Serviceability Sensitivity Analysis of Wood Floors Using OpenSees

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Introduction

- ❑ Annoying vibrations in wood floors has become a major issue due to:
  - The widespread use of engineered wood I-joist systems.
  - Longer spans and lighter construction.
- ❑ Footfall impact has been the most common source of annoying vibrations.
- ❑ Performance requirement is determined by human acceptance of the vibrational response.
- ❑ Over the years design recommendation has been to limit deflection under a uniformly distributed static load of 1.9 kN/m^2 (40 psf) of span/360. This requirement is insufficient in avoiding excessive vibrations.
- ❑ Some of the recent vibrations criteria require intensive calculations and knowledge of structural dynamics and are difficult to consider during the design stage.
- ❑ Several researchers have noted that the assumption of continuous sheathing is acceptable when considering deflections and vibrations.
- ❑ The objectives of the current project are to:
  - Provide a tool for designers to evaluate the floor systems at the design stage without requiring knowledge of structural dynamics and the difficulties associated with modeling in a finite element analysis software.
  - Compare the responses of floors with continuous and jointed sheathing.
- ❑ The Excel user interface is shown in Fig.1.
- ❑ Figure 2 show the typical model set up used in OpenSees.
- ❑ The acceptability criteria focus on ways to predict displacements, natural frequencies, and one-second root-mean-square acceleration and compare them to acceptable limits.

Methods

- ❑ For this project, OpenSees FEM program is used.
- ❑ The program was calibrated using the experimental work done by John Wolfe (2007).
- ❑ Figure 3 shows Wolfe's floor system used for this project.
- ❑ Several sensitivity analyses were performed to compare floor system modeled with jointed versus continuous sheathing.
- ❑ System parameters are given in Table 1.

Discussion/Conclusions

- ❑ As seen in Figs. 4, 5, and Table 2, compared to floors with continuous sheathing, floors with jointed sheathing have:
  - Higher displacements.
  - Lower natural frequencies.
  - Higher one-second root-mean-square acceleration responses.
- ❑ In order to obtain more accurate vibration results, floor systems should be modeled with jointed sheathing.
- ❑ The program developed in this project is a useful tool as it allows users to evaluate floors against acceptable values without dealing with structural dynamics and modeling in FEM software.

