CHAPTER III
EVALUATION OF EXPERIMENTAL WORK

3.1 Existing Tolerance Criteria

The objective of this study is to determine which acceptability design method best predicts the response of the floor systems. Six floor systems were constructed with three different bracing configurations. This chapter evaluates each floor system with respect to the various acceptability criterion and compares the calculated values to the results of each floor system. The effect of different diagonal bracing configurations on the response of the floor systems is also discussed. Appendix C contains an example calculation of a floor system (24-360H) for each criterion.

3.1.1 Evaluation of Existing Tolerance Criteria

3.1.1.1 Swedish Criterion

The Swedish acceptability criterion was developed by Ohlsson (1988a) and was published by the Swedish Council for Building Research (Ohlsson 1988b). Although this design procedure was developed by testing only wood floor components, Ohlsson states that it can be used for any floor system regardless of material used. For a floor to be considered acceptable, it must pass three different tests: static load, impulse velocity response, and a continuous loading. A floor must have a fundamental frequency greater than 8 Hz before the criterion can be applied. In this study, only one floor system had a fundamental frequency less than 8 Hz. For comparison purposes, this floor (16-360) will be analyzed with the rest of the floor systems.

A floor system must first undergo a static deflection test. Ohlsson’s design guide specifies that a floor must deflect no more than 0.059 in. (1.5 mm) for a 225 lb (1.0 kN) load. To experimentally evaluate this requirement, a 225 lb concentrated load was placed at the midspan and deflection readings were taken. All floor systems passed this test.

The impulse velocity response is the initial vertical vibration velocity caused by an idealized impulse (Ohlsson 1988b). However, the time response recorded for each floor system were measured in terms of acceleration and not velocity. Since velocity traces were not taken for any of these floor systems, the impulse velocity response can only be calculated using Equation 1.8 which is repeated here for convenience:

$$h'_{\max} = \frac{4\left(0.4 + 0.6N_{40}\right)}{gBL + 200} \quad \text{(m/s/Ns)} \qquad (1.8)$$

To use this equation, one must first find the number of frequency modes, N_{40}. Ohlsson (1988a) plotted the modal number versus the standard resonant frequency for different values of D_y/D_x and L/B. The ratios L/B vary from 1.00 to 0.25 with D_y/D_x values plotted between 1.000

and 0.0005 for these charts. Since the floors tested in this report had an L/B ratio greater than 1.0 and a D_y/D_x ratio less than 0.0005, Ohlsson's second design is not applicable.

The third requirement for the Swedish design guide is a continuous loading test. Ohlsson states that this requirement should only be applied to floors with a span length greater than 13 ft (4 m). Although the floor systems tested had a span length greater than 13 ft, other physical dimensions, such as D_y/D_x, do not fit this guideline. Therefore this design requirement is also not applicable to the floor systems tested.

Since two of the three requirements for the Swedish design guide were found to not apply, this criterion does not apply to the floors tested in this study. Calculated values from the Swedish criterion are tabulated in Table 3.1 with an example calculation found in Appendix C.

Table 3.1 Acceptability Rating of All Floors From the Swedish Building Technology Design Guide

Floor Designation	Span Length (ft)	Midspan $\Delta_{meas.}$ (in.)	Δ_{limit} (in.)	Does Floor Satisfy 1st check?	h'_{max} (mm/s/Ns)	σ_o (s^{-1})	Does Floor Satisfy 2nd Check?	Swedish Acceptability Rating
16-360H	34.00	0.034	0.059	YES	NA	0.08	NA	NA
16-360XH	34.00	0.026	0.059	YES	NA	0.08	NA	NA
16-360X	34.00	0.030	0.059	YES	NA	0.08	NA	NA
16-480H	31.25	0.028	0.059	YES	NA	0.09	NA	NA
16-480XH	31.25	0.024	0.059	YES	NA	0.09	NA	NA
16-480X	31.25	0.027	0.059	YES	NA	0.09	NA	NA
16-720H	27.29	0.023	0.059	YES	NA	0.12	NA	NA
16-720XH	27.29	0.020	0.059	YES	NA	0.12	NA	NA
16-720X	27.29	0.023	0.059	YES	NA	0.12	NA	NA
24-360H	30.00	0.037	0.059	YES	NA	0.09	NA	NA
24-360XH	30.00	0.030	0.059	YES	NA	0.09	NA	NA
24-360X	30.00	0.032	0.059	YES	NA	0.09	NA	NA
24-480H	27.67	0.030	0.059	YES	NA	0.11	NA	NA
24-480XH	27.67	0.026	0.059	YES	NA	0.11	NA	NA
24-480X	27.67	0.028	0.059	YES	NA	0.11	NA	NA
24-720H	24.50	0.023	0.059	YES	NA	0.14	NA	NA
24-720XH	24.50	0.018	0.059	YES	NA	0.14	NA	NA
24-720X	24.50	0.020	0.059	YES	NA	0.14	NA	NA

U = Unacceptable M = Marginal A = Acceptable NA = Not Applicable

3.1.2 Australian Criterion

The *Australian Standard Domestic Metal Framing Code* (1993) is very similar to Ohlsson's design guide but is easier to use. It was developed for cold formed steel floor systems having a fundamental frequency greater than 8 Hz. There are only two serviceability requirements a floor system must satisfy to be considered acceptable. The first test is a static deflection test. For this test, the floor is required to not deflect more than 0.079 in. (2.0 mm) for a 225 lb (1.0 kN) concentrated load placed anywhere on the floor. For this study, each floor was tested by placing a 225 lb static concentrated load at midspan. All floors met this criterion, as can be seen in Table 3.2.

