

## Chapter 4

### Conclusions and Recommendations

#### 4.1 Conclusions

A study on the effective moment of inertia of girders that support concrete slabs using joist seats as the horizontal shear connections, and a cost efficiency analysis comparing composite and non-composite floor systems that meet vibrations design standards, were conducted. In the effective moment of inertia study: 1) the accuracy of the current Design Guide relationship was assessed, 2) a new relationship was proposed, and 3) suggestions for FE-modeling were made. The conclusions from these areas are summarized below followed by the conclusions from the cost study.

**Girder Effective Moment of Inertia.** This study was undertaken because over-prediction of girder effective moment of inertia was the suspected cause of several recent vibrations problems in floors supported by widely spaced LH-series joists. Eight purpose built floors of the type in question were subjected to experimental tests of girder effective moment of inertia and girder frequency. Frequencies were measured for two live loading cases. Three separate test specimens were made with each floor by changing the seat-to-girder connections between bolted, welded, and reinforced.

*Assessment of Design Guide Relationship.* The current AISC/CISC Design Guide 11 provisions for effective moment of inertia of joist-girders and girders with joist seats as horizontal shear connections assume that the effective moment of inertia is equal to

$$I_{eff} = I_g + (I_{comp} - I_g) / 4 \quad (2.1)$$

where no distinctions between various types of joist supported floor systems are made. However,  $I_{eff}$  depended largely on the joist type and seat connection type used. As a result, in several cases the measured composite factor was much lower than the predicted value of  $1/4$ , which caused several frequencies to be lower than predicted. Figure 4.1, a scatter plot of measured and Design Guide predicted frequencies, shows that the majority of predictions were high; the measured frequencies were approximately 75 % to 110 % of predicted, with all but the K-reinforced-floors falling below 100 %.

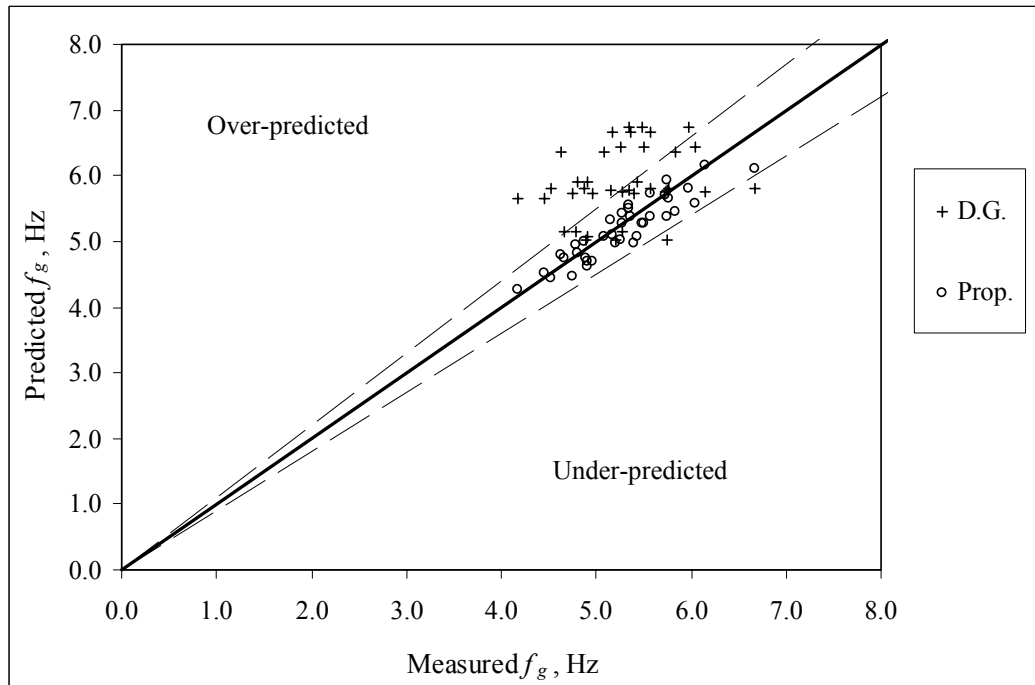
*Proposed Relationship.* It was found that girder stiffness could be predicted based on the joist type and seat connection type, and independent of joist spacing and girder type. The experimental results compared best with the following proposed relationship:

$$I_{eff} = I_g + I_s + \alpha_1(I_{comp} - I_s - I_g) \quad (2.15)$$

where  $I_s$  is the moment of inertia of the transformed concrete section, and the composite factor,  $\alpha_1$ , is as given in Table 2.23, reproduced below for convenience. It was found that, with a few higher exceptions, the measured frequencies were 97% to 105 % of frequencies predicted using the proposed relationship—compared to 75 % to 110 % with the current relationship—a substantial improvement in accuracy, which can be seen in Figure 4.1.

**Table 2. 23—Joist and Seat Connection Type Dependant Variables**

Joist-Seat Conn.	$\alpha_1$	$I_{seat}$ for FEM
K-bolted	0.17	0.0032
K-welded	0.12	0.0021
K-reinforced	0.26	0.0065
LH-bolted	0.06	0.015
LH-welded	0.03	0.009
LH-reinforced	0.10	0.023



**Figure 4. 1—Comparison of Proposed and Design Guide Predicted Frequencies**

*Suggested FEM Methods.* A secondary goal of the study was to find an accurate method of predicting stiffness and, thus frequency, with FE modeling. As in this research, previous researchers have used FEA to accurately predict frequency for systems of known stiffness. However, only limited success has been had using the models to predict the frequency of joist supported systems of unknown stiffness, because no guidelines were available for estimating seat element stiffness. Along with the composite factors, guidelines for FEM seat element stiffness, for use with the method of modeling described in Section 2.4, are suggested in Table 2.23. It was shown that measured frequencies were approximately 97% to 107 % of frequencies for models with the suggested seat elements. Thus, the method gave slightly less accuracy than the proposed relationship, but more accuracy than the current Design Guide relationship.

**Cost Study.** To compare the cost of composite and non-composite floors that satisfy the Design Guide criterion for walking excitation, four typical size bays were analyzed using commercial design software, which finds the least expensive member configuration for a given bay size. All acceptable bay configurations of member sizes and spacing were evaluated for least non-composite cost, and then least composite cost.

In the first of three trials, member camber was not assumed and thereby initial deflections were limited to  $L/360$ . Composite construction did not lessen cost with this restriction, because member sizes for each bay were governed by the initial deflection limit. On the other hand, significant cost savings can be made using composite construction under the parameters of the other two trials, which both had an initial dead load deflection limit of  $L/240$ . With a liberalized initial deflection allowance, composite systems had a 11%-15% cost savings depending on the shear stud cost used for the evaluation.

## 4.2 Recommendations

**Girder Effective Moment of Inertia.** Despite the success in proposing a more accurate method of prediction, there are aspects of the behavior of the studied systems that remain unclear. Contrary to the measured data, small FEM effects resulted from variations in joist spacing. In the modeling, the reduction in stiffness resulting from increased joist spacing was slight, but evident nevertheless.

Similar model effects were found with respect to girder type. The joist-girder flange

models rotated locally slightly more than girders when transferring seat moments, resulting in less seat stiffness, and thus less overall stiffness. This is consistent with the expected behavior of the two type girders, but could not be concluded from the measurements.

No provisions for these finding were made in the proposed relationship. Further study of the effects of joist spacing and girder type might justify a slight liberalization of the proposed relationship. However, it is not evident that the effect of these variables is large enough to render the proposed relationship inaccurate.

It is recommended that future tests of horizontal seat stiffness have provisions for two factors. First, the horizontal load-deflection relationship should be defined at several points along the joist span, not only directly above the girders. Second, it should be ensured that rotation of the top of the seat/joist is not inhibited by the test apparatus so that the moment of inertia can be accurately determined with the cantilever deflection equation.

**Cost Study.** The cost study showed that factors such as initial dead load deflection can determine the least expensive of composite and non-composite construction. A study of the same nature, considering a range of slab properties and other size bays, could produce a useful design aid.

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