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ENHANCEMENT OF DEFLECTION SERVICEABILITY PERFORMANCE OF METAL WEB JOIST TIMBER FLOORS USING STRONGBACKS

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ABSTRACT: This paper presents the study on the serviceability performance of the floors constructed with metal web joists with focus on the deflection at floor centre under 1 kN point load. The studied parameters included spacing of joists, type, size, number and location of strongback, and ceiling. The test results indicate that joist spacing, strongback bracings and ceiling significantly influenced the maximum displacement of metal web joist floors. The decrease in joist spacing, the increase in number and size of strongback bracings, and the use of ceiling all largely reduced the maximum displacement of the floors. On average, the calculated displacements based on the design equations in the UK National Annex to Eurocode 5 are close to those measured.

KEYWORDS: Timber floors, Metal web joists, Strongback, Serviceability Limit States, Deflection, Eurocodes

1 INTRODUCTION [123]

In the past few decades, metal web engineered timber joists have been largely used to construct intermediate-span timber floors in low-rise houses and long-span floors in commercial buildings. However, their design is often controlled by unit point load deflection serviceability limit state criterion according to EN 1995-1-1 and the UK National Annex. A project *Experimentally evaluating the vibrational performance of metal-web joist floors enhanced using strongback bracing* was conducted on behalf of the Metal Web Working Group, comprising ITW Alpine, Gang Nail Systems, MiTek Industries Ltd and Wolf Systems. The series tests on metal web joist floors were intended to experimentally evaluate the effects of joist spacing, strongback bracings and ceiling on the vibrational performance of the floors so as to assess Eurocode 5 design criteria.

2 EXPERIMENTAL WORK

Nine floors (Floors A to I) were included for this series of tests, with the variations on the following parameters: joist spacing, strongback (with or without), number and location of strongback, size of strongback, type of strongback and ceiling (with or without). Figure 1 shows a typical metal web joist floor (Floor A). Figure 2 shows a strongback fitted along mid-span of a floor.

***Figure 1*:** A typical metal web joist floor (Floor A)

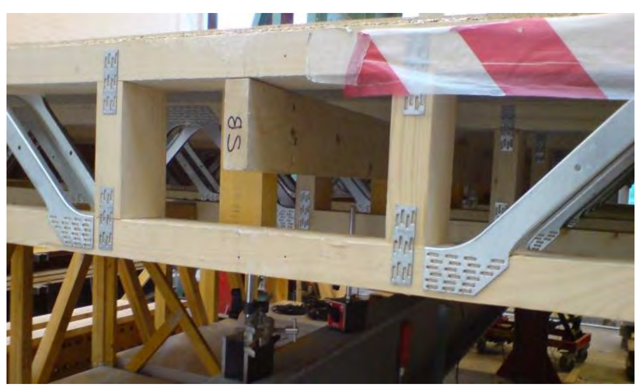

***Figure 2:** A TR26 strongback at mid-span in Floor E*

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3 TEST RESULTS AND DISCUSSION

3.1 Maximum displacements under 1 kN point load

Figure 3 shows the measured maximum displacements at the floor centre under 1 kN point load for all nine floors.

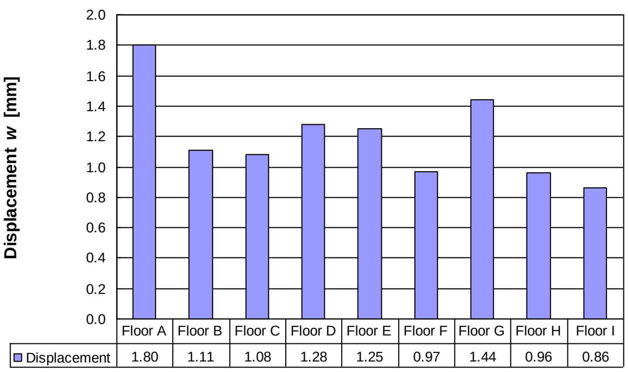

Figure 3: *Measured maximum displacements under 1 kN point load for all floors*

For the same flooring configuration, a reduction in joist spacing largely decreased the maximum displacement. For the floors without strongback and ceiling (Floors A and G), the maximum displacement *w* decreased from 1.80 mm to 1.44 mm, down by 0.36 mm or 20%. For the floors with strongback but without ceiling (Floors E and H), *w* decreased from 1.25 mm to 0.96 mm, down by 0.29 mm or 23.2%. For the floors with strongback and ceiling (Floors F and I), *w* decreased from 0.97 mm to 0.86 mm, down 0.11 mm or by 11.3%, which is not as much as those for the floors without ceiling.

