Bridging Your Innovations to Realities

midas Civil
Dynamic Analysis

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## 1. Introduction

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2. Eigen Value Analysis

Procedure of Eigenvalue Analysis:

1. Specifying Structure Mass
2. Defining Eigenvalue Analysis Control
3. Eigenvalue Results
2. Eigen Value Analysis

Lumped mass can be defined in:

1. Model -> Structure Type.
2. Model -> Masses -> Nodal Masses
3. Model -> Masses -> Load to Masses
Consider off Diagonal mass

Consider the mass at the centroid of the section
If the offset is defined.
2. Eigen Value Analysis

Consistent Mass can be defined in:

1. Model -> Structure Type.
2. Model -> Masses -> Load to Masses
2. Eigen Value Analysis

Step 2: Defining Eigen Value Analysis Control

Analysis -> Eigen Value Analysis Control

**Subspace Iteration**

This method is effectively used when performing eigenvalue analysis for a finite element system of a large scale (large matrix system)

**Lanczos**

Tri-diagonal Matrix is used to perform eigenvalue analysis. This method is effectively used when performing eigenvalue analysis for lower modes. If the model is complex this analysis is fast.
2. Eigen Value Analysis

Analysis -> Eigen Value Analysis Control

Ritz Vectors

Unlike the natural eigenvalue modes, load dependent Ritz vectors produce more reliable results in dynamic analyses with relatively fewer modes. The Ritz Vectors are generated reflecting the spatial distribution or the characteristics of the dynamic loading.
2. Eigen Value Analysis

To convert the final stage Cable forces to be used for determining cable stiffness for the Eigen Value Analysis
2. Eigen Value Analysis

Step 2: Eigen Value Analysis Results

A) Natural modes (or mode shapes)
B) Natural periods (or frequencies)
C) Modal participation factors.
D) Effective modal mass.

- Eigenvalue analyses must precede dynamic analyses such as Modal Time History analysis or Response spectrum analysis.
- The response spectrum analysis uses the natural periods from the eigenvalue analysis.
3. Response Spectrum Analysis

**Purpose of RS analysis:**

Dynamic analysis of a structure subjected to earthquake excitation using the response spectrum.

Response Spectrum is a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock.
3. Response Spectrum Analysis

**Eigenvalue Analysis is must.**
3. Response Spectrum Analysis

Procedure of Response Spectrum Analysis:

1. Response Spectrum Functions
2. Response Spectrum Load Cases
3. Response Spectrum Results
3. Response Spectrum Analysis

Step 1: Response Spectrum Functions

Load -> Response Spectrum Analysis -> Response Spectrum Analysis Functions

Design Spectrum in the database of Midas Civil can be used

**Normalized Acceleration** : Spectrum obtained by dividing the acceleration spectrum by the acceleration of gravity

**Acceleration** : Acceleration spectrum

**Velocity** : Velocity spectrum

**Displacement** : Displacement spectrum
3. Response Spectrum Analysis

Step 1: Response Spectrum Load Cases

**Load -> Response Spectrum Analysis -> Response Spectrum Load Cases**

**Excitation Angle**

When the seismic excitation direction is parallel to the X-Y plane (Direction='X-Y'), the sign of the seismic loading angle [Degree] is referenced to the Z-axis using the right hand rule. The angle is zero at the GCS X-axis.
3. Response Spectrum Analysis

**SRSS: Square Root of Sum of the Squares**

\[ R_{\text{max}} = \left[ R_1^2 + R_2^2 + \cdots + R_n^2 \right]^{1/2} \]

**CQC: Complete Quadratic Combination**

\[ R_{\text{max}} = \left[ \sum_{i=1}^{N} \sum_{j=1}^{M} R_i \rho_i \rho_j \right]^{1/2} \]

Where

\[ \rho_y = \frac{8 \zeta^2 (1 + r) r^{3/2}}{(1 - r^2)^2 + 4 \zeta^2 r (1 + r)^2} \quad r = \frac{\omega_i}{\omega_j} \]

- \( R_{\text{max}} \): the representative maximum value for a particular response
- \( R_i \): the peak value of the particular response for the \( i \)-th mode
- \( r \): the ratio of the natural frequency at the \( i \)-th mode to the natural frequency at the \( j \)-th mode
- \( \zeta \): damping ratio

