Theme A: What does the engineering community need now/soon in terms of joint modelling, and what will it do when it has it?

Structural Assemblies

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Needs of the engineering community in terms of joint modelling for structural assemblies:

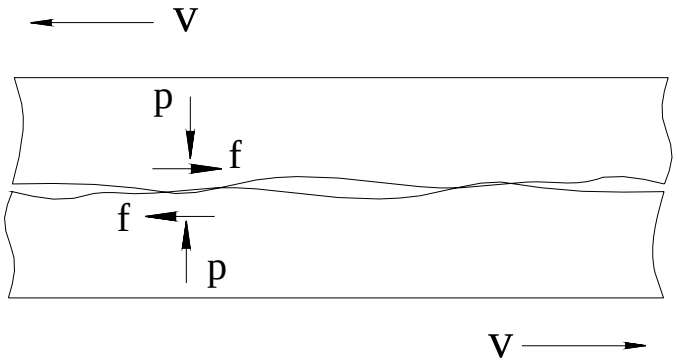
1. **Understand the fundamental physics associated with jointed interfaces**

   Interfacial interactions: friction, impact

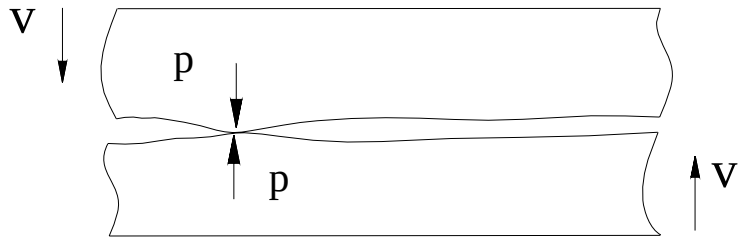
   Strongly nonlinear phenomena: unmodeled dynamics vs. uncertainty

2. **Develop analytical and numerical models suitable for structural dynamic studies that can reproduce the physics**