The introduction of ceiling significantly enhanced the stiffness of the floor so as to reduce the displacement. For the floors with 600 mm joist spacing (Floors E and F), the maximum displacement *w* decreased from 1.25 mm to 0.97 mm, down by 0.28 mm or 22.4%. For the floors with 400 mm joist spacing (Floors H and I), *w* decreased from 0.96 mm to 0.86 mm, down 0.10 mm or by 10.4%, which is not as significant as those with 600 mm joist spacing.

The use of strongbacks greatly enhanced the stiffness of the floor and lowered the maximum displacement. For the floors with 600 mm joist spacing (Floors A, E and D), the maximum displacement *w* decreased from 1.80 mm to 1.25 mm for the floor with a single strongback at the mid-span (Floor E) and to 1.28 mm for the floor with two strongbacks each situating at the third-span (Floor D), down by 0.55 mm and 0.52 mm or 30.5% and 28.9% respectively. This means that the effectiveness of enhancement in stiffness largely depends on the location where the strongback is put. The nearer the strongback is put to the mid-span, the more effective the stiffness enhancement is. Meanwhile for the floors with 400 mm joist spacing (Floors G and H), *w* decreased from 1.44 mm to 0.96 mm, down 0.48 mm or by 33.3%.

The increase in the size of strongbacks greatly enhanced the stiffness of the floor so as to lower the maximum displacement when strongbacks were placed at the same location. For the floors with 600 mm joist spacing (Floors A, E and B), the maximum displacement *w* decreased from 1.80 mm to 1.25 mm for the floor with a 35 mm × 97 mm TR26 strongback at the mid-span (Floor E) and further to 1.11 mm for the floor with a 47 mm × 147 mm TR26 strongback at the mid-span (Floor B), down by 0.55 mm and 0.69 mm or 30.5% and 38.3% respectively.

Similar to the size of strongbacks, the type of strongbacks should also influence the stiffness of the floor. The stiffer the strongback, the stiffer the floor and the lower the maximum displacement. In this investigation, two strongbacks had similar stiffnesses, 12669 N/mm^2 for the 47 mm × 147 mm TR26 strongback versus 11200 N/mm^2 for the 45 mm × 147 mm Kerto S strongback. Very little enhancement in floor stiffness was expected and also little variation in the maximum displacement was observed, 1.11 mm for the floor with 47 mm × 147 mm TR26 strongback (Floor B) versus 1.08 mm for the floor with 45 mm × 147 mm Kerto S strongback (Floor C).

The increase in strongback size had little effect on the first two modal frequencies of the floors but largely influenced the higher modal frequencies. The increase in strongback size largely increased the higher modal frequencies.

3.2 COMPARISON WITH EC5-1-1 AND UK NA

The maximum deflection of a timber floor under 1 kN point load is normally checked for assessing the vibrational performance of the floor. The design equations provided by the UK National Annex to EN 1995-1-1 were used to calculate the maximum deflections of all floors under 1 kN point load and compare with the measured ones.

On average, the calculated maximum displacements were only 2% larger than those measured. However, the variations were very large, from -16.1% (Floor G) to +31.1% (Floor F). No clear trend was observed between the calculated and measured maximum displacements.

The design limit for the deflection of all testes floors was calculated as 1.36 mm. Clearly, all the floors with strongbacks are adequate to the serviceability requirements with respect of deflection except the two without strongbacks. This indicates for the current span, strongbacks are desperately needed to evenly distribute the floor loading and lower the maximum displacement.

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