The second criterion compares the maximum impact velocity, V_{max} (Equation 1.15), to a function of the damping coefficient, σ_o (Equation 1.9) which is shown below for convenience.

$$\sigma_o = f_1\zeta \quad \text{(Hz)} \tag{1.9}$$

where

f_1 = Fundamental frequency (Hz)

ζ = Modal Damping Ratio (which may be assumed to be 0.9 unless other values are found to be more appropriate)

The Australian Code recommends a value of maximum impact velocity that is similar to the impulse velocity response, h'_{max}, in the Swedish criterion. V_{max} is the maximum vertical velocity response of a floor system when subjected to a unit impulse load of 1.0 N-s. All floors failed this design check as shown in Table 3.2; see Appendix C for a sample calculation.

Table 3.2 Acceptability Rating of All Floors From the Australian Standard Domestic Building Metal Framing Code

Floor Designation	Span Length (ft)	Midspan $\Delta_{meas.}$ (in.)	Midspan Δ_{max} (in.)	Does Floor Satisfy 1st check?	V_{max}^{*} (mm/s/Ns)	$1.2 + 2\sigma_o$ (s^{-1})	Does Floor Satisfy 2nd Check?	Australian Acceptability Rating
16-360H	34.00	0.034	0.0787	YES	1.99	1.34	NO	U
16-360XH	34.00	0.026	0.0787	YES	1.99	1.34	NO	U
16-360X	34.00	0.030	0.0787	YES	1.99	1.34	NO	U
16-480H	31.25	0.028	0.0787	YES	1.95	1.36	NO	U
16-480XH	31.25	0.024	0.0787	YES	1.96	1.36	NO	U
16-480X	31.25	0.027	0.0787	YES	1.95	1.36	NO	U
16-720H	27.29	0.023	0.0787	YES	1.88	1.39	NO	U
16-720XH	27.29	0.020	0.0787	YES	1.89	1.39	NO	U
16-720X	27.29	0.023	0.0787	YES	1.89	1.39	NO	U
24-360H	30.00	0.037	0.0787	YES	1.88	1.36	NO	U
24-360XH	30.00	0.030	0.0787	YES	1.88	1.36	NO	U
24-360X	30.00	0.032	0.0787	YES	1.88	1.36	NO	U
24-480H	27.67	0.030	0.0787	YES	1.84	1.38	NO	U
24-480XH	27.67	0.026	0.0787	YES	1.84	1.38	NO	U
24-480X	27.67	0.028	0.0787	YES	1.84	1.38	NO	U
24-720H	24.50	0.023	0.0787	YES	1.78	1.41	NO	U
24-720XH	24.50	0.018	0.0787	YES	1.78	1.41	NO	U
24-720X	24.50	0.020	0.0787	YES	1.78	1.41	NO	U

U = Unacceptable M = Marginal A = Acceptable NA = Not Applicable

[*] See Appendix C for example calculations

3.1.3 Canadian Criterion

The recommended design procedure used in Canada was developed by Onysko from an extensive survey and testing program performed in the 1970's (Onysko 1985). He found that dynamic response due to an impact load and deflection due to a concentrated static load were the best parameters that correlated to perceived acceptability. Since damping is a parameter that is usually unknown to the design engineer, he developed a criterion based on the static deflection of a floor due to a static concentrated load. In this study, each floor was subjected to a static concentrated load of 225 lb as discussed in Section 2.3.2.1. Table 3.3 gives the results for the measured and required deflection of each floor. The required deflection, $\Delta_{required}$, was found by using Equation 1.11. Fourteen floors were rated as unacceptable with two floors rated as marginal and two others rated as acceptable, as shown in Table 3.3. To achieve a marginal rating, the floor must have a deflection less than ten percent above the maximum allowed deflection.

Table 3.3 Acceptability Rating of All Floors From the National Building Code of Canada Design Guide

Floor Designation	Span Length (ft)	Midspan $\Delta_{Meas.}$ (in.)	Midspan $\Delta_{Required}^{*}$ (in.)	Acceptability Rating
16-360H	34.00	0.034	0.015	U
16-360XH	34.00	0.026	0.015	U
16-360X	34.00	0.030	0.015	U
16-480H	31.25	0.028	0.017	U
16-480XH	31.25	0.024	0.017	U
16-480X	31.25	0.027	0.017	U
16-720H	27.29	0.023	0.020	U
16-720XH	27.29	0.020	0.020	M
16-720X	27.29	0.023	0.020	U
24-360H	30.00	0.037	0.018	U
24-360XH	30.00	0.030	0.018	U
24-360X	30.00	0.032	0.018	U
24-480H	27.67	0.030	0.020	U
24-480XH	27.67	0.026	0.020	U
24-480X	27.67	0.028	0.020	U
24-720H	24.50	0.023	0.023	M
24-720XH	24.50	0.018	0.023	A
24-720X	24.50	0.020	0.023	A

U = Unacceptable M = Marginal A = Acceptable NA = Not Applicable

[*] See Appendix C for example calculations

3.1.4 Murray's Criterion

Murray (1991) developed a design procedure to rate the acceptability of concrete floor systems supported by either steel beams or steel joists. This criterion was examined in this study to determine if it can be applied to lightweight floor systems. The fundamental frequency of the floor must first be less than 10 Hz before this criterion can apply. This criteria does not apply to six of the floors tested since they have a measured frequency greater than 10 Hz.

