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Dynamic Performance of Australian Domestic Floors

Propriétés dynamiques des planchers de bâtiments australiens

Dynamische Eigenschaften australischer Wohnhausdecken

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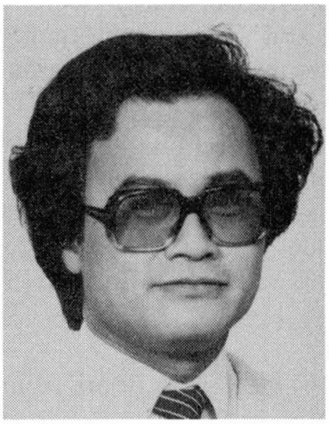

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SUMMARY

This paper examines the dynamic characteristics of currently used Australian domestic floors of timber and steel joists with timber decking. The responses of these floors to concentrated loads and to a unit impulse are evaluated.

RESUME

L'article présente les caractéristiques dynamiques des planchers à platelage en bois et poutrelles profilées en bois ou en acier, tels qu'ils sont actuellement réalisés en Australie dans les immeubles à usage d'habitation. Il expose le comportement de ces planchers sous charge concentrée et sous l'effet d'une force impulsive unitaire.

ZUSAMMENFASSUNG

Der Beitrag untersucht die Schwingungsmerkmale von Zwischendecken aus Holz- oder Stahlunterzügen mit Holzbelag, wie sie gegenwärtig in australischen Wohnhäusern Verwendung finden. Dazu wurde das Deckenverhalten unter einer Einzellast und einer Einheitsimpulslast ausgewertet.

1. INTRODUCTION

The current design of Australian domestic light-floor systems has been based on static deflection to ensure that the floors have adequate stiffness. Current deflection limits vary for different types of floor systems or construction materials. The aim of this study is to establish design criteria for dynamic performance independent of construction materials and structural configurations. The paper evaluates, by computation, the dynamic characteristics of Australian domestic floor systems which are currently in use and are known to be satisfactory. The responses of these floors to a concentrated load and to an unit impulse are evaluated.

2. AUSTRALIAN DOMESTIC FLOOR SYSTEMS

2.1 Structural Configurations

This paper covers joist-only flooring systems which represent the majority of upper storey floors in domestic construction. Timber joists are generally either nailed or glued and nailed to the timber floorboards. Steel joists are generally either screwed or glued and screwed to the timber floorboards.

Due to various practical reasons, Australian floor systems are built over a fairly limited range of parameters. Joist spacing is usually 450 or 600 mm. The thickness of floor board is 19 mm for 450 mm joist spacing and 22 mm for 600 mm joist spacing. The range of joist spans is 2–6 m. The sizes of timber joists are given in the Australian National Timber Framing Code [1]. The sizes of steel joists are given by the product manufacturers, such as Lysaght [2] for open C sections or Spantec [3] for box sections.

In this study, three floor systems are examined: (a) timber joist floors; (b) steel joist floors using open C section joists; and (c) steel joist floors using box section joists.

2.2 Current Design Criteria

The current design criteria for Australian domestic light-floor systems is based on controlling static deflection of a single joist under the design loading. The effect of floorboards is neglected. Current deflection limits vary for different types of floor systems:

- for floor system with steel C section joists, the limiting deflection is span/750 under dead load plus live load of 1.5 kPa;
- for floor system with steel box section joists, the limiting deflection is span/500 under dead load plus live load of 1.5 kPa; and
- for floor system with timber joists, the limiting deflection is span/360 or 9 mm under live load of 1.5 kPa.

Individual floor systems designed using these criteria have been found satisfactory in actual practice. It is the purpose of this paper to find a single rational criteria which can be calibrated against these known satisfactory performance.

3. EVALUATION OF DYNAMIC PERFORMANCE

3.1 General

Various parameters have been used in literature for assessing the dynamic performance of floor systems. They include:

- frequency-weighted root-mean-square acceleration of the response caused by a footfall impact [4];

