

Geometric Simplification of a Wooden Building Connector in Dynamic Finite Element Model

ACOUSTICS 2012 - Nantes

A. Tribaleau^{†,‡},

N. Tahani[†], B. Brouard[†], J.M. Génevaux[†], O. Dazel[†],

[†]LAUM, UMR CNRS 6613, Avenue Olivier Messiaen, 72085 LE MANS

[‡]CRITT Bois, 27 rue Philippe Séguin, 88051 EPINAL

27 April 2012



Context and aim

Quick description



Context in building acoustic :

- PhD thesis on prediction of sound insulation of wooden joist floors
- Unknown dynamic behavior of wooden building connector (\neq static behavior)
- Determinant in flanking transmission of vibration and boundary conditions of floor

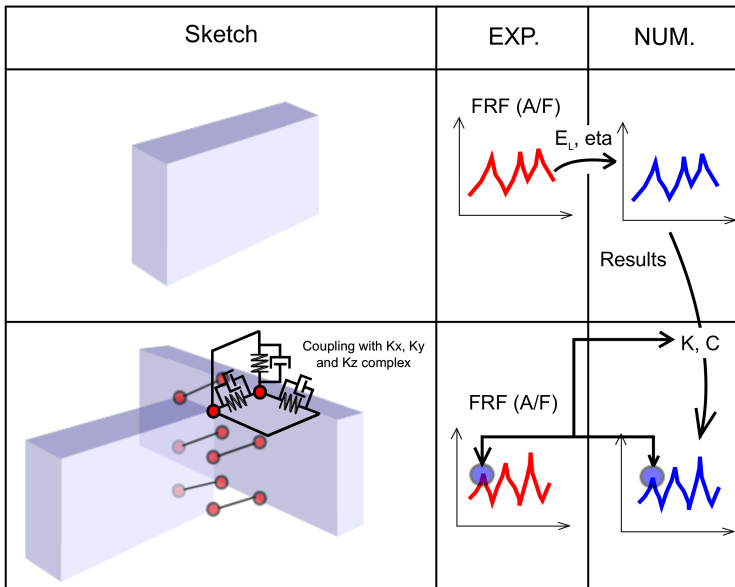
Aim :

- Simplified model of the wooden connector (stiffness and damping)
- To be used in a FE method (large structure : floor)

Outlines

- 1 Introduction
 - Context and aim
 - Method description
- 2 Modal analysis of joist
 - Mechanical properties of wooden joists
 - Resonance frequency
 - Damping factor estimation
 - Comparison with a numerical model
- 3 Modal analysis of the assembly (joist + connector + beam)
 - Case study
 - Simplified model
 - Method for determining connector's stiffness
 - Comparisons between numerical and experimental results
- 4 Conclusion and perspectives

Method description



Modal analysis of joist

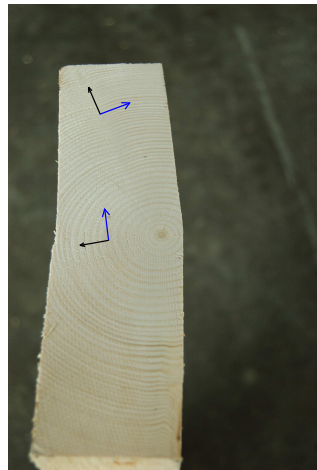
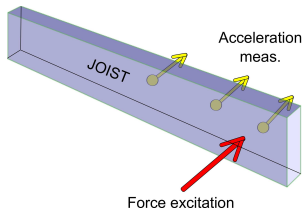
Mechanical properties of wooden joists

Known :

- Wood species : spruce
- Anisotropic material
- Size : $4500 \times 220 \times 60$ [mm]
- $\rho \approx 440 \pm 30$ [$\text{kg} \cdot \text{m}^{-3}$]
- No machining after drying and sawing

Unknown :

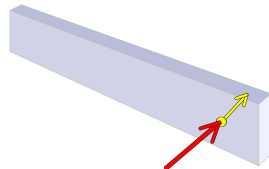
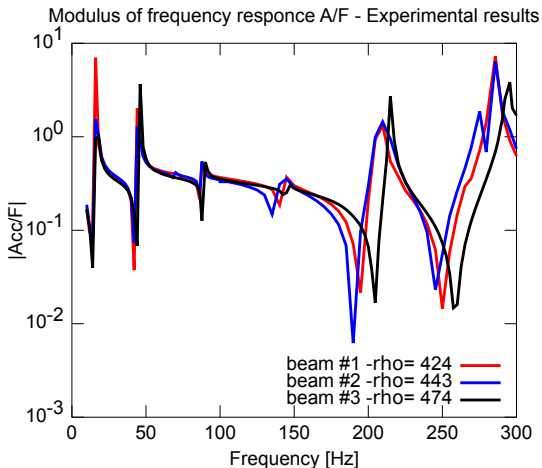
- Axial Young's modulus (E_L) and others
- Damping factor



