was tested in a previous contract for CMHC [Bradley, 1989]. Sound transmission class (STC) and impact insulation class (IIC) measurements were repeated and additional surface layers were re-installed for this work. There are differences between this set of results and those in the previous report. These can be attributed to unknown differences in construction.

Table 1: Basic floor constructions tested.

| Floor | | Construction |
|---|---|---|
| Joist1 |  | 16 mm tongue and groove plywood<br>240 x 38 mm wood joists<br>three layers of 90 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>two layers of 16 mm drywall |
| Joist2 |  | 16 mm tongue and groove plywood<br>240 x 38 mm wood joists<br>one layer of 90 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall |
| Truss1 |  | 16 mm tongue and groove plywood<br>240 x 38 mm wood trusses<br>two layers of 90 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall |
| Truss2 |  | 16 mm tongue and groove plywood<br>300 x 38 mm wood trusses<br>three layers of 75 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall |

| | | |
|---|---|---|
| Truss3 |  | 16 mm tongue and groove plywood<br>400 x 38 mm wood trusses<br>280 mm thickness of glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall |
| Conc1 |  | 150 mm concrete slab |
| Djoist1 |  | 16 mm tongue and groove plywood<br>19 mm wood fibre board<br>240 x 38 mm wood joists on 290 mm headers<br>200 mm thickness of glass fiber batts<br>13 mm Ethafoam between floor and ceiling headers<br>140 x 38 mm wood joists<br>150 mm thickness of glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall |
| Djoist2 |  | 16 mm tongue and groove plywood<br>19 mm wood fibre board<br>240 x 38 mm wood joists on 290 mm headers<br>200 mm thickness of glass fiber batts<br>13 mm Ethafoam between floor and ceiling headers<br>140 x 38 mm wood joists<br>150 mm thickness of glass fiber batts<br>one layer of 16 mm drywall |

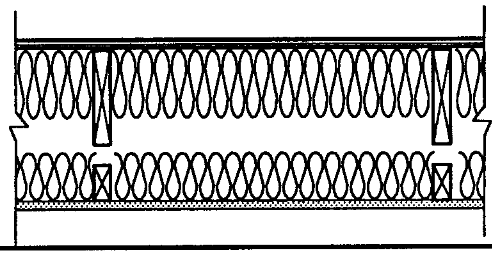
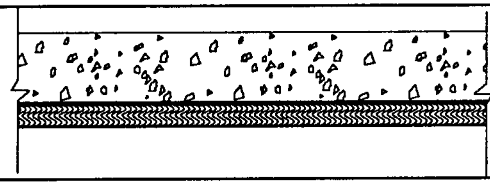
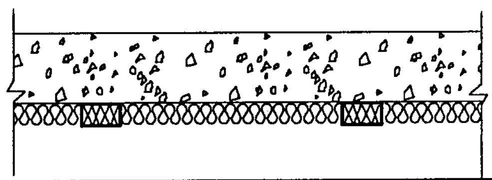
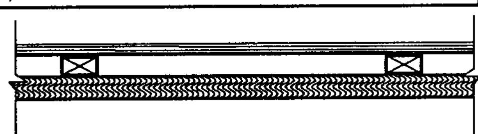
| | | |
|---|---|---|
| Djoist3 |  | 16 mm tongue and groove plywood<br>240 x 38 mm wood joists on 290 mm headers<br>200 mm thickness of glass fiber batts<br>13 mm Ethafoam between floor and ceiling headers<br>140 x 38 mm wood joists<br>150 mm thickness of glass fiber batts<br>one layer of 16 mm drywall |

Table 2: Floating floor descriptions.

| Floor | | Construction |
|---|---|---|
| Float1 |  | 40 mm thick layer of concrete resting on 25 mm AF530 glass fibre board |
| Float2 |  | 40 mm thick layer of concrete resting on 21 mm soft neoprene pads with AF331 glass fiber batts in the cavity. |
| Float3 |  | 16 mm thick layer of plywood resting on 40 x 90 mm wood strapping laid on 25 mm AF570 glass fibre board |

## TABLES OF SINGLE NUMBER DESCRIPTORS

### Summary Tables

Table 3 shows the matrix of results for the main part of the measurement series. Basic floor types are identified by the code letters and names explained above, as are the floating floors or coverings on top. In a few cases, a single layer of concrete 40 mm thick was laid directly on top of the floor structure. These cases are also identified in the table.

### *Improvements for five standard floor toppings*

Frequently, the improvement that can be expected due to a floor topping is of interest. Table 4 shows improvements in STC, IIC and TMR due to the five toppings used. From this table, one can see that the addition of a soft floor covering or a floating slab does not always give the same improvement for all floor types. If, however, floors of the same general type are considered, the improvement is roughly the same. For example for wood joist or truss structures, adding carpet to a improves IIC by about 8 and TMR by 2 to 5; a carpet and underpad improve IIC by about 25 and TMR by about 15; and Float1 and Float2 improve IIC by about 12 points and TMR by about 15. There are some deviations but these are useful approximations.

Table 3: Summary of STC, IIC and TMR Ratings for main series of measurements.

| | STC | | | | | | IIC | | | | | | TMR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Floor Type** | **Bare** | **C** | **CU** | **F1** | **F2** | **F3** | **Bare** | **C** | **CU** | **F1** | **F2** | **F3** | **Bare** | **C** | **CU** | **F1** | **F2** | **F3** |
| Joist1 | 55 | 58 | 58 | | | | 51 | 65 | 80 | | | | 40 | | | | | |
| Joist2 | 49 | | | 60 | 59 | 57 | 44 | | | 57 | 58 | 51 | 33 | | | 55 | 56 | 45 |
| Joist2 + 40 mm concrete | 59 | 59 | 58 | | | | 40 | 73 | 84 | | | | 54 | 54 | 65 | | | |
| Truss1 | 48 | 50 | 50 | 60 | 60 | 55 | 40 | 47 | 66 | 52 | 52 | 46 | 34 | 39 | 55 | 51 | 51 | 43 |
| Truss2 | 55 | 57 | 56 | 62 | 62 | 60 | 48 | 57 | 72 | 59 | 60 | 50 | 37 | 40 | 54 | 55 | 55 | 43 |
| Truss3 | 54 | 56 | 56 | 60 | 60 | 57 | 49 | 57 | 70 | 55 | 59 | 51 | 39 | 41 | 51 | 49 | 49 | 41 |
| 150 mm concrete | 52 | 52 | 51 | 62 | 62 | 61 | 25 | 68 | 86 | 71 | 64 | 63 | 50 | 67 | 83 | 58 | 56 | 56 |
| Djoist1 | 59 | 59 | 59 | | | | 56 | 64 | 81 | | | | 48 | 50 | 58 | | | |
| Djoist1 + 40 mm concrete | 61 | | | | | | 63 | | | | | | 61 | | | | | |
| Djoist2 | 57 | | | | | | 54 | | | | | | 40 | | | | | |
| Djoist2 + 40 mm concrete | 61 | | | | | | 59 | | | | | | 54 | | | | | |
| Djoist3 | 55 | | | | | | 52 | | | | | | 38 | | | | | |

Table 4: Improvements in single number ratings relative to the bare floors for main series of measurements.

| | STC | | | | | IIC | | | | | TMR | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bare Floor Type** | C | CU | F1 | F2 | F3 | C | CU | F1 | F2 | F3 | C | CU | F1 | F2 | F3 |
| Joist1 | 3 | 3 | | | | 14 | 29 | | | | 5 | 18 | | | |
| Joist2 | | | 11 | 10 | 8 | | | 13 | 14 | 7 | | | 22 | 23 | 12 |
| Joist2 + 40 mm concrete | 0 | -1 | | | | 33 | 44 | | | | 0 | 11 | | | |
| Truss1 | 2 | 2 | 12 | 12 | 7 | 7 | 26 | 12 | 12 | 6 | 5 | 21 | 17 | 17 | 9 |
| Truss2 | 2 | 1 | 7 | 7 | 5 | 9 | 24 | 11 | 12 | 2 | 3 | 17 | 18 | 18 | 6 |
| Truss3 | 2 | 2 | 6 | 6 | 3 | 8 | 21 | 6 | 10 | 2 | 2 | 12 | 10 | 10 | 2 |
| 150 mm concrete | 0 | -1 | 10 | 10 | 9 | 43 | 61 | 46 | 39 | 38 | 17 | 33 | 8 | 6 | 6 |
| Djoist1 | 0 | 0 | | | | 8 | 25 | | | | 2 | 10 | | | |

## Some Specific Comparisons

### *Adding concrete directly to a joist floor*

Some interesting questions can be answered using the data collected. For example, concrete toppings are often laid directly on top of wood joist or truss floors to improve their sound insulation. Table 5 summarizes results for the two cases that were measured. In one case, the increase in STC is 10, in the other only 2. This latter small difference is taken to be an indication of the flanking transmission in the laboratory discussed earlier. The TMR values in this table consistently show an improvement, but the IIC ratings do not. This is because the IIC rating is controlled by the high frequency sound levels in one case.