   Employ material, surface profile, lubricant/contamination and loading data only

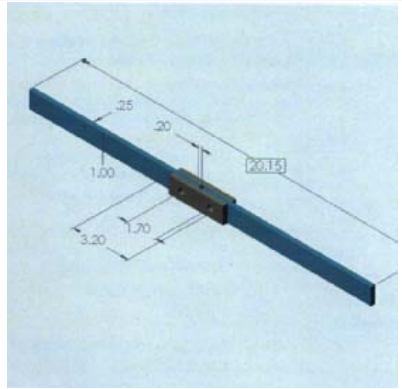


Tangential direction

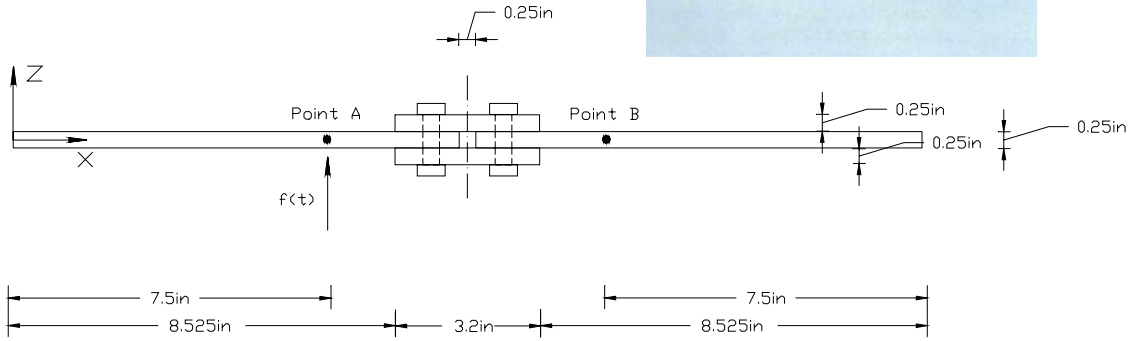


Normal direction

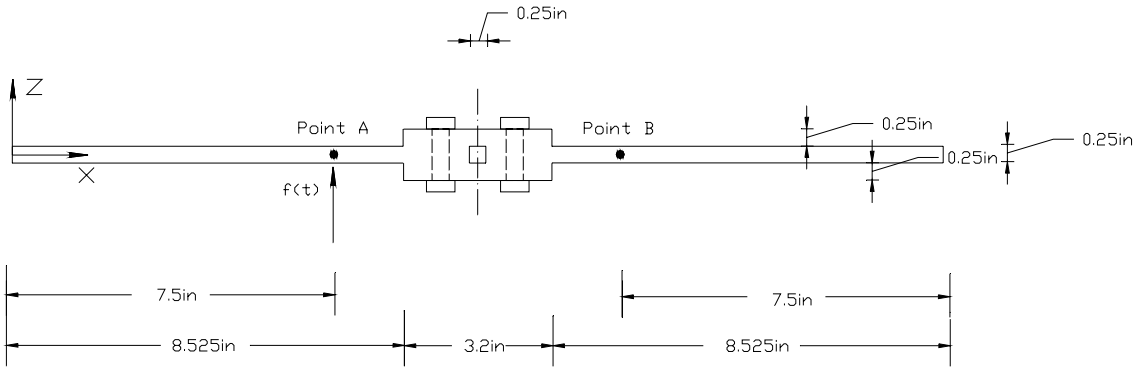
- Compare response of a jointed beam and a monolithic beam
- Free-free boundary conditions
- Transient (hammer) tests



The jointed beam



The monolithic beam



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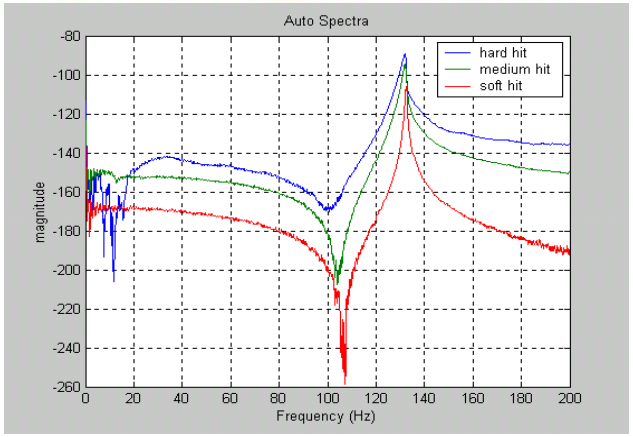
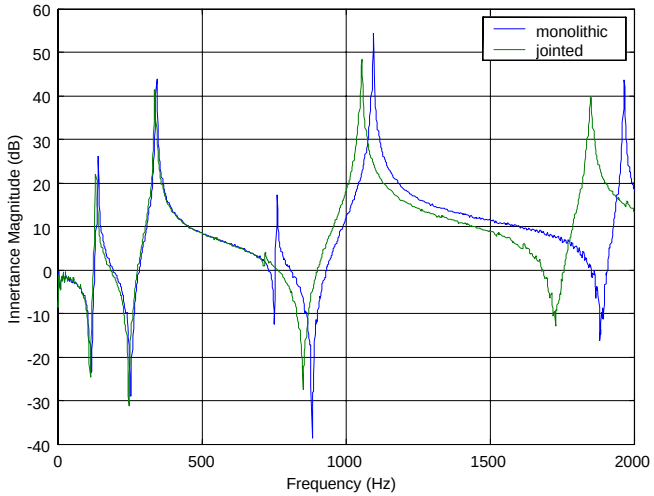


1st mode autospectra of the jointed beam under different level impulses



Inertance FRFs for the two beams (both med. hit)

Natural Frequencies (Hz)		
	Monolithic Beam	Jointed Beam
f_1	140.92	132.26 (-6.1%)
f_2	343.30	336.80 (-1.9%)
f_3	764.67	715.43 (-6.4%)
f_4	1105.80	1052.37 (-4.8%)
f_5	1970.77	1846.62 (-6.3%)
Modal Damping Ratios		
	Monolithic Beam	Jointed Beam
z_1	0.17%	0.69%(+306%)
z_2	0.05%	0.15%(+200%)
z_3	0.03%	0.13%(+333%)
z_4	0.03%	0.11%(+267%)
z_5	0.01%	0.18%(+1700%)

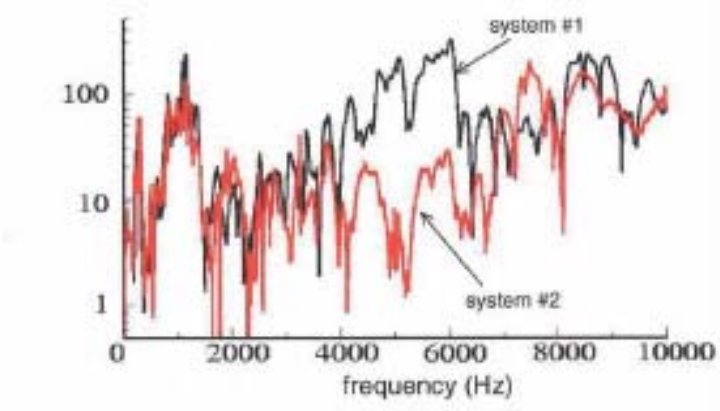
As clearly seen in the previous slide, structural joints and interfaces can have a significant effect on the dynamics of structural assemblies

Make the structure more compliant

Often the major source of damping

The problem:

In general, the local damping and stiffness associated with a single joint are nonlinear, time-varying, and not repeatable when measured, either directly or indirectly, due to factors such as wear, contamination, etc.



