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FIRE RESISTANCE TESTING OF LOADED TIMBER FLOORS

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Fire Resistance Testing of Loaded Timber Floors

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ABSTRACT

This paper is an updated summary of a paper presented at the 1985 IPENZ Conference. Since that time one further loaded floor test has been completed and the results are taken into account.

The paper outlines why the tests are required and the logic that has been applied in the selection of the components and applied loads for the tests carried out by the Building Research Association of New Zealand (BRANZ).

With the limited number of tests available, guidance is given as to how the results of a test may be applied to other situations which have not been specifically tested.

THE FIRE RESISTANCE TEST

The New Zealand fire safety bylaw, NZS 1900 Chapter 5 "Fire Resisting Construction and Means of Egress" requires fire resistance ratings (FRR) for floors used in certain situations. The FRR is assigned on the basis of results of a standard fire resistance test. In the case of a floor the test is carried out with the heating applied to the underside as the spread of fire from the top down is not regarded as a serious problem.

Fire resistance tests examine the resistance of the construction to spread of fire in relation to three criteria:

- *Insulation* — the ability to prevent excessive temperature rise on the top surface
- *Integrity* — the ability to prevent the passage of flames or hot gases
- *Structural Adequacy* — The ability to remain in place and support the applied load.

The fire resistance is the time in minutes until the specimen fails to satisfy any of these criteria or until the test is stopped.

TEST SPECIMEN CONSTRUCTION

The test specimen is constructed to represent as closely as possible the construction of a floor in a real building, however the testing equipment available places some limitations on the spans, loading and support conditions which can be tested.

Currently specimens are constructed with simply supported joists spanning in the long dimension of the furnace. The side joists are free to move vertically, but are attacked by the fire on one side only and hence provide some restraint to the specimen. Figure 1 shows the edge details used.

The framing is of the size, species and grade to be used in practice, and is tested in a nominally dry condition of less than 16% moisture content. The joists, dwangs and blocks are spaced as used in practice except that they may be modified at the edges to fit into the furnace.

The linings are of the thickness and grade as intended to be used in practice, and are fixed as in practice. Several methods of fixing may be examined in the same test.

LOADING

In designing a floor for a building the load to be applied is usually specified by NZS 4203 Code of Practice for General Structural Design and Design Loadings for Buildings. This leads to a wide variety of configurations and loadings. In the case of a test specimen, since it is desirable that the result should apply to as many real situations as possible, the load is chosen to produce the maximum permissible bending stress in the joists. Deflection limitations which may govern the design of a floor are ignored for the specimen as the performance under fire attack is stress-dependent.

The span, joist size and spacing are fixed, and the maximum permissible stress is as defined in NZS 3603 Code of Practice for Timber Design. This standard requires the duration of the load to be taken into account when calculating the maximum permissible stress, and in order to allow this to be representative of the factor normally used, a preload period of one week is applied before the test.

In some cases the test client may wish to use a different method for determining the load to apply to his test specimen, and limit the application of the results accordingly.

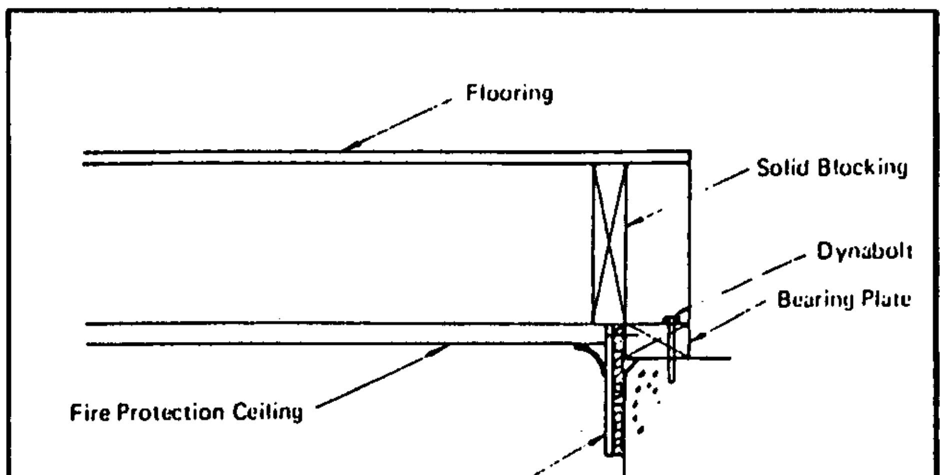

Figure 1: Specimen Edge Details.