The required damping for the test floors was determined using Equation 1.19. The maximum initial amplitude, A_o, was calculated since it was not measured in the tests. The required damping was found to be extremely high as shown in Table 3.4. This result is because of large initial amplitude values coupled with relatively high frequencies.

Murray's criterion was developed for composite steel joist or steel beam concrete floor systems with a comparatively large moment of inertia and also a much larger mass than the floors tested in this study. As a result, the floors used to develop the criterion had a much smaller displacement due to a heel drop. It is concluded that, because Murray's criterion is designed to be used with more rigid and heavier floor systems, where the typical required damping is between 4% and 10%, it is not applicable to steel joist supported wood floor systems as reported in this study.

Table 3.4 Acceptability Rating of All Floors From Murray's Criterion

Floor Designation	Span Length (ft)	Meas. Freq. (Hz)	Is Freq. Less Than 10 Hz ?	Calc. Ao* (in.)	% Damping Req'd*	Murray's Acceptability Rating
16-360H	34.00	7.81	YES	0.085	25.8	NA
16-360XH	34.00	7.81	YES	0.085	25.8	NA
16-360X	34.00	7.81	YES	0.085	25.8	NA
16-480H	31.25	8.94	YES	0.090	30.6	NA
16-480XH	31.25	9.00	YES	0.090	30.8	NA
16-480X	31.25	8.94	YES	0.090	30.6	NA
16-720H	27.29	10.69	NO	0.087	35.1	NA
16-720XH	27.29	10.75	NO	0.087	35.3	NA
16-720X	27.29	10.75	NO	0.087	35.3	NA
24-360H	30.00	8.94	YES	0.096	32.5	NA
24-360XH	30.00	8.94	YES	0.096	32.5	NA
24-360X	30.00	8.94	YES	0.096	32.5	NA
24-480H	27.67	9.94	YES	0.097	36.2	NA
24-480XH	27.67	9.75	YES	0.096	35.3	NA
24-480X	27.67	9.81	YES	0.096	35.6	NA
24-720H	24.50	11.60	NO	0.092	40.0	NA
24-720XH	24.50	11.56	NO	0.092	39.8	NA
24-720X	24.50	11.50	NO	0.092	39.5	NA

U = Unacceptable M = Marginal A = Acceptable NA = Not Applicable

[*] See Appendix C for example calculations

3.1.5 Johnson's Criterion

Johnson (1994) developed an acceptability criterion based on frequency alone. He tested 86 *in situ* wood floor systems while under construction. He proposed a simple check that states that a wood floor must have a fundamental frequency greater than 15 Hz while supporting only its self weight. All steel joist supported floor systems in this study had a fundamental frequency less than 15 Hz. Therefore all floor systems are considered to be unacceptable according to this criterion. A reason that all steel joist supported wood floor systems have a smaller frequency is because the span lengths for the floors tested are significantly longer than those for most of the floors tested by Johnson (1994) and Shue (1995).

3.1.2 Selection of Acceptable Criterion

Table 3.5 summarizes the acceptability of each floor system based on each criterion considered along with the subjective evaluation. The subjective evaluation was performed as discussed in section 2.2.3.4. All floors tested were found to have a subjective evaluation rating of unacceptable. This does not allow one to effectively evaluate any criterion unless it rates all the floors accordingly.

Ohlsson's and Murray's criteria did not apply to any of the floor systems tested since the physical dimensions of these floors were not addressed in each design guide. The Canadian design guideline was the only criterion that rated any of the floors as acceptable. The Australian Code and Johnson's criterion categorized all of the floors as being unacceptable just as the subjective evaluation.

It must be emphasized that the subjective evaluation were obtained using bare floors, that is, furniture, walls, etc. were not present, Subjective evaluation of floors supporting normal residential or office furniture, partitions, etc. most likely will be substantially different.

Table 3.5 Comparison of Each Acceptability Criterion and Subjective Evaluation

Floor Designation	Swedish Acceptability Rating	Australian Acceptability Rating	Canadian Acceptability Rating	Murray's Acceptability Rating	Johnson's Acceptability Rating	Subjective Evaluation Rating
16-360H	NA	U	U	NA	U	U
16-360XH	NA	U	U	NA	U	U
16-360X	NA	U	U	NA	U	U
16-480H	NA	U	U	NA	U	U
16-480XH	NA	U	U	NA	U	U
16-480X	NA	U	U	NA	U	U
16-720H	NA	U	U	NA	U	U
16-720XH	NA	U	M	NA	U	U
16-720X	NA	U	U	NA	U	U
24-360H	NA	U	U	NA	U	U
24-360XH	NA	U	U	NA	U	U
24-360X	NA	U	A	NA	U	U
24-480H	NA	U	A	NA	U	U
24-480XH	NA	U	U	NA	U	U
24-480X	NA	U	U	NA	U	U
24-720H	NA	U	M	NA	U	U
24-720XH	NA	U	A	NA	U	U
24-720X	NA	U	A	NA	U	U