Where we are:

The computed (from measured data) shock response spectra of identical shell structures, each connected to a base by nominally identical joints. The vast difference in spectra illustrates the variability in properties among even nominally identical joints. (Segalman, et al., 2007)

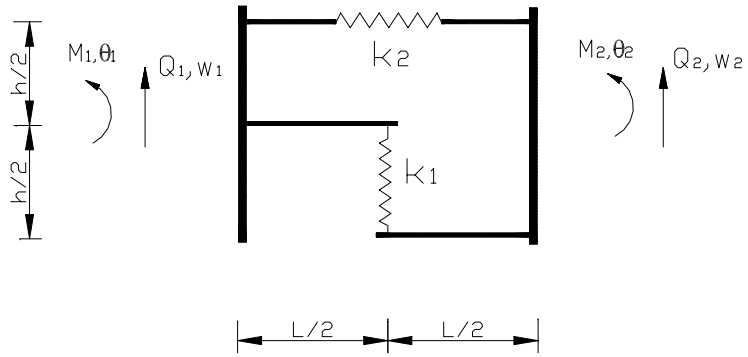
What would we do with a physics-based modelling capability?

Better reconcile the computed response at mid- to high-frequencies with observed data

Determine nominal response profiles within required confidence intervals

More effective evaluation of performance, reliability, design effectiveness

- Linear elastic beam element can be represented by the following arrangement

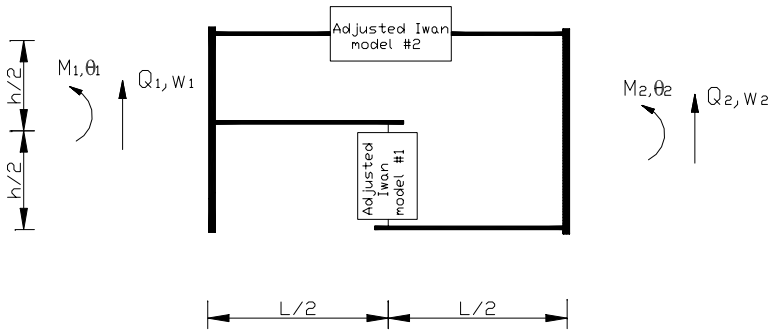


$$\begin{Bmatrix} Q_1 \\ M_1 \\ Q_2 \\ M_2 \end{Bmatrix} = \frac{EI}{L} \begin{bmatrix} \frac{12}{L^2} & \frac{6}{L} & -\frac{12}{L^2} & \frac{6}{L} \\ \frac{6}{L} & 4 & -\frac{6}{L} & 2 \\ -\frac{12}{L^2} & -\frac{6}{L} & \frac{12}{L^2} & -\frac{6}{L} \\ \frac{6}{L} & 2 & -\frac{6}{L} & 4 \end{bmatrix} \begin{Bmatrix} w_1 \\ \theta_1 \\ w_2 \\ \theta_2 \end{Bmatrix}$$

$$k_1 = 12\frac{EI}{L^3}$$

$$k_2 = 4\frac{EI}{Lh^2}$$

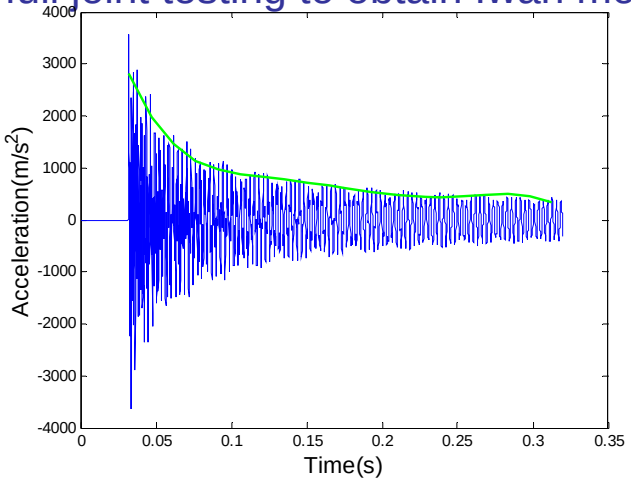
- The adjusted Iwan beam element is formed by replacing the linear springs with adjusted Iwan models. Iwan parameters are currently fit from whole-joint experimental data. *Can Iwan or equivalent model parameters be determined directly from material, surface and loading data?*

