Dynamic Response and Progressive Failure of Special Structures

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Introduction:

• Structural dynamics is concerned of structural behavior under dynamic loading. Dynamic loading include wind, people, earthquakes, blast,.. Etc.

• Dynamic loads varying with time, became an essential structural analysis nowadays, because it can have a significantly larger effect than static loading of same magnitude due the amplification factor.

• It is so important to understand the structure behavior under a time function varying load, to calculate natural frequencies and modal shapes.
Objectives:

1. Observe the Dynamic response of different structural configurations. Varying the mass and testing different structural setups (trusses, multistory building)

2. Understand the behavior of structures under a certain dynamic loading. For the same structural setup applying different sets of frequencies and accelerations.


Fig (1) Shaker System
Attached Shaker Dimensions (in)

Attachment Plate

Dimensions: (in)
Horizontal Shaker Dimensions (in)
Structural Models

1. Trusses

2. Multi Story Building
Trusses:

Truss 1

Truss 2
Trusses:

Truss 3

Truss 4
Multistory building:

Building 1
Multistory building: Building 2
Multistory building:

Building 3
Multistory building:

Building 4
Modal Analysis:

- Modal analysis is the study of dynamic properties of structures under vibrational excitation.

- Experimental modal analysis is the field of measuring and analyzing the dynamic response of structures and or fluids when excited by an input.

- Typical excitation signals can be classified as impulse, broadband, swept sine, chirp, and many others; each one has its own advantages and disadvantages.

- The analysis of the signals typically relies on Fourier analysis. The resulting transfer function will show one or more resonances, whose characteristic mass, frequency, and damping can be estimated from the measurements.

- Figure (1) Shows how input force is converted to a vibration
1. Experimental Measurements
   a. Trusses
   b. Multistory Buildings

2. SAP Modeling Mode Shapes
   a. Trusses
   b. 2D Frames
Experimental Measurements

8 story Building 1: $F_q: 19 \text{ Hz}, A: 5 \text{m/sec}^2$
Experimental Measurements

Mass + 8 story Building 1: $f_q$: 8 Hz, $A$: 2.5 m/s$^2$
Experimental Measurements

Mass + 8 story Building 1: Fq:10 Hz, A: 3.4m/sec²
Experimental Measurements

mass + 13 story Building : Fq:15Hz, A: 3.3m/sec²
Experimental Measurements

Truss 4: \( Fq: 6 \text{ Hz}, A: 1\text{m/sec}^2 \)
Experimental Measurements

Truss 4: Fq: 9-15 Hz, A: 1-2 m/sec²
Experimental Measurements

Truss 4: Damaged
Experimental Measurements

Truss 2: Fq:15 Hz, A: .5m/sec²
Experimental Measurements

Truss 2: Fq:12 Hz, A: 2 m/sec² Damage
Experimental Measurements

Mass+Truss 2: Fq:11 Hz, A: 2.5m/sec²
Experimental Measurements

Removed Truss members 2: $F_q:10 \text{ Hz}, A: 2.7 \text{m/}sec^2$
Calculated Data

SAP Modeling Mode Shapes

a. Trusses

b. 2D Frames

c. Structural Beams
Calculated Simulations: Trusses

Deformed Mode 1
Calculated Simulations: Trusses

Deformed Mode 4
Calculated Simulations: Trusses

Deformed Mode 11
Calculated Simulations: Frames

Undeformed Frame

Deformed Mode 1
Calculated Simulations: Frames

Deformed
Mode 2
Calculated Simulations: Frames

Deformed Mode 4
Calculated Simulations: Frames

Deformed Mode 12
Results and Discussions

• Different structure types vary in their response, even if it was made of the same material.

• Limitations of minimum frequency were one of the issues, that prevent us from getting the resonance for the high tower structure.

• Adding extra masses didn’t help us that much, because still the maximum displacement was at the top.
Conclusions and Significance

• Response of any Dynamic structure depends on its natural frequency.

• Dynamic excitation depends on several factors: the dynamic history, amplitude, and frequency.