SUSPENDED CEILING SYSTEMS

(The Seismic hazard and damage problem and some practical solutions)

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SYNOPSIS

Substantial evidence from earthquake damage indicates that modern, gravity design only, suspended ceilings with light metal grids and lay-in tiles or light fittings, may result in life hazards, costly damage and disruption of function of buildings in severe or even moderately intense earthquakes.

The authors discuss the theoretical problem of seismic ceiling design and give a number of professionally engineered solutions suitable for both rigid and flexible structures.

Suggestions are made for further study of some aspects not fully investigated at present.

1.0 INTRODUCTION

Traditional structures usually were low and had many walls. Thus they were much stiffer than modern buildings and the problem of hazards due to ceilings was not evident prior to about 1964. Since then however, as a result of damage in several earthquakes, the profession became alerted to the seriousness of the position. Of particular concern was that damage to integrated ceilings was experienced in events of only moderate intensity eg Gisborne earthquake, New Zealand 1966 (MM7)[1]. An important economic point of consideration is that ceiling damage, together with the usually associated extensive partition damage, often occurred in buildings structurally little affected. In addition to the direct costs, very high losses due to the disruption of function of a building result. A most graphic example is the damage to the Banco Central, during the Managua earthquake of 1972. (Fig. 1). Ceiling tiles are often made of heavy materials such as gypsum, hence together with the support rails and integrated associated light fittings they present a significant life hazard and have a tremendous potential for panic.

2.0 TRADITIONAL SUSPENDED CEILINGS

Suspended ceilings have come into wide-spread use in many countries during the last 20 years, primarily to provide a rapid means of erecting a ceiling to meet a wide range of architectural and services requirements. Design considerations were gravity forces and the provision of just sufficient stiffness to ensure good appearance.

A typical system is shown in Figure 2. In some arrangements the cross members are carrying channels above the main runners. Older systems had no cross members.

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3.0 PRINCIPAL SEISMIC EFFECTS AND COUNTER MEASURES

Hazardous ceiling damage may be the result of either the dynamic response of the ceiling itself or due to stresses induced by the building and/or partitions deformations[2]. The motions causing excitation of the ceiling are those transmitted by the floor above and may reach accelerations in excess of 1g[3].

The earliest observed ceiling failures were the result of lack of positive positioning of the T-rails relative to each other. Although the clearance between tiles and supporting rails in any one row is too small to allow tiles to drop, a "compression wave" due to horizontal earthquake effects (at right angle to the T-rails) may aggregate the clearance between tiles and rails until in one row the space is sufficient for the tiles to drop. The rest follow.

In regions of low seismicity the above shortcoming can be overcome by the use of spreaders holding the T-rails in position relative to each other. To provide adequate seismic resistance against moderate or intense responses a number of other more complex effects must be considered.

In truly rigid buildings such as those with adequate shear walls, ceilings may be braced off the building, provided all ceiling members, splices and connections in the load path are designed for the real forces. Because mass production requires fabrication methods that are detrimental to ductile behaviour (Fig.5) the possibilities of departure from the intended load path should be examined otherwise local failure may occur (Fig. 4) before redistribution takes place.

In modern buildings ceiling systems must usually be considered in conjunction with the associated removable partitioning. The approach is as a rule to independently brace the ceiling from the floor above. A good way of doing this is by means of inclined wire braces together with adjustable vertical struts (Fig. 3). The latter have an important function: simple statics indicates that at a bracing point the horizontal seismic load, and the inclined tension of the brace require a vertical component for balance. Except where response is low and/or bracing points very frequent, gravity loads that can be locally materialised are inadequate to furnish this component, and struts are required. Fig. 3 is an arrangement suggested by J F Meehan.

In flexible buildings, clearances must be provided at the junction of ceilings and partitions. Ceilings are designed to move with the floor above, partitions usually with the floor below. Figure 7 shows a suitable detail. An edge member independent of the wall, to tie ends of cross members and support end tiles, should be used to avoid the danger of loss of end tiles.

In regions of higher seismicity ceiling tiles should be positively held down to prevent them from dropping due to upward vertical effects. The design of the holding devices must allow easy removal and replacement of tiles from below for services access to the ceiling. Figure 6 shows an adequate device.

4.0 CODE PROVISIONS

A number of codes have provisions for seismic design of ceilings including NZS 4203:1976[4], which requires heavier ceilings to be designed for loading of 0.6 g to 1.0 g in the zone of highest seismicity. ATC-3, 1978[5] specifies loadings of 0.24g to 0.54 g. These values are by no means excessively conservative[3].