Table 5: Effect of adding concrete directly on joist floor.

| Floor | STC | IIC | TMR |
|---|---|---|---|
| Joist2 | 49 | 44 | 33 |
| Joist2 + 40 mm concrete | 59 | 40 | 54 |
| Improvement | 10 | -4 | 21 |
| Djoist1 | 59 | 56 | 48 |
| Djoist1 + 40 mm concrete | 61 | 63 | 61 |
| Improvement | 2 | 7 | 13 |

### *Differences between floating floor types*

The differences in Table 4 allow one to draw some conclusions about the effectiveness of the types of floating floors used. Float1 and Float2 used a 40 mm concrete slab with two different methods for support. They give about the same single number ratings. Float3 used a much lighter 16 mm plywood raft and was clearly less effective. The design of floating floors is discussed later.

### *Effect of truss depth*

One factor that was varied in the measurements was the depth of the wood trusses used. Two effects should be at work here: 1) as the cavity depth increases, the sound insulation is expected to increase, and 2) as the truss depth increases, the floor stiffness increases. This should result in less impact sound. Table 6 and Fig. 1 show results for the joist floors and the truss floors tested. The double joist system is included in this table for interest although it is not a fair comparison. The trends are fairly clear; there is a tendency toward improved insulation as the cavity and joist depth increase. The double joist system, with its extra layers of material and superior isolation between the floor and ceiling system, is noticeably better.

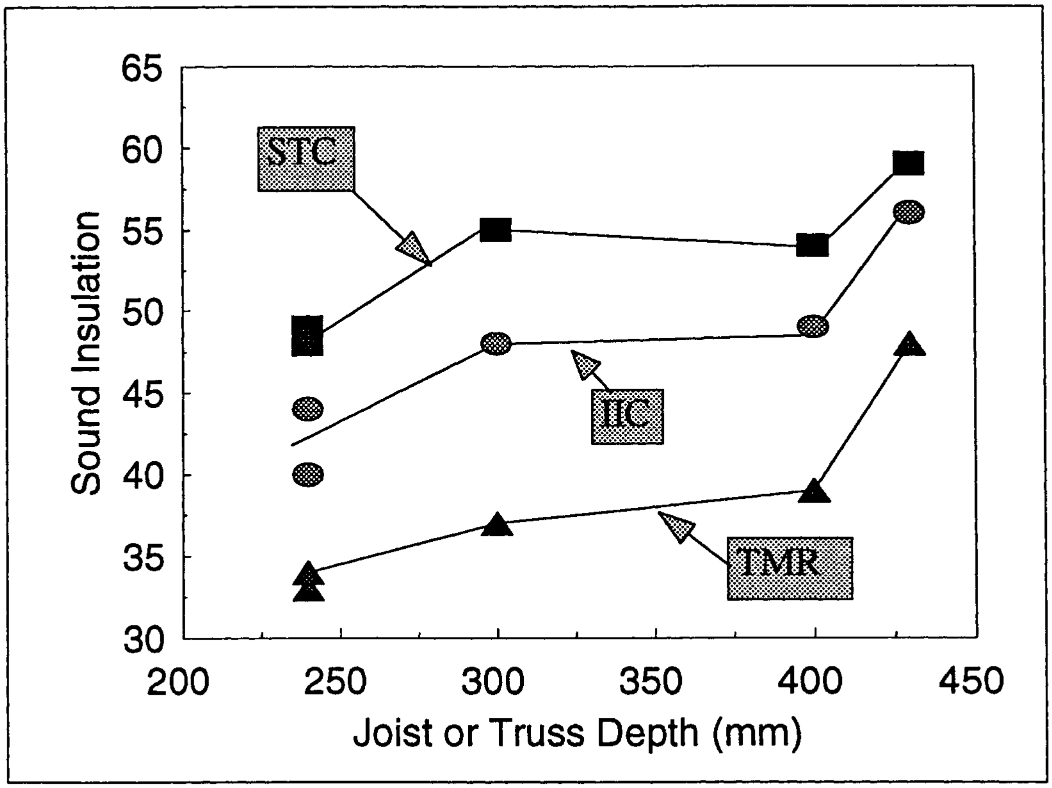



*Figure 1: Effect of increasing joist or truss depth on sound insulation ratings.*

Table 6: Effect of joist or truss depth on floor sound transmission.

| Floor | Joist or truss depth (mm) | STC | IIC | TMR |
|---|---|---|---|---|
| Joist2 | 240 | 49 | 44 | 33 |
| Truss1 | 240 | 48 | 40 | 34 |
| Truss2 | 300 | 55 | 48 | 37 |
| Truss3 | 400 | 54 | 49 | 39 |
| Djoist1 | 430 | 59 | 56 | 48 |

### *Effect of sound absorbing material in floating floor cavity*

The 150 mm concrete slab was tested with the 40 mm concrete slab on soft neoprene pads (Float2) with and without sound absorbing material in the cavity. Table 7 shows the results. The IIC ratings are increased, but the other ratings show no clear improvement.

Table 7: Effect of adding sound absorbing material in cavity of Float2 and of increasing cavity depth in Float3.

| Floor | STC | IIC | TMR |
|---|---|---|---|
| 150 mm concrete slab, Bare | 52 | 25 | 50 |
| *Improvement due to addition of glass fibre in cavity* | | | |
| 40 mm concrete on 21 mm thick neoprene pads on 150 mm concrete slab | 61 | 57 | 58 |
| 40 mm concrete on 21 mm thick neoprene pads with AF331 in cavity on 150 mm concrete slab | 62 | 64 | 56 |
| *Improvement due to increasing thickness of wood strapping* | | | |
| 16 mm thick layer of plywood resting on 40 x 90 mm wood strapping laid on 25 mm AF570 glass fibre board on 150 mm concrete slab | 61 | 63 | 56 |
| 16 mm thick layer of plywood resting on two layers of 40 x 90 mm wood strapping laid on 25 mm AF570 glass fibre board on 150 mm concrete slab | 62 | 66 | 59 |

### *Effect of depth of floating floor cavity*

Table 7 also shows the effect of increasing the thickness of the wood strapping under the 16 mm plywood used in Float3. The ratings from the tapping machine, IIC and TMR, show an improvement.

### *Effect of stiffness of floating floor support pads*

At one point in the measurements, several different types of support pads were used. The stiffness of these pads is given in Table 8. These supports were placed under the concrete slab in a standard pattern. The 21 mm thick neoprene foam pads were used as standard under Float2.

Table 9 shows the measured sound insulation results for the different pads supporting the 40 mm concrete slab on top of Joist2. As the stiffness decreases, the IIC ratings improve. There is no clear improvement seen with the other rating systems.

Table 8: Stiffness of floating floor support pads.

| Material | Stiffness (N/m) |
|---|---|
| Hard rubber blocks | 61217 |
| Brown composite damping material (CDM) | 57500 |
| Neoprene Lab Stoppers, 18 mm thick | 44500 |
| Green CDM | 32100 |
| Neoprene Foam, 21 mm thick | 14500 |
| AF530 | 4250 |
| AF570 | 5700 |

Table 9: Effect of different support pads on sound transmission. Basic floor is Joist2. The slab is the 40 mm concrete layer.

| Pads | STC | IIC | TMR |
|---|---|---|---|
| Hard rubber blocks, standard pattern | 58 | 46 | 56 |
| Brown CDM | 59 | 48 | 57 |
| Neoprene Lab Stoppers, 18 mm thick | 59 | 53 | 56 |
| Green CDM | 59 | 54 | 56 |
| Neoprene Foam, 21 mm thick | 58 | 55 | 56 |
| AF530 | 60 | 57 | 55 |

### *Effect of position of pads supporting the floating floor with joist floors*

Not shown in Table 9 are the results found when the support pads were moved so all were directly on a joist or all between joists. There was no effect on the single number ratings.

## DESIGN AND INSTALLATION OF FLOATING FLOORS

### Design

In designing a floating floor, take the following steps:

- Design the floating slab to have adequate structural strength for the load it is to support. The thickness will be determined in part by the method of support.

- Select a resilient support whose load-bearing characteristics are appropriate for the floating slab. For example, precompressed fiberglass floor isolation board used to support a concrete floating slab usually has a density of 64 to 192 kg/m$^3$.

- Ensure that the resilient support has the required life expectancy for both static and dynamic design loads.

- Ensure that the floating slab will not contact the building structure. For example, fill the gap between the floating slab and the wall with a resilient material such as low-density fiberglass to prevent contact between the edge of the floating slab and the wall. Figures 2, 3, 4 and 5 show edge details. The fiberglass at the edge of the floating slab is recessed to leave a space for the caulking. The caulking, when applied in the recessed groove, is then protected against wear.