**ABS: Absolute Sum**

\[ R_{\text{max}} = |R_1| + |R_2| + \cdots + |R_n| \]

**Linear: Linear Sum**

\[ R_{\text{max}} = \sum C_i R_i \]

**Complete Quadratic Combination (CQC) method:** This combines the spectral results using structural damping and a weighted ratio of relative frequencies. The act of combination removes the sign of the result, thus leaving only a magnitude for the final answer.
3. Response Spectrum Analysis

Add Signs (+,-) to the results:
Specify whether to restore the signs deleted during the mode combination and specify the restoration method.

Along the Major Mode Direction:
Restore the signs according to the signs (+, -) of the principal mode for every loading direction.

Along the Absolute Maximum Value:
Restore the signs according to the signs of the absolute maximum values among all the modal results.

Select Mode Shapes
Select modes for modal combination. Using the Select Mode Shapes option, linearly combine the modes while entering the Mode Shape Factors directly.
3. Response Spectrum Analysis

For finding the spectral curve for different damping ratio the following Methods are used:

1. **Correction by Damping Ratio**: When a single spectrum is selected, a modifying equation is used to adjust the spectrum to apply to each mode having a corresponding damping ratio.

   \[ C_{hr} = \frac{1.5}{40h + 1} + 0.5 \quad (h = \text{damping ratio}) \]

**Interpolation of Spectral Data**

Select the method of interpolating the response spectrum load data.
- **Linear**: Linear interpolation method
- **Logarithm**: Log-scale interpolation method
3. Response Spectrum Analysis

**Modal**
User defines the damping ratio for each mode, and the modal response will be calculated based on the user defined damping ratios.

**Mass & Stiff Prop.**
Damping coefficients are computed for mass proportional damping and stiffness proportional damping.

\[
\bar{C}_g = \bar{a}_0 \bar{M}_g + \bar{a}_1 \bar{K}_g
\]

**Strain Energy Prop.**
Damping ratios for each mode are automatically calculated using the damping ratios specified for element groups and boundary groups in *Group Damping*, which are used to formulate the damping matrix.
Procedure of Pushover Analysis:

1. Define Pushover Global Control
2. Define Load Cases
3. Define Hinge Properties
4. Assign Hinge Properties
5. Results
4. Pushover Analysis

Design -> Pushover Analysis -> Pushover Global Control

Select the load case as initial load for pushover analysis

Stiffness Reduction Ratio for the Skeleton Curve
4. Pushover Analysis

Design -> Pushover Analysis -> Pushover Load Cases

**Use Initial Load**: Accumulate the reaction/story shear/displacement due to the initial load to the pushover analysis result.

**Reaction / Story Shear by Initial Load**: Accumulate the reaction/story shear due to the initial load.

**Displacement by Initial Load**: Accumulate the displacement due to the initial load.
Increment Method:

Load Control: When the Hinges are Bilinear/Trilinear Type

Displacement Control: When the hinges are FEMA type

Load Pattern

Load Pattern: Select the load pattern out of Mode Shape, Modal and uniform acceleration

Mode: Select the mode
4. Pushover Analysis

Design -> Pushover Analysis -> Pushover Hinge Properties

**Interaction Type:**

Select None for Beam elements
Select P-M-M in Status Deformation for Column Elements

**Components:**

Always Select Fx for columns (PMM interaction)
Types of Time History Analysis:

Boundary Nonlinear Time History Analysis.

Boundary nonlinear time history analysis is used to analyze structures with nonlinear support conditions such as base isolators, viscous dampers in a seismic event.

Inelastic Time History Analysis.