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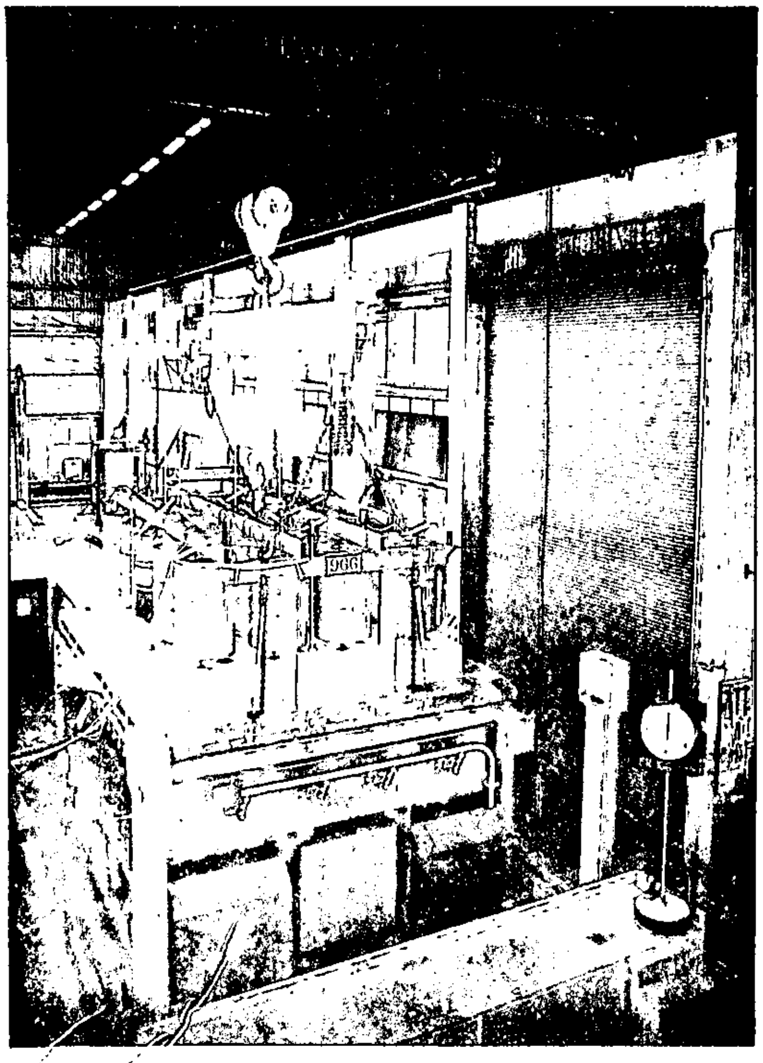

Figure 2: Fire Test Set-up.

TEST PROCEDURE
The specimen is mounted on a concrete frame which is placed over the 4 x 3 metre opening of the test furnace. The load is applied by means of drums partially filled with water. The drums have feet mounted on swivels to ensure that full contact with the specimen is maintained and eccentric point loading is avoided (see Figure 2).

The temperature and pressure conditions in the furnace are controlled to be in accordance with those specified in the test standard. The temperature and deflection of the top side of the specimens are monitored to determine failure points in terms of the insulation and structural adequacy, and the integrity criterion is examined by observation and by testing for ignition of a standard cotton wool pad.

The test is continued, usually until a failure point has been reached, then the furnace is extinguished, the load is removed from the specimen and the specimen is removed from the furnace and extinguished for further examination.

RESULTS TO DATE
To date four tests have been carried out using the BRANZ testing rig. The failure in all cases has been by a penetration of the flooring material by a foot of a drum. This allows flames to pass through the specimen and constitutes a failure of integrity. The degradation of the mechanical properties of the flooring material which leads to this failure appears to be due to the combined effects of the applied load and the heat and the moisture evaporating from the ceiling lining and framing.

In three of the four tests, a bending failure of a joist closely followed the penetration of the flooring and in each case the ceiling lining had either partially or completely fallen off by the end of the test. In the other test the lining remained in place for the duration of the test and a structural failure did not occur. The lining in this case was of a similar type and thickness to that of another specimen on which the lining did not remain in place, and achieved approximately 30 minutes greater fire resistance.

In all cases the integrity and/or structural adequacy failed before the temperature rise on the top of the specimen had reached 100°C, i.e., before the flooring material had lost all its moisture. From the results of these tests some tentative generalisations can be made:

(i) Given that the load is applied to produce maximum permissible bending stress and that the ceiling lining does not remain in place it is likely that an integrity failure will occur at about the same time as a structural failure of a joist.