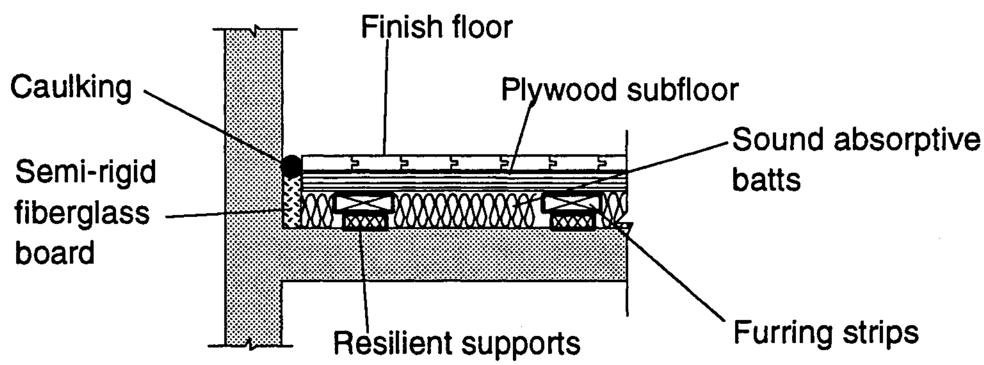



*Figure 2: Example of lightweight wood floating floor supported on resilient pads. The floating slab should not be in contact with the main building structure nor the structural slab below.*

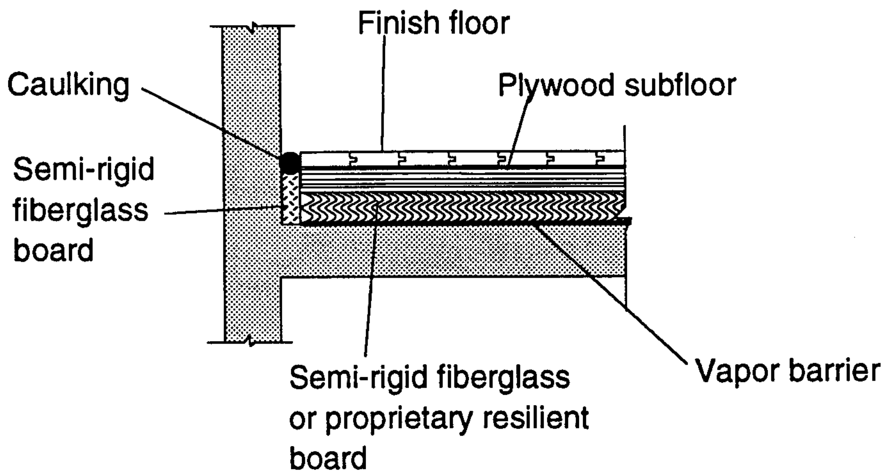



*Figure 3: Example of lightweight wood floating floor supported on a resilient mat. The floating slab should not be in contact with the main building structure nor the structural slab below. The floating slab could be formed from layers of plywood glued together to form a continuous slab.*

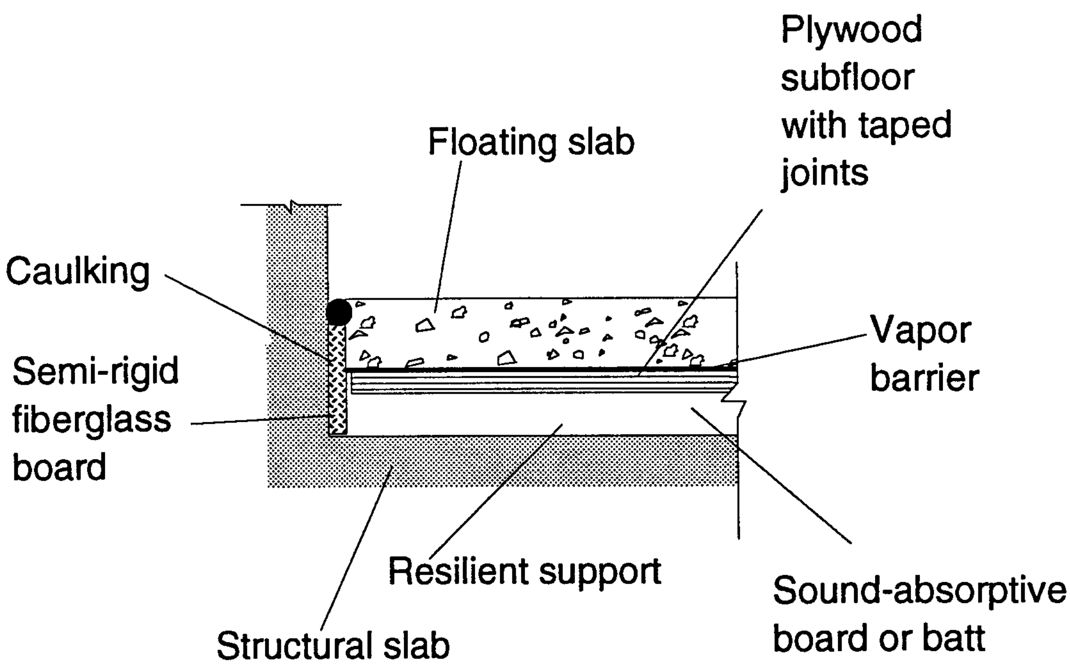



*Figure 4: Example of concrete floating floor supported on resilient pads. The floating slab should not be in contact with the main building structure nor the structural slab below.*

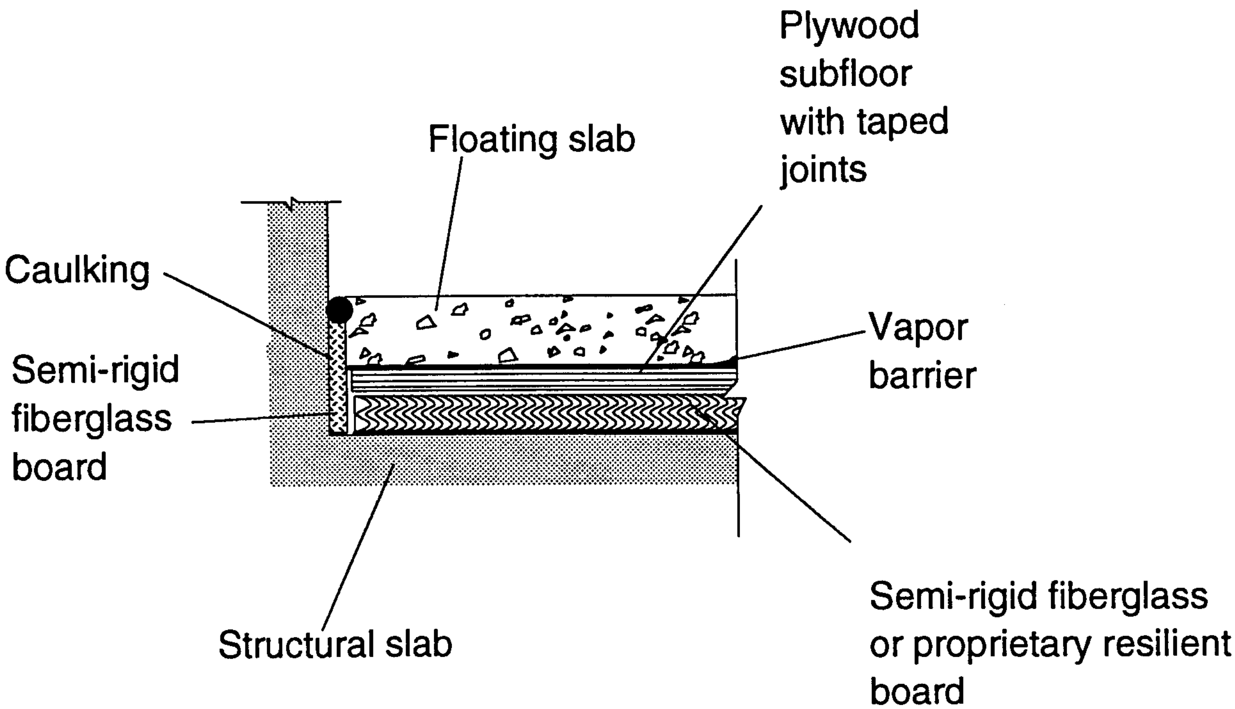



*Figure 5: Example of concrete floating floor supported on a resilient mat. The floating slab should not be in contact with the main building structure nor the structural slab below.*

- Avoid penetrations of the floating slab by pipes, ducts, etc., but where a penetration is essential (as, for example, a drainage pipe), ensure that it does not form a rigid connection between the floating slab and the structural slab or walls (see Figs. 6, 7 and 8 for examples).