Inelastic time history analysis is dynamic analysis, which considers material nonlinearity of a structure.
5. Time History Analysis

- Non-linear model of structure:
  - Structure
  - Non-linear behaviour
  - Finite element model
  - Hysteretic models

- Seismic input:
  - Ground motion time-history
  - Spectrum-compatible earthquakes
  - Recorded earthquakes

- Analysis:
  - Non-linear dynamic response
  - Displacement vs. time
  - Acceleration vs. time
5. Time History Analysis

Linear Case

\[ M \ddot{x} + C \dot{x} + Kx = -M \ddot{x}_g(t) \]

Non Linear Case

\[ M \ddot{x} + R(x,x_a) + F_S(x) = -M \ddot{x}_g(t) \]

\[ R(x,x_a) : \text{Viscous Damping} \]

\[ F_s(x) : \text{Variable Stiffness} \]
5. Time History Analysis

Procedure of Time History Analysis:

1. Define Properties of Non linear Links
2. Input Non Linear Links
3. Define Time History Load Case
4. Time Forcing Function
5. Ground Acceleration
6. Perform Non Linear Time History Analysis
7. Check the Results
5. Time History Analysis

Step 1: Defining Properties of Non Linear Links

Model -> Boundaries -> General Link Properties
5. Time History Analysis

Base Isolators Provided in midas Civil

- Viscoelastic Damper
- Gap
- Hook
- Hysteresis System
- Base Rubber isolator
- Friction Pendulum System isolator

Base Isolators

- Lead Rubber Bearing Isolator
- Friction Pendulum System Isolator

Geometry of Elastomeric Bearings

Spherical Sliding Bearing: Friction Pendulum System (FPS)
Step 2: Assigning the general Links

Model -> Boundaries -> General Link
5. Time History Analysis

Step 2: Assigning the general Links

Model -> Boundaries -> General Link
5. Time History Analysis

Step 2: Assigning the general Links

Model -> Boundaries -> General Link

The diagram shows a window for adding or modifying general link properties. It includes fields for name, application type, property type, description, self weight, use mass, and linear and nonlinear properties. The nonlinear properties include stiffness (k), yield strength (F_y), and other parameters. The equation shown in the diagram is:

\[ f = r \cdot k \cdot d + (1 - r) F_y \cdot z \]

\[ z = \frac{k}{F_y} [1 - |z| \{ \alpha \cdot \text{sign} (d \cdot z) + \beta \}] \cdot d \]
5. Time History Analysis

Step 2: Define Time History Load Case

Load -> Time History Analysis Data -> Time History Load Case

**Transient:**
Time history analysis is carried out on the basis of loading a time load function only once. This is a common type for time history analysis of earthquake loads.

**Periodic:**
Time history analysis on the basis of repeatedly loading a time load function, which has a period identical to End Time. This type is applicable for machine vibration loads.
5. Time History Analysis

Step 2: Define Time History Load Case

Load -> Time History Analysis Data -> Time History Load Case

**Order in Sequential Loading:**

Select a time history analysis condition previously defined, which precedes the time history analysis condition currently being defined. The Analysis Type and Analysis Method for the current time history analysis condition must be consistent with those for the preceding load condition.
5. Time History Analysis

**Damping Method:**

the damping method can be one of:

1. Modal
2. Element Mass & Stiffness Proportional
3. Strain Energy Proportional

For Element Mass & Stiffness Proportional the relevant has to be provided in:

**Model -> Properties -> Group Damping: Element Mass and Stiffness Proportional**
5. Time History Analysis

Load -> Time History Analysis Data -> Time Forcing Function

The user can select the time history function from the list of various database earthquake or can generate its own:
5. Time History Analysis

Load -> Time History Analysis Data -> Ground Acceleration

Select the Earthquake for X, Y and Z direction

Rotational angle about GCS Z-axis signifying the direction of the horizontal component of the ground acceleration. Sign convention is (+) in the counter-clockwise direction and (-) in the clockwise direction, with reference to the X-axis.
5. Time History Analysis

Load -> Time History Analysis Data -> Dynamic Nodal Loads

The user can do the time history analysis with Moving loads using this feature. The user needs to define the moving loads as Dynamic Nodal Loads.
5. Time History Analysis

Load -> Time History Analysis Data -> Time Varying Static Load

This function is used to reflect the effect of the self-weight in the time history analysis due to seismic loads

1. Define the self-weight using a Time Forcing Function
2. Assign the Time History Load Case for the self-weight.
3. Define a Time History Load Case for the seismic load, selecting the previously defined self-weight time history load case as "Subsequent to Load Case" under "Order in Sequential Loading".
4. Then perform analysis.
In a structure with multiple supports, different time history forcing functions in terms of ground acceleration can be applied to different supports at varying times.
Thanks