(ii) One of the test results indicates that if the ceiling lining remains in place then the integrity failure will occur first. A considerable increase in fire resistance can be achieved by choosing a lining which will remain in place.

(iii) An insulation failure is never likely to be the first failure as this follows the evaporation of all the water, by which time a failure of integrity and/or structural adequacy will have occurred.

Clearly these generalisations cannot be taken as being universally valid on the basis of four test results, however they can be used as a guide for designing future test specimens and as a basis for recommending possible variations from tested systems.

VARIATIONS FROM THE TEST SPECIMEN
Due to limitations of the testing equipment it is impossible to test every configuration of floor system which could be used in practice. The test itself is complicated and expensive, so each specimen should be chosen to gather the most information about the floor system in order to allow the maximum variation.

There are a number of factors which must be taken into account when applying the results of a test on one particular element of construction to other elements of the same type — that is, which use the same basic construction methods, and the same fire protection system. Note that at this stage variations for each case must be made on their individual merits, since there is currently no formally accepted set of guidelines. These are the factors:

Stress
Any variation of the test system must not be subjected to a higher stress than was the test specimen. Normally the floor system is tested at its maximum permissible stress, and therefore another timber floor will not be subjected to any higher stress. If for any reason the stress in the test specimen were reduced to less than the maximum permissible stress then the actual stress would become the upper limit for any valid variation.

Span
If the span were changed from that of the test specimen, the floor framing would be designed such that the limiting stress as above would not be exceeded. In fact in the majority of cases the design of the floor is governed by some criterion other than strength, e.g. deflection, and the stress would be less than the maximum permissible stress.

It can be shown that if the span is varied but the joist size is not decreased then the curvature of the joists will not be increased. The important effect of this is that the stress in the ceiling lining and its fixings will not be increased and it is therefore not likely to fall off any earlier than it did in the test. The length of time that the lining remains in place can have a significant effect on the fire resistance, and it is therefore important that it is not reduced.

Joist Spacing
The fire protection of the framing and flooring material depends on the ceiling material remaining in place, which in turn depends on the fixing. Generally the ceiling is fixed to the floor joists, and hence their spacing affects the degree of fixing. If the joists were spaced at a greater distance apart than those tested there is no guarantee that the protective ceiling would remain in place.

The stress in the flooring material also depends on the distance it has to span between joists and if this is increased an earlier integrity failure may occur.

For these reasons the result of a test should only be applied to floors with the same or smaller spacing between joists. Usually the test is done with the joists spaced at 600 mm centres, which is the maximum that is likely to be used in practice.

Joist Dimensions
As timber heats it loses its strength gradually until it reaches about 300°C and begins to char. Heat attacks the joists mostly from the bottom by conduction through the ceiling lining and the nails, but also by radiation on the sides. This results in a temperature gradient in the joist during the test and a consequent reduction in strength towards the bottom fibre, with the charred timber assumed to have zero strength. Thus the effective cross-section of the joist is gradually reduced as the test proceeds.

If the depth of the joist were reduced, keeping the thickness constant, the loss of effective cross-section would proceed at the same rate and the proportion of original strength remaining at any given time would be less for the smaller joist.

Another factor affected by the depth of the joists is the amount of heat which attacks the flooring material. This will be increased if the joist depth is reduced and the mechanical properties of the flooring will degrade at a faster rate, leading to an earlier failure of integrity.

For these reasons it is recommended that the joist size not be reduced from the test specimen, regardless of any reduction in span or load.

Strength considerations as above, and also avoidance of a reduction in the degree of fixing of the linings, dictate that the joist thickness should not be reduced.

Support Conditions
The test is carried out with the specimen simply supported, with the edge details chosen to simulate the joists landing on the top plate of a timber framed wall. In general this is a worst case, however there are some situations in which the joist support conditions should be treated with some caution. It is recommended that until other support methods have been tested the joists should be supported in a similar manner to, or more rigidly than the test specimen.

CONCLUSION
Fire resistance is a requirement of the New Zealand bylaws and is established by test. The test specimen is constructed as similarly as possible to a real construction and is loaded to produce an upper limit of bending stress in the joists.

Results to date indicate that the specimen is likely to fail either by loss of integrity or by a failure in bending of a joist. The fire resistance and the method of failure is affected by the ability of the ceiling lining to remain in place.

Within certain limits it is possible to apply the fire resistance achieved by test to other floors of similar construction.

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