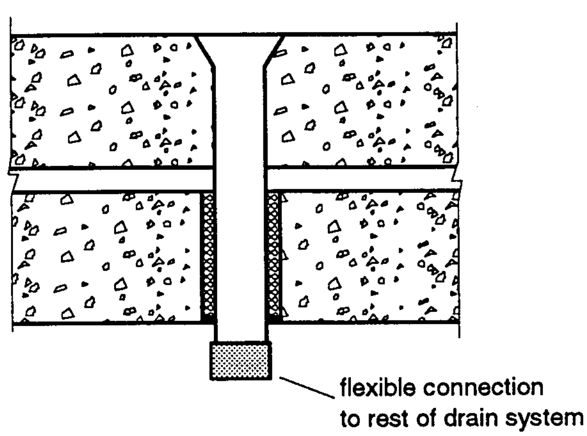



*Figure 6: Example of drain installation through a floating floor.*

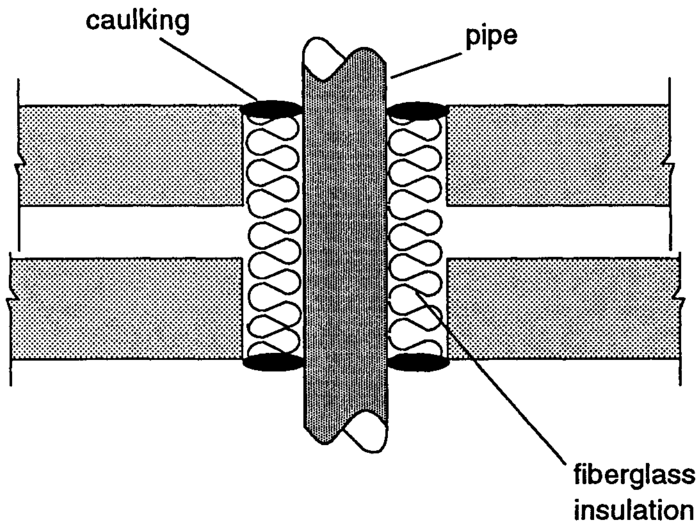



*Figure 7: Example of pipe installation through a floating floor.*

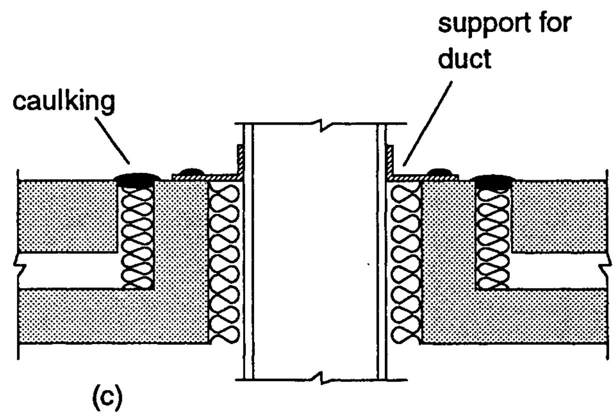



*Figure 8: Example of duct installation through a floating floor.*

- Protect fiberglass material from possible water damage. For example, if precompressed fiberglass floor isolation board is used as the resilient support, protect the fiberglass with a plastic sheet to prevent moisture from the concrete structural slab from damaging the fiberglass.

- Before pouring a floating slab, inspect the surface and the perimeter of the surface on which the concrete is to be poured to ensure they are not damaged.

- Ensure the structural floor is clean and smooth before laying down the resilient supports. This avoids short-circuiting of the floating slab to the structure by debris, for example (see Fig. 9).

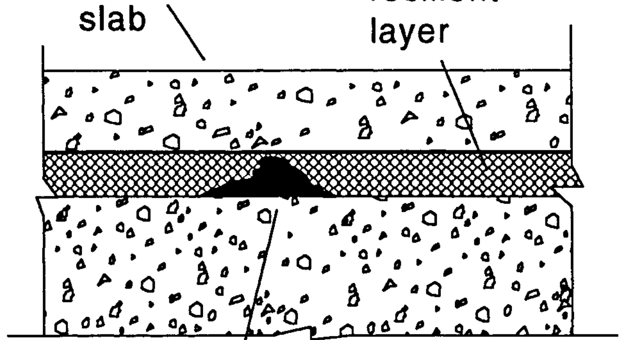



*Figure 9: Short-circuiting of a concrete floating slab by debris.*

- Before pouring a floating concrete slab, cover the resilient material or supports with plywood (or fiberboard); tape the joints between plywood sheets; cover the top surface of the plywood with an impervious plastic sheet to provide a surface on which to pour the floating slab and a hard surface to walk on during construction.
- Provide sufficient ventilation during the pouring and setting of a large concrete floating slab to carry away moisture.
- Do not use designs that require the upper slab to be held down by screws that penetrate the resilient layer and connect the floating slab to the structural floor. These screws "short-circuit" the resilient layer and reduce sound insulation. Such designs are not true floating floors (see Fig. 10).

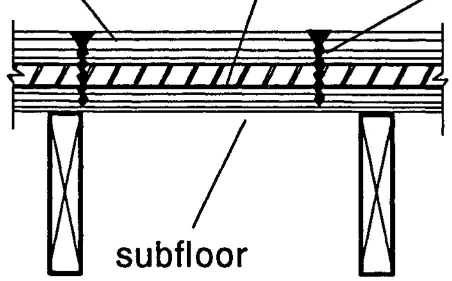



*Figure 10: Short-circuiting of a wooden floating slab by overly long screws.*

## How to Improve the Impact Sound Insulation of Joist or Truss_Floor Constructions

*Method 1:*

- Increase the mass of the floor layer. For example, add a layer of concrete or layers of gypsum board and plywood.
- Increase the mass of the ceiling layer and be sure it is suspended resiliently from the floor construction. In critical situations, use neoprene and spring supports that provide a static deflection of about 15 mm when loaded by the ceiling.
- Fill the floor cavity between the ceiling and the floor at least 3/4 full with sound-absorptive material if this has not already been done.
- Install a good quality carpet and soft underpad.

*Method 2:*

- Install a floating floor slab on the floor.
- Install a good quality carpet and soft underpad.

## Some Installation Details

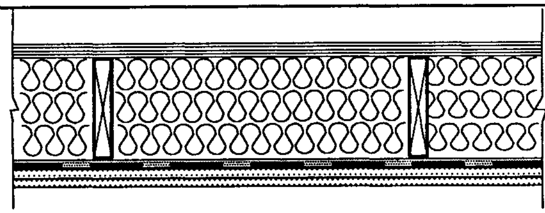
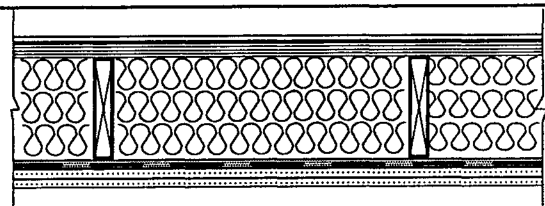
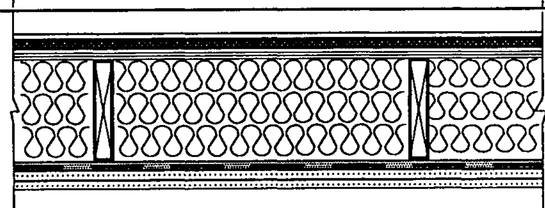
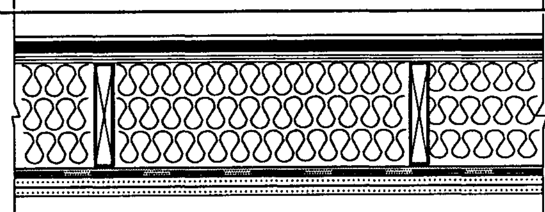
As the measurement data suggest, floating slabs are most effective if they are relatively heavy, for example at least 50 mm of concrete. In large mechanical rooms, the concrete slab is often 100 mm thick. Lighter slabs, of thick plywood for example, are often useful in remedial work where the structure of the building cannot support much additional weight, or for reasons of economy.

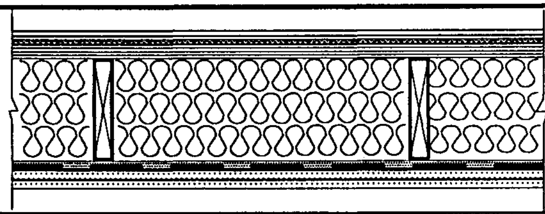
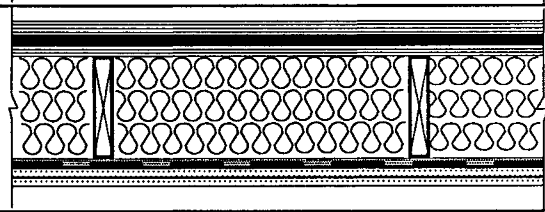
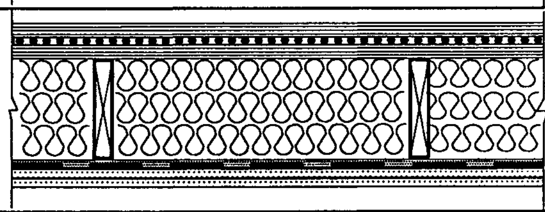
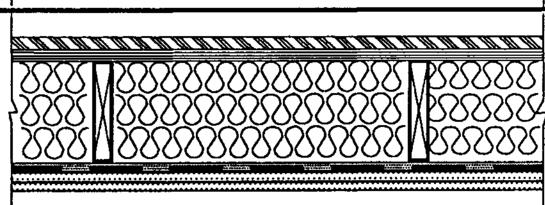
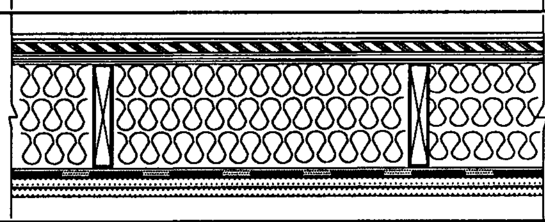
Examples of floating wood slabs supported on pads and mats are shown in Figs. 2 and 3. The corresponding concrete versions are shown in Figs. 4 and 5. Lightweight floating slabs are usually less effective than slabs of heavier concrete and may even decrease the structureborne sound insulation at low frequencies rather than improve it. Adding a carpet and underpad on top of a floating slab further improves the impact sound insulation.