U = Unacceptable M = Marginal A = Acceptable NA = Not Applicable

3.2 Prediction of Deflection

3.2.1 Calculation of Effective Moment of Inertia

Moment of inertia is a measure of resistance to rotation of a section when an external force is applied to the section. This value is determined based on the physical properties of the cross section being examined. This property is used to predict the behavior of the floor when subjected to an external force. When predicting the effective moment of inertia of a steel joist, it was assumed in the past that 85 percent of the gross moment of inertia of the chords was effective. Kitterman (1994) modeled twenty-five different joist configurations, varying their span-to-depth ratio, and found the effective moment of inertia to be 65-87 percent of the gross moment of inertia.

Band (1996) modeled twenty round rod web steel joists using the finite element program SAP90 (Wilson and Habibullah 1992) along with ten full scale tests to derive Equation 3.1. This reduction equation predicts the effective moment of inertia for span to depth ratios between 10 and 24. Taking the measured angle sizes of the top and bottom chords, one can calculate the gross moment of inertia of a joist. The gross moment of inertia is then multiplied by the percent I_{chords} to get the effective moment of inertia of the joist:

$$\% I_{chords} = 72.1 + 0.725\left(\frac{L}{D}\right) \tag{3.1}$$

Table 3.6 lists the calculated values for each two-joist system without sheathing attached and compares the measured results to the calculated moment of inertia using the chord properties and Equation 3.1. The calculations for the effective moment of inertia are shown in Appendix B.

Table 3.6 Effective Moment of Inertia: Calculated versus Measured

Floor System	Calculated I_{eff} (in.^{4})	Measured I_{eff} (in.^{4})	% Difference
2J16-720	59.24	59.05	0.32
2J24-720	58.32	57.60	1.23

Two two-joist floor systems, using round web members, were built, as discussed in Section 2.3, to determine the amount of composite action taking place between the joists and the OSB sheathing. A test was performed with and without the OSB sheathing attached to the joists for each floor. An incremental concentrated static load was placed at the center of the joists and the midspan deflection was recorded. The two joists for each test are distinguished as the north joist and the south joist based on their orientation in the laboratory.

The slope of a straight line that best fit the load versus deflection points was found. The moment of inertia was then determined by rearranging Equation 1.2 and replacing the variables L/Δ with the slope of the straight line that best fit the load versus deflection points. Table 3.7 lists the calculated values for the moment of inertia taken from the measured deflection values due to a 300 lb midspan concentrated load for the two-joist tests.

Table 3.7 Measured Moment of Inertia

Floor Designation	Without Sheathing				With Sheathing				
	North Joist $\Delta_{meas.}$ (in.)	South Joist $\Delta_{meas.}$ (in.)	Average of Joists $\Delta_{avg.}$ (in.)	$I_{eff.}$ (in.^{4})	North Joist $\Delta_{meas.}$ (in.)	South Joist $\Delta_{meas.}$ (in.)	Average of Joists $\Delta_{avg.}$ (in.)	$I_{t.}$ (in.^{4})	B_e (in.)
2J16-720	0.116	0.137	0.127	59.05	0.122	0.124	0.123	60.91	2.77
2J24-720	0.089	0.097	0.093	57.60	0.091	0.093	0.092	58.16	0.82

To determine the effective width of the OSB sheathing, the same deflection tests used for tee-beam floors constructed of wood I-joists, solid sawn wood joists, and wood trusses was utilized (Runte 1993). Using the modulus of elasticity (580,000 psi) value for the panel dry axial stiffness listed in the American Plywood Association Technical Note N375B (1995) for the modulus of elasticity for OSB, the effective width for each floor was calculated.

The effective panel width, B_e, is the width of OSB that contributes to the stiffness of the floor system. The results indicate that OSB sheathing contributes very little to the overall effective moment of inertia of the floor system and can be ignored. Thus, to calculate the effective moment of inertia of the floor system, one should only use the effective moment of inertia of the steel joist calculated by Band's equation.

3.2.2 Load Reduction Factor

The Australian Standard Domestic Framing Code (1993) uses a reduction factor, K_d, to estimate the midspan deflection of a floor system. The factor K_d (Equation 1.12) is based on the stiffness properties of the joists and sheathing. The applied load, P, is multiplied by K_d to estimate the amount of load that is resisted only by the center joist. The midspan deflection is calculated using Equation 1.11 which is a modification of the deflection equation of a simple joist or beam. Figure 3.1 is a plot of the predicted deflection of the center joist using the Australian Code versus the measured deflection of the center joist for all multi-joist floor systems tested with a 225 lb concentrated load placed at midspan. It can be seen that none of the floors were within 10 percent of the measured deflection. Appendix C contains an example calculation of a floor system (24-360H) for the load reduction factor method.