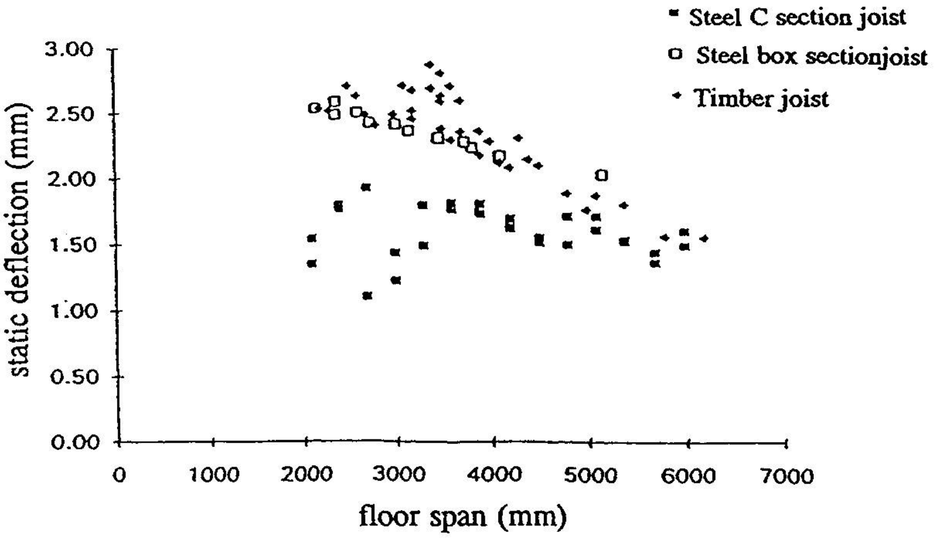

Fig. 1 Static deflection of Australian floors to a point load of 1kN

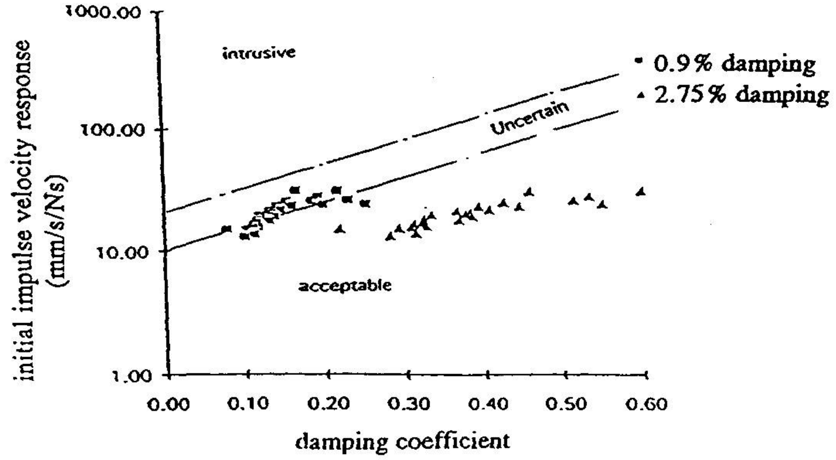

Fig. 2 Impulse velocity response of Australian steel joist floors vs damping

- initial impulse velocity response under a idealised vertical force impulse of 1 Ns [5]; and
- static deflection under a concentrated force of 1kN [6].

In this paper, the initial impulse velocity response and static deflection are used to assess the dynamic characteristics of Australian floors.

3.2 Static Deflection Under a Concentrated Load

The static deflection under a concentrated load of 1 kN applied at the centre of the floor has been computed for the range of Australian floors described above. The floor system is modelled as a grid to account for the stiffness of the flooring in the direction normal to the joists, i.e. allowing the concentrated load to be shared between the adjacent joists.

The results are given in Fig.1, where it can be seen that the ranges of the deflections are:

- 1.5–3 mm for timber joist floors;
- 1–2 mm for floors with steel C section joists; and
- 2–2.5 mm for floors with steel box section joists.

It is noted that the above results are computed using the specified design properties of timber and steel as given in the Australian Standards. It is well known that specified timber design properties are generally conservative because of the inherent variability of timber. Timber floors are generally stiffer than anticipated in design.

The Swedish building code suggested a limit of 1.5 mm/kN, and the Canadian Standards suggested a limit of 0.5–1 mm maximum deflection under 1 kN. It appears that Australian floors are considerably more flexible than those in Sweden and Canada.

3.3 Initial Impulse Velocity Response of Australian Floors

Initial impulse velocity response h'_{max} under an idealised vertical force impulse of 1 Ns has been calculated using Ohlsson's formula [5]. The floors are modelled as grillages with simply supported edges. The results are discussed as follows:

3.3.1 Damping effect

Ohlsson proposed that the initial impulse velocity response should be related to the damping ratio, ζ, and the lowest natural frequency of the floor, f_1, because of their obvious effects on human response [5]. The evaluation of the damping ratio is very complicated and depends on uncertainties such as the influence of the occupant, floor coverings, partitions, furnishings. Values quoted in the literature range between 0.8 and 3%. At the design stage, the damping ratio will have to be guessed. Figure 2 shows the initial impulse velocity response plotted against damping coefficient σ_0 ($\sigma_0 = f_1.\zeta$) for the steel joist floors. It illustrates the sensitivity of the dynamic responses to different assumed damping ratios. If dynamic performance criteria is to be established based on this model then it is highly dependent on the assumed damping value.

3.3.2 Floor span

The initial impulse velocity responses have been plotted against the floor spans in Fig. 3 (with floor mass only) and Fig. 4 (with floor mass and 30 kg/m^2 live load) for both steel and timber joist floors. As seen in Figs 2 and 3, both steel and timber joist floor systems have very similar initial impulse velocity responses despite the fact that they have very different stiffnesses, as shown by their deflections under a concentrated load in Fig. 1. This is rather puzzling since it is expected that the initial impulse velocity response would have a strong correlation with stiffness.