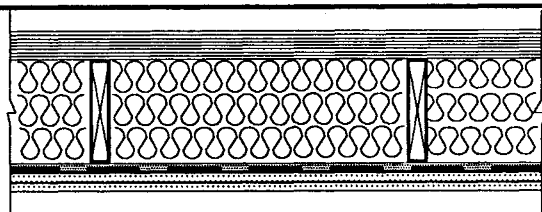
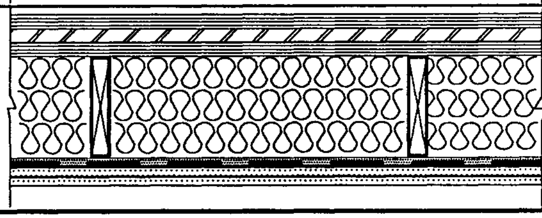
Tables giving the sound insulation ratings for all of the floors tested are given on the following pages.

## SOUND INSULATION RATINGS FOR ALL FLOORS TESTED

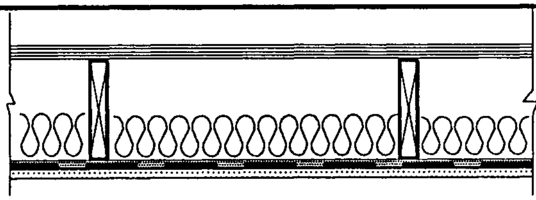
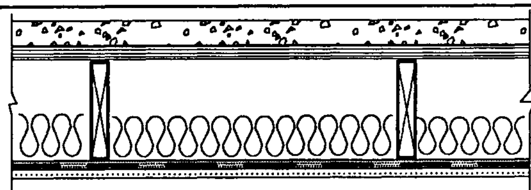
### Joist1 Floors

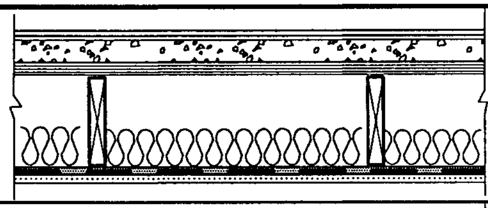
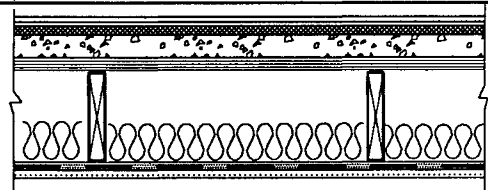
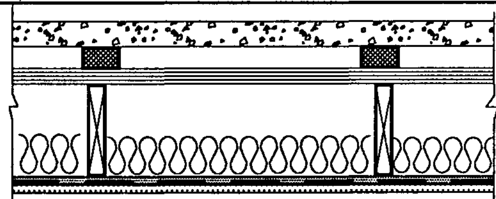
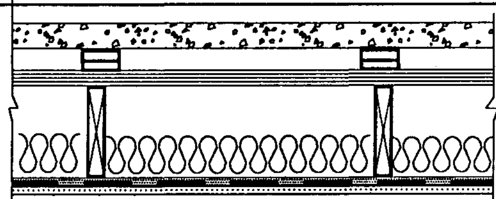
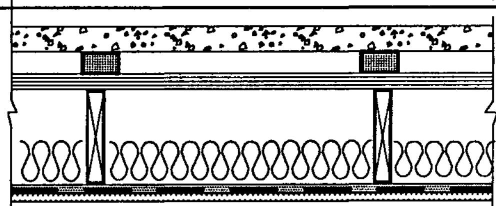
| TestID | | Floor Topping or Covering | STC | IIC | TMR |
|---|---|---|---|---|---|
| TL-90-135 |  | Joist1<br>16 mm tongue and groove plywood<br>240 x 38 mm wood joists<br>three layers of 90 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>two layers of 16 mm drywall | 55 | 51 | 40 |
| TL-90-136 |  | Joist 1 + Grey Carpet | 58 | 65 | 45 |
| TL-90-137 |  | Joist 1 + 9mm foam underpad and grey carpet | 58 | 80 | 72 |
| TL-90-138 |  | Joist 1 + 6mm felt and grey carpet | 59 | 69 | 72 |

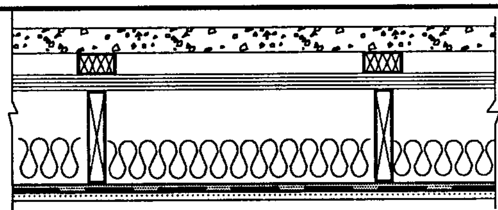
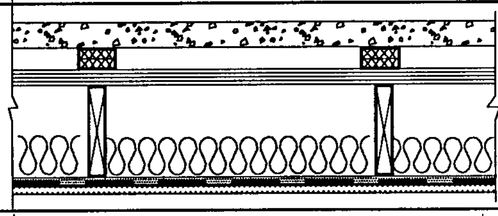
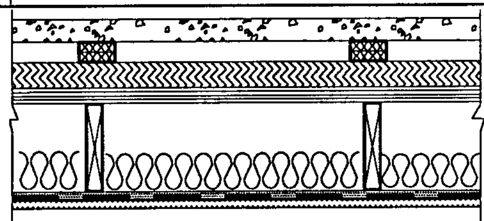
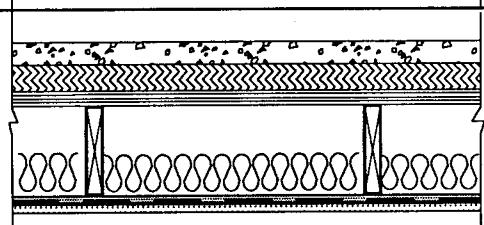
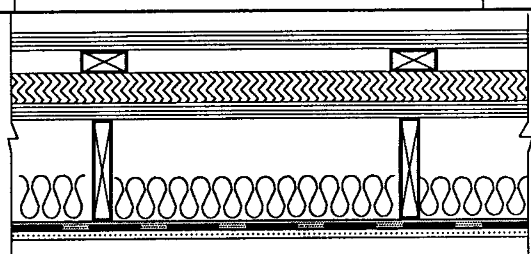
| | | | | | |
|---|---|---|---|---|---|
| TL-90-139 |  | Joist 1 + Brown Foam-backed carpet | 58 | 65 | 45 |
| TL-90-140 |  | Joist 1 + 16 mm plywood raft on 6 mm felt | 61 | 57 | 56 |
| TL-90-141 |  | Joist 1 + 16 mm plywood raft on 3 mm neoprene | 60 | 56 | 55 |
| TL-90-142 |  | Joist 1 + 18 mm Wonderboard screwed to plywood | 62 | 53 | 53 |
| TL-90-143 |  | Joist 1 + Grey carpet on 18 mm Wonderboard screwed to plywood | 62 | 68 | 54 |

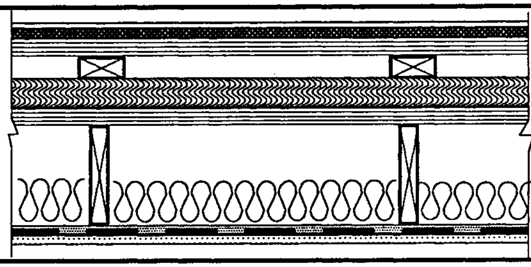
| | | | | | |
|---|---|---|---|---|---|
| TL-90-144 |  | Joist 1 + Additional 16 mm plywood layer screwed to floor | 59 | 54 | 40 |
| TL-90-145 |  | Joist 1 + 16 mm plywood raft glued to 11 mm fibreboard | 62 | 58 | 56 |

## Joist 2 Floors

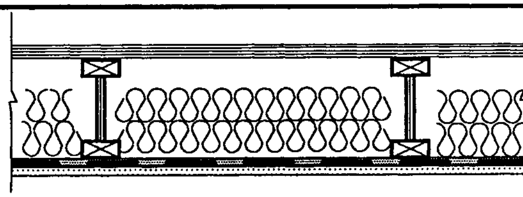
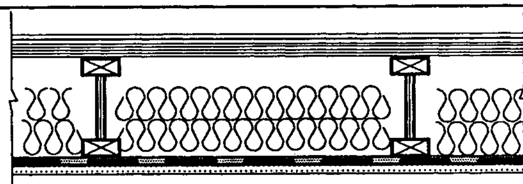
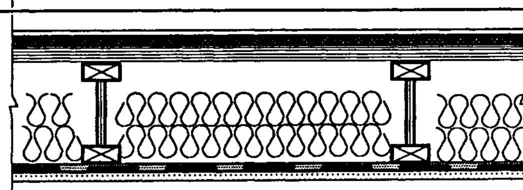
| | | | | | |
|---|---|---|---|---|---|
| TL-91-004 |  | Joist2<br>16 mm tongue and groove plywood<br>240 x 38 mm wood joists<br>one layer of 90 mm thick glass fiber batts<br>13 mm resilient metal channels,<br>600 mm oc<br>one layer of 16 mm drywall | 49 | 44 | 33 |
| TL-91-001 |  | Joist 2 + 40 mm concrete on building paper | 59 | 40 | 54 |