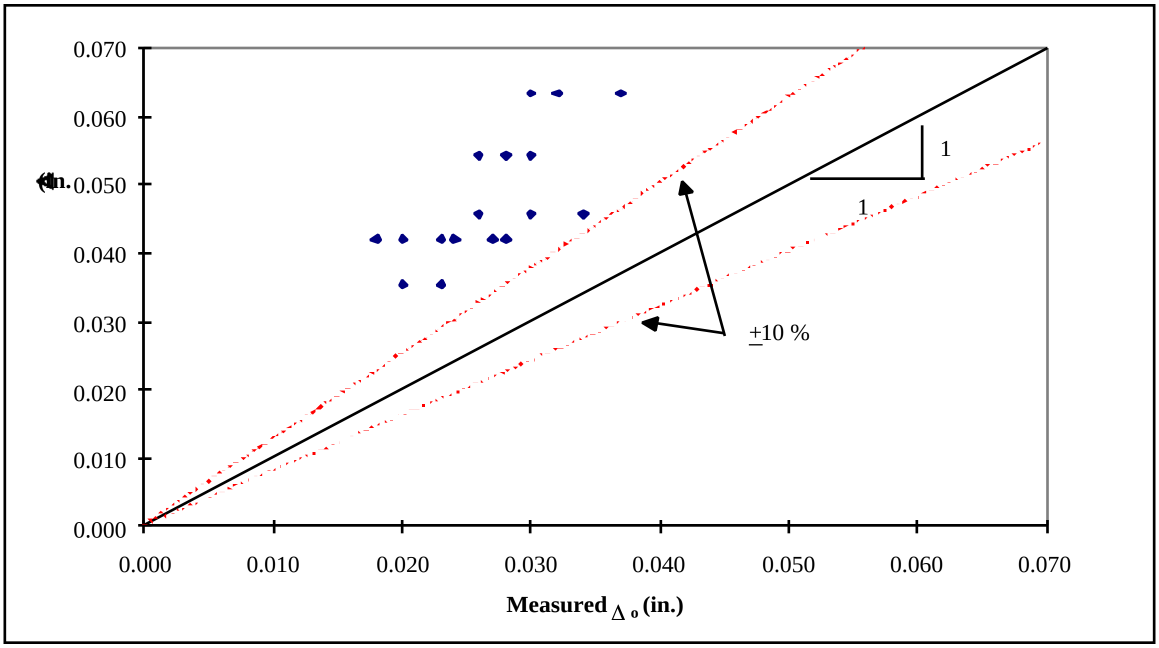

Figure 3.1 Midspan Deflection: Australian Predicted versus Measured

3.2.3 Load Sharing Prediction, N_{eff}

The number of joists that contribute to resisting an applied load is called the number of effective joists, N_{eff}. The joist that is directly underneath the load is considered to be fully effective and the neighboring joists to be less effective as the distance from the fully loaded joist increases. The location where there is no deflection is called x_o and is discussed in Section 1.4.3. Any joists beyond x_o do not contribute to the resistance to the applied load and are not considered. The following sections describe experimental methods to determine and mathematical procedures to predict N_{eff}.

3.2.3.1 Experimental Method

The number of effective joists is defined as the maximum dynamic amplitude of a floor system due to a heel drop on a tee-beam, A_{ot}, divided by the maximum dynamic amplitude due to a heel drop on a floor system, A_o. Since the dynamic amplitude of the multi-joist and the two-joist tests were not measured, the static displacement for each floor system was used instead to determine A_{ot} and A_o. The procedure used to obtain A_{ot} is described in Section 2.2.3.3 and A_o is described in Section 2.3.2.1. Table 3.8 lists the values measured for each floor system and also lists the calculated N_{eff} for each floor system.

Table 3.8 Measured Data of Multi-Joist Floor Systems

Floor Name	Span Length (ft)	Joist Spacing (in.)	Measured A_{ot}^{*} (in.)	Measured A_{o}^{**} (in.)	Measured N_{eff} A_{ot}/A_{o}
16-360H	34.00	16	0.177	0.034	5.21
16-360XH	34.00	16	0.177	0.026	6.81
16-360X	34.00	16	0.177	0.030	5.91
16-480H	31.25	16	0.138	0.028	4.91
16-480XH	31.25	16	0.138	0.024	5.73
16-480X	31.25	16	0.138	0.027	5.10
16-720H	27.29	16	0.092	0.023	3.98
16-720XH	27.29	16	0.092	0.020	4.58
16-720X	27.29	16	0.092	0.023	3.98
24-360H	30.00	24	0.127	0.037	3.45
24-360XH	30.00	24	0.127	0.030	4.25
24-360X	30.00	24	0.127	0.032	3.98
24-480H	27.67	24	0.100	0.030	3.33
24-480XH	27.67	24	0.100	0.026	3.85
24-480X	27.67	24	0.100	0.028	3.57
24-720H	24.50	24	0.069	0.023	3.02
24-720XH	24.50	24	0.069	0.018	3.86
24-720X	24.50	24	0.069	0.020	3.47

* Two-joist line tests

** Multi-joist line tests

3.2.3.2 SJI and AISC Equations to Predict N_{eff}

A mathematical method to predict the number of effective joists, N_{eff}, uses equations developed through research sponsored by the Steel Joist Institute (SJI) and the American Institute of Steel Construction (AISC). These equations were developed for use with steel joist or beam concrete slab floor systems, as discussed in Sections 1.4.3.1 and 1.4.3.2. The SJI equation is limited to a spacing less than 30 in. and the AISC equation is limited to a spacing greater than 30 in. Thus the AISC equation is not applicable to the floors studied here.