Joist section

Modal analysis of joist

Resonance frequency - Elastic modulus estimation



● Free-free boundary condition

6 first resonance frequency [Hz]			
Mode	#1	#2	#3
1	16.2	16.6	16.8
2	44.4	44.6	46.1
3	86.5	86.6	88.5
4	140	143	146
5	207	207	215
6	286	286	293

→ Determine the longitudinal Young's

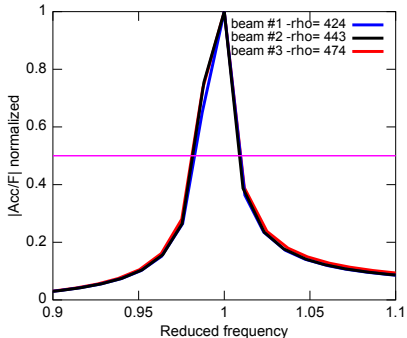
modulus

Modal analysis of joist

Damping factor estimation

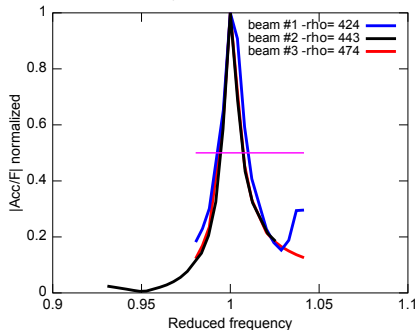
First mode : ≈ 16 Hz

Modulus of frequency response A/F - 1st mode - normalized



Fifth mode : ≈ 210 Hz

Modulus of frequency response A/F - 5th mode - normalized

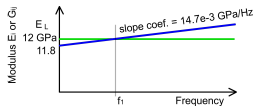


Damping factor (η)			
Mode	#1	#2	#3
1		1.4 %	
2		0.8 %	
3	-	-	-
4			
5	0.7 %	0.9 %	0.6 %
6	0.8 %	0.7 %	0.8 %

Modal analysis of joist

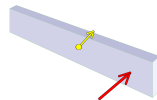
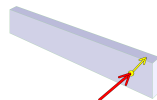
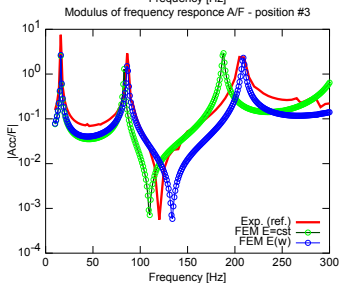
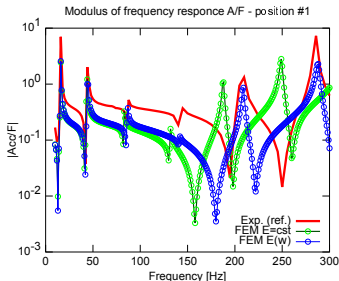
Comparison with numerical model

- Numerical model with *Freefem++*
- Test with constant or variable orthotropic Hook's law material
- Structural damping ($\eta = 0.01$)




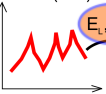
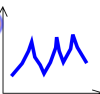
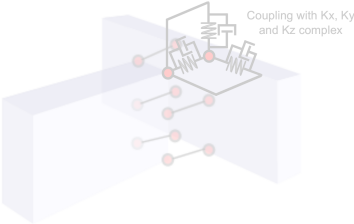


Legend

- Experimental results
- FEM results ($E_i, G_{ij} = cst$)
- FEM results ($E_i(\omega), G_{ij}(\omega)$)



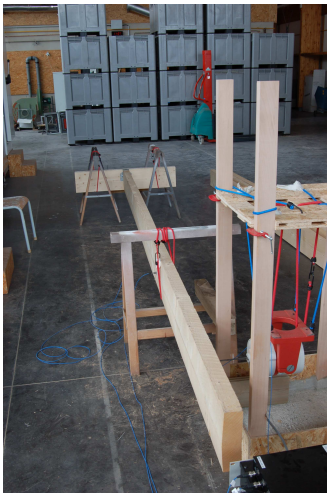
Modal analysis of joist

Synthesis

Sketch	EXP.	NUM.
	<p>FRF (A/F)</p>  <p>E_L, η</p>	
 <p>Coupling with K_x, K_y and K_z complex</p>	<p>FRF (A/F)</p>  <p>K, C</p>	 <p>✓</p>