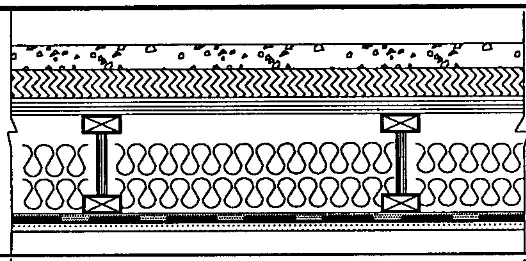
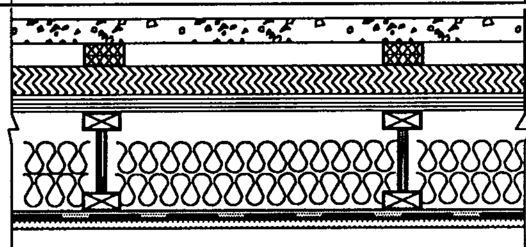
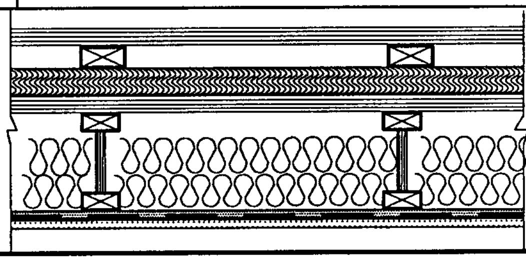
| | | | | | |
|---|---|---|---|---|---|
| TL-91-002 |  | Joist 2 + Carpet on 40 mm concrete on building paper | 59 | 73 | 54 |
| TL-91-003 |  | Joist 2 + Carpet and underpad on 40 mm concrete on building paper | 58 | 84 | 65 |
| TL-91-005 |  | Joist 2 + 40 mm concrete on hard neoprene pads | 58 | 46 | 56 |
| TL-91-006 |  | Joist 2 + 40 mm concrete on soft cork pads | 59 | 54 | 56 |
| TL-91-007 |  | Joist 2 + 40 mm concrete on hard cork pads | 59 | 48 | 57 |

| | | | | | |
|---|---|---|---|---|---|
| TL-91-010 |  | Joist 2 + 40 mm concrete on soft neoprene pads | 59 | 53 | 56 |
| TL-91-011 |  | Joist 2 + 40 mm concrete on very soft neoprene pads | 58 | 55 | 56 |
| TL-91-012 |  | Joist 2 + Float2 | 59 | 58 | 56 |
| TL-91-013 |  | Joist 2 + Float1 | 60 | 57 | 55 |
| TL-91-014 |  | Joist 2 + Float3 | 57 | 51 | 45 |

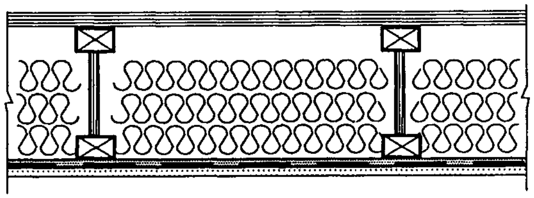
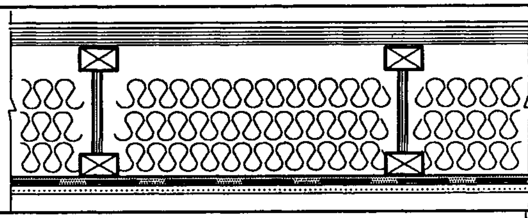
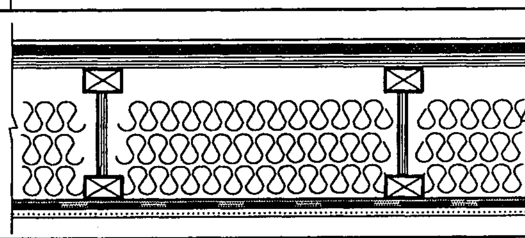
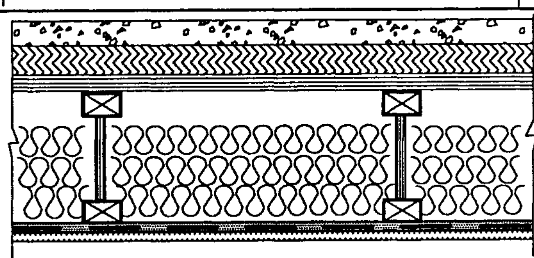
| | | | | | |
|---|---|---|---|---|---|
| TL-91-015 |  | Joist 2 + Carpet and underpad on Float3 | 57 | 75 | 63 |

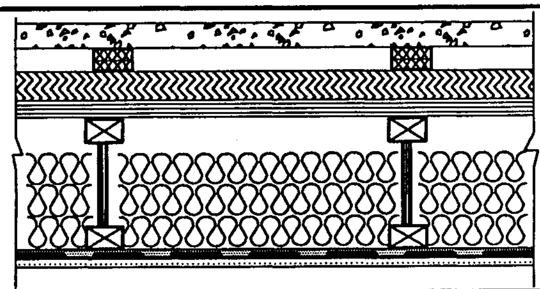
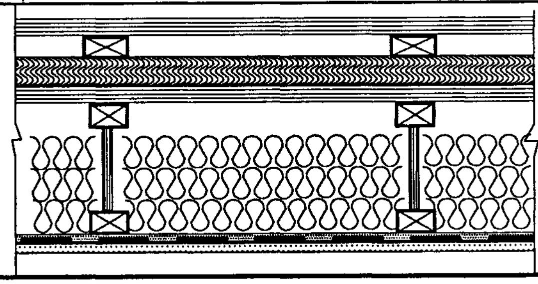
## Truss1 Floors

| | | | | | |
|---|---|---|---|---|---|
| TL-91-080 |  | Truss1<br>16 mm tongue and groove plywood<br>240 x 38 mm wood trusses<br>two layers of 90 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall | 48 | 40 | 43 |
| TL-91-088 |  | Carpet + Truss1 | 50 | 47 | 39 |
| TL-91-089 |  | Carpet and underpad + Truss1 | 50 | 66 | 55 |

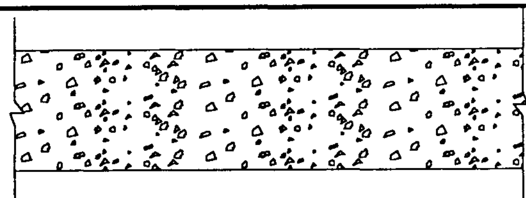
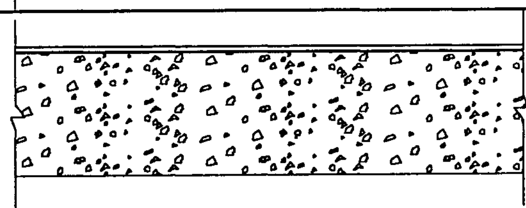
| | | | | | |
|---|---|---|---|---|---|
| TL-91-112 |  | Float1 + Truss1 | 60 | 52 | 51 |
| TL-91-113 |  | Float2 + Truss1 | 60 | 52 | 51 |
| TL-91-114 |  | Float3 + Truss1 | 55 | 46 | 43 |

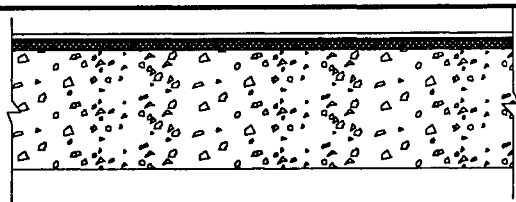
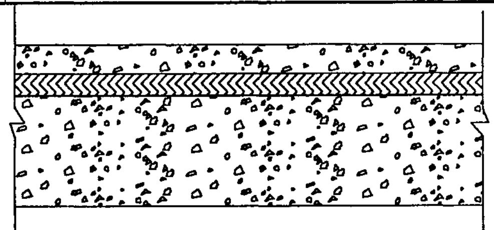
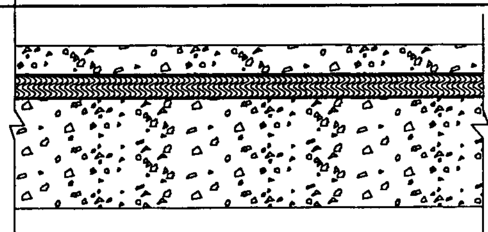
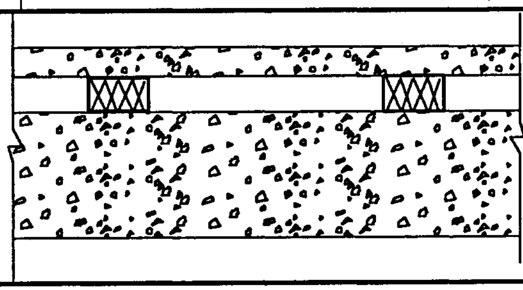
## Truss2 Floors