Figure 3.2 compares predicted and measured number of effective joists for the floors tested. The SJI equation underpredicts the number of effective joists for all floors tested, as can be seen in the figure. Results for each multi-joist line floor system are tabulated in Table 3.9. Appendix C contains an example calculation for determining N_{eff} of floor 24-360H using the SJI equation.

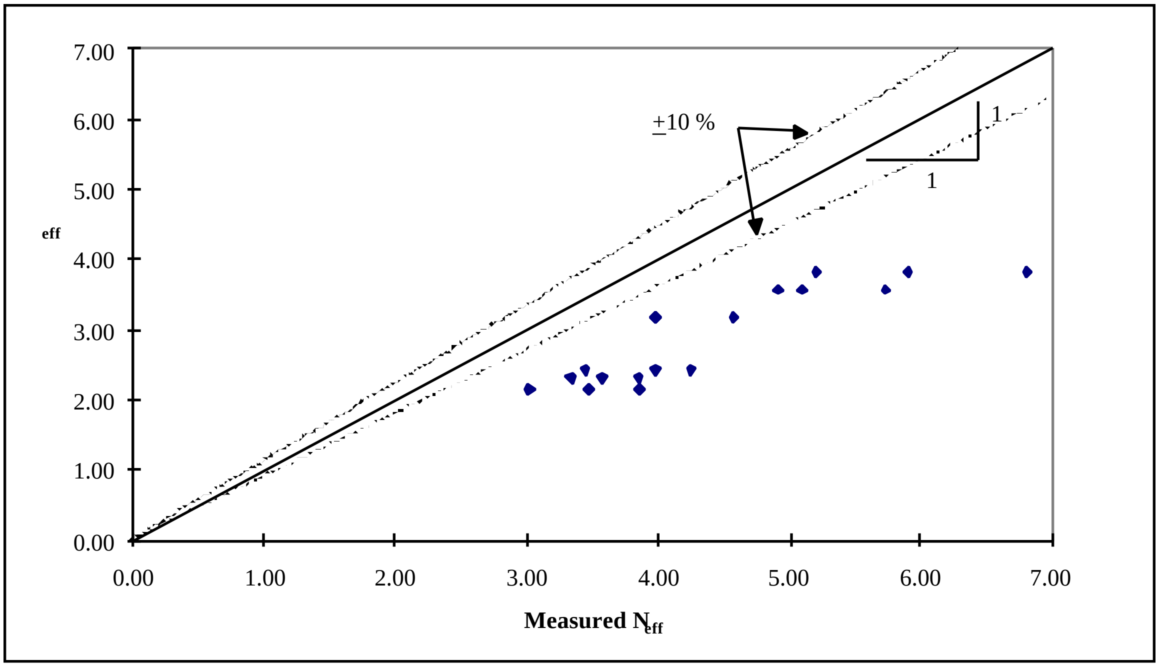

Figure 3.2 Number of Effective Joists: SJI Predicted versus Measured

Table 3.9 Number of Effective Joists: Predicted and Measured

Floor	Number of Effective Joists, N_{eff}		
Name	Measured	SJI	Kitterman
16-360H	5.21	3.83	5.73
16-360XH	6.81	3.83	5.73
16-360X	5.91	3.83	5.73
16-480H	4.91	3.57	4.62
16-480XH	5.73	3.57	4.62
16-480X	5.10	3.57	4.62
16-720H	3.98	3.17	3.47
16-720XH	4.58	3.17	3.47
16-720X	3.98	3.17	3.47
24-360H	3.45	2.44	3.98
24-360XH	4.25	2.44	3.98
24-360X	3.98	2.44	3.98
24-480H	3.33	2.32	3.28
24-480XH	3.85	2.32	3.28
24-480X	3.57	2.32	3.28
24-720H	3.02	2.15	2.58
24-720XH	3.86	2.15	2.58
24-720X	3.47	2.15	2.58

Note: Shaded cells are within 10% of Measured

3.2.3.3 Kitterman Equation

Based on work Shamblin (1989) had performed, Kitterman (1994) developed an equation (Equation 1.31) that predicts the number of effective joists for all beam or joist spacings for steel beam or joist concrete floor systems. Figure 3.3 graphically shows the relationship between the predicted and measured values for the number of effective joists. The Kitterman equation predicts eight of the eighteen floor systems within ten percent of the measured values of N_{eff} as shown in Table 3.9. Appendix C contains an example calculation to determine N_{eff} of floor system 24-360H using the Kitterman equation.