5.0 ECONOMIC CONSIDERATIONS

In the case of light weight ceilings which do not provide significant life hazards, and provided light fittings have independent attachments to the floor above, a decision to provide seismic protection must be made on economic grounds. A particular study appropriate for a area of intermediate seismicity indicated that about 15% of the cost of a ceiling could be spent on protection to avoid direct losses.[1]

6.0 FUTURE WORK

The formation of wave motions in ceilings under combined vertical and horizontal effects is difficult to predict and would best be resolved by tests on large size models.

7.0 CONCLUSION

Integrated suspended ceiling systems subjected to earthquake motions, have been shown to have a high potential for both life risk and economic losses unless very carefully engineered.

Notwithstanding the improvements that have been made in recent years, for any particular ceiling-partition system to perform adequately in a given building, requires a good basic understanding of its intended performance by the designer, field supervisor and erector.

The dynamic response of large ceilings should be further investigated.

8.0 REFERENCES

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3 KELLY, T E, *Floor Response of Yielding Structures*, Bull. NZNSEE, Vol. 11, No. 4, 1978.

4 NZS 4203:1976, *Code of Practice for General Structural Design and Design Loading for Buildings*.

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Fig 1 Managua 1972, Bauco Central

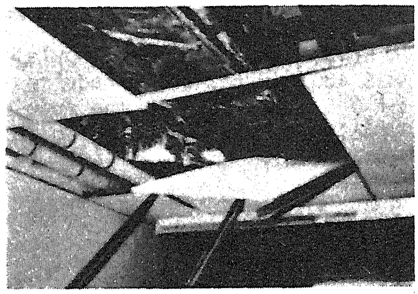

Fig.4 San Fernando
Failure of Cross Runner Joints

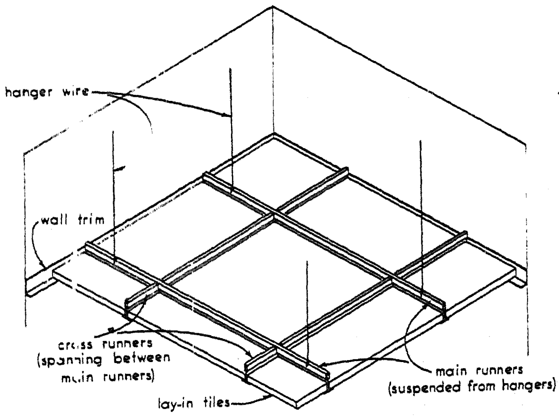

Fig.2 Two-way Inplane Suspended Ceiling Grid System

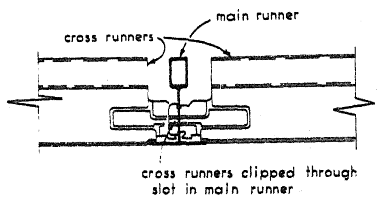

Fig.5 Cross Runner Joint

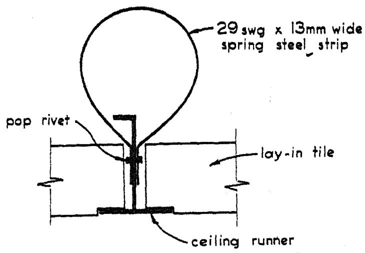

Fig.6 Balloon Spring Tile Clip

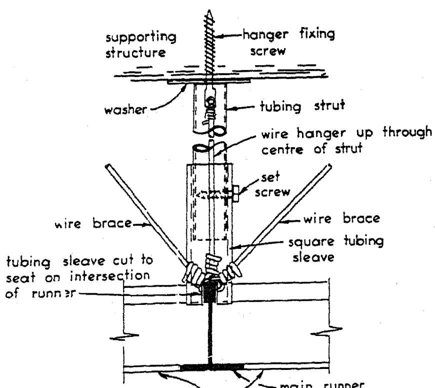

Fig.3 Bracing & Strut

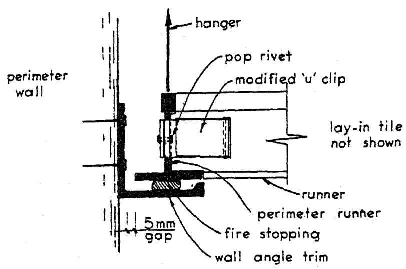

Fig.7 Ceiling Perimeter Detail