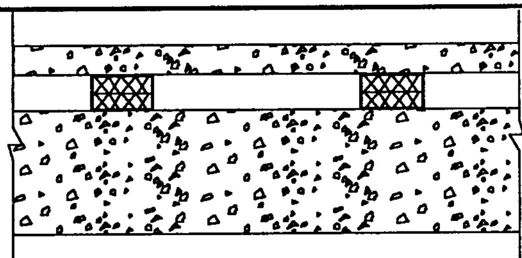
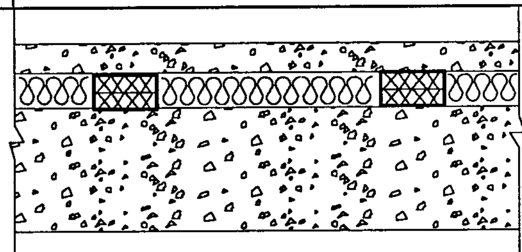
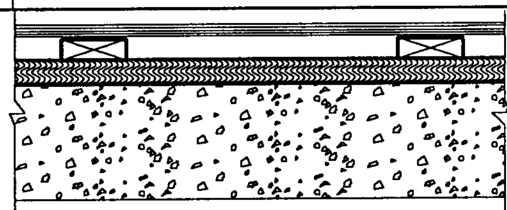
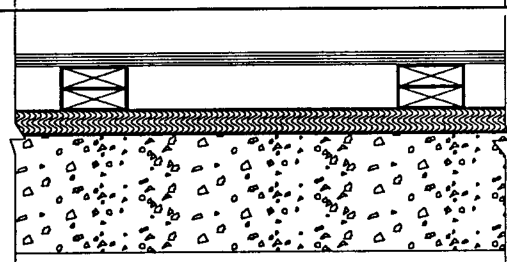
| | | | | | |
|---|---|---|---|---|---|
| TL-91-119 |  | Truss2<br>16 mm tongue and groove plywood<br>300 x 38 mm wood trusses<br>three layers of 75 mm thick glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall | 55 | 48 | 37 |
| TL-91-120 |  | Carpet + Truss2 | 57 | 57 | 40 |
| TL-91-121 |  | Carpet and underpad + Truss2 | 56 | 72 | 54 |
| TL-91-122 |  | Float1 + Truss2 | 62 | 59 | 55 |

| | | | | | |
|---|---|---|---|---|---|
| TL-91-131 |  | Float2 + Truss2 | 62 | 60 | 55 |
| TL-91-133 |  | Float3 + Truss2 | 60 | 50 | 43 |

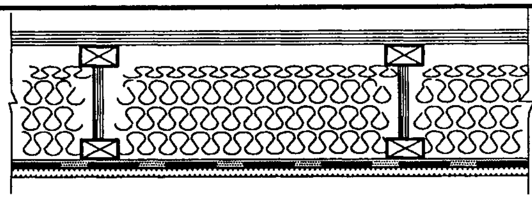
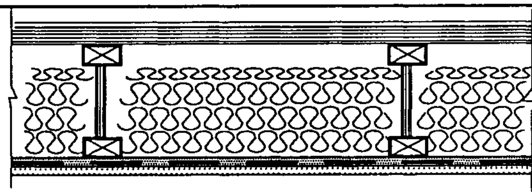
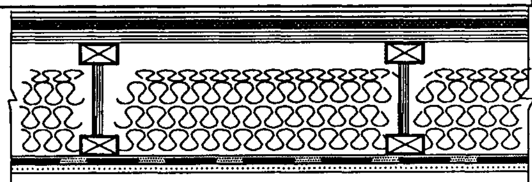
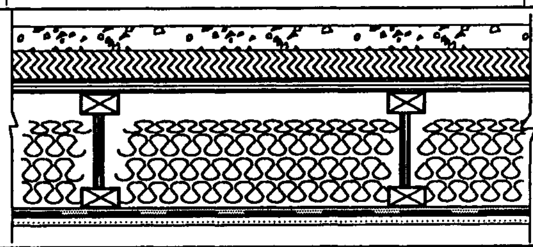
## Concl Floors

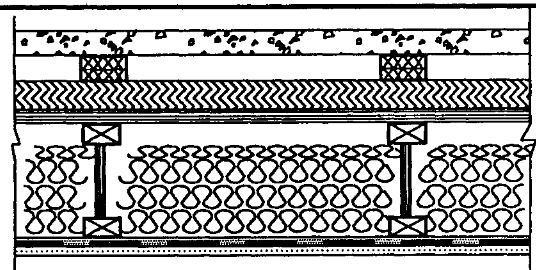
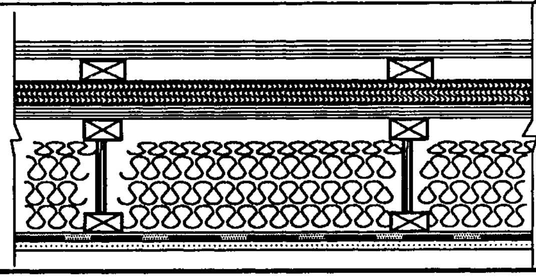
| | | | | | |
|---|---|---|---|---|---|
| TL-91-138 |  | Concl<br>150 mm concrete slab | 52 | 25 | 50 |
| TL-91-139 |  | Carpet + 150 mm concrete slab | 52 | 68 | 67 |

| | | | | | |
|---|---|---|---|---|---|
| TL-91-140 |  | Carpet and underpad + 150 mm concrete slab | 51 | 86 | 83 |
| TL-91-145 |  | Float1: 40 mm concrete slab floating on 25 mm AF530 on top of 150 mm concrete slab | 62 | 71 | 58 |
| TL-91-146 |  | 40 mm concrete slab floating on 25 mm AF570 on top of 150 mm concrete slab | 62 | 65 | 58 |
| TL-91-147 |  | 40 mm concrete slab on 18 mm neoprene lab stoppers + 150 mm concrete slab | 60 | 56 | 54 |

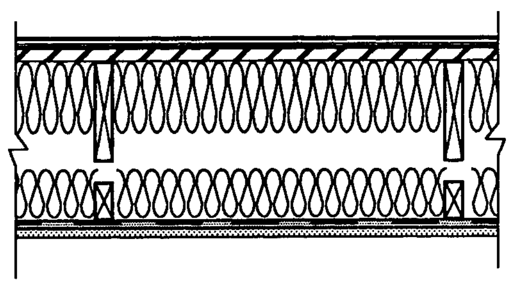
| | | | | | |
|---|---|---|---|---|---|
| TL-91-148 |  | 40 mm concrete slab on 21 mm soft neoprene foam pads (Float2) with no AF331 in the cavity + 150 mm concrete slab | 61 | 57 | 58 |
| TL-91-149 |  | Float2 + 150 mm concrete slab | 62 | 64 | 56 |
| TL-91-150 |  | Float3 + 150 mm concrete slab | 61 | 63 | 56 |
| TL-91-153 |  | Float3 but with 80 mm deep furring + 150 mm concrete slab | 62 | 66 | 59 |

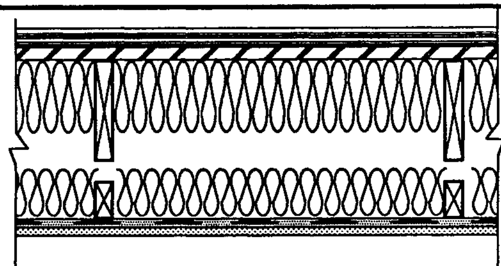
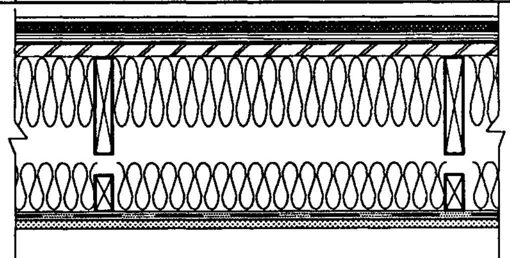
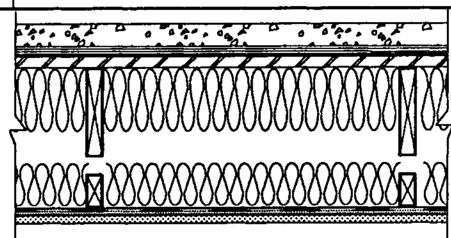
## Truss3 Floors

| | | | | | |
|---|---|---|---|---|---|
| TL-91-158 |  | Truss3<br>16 mm tongue and groove plywood<br>400 x 38 mm wood trusses<br>280 mm thickness of glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall | 54 | 49 | 39 |
| TL-91-159 |  | Carpet + Truss3 | 56 | 57 | 41 |
| TL-91-160 |  | Carpet and underpad + Truss3 | 56 | 70 | 51 |
| TL-91-163 |  | Float1 + Truss3 | 60 | 55 | 49 |