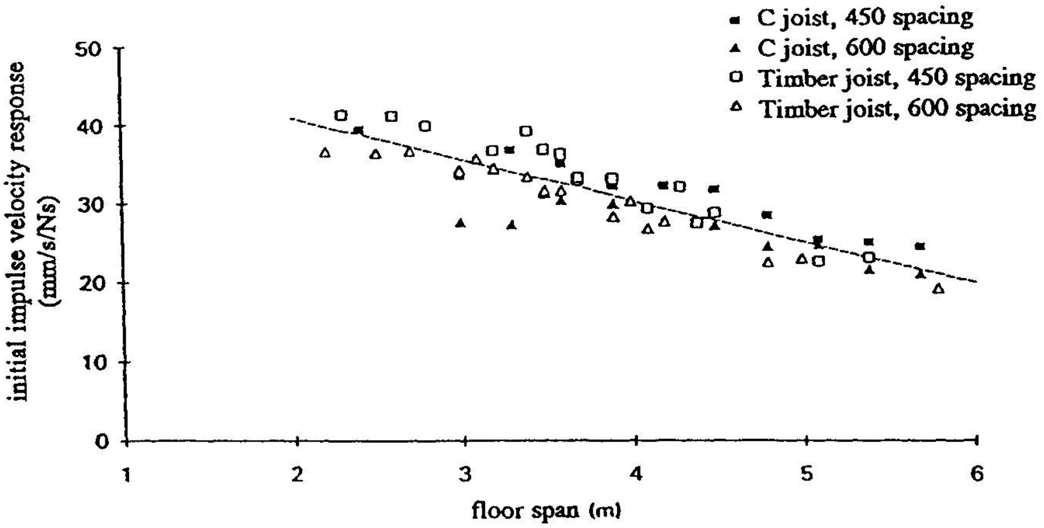

Fig.3 Impulse velocity response of Australian floors vs floor span (with floor mass only)

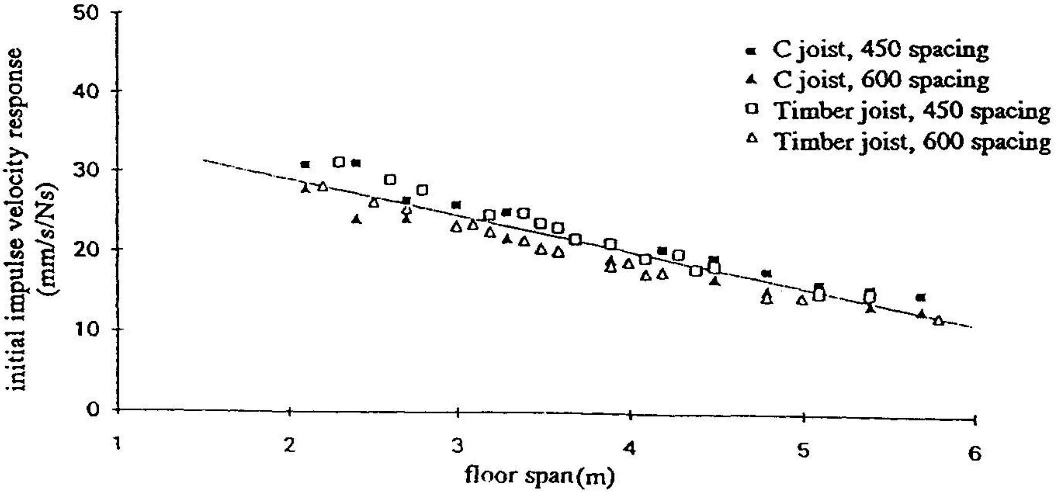

Fig.4 Impulse velocity response of Australian floors vs floor span (with floor mass plus 30kg/mm^2 live load)

The correlation between the initial impulse velocity response and the floor span is strong and appears to be independent of the construction material.

3.3.3 Other design parameters

The following points are also noted from the results:

- The natural frequencies of all floors calculated using Ohlsson's formula [5] are found to be in the range 8–40 Hz. The natural frequency decreases with increasing floor span.
- The ratio of span to width of the floor (L/B) has a relatively insignificant effect on the dynamic responses of the floors. For example, increasing L/B of a given floor system from 0.25 to 1 will change the value of h'_{max} from 13.95 to 13.45 mm/s/Ns.
- Changing the joist spacing from 450 to 600 mm slightly decreases the value of h'_{max} (see Figs 3 and 4).
- Changing the mass of the floor has a much larger effect on the values of h'max see Figs 3 and 4. Increasing the mass of the floor reduces the values of h'_{max}.

4. CONCLUSION

The computed static deflection behaviour under a concentrated load of 1 kN indicates that Australian-designed lightweight floors are more flexible than those in Sweden and Canada, but gives results that appear to be material-dependent.

For the limited range of currently accepted Australian floor systems, the initial impulse velocity response h'_{max} under an unit impulse of 1 Ns appears to be a more consistent dynamic performance indicator. It has strong correlation with floor span and is independent on the construction material of floor systems.

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