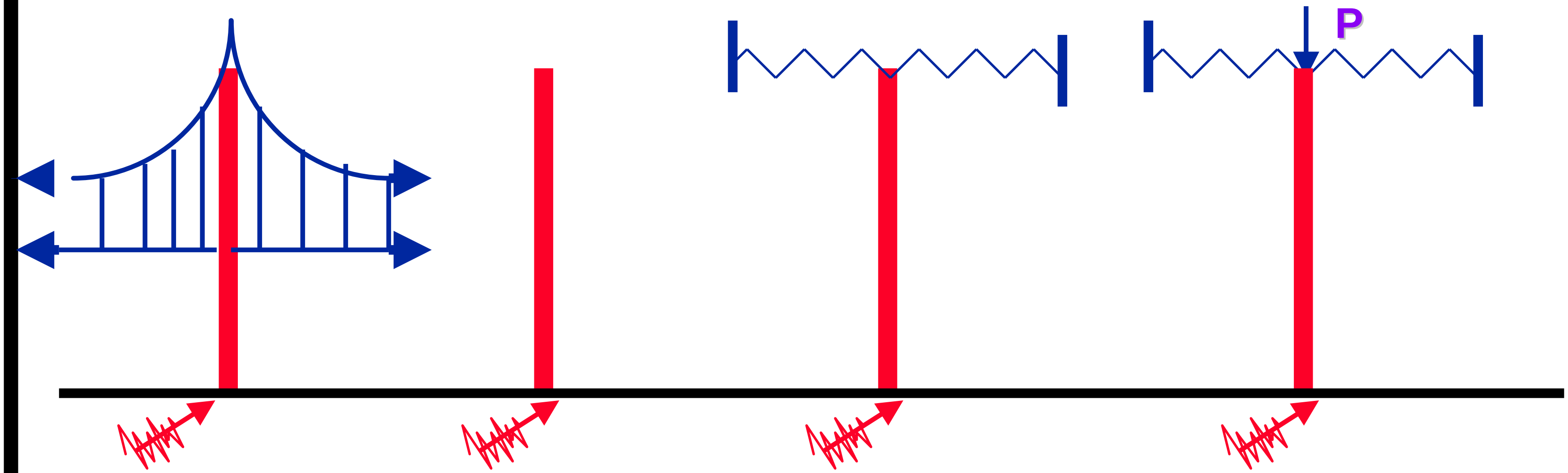
A New Method for Determining the Modal Participation Factor in Support Motion Problems Using MSC/NASTRAN



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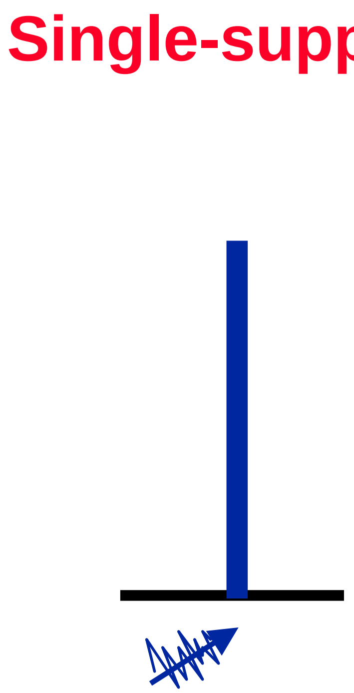