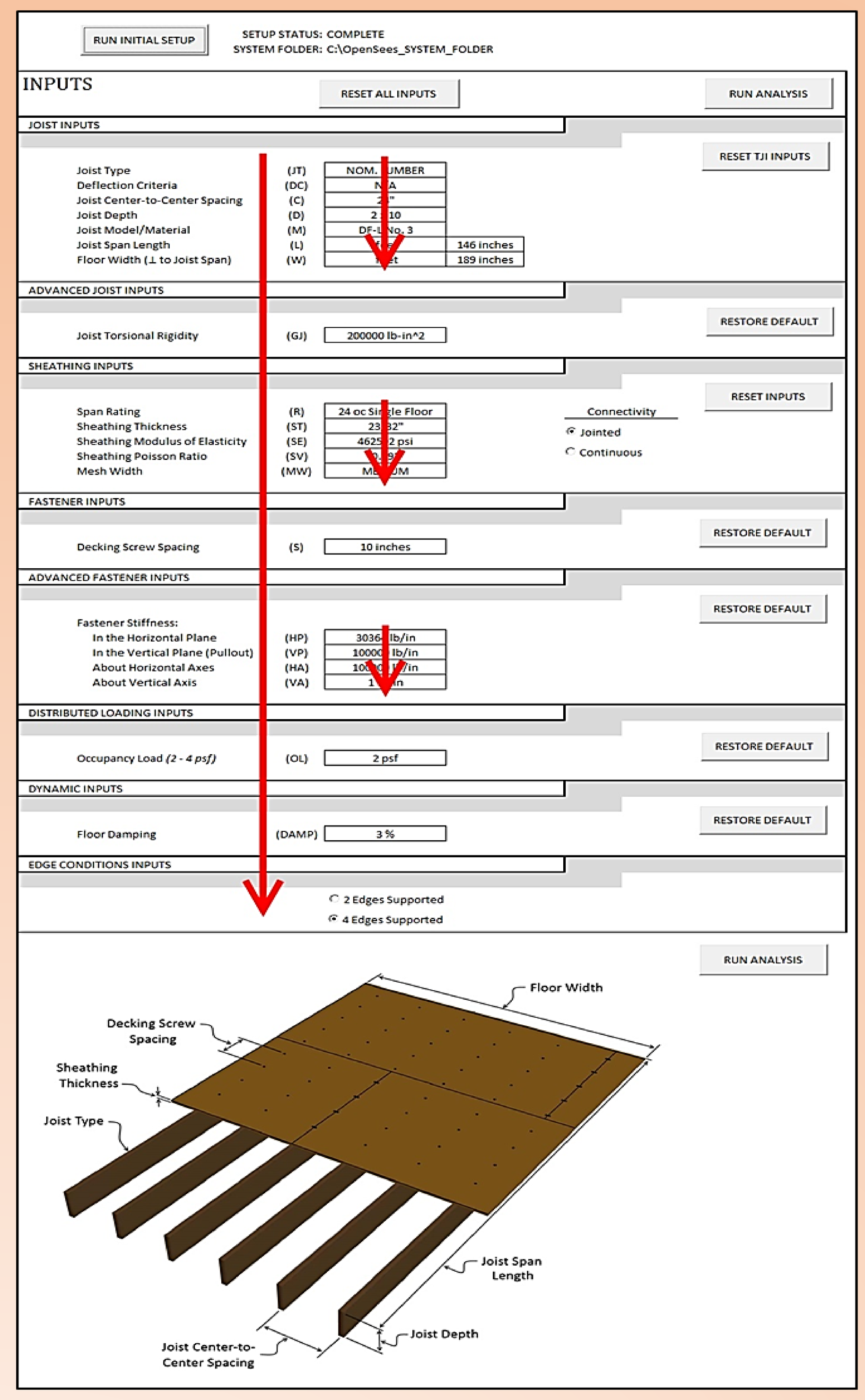

Figure 1. Excel interface

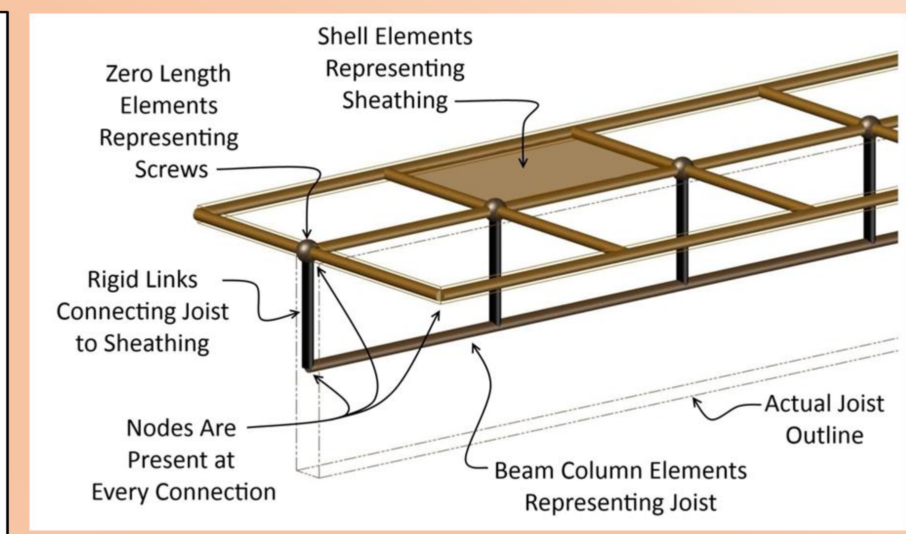

Figure 2. Typical OpenSees model setup

Figure 3. Wolfe's floor without sheathing

Joist Type	Engineered I-joist
Floor Span	4.94 m
Floor Width	Varied from 1.27 m to 5.33 m
Joist Center-to-Center Spacing	406 mm
Joist Depth	241 mm
Joist Model	110
Joist Torsional Rigidity (GJ)	574 N.m^2
Span Rating	24 o.c. Single floor
Sheathing Thickness	18.3 mm
Sheathing Modulus of Elasticity	3.19 GPa
Sheathing Poisson Ratio	0.092
Fastener Spacing	254 mm
Fastener Stiffness (Horizontal Plane)	5,318 N/mm
Fastener Stiffness (Vertical Plane – Pullout)	17,513 N/mm
Fastener Stiffness (Horizontal Axis)	17,513 N/mm
Fastener Stiffness (Vertical Axis)	0 N/mm
Occupancy Load	0.096 kPa
Floor Damping	3 %