Modal analysis of the assembly

First case study

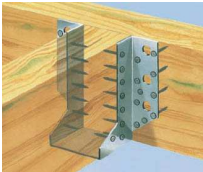
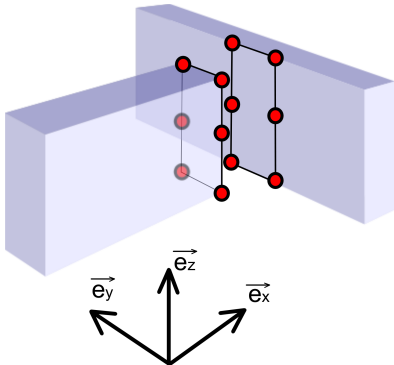


- Force along horizontal direction (y-axis)
- Free boundary conditions

Modal analysis of the assembly

Simplified model

FEM matrix construction with coupling :

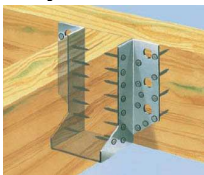
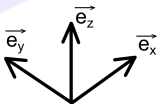
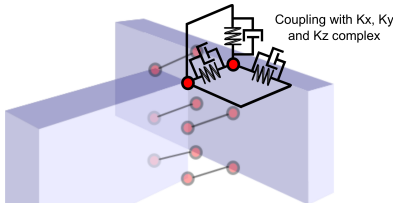


- FEM applied on joist and beam
- Choose vertices on the border of section

Modal analysis of the assembly

Simplified model

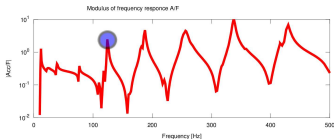
FEM matrix construction with coupling :



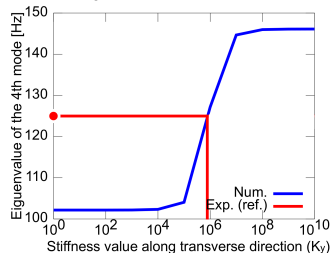
- Additional strain and dissipative energy (coupling matrix stiffness)
- Mass of connector is neglected

Modal analysis of the assembly

Method for determining connector's stiffness



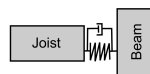
Variation of the eigenvalue - fonction of the stiffness along y-axis



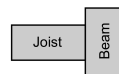
Weak coupled structure



Coupled structure

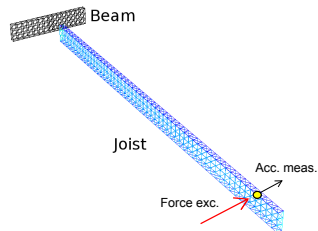
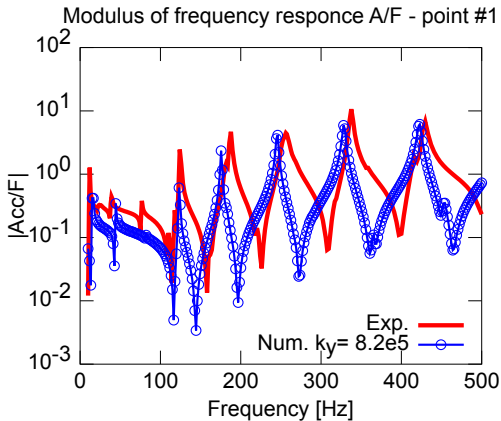


Strongly coupled structure (gluing mesh)



Modal analysis of the assembly

Response frequency - comparison between num. and exp. results



Conclusion and perspectives

- Simplified model to reduce geometric complexity
- Stiffness value K_y has been determined
- Good agreement on resonant frequency (\neq on anti-resonant freq.)

Further work

- Estimate damping along tested axis (y-axis)
- Behavior along other axis : K_x, K_z value ?
- Refine the Hook law model of material

Perspectives

- Assembly wall and floor : flanking transmission quantification
- Understand the influence of stiffness value along each direction on flanking transmission
- Design better connectors for reducing vibration transfer

Thanks for your attention