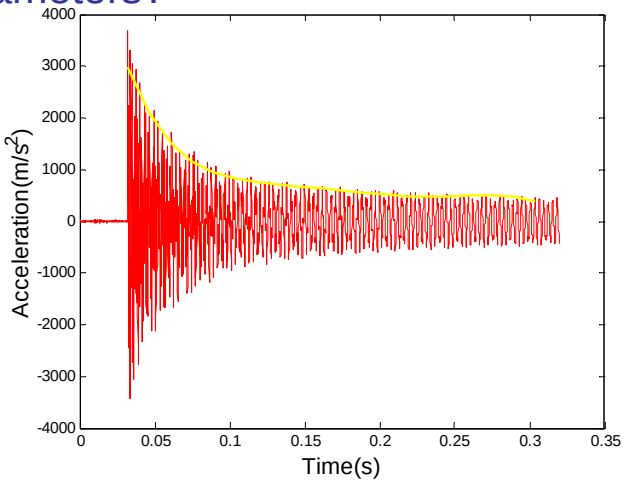


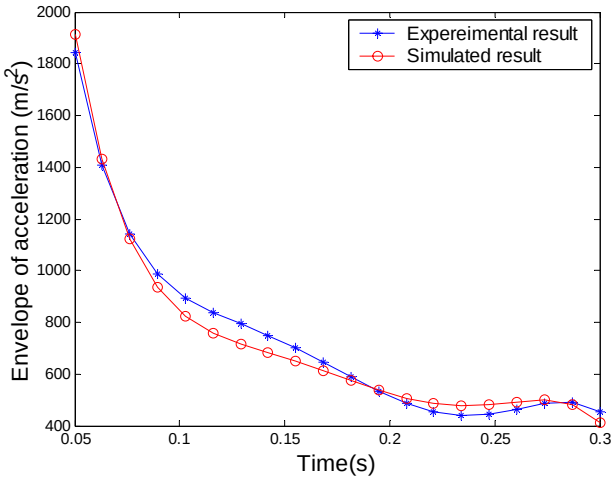
$$\begin{Bmatrix} Q_1 \\ M_1 \\ Q_2 \\ M_2 \end{Bmatrix} = \begin{Bmatrix} f_1(\Delta_1, \hbar_1) \\ \frac{L}{2} f_1(\Delta_1, \hbar_1) + \frac{h}{2} f_2(\Delta_2, \hbar_2) \\ -f_1(\Delta_1, \hbar_1) \\ \frac{L}{2} f_1(\Delta_1, \hbar_1) - \frac{h}{2} f_2(\Delta_2, \hbar_2) \end{Bmatrix}_i$$

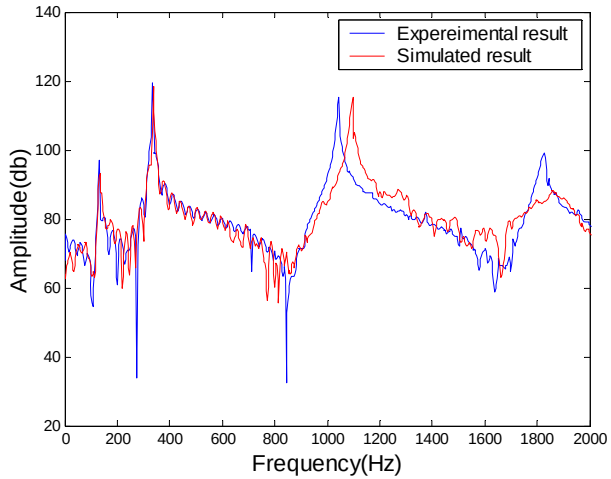
$$\Delta_1 = \frac{L}{2}(\theta_1 + \theta_2) + (w_1 - w_2) \qquad \Delta_2 = \frac{h}{2}(\theta_1 - \theta_2)$$

- Comparison of experimental and simulated accelerations using the identified parameters, at point A: Max(NEE)=4.2%; Ave(NEE)=2.1%. Can this level of correspondence be accomplished without full joint testing to obtain Iwan model parameters?









Points for discussion

For structural assemblies containing joints and interfaces, *structural dynamic models* are generally reduced order models requiring full joint experimental data to define model parameters.

A more thorough understanding of joint physics may permit determination of critical joint model parameters directly from material, surface and load data obtained from micro/mesoscale experiments on standardized specimens.

How to reconcile the question of complex, often unmodeled dynamics with systematic uncertainties?

Is it time to establish a one or more benchmark problems that the community-at-large can participate in and contribute to?