Table 1. Constant parameters for a floor system with all edges simply supported

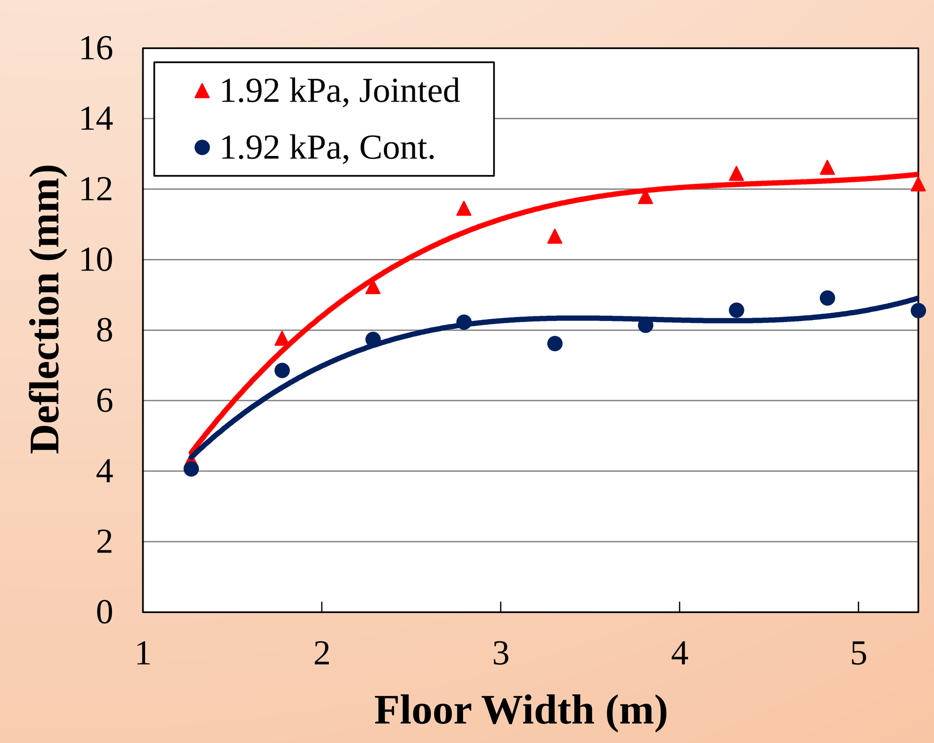

Figure 4. Floor displacement under a uniform load of 1.92 kPa

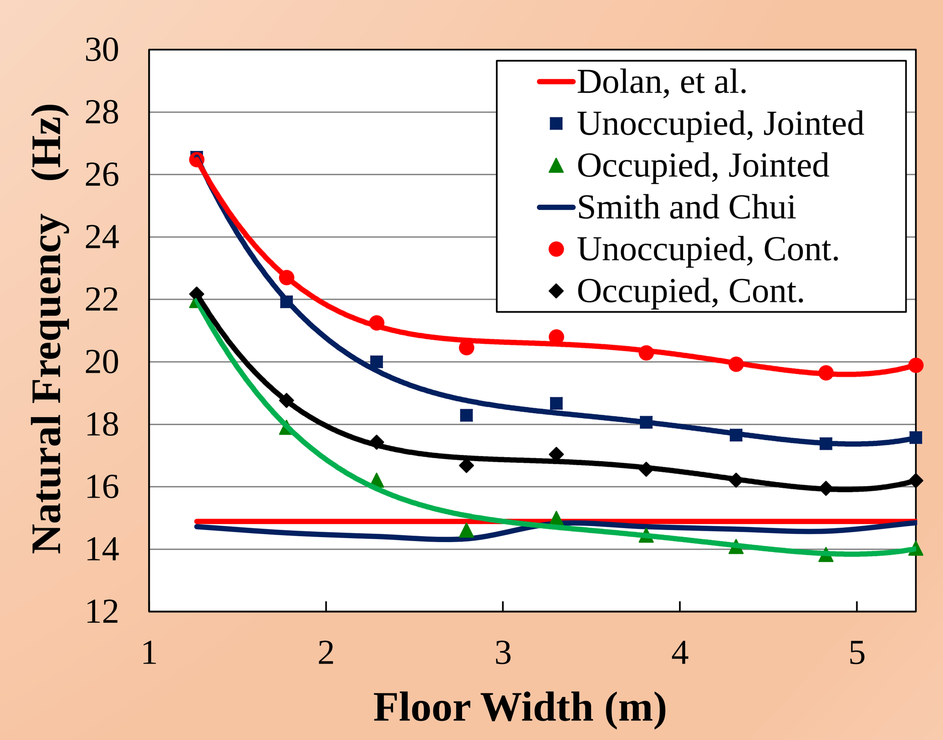

Figure 5. Natural frequency versus floor width

Force	Deflection[1]		Natural Frequency[2]				Root-Mean-Square Acc.[3]	
			Unoccupied		Occupied			
	Ave.	Max	Ave.	Max	Ave.	Max	Ave.	Max
1.92 kPA	32	45	8	12	10	13	17	38
1 kN	12	15						

[1] Higher deflection for jointed compared to continuous
[2] Lower natural frequency for jointed compared to continuous
[3] Higher root-mean-square acceleration for jointed compared to continuous

Table 2. Percent difference between jointed and continuous sheathing systems