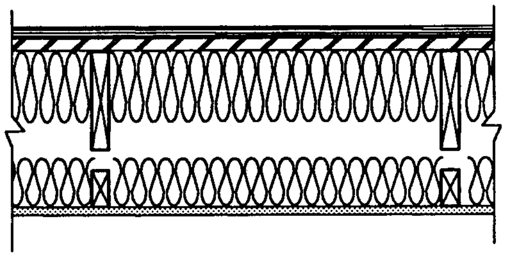
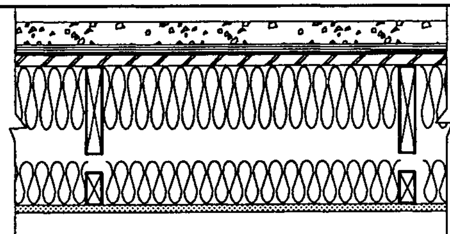
| | | | | | |
|---|---|---|---|---|---|
| TL-91-164 |  | Float2 + Truss3 | 60 | 59 | 49 |
| TL-91-165 |  | Float3 + Truss3 | 57 | 51 | 41 |

## Djoist1 Floors

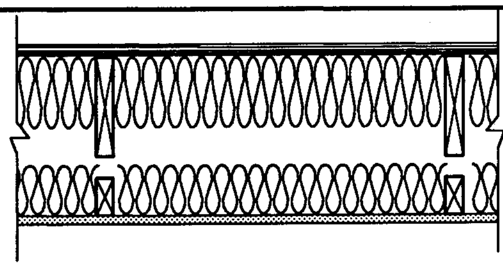
| | | | | | |
|---|---|---|---|---|---|
| TL-91-166 |  | Djoist1<br>16 mm tongue and groove plywood<br>19 mm wood fibre board<br>240 x 38 mm wood joists on 290 mm headers<br>200 mm thickness of glass fiber batts<br>13 mm Ethafoam between floor and ceiling headers<br>140 x 38 mm wood joists<br>150 mm thickness of glass fiber batts<br>13 mm resilient metal channels, 600 mm oc<br>one layer of 16 mm drywall | 59 | 56 | 48 |

| | | | | | |
|---|---|---|---|---|---|
| TL-91-167 |  | Carpet + Djoist1 | 59 | 64 | 50 |
| TL-91-168 |  | Carpet and underpad + Djoist1 | 59 | 81 | 58 |
| TL-91-169 |  | 40 mm concrete + Djoist1 | 61 | 63 | 61 |

## Djoist2 Floors

| | | | | | |
|---|---|---|---|---|---|
| TL-91-171 |  | Djoist2<br>16 mm tongue and groove plywood<br>19 mm wood fibre board<br>240 x 38 mm wood joists on 290 mm headers<br>200 mm thickness of glass fiber batts<br>13 mm Ethafoam between floor and ceiling headers<br>140 x 38 mm wood joists<br>150 mm thickness of glass fiber batts<br>one layer of 16 mm drywall | 57 | 54 | 40 |
| TL-91-170 |  | 40 mm concrete on top of Djoist2 | 61 | 59 | 54 |

## Djoist3 Floors

| | | | | | |
|---|---|---|---|---|---|
| TL-91-172 |  | Djoist3<br>16 mm tongue and groove plywood<br>240 x 38 mm wood joists on 290 mm headers<br>200 mm thickness of glass fiber batts<br>13 mm Ethafoam between floor and ceiling headers<br>140 x 38 mm wood joists<br>150 mm thickness of glass fiber batts<br>one layer of 16 mm drywall | 55 | 52 | 38 |

# APPENDIX A: DERIVATION OF TAPPING MACHINE RATING (TMR)

The data from the research project [NRCC CR6132.2] showed poor correlation between the impact insulation class and single number ratings for the walker sound levels. Nevertheless, there was good correlation between the one-third octave band levels from ISO machine and the walker. This suggested that if the spectra from the ISO machine were treated differently, single number ratings could be calculated that would correlate better with walker ratings.

A new rating was developed by "correcting" the spectrum for all tapping machine tests and summing the energy from 50 to 500 Hz. Table A1 shows the values that were added to the measured tapping machine levels in the bands from 50 to 100 Hz to correct the spectrum. The average level so obtained is then subtracted from 130. The number obtained is rounded to the nearest decibel and is called here TMR — the tapping machine rating. This procedure means that TMR increases as the insulation against impact noise improves. The number 130 is chosen arbitrarily to make an acceptable TMR value be 50 or more.

Table A1: Increments added to ISO machine levels to improve correlation of single number ratings with walker ratings.

| **Frequency** | **Increment** |
|---|---|
| 50 | 15 |
| 63 | 15 |
| 80 | 10 |
| 100 | 5 |

## APPENDIX B: PHYSICAL INFORMATION ON MATERIALS USED

Table B1: Physical information on materials used.

| | Surface Density $kg/m^2$ | Weight kg |
|---|---|---|
| **Sound absorbing materials** | | |
| 270 mm glass fibre batt insulation (3 layers of 90 mm), density 13.5 $kg/m^3$ | 3.7 | 21 |
| 180 mm glass fibre batt insulation (2 layers of 90 mm), density 13.5 $kg/m^3$ | 2.4 | 14 |
| | | |
| **Structural materials for basic floors** | | |
| 150 mm reinforced concrete slab, 2380 $kg/m^3$ | 357 | 2056 |
| 16 mm tongue and groove plywood, screws applied 400 mm oc at the edge and in the field | 7.5 | 43.3 |
| 13 mm resilient metal channels, 600 mm oc, 0.24 kg/m. 5 used | | 2.9 |
| 16 mm drywall | 11.1 | 63.9 |
| 235 mm wood joists, 400 mm oc. Joist length 2.35 m. 4.4 kg/m, 10.3 kg/joist. 7 joists used | | 72.1 |
| 235 mm wood trusses, 400 mm oc. 7 trusses used. 10.9 kg/truss. Formed from 4x9 cm wood studs and solid web of 11 mm waferboard. Truss length 2.36 m. 4.6 kg/m | | 76.3 |
| 300 mm wood trusses, 400 mm oc. 7 trusses used. 12.1 kg/truss. Formed from 4x9 cm wood studs and solid web of 11 mm waferboard. Truss length 2.36 m. 5.1 kg/m | | 84.7 |
| 400 mm wood trusses, 400 mm oc, 12.25 kg/truss, 5.21 kg/m. 7 trusses used. Truss length 2.35 m. Formed from 4x9 cm wood studs and 11 mm plywood web | | 85.8 |

| | | |
|---|---|---|
| **Floor coverings** | | |
| 10 mm thick, grey loop pile carpet. The pile was 9 mm and the jute backing was 1 mm thick | 2.9 | 16.4 |
| 10 mm thick brown foam-backed carpet. The pile was 5 mm thick, the jute backing was 1 mm thick and the foam layer was 4 mm thick | 2.3 | 13.3 |
| 6 mm thick felt carpet underpad (coated one side) | 1.7 | 9.8 |
| 9 mm thick blue foam carpet underpad | 0.4 | 2.3 |
| | | |
| **Materials for floating floors** | | |
| 16 mm laminated plywood, two layers of 8 mm plywood laminated together | 18 | 103.7 |
| 40 mm reinforced lightweight concrete slab, 1915 $kg/m^3$ | 76.6 | 441.2 |
| 19 mm Wonderboard, two 6 mm layers laminated with 6 mm mortar (cement slurry) | 23.2 | 133.6 |
| 25 mm AF530 glass fiber board, 50 $kg/m^3$ | 1.2 | 7.2 |
| 25 mm AF570 glass fiber board, 113.7 $kg/m^3$ | 2.8 | 16.4 |
| 19 mm wood fibreboard | 5 | 30 |
| 11 mm wood fibreboard | 2.9 | 16.8 |

## REFERENCES

ASTM E413 Classification for Rating Sound Insulation.

ASTM E492, Standard Method of Laboratory Measurement of Impact Sound Transmission through Floor-ceiling Assemblies using the Tapping Machine.

ASTM E90 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions.

ASTM E989, Classification for Determination of Impact Insulation Class.

Bodlund, Kaj, "Rating of Impact Sound Insulation between dwellings", Statens Provningsanstalt, Technical Report 1985:01, also J. Sound and Vibration, 102(3), p381, 1985.

Note: The study carried out by Bodlund [Bodlund, 1989] in 22 different apartments gives information that allows estimation of impact noise criteria for use in multi-family homes. In that work he found that a subjective score of 4.4 corresponded to about 51% of occupants judging the impact sound insulation as good or very good. Alternatively, more than 20% of the persons interviewed judged the impact sound insulation as quite unsatisfactory. This subjective score of 4.4 was taken as indicating an acceptable construction.

Bodlund gave a relationship between $L'_{n,w}$, the ISO R717 single number rating for impact noise transmission , and the subjective score S as

$$L'_{n,w} = 80.6 - 5.48 S.$$

Impact insulation class (IIC) is approximately related to $L'_{n,w}$ by IIC = 110 - $L'_{n,w}$. Thus, using to Bodlund's criterion of S greater than or equal to 4.4, for user satisfaction the IIC should be greater than 54. This figure agrees very well with the recommendation of IIC 55 given above.

Bradley, C.W. "Sound Performance of wood Floor/Ceiling Assemblies (Stage II)", Report 89-114. 1989

ISO 717 Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation.

JIS 1418, Japanese National Standard describing impact testing of floors.

Warnock, A.C.C. "Investigation of the Tire Impact Machine as a Standard Device for Rating Impact Sound Transmission of Floors", NRCC Report CR6132.2.