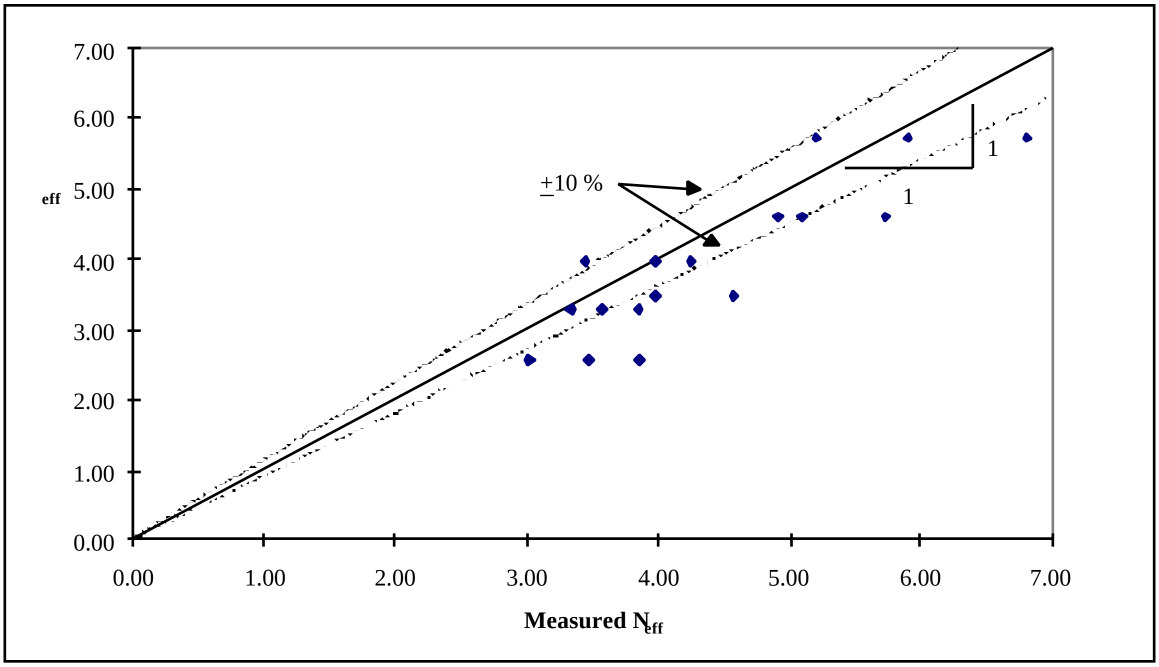

Figure 3.3 Number of Effective Joists: Kitterman Predicted versus Measured

3.2.4 Conclusions for Predicting Deflection

Three methods for predicting deflection were evaluated: Australian Code, SJI, and Kitterman. Of the three methods, Kitterman's was the only method to predict the measured deflection of any floor within ten percent. For this reason, the Kitterman equation is considered the best of the evaluated methods to predict measured deflection for steel joist supported wood floor systems.

3.3 Prediction of Frequency

To obtain the fundamental frequency of a floor system, a fast fourier transform (FFT) is performed on the acceleration trace due to a heel drop as explained in Section 2.2.3.1. The FFT allows one to view the power spectrum of the acceleration trace. The power spectrum is a graph of the frequency domain versus relative power. This graph allows one to see the amount of influence each frequency has in contributing to the acceleration trace. Appendix A shows for each floor system, two acceleration traces caused by a heel drop and the corresponding power spectra.

The fundamental frequency can be predicted using Equation 1.24 which is repeated here for convenience:

$$f = 157\sqrt{\frac{gEI_t}{wL^4}} \quad \text{(Hz)} \tag{1.24}$$

It is a modification of the frequency model for simply supported rectangular plates where D_y/D_x is less than 0.01 (Equation 1.6).

The measured fundamental frequency was determined as discussed in Section 2.2 for each floor system and is tabulated in Table 3.10. Figure 3.4 is a plot of the predicted frequency versus the measured frequency. One can see that the predicted frequency for all floor systems was higher than the measured frequency.

Table 3.10 Fundamental Frequency: Predicted versus Measured

Floor Name	Span Length (ft)	Inertia Transformed* (in^4)	Total Weight Supported per Joist (lb/ft)	Calculated Frequency** (Hz)	Measured Frequency (Hz)	Percent Difference %
16-360H	34.00	60.91	10.76	8.23	7.81	-5.4
16-360XH	34.00	60.91	10.76	8.23	7.81	-5.4
16-360X	34.00	60.91	10.76	8.23	7.81	-5.4
16-480H	31.25	60.91	10.76	9.75	8.94	-9.0
16-480XH	31.25	60.91	10.76	9.75	9.00	-8.3
16-480X	31.25	60.91	10.76	9.75	8.94	-9.0
16-720H	27.29	60.91	10.76	12.78	10.69	-19.6
16-720XH	27.29	60.91	10.76	12.78	10.75	-18.9
16-720X	27.29	60.91	10.76	12.78	10.75	-18.9
24-360H	30.00	58.16	12.26	9.68	8.94	-8.3
24-360XH	30.00	58.16	12.26	9.68	8.94	-8.3
24-360X	30.00	58.16	12.26	9.68	8.84	9.5
24-480H	27.67	58.16	12.26	11.38	9.94	14.5
24-480XH	27.67	58.16	12.26	11.38	9.75	16.7
24-480X	27.67	58.16	12.26	11.38	9.81	16.0
24-720H	24.50	58.16	12.26	14.51	11.60	-25.1
24-720XH	24.50	58.16	12.26	14.51	11.56	-25.5
24-720X	24.50	58.16	12.26	14.51	11.50	-26.2

*Determined from two-joist line tests with OSB subflooring

**See Appendix C for an example calculation

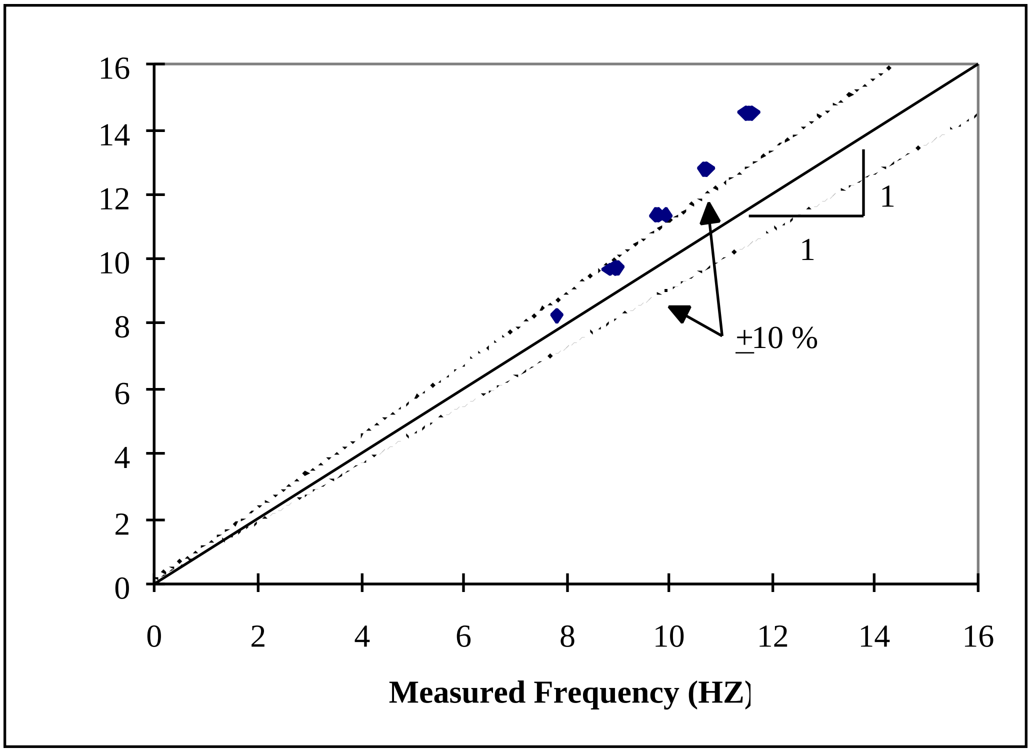

Figure 3.4 Fundamental Frequency: Predicted versus Measured

3.4 Effect of Diagonal Bracing

For each floor system, three diagonal bracing configurations were used in the tests, as discussed in Section 2.2.2. Table 3.11 summarizes the deflection of each floor system with the three bracing configurations tested. There was a significant difference in midspan deflection based on the type of diagonal bracing used, as can be seen in Figure 3.5. A reason for this is that as the bracing configuration becomes more rigid, it allows the nearby joists to become more effective in load sharing, which, in turn, increases the number of effective joists (Section 3.2.3) and reduces the deflection.

Table 3.11 Effect of Diagonal Bracing on Midspan Deflection

Floor Designation	Midspan Deflection for Each Diagonal Bracing Configuration for a 225 lb Concentrated Load at Midspan (in.)		
	H (Horizontal)	X (Cross)	XH (Cross-Horizontal)
16-360	0.034	0.030	0.026
16-480	0.028	0.027	0.024
16-720	0.023	0.023	0.020
24-360	0.037	0.032	0.030
24-480	0.030	0.028	0.026
24-720	0.023	0.020	0.028

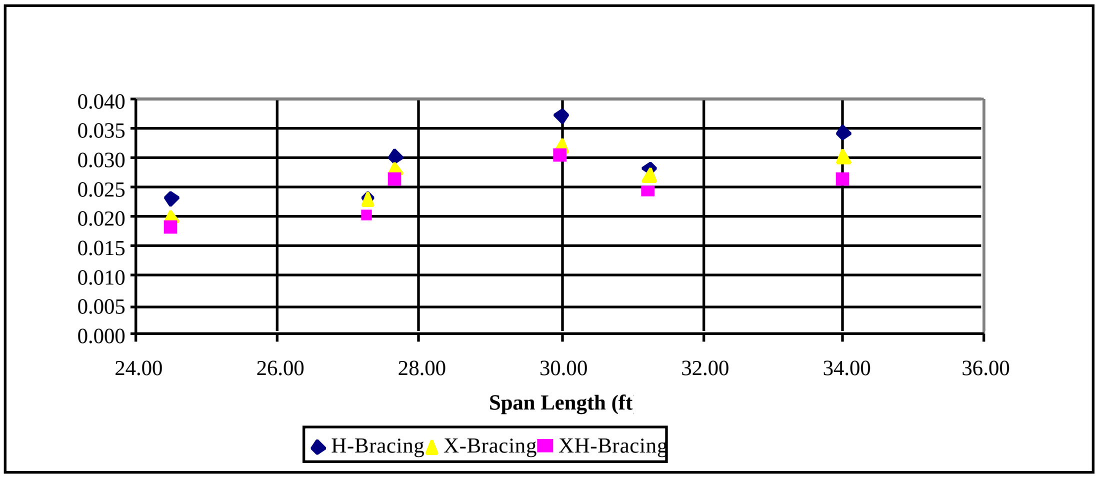

Figure 3.5 Deflection versus Span Length for Each Diagonal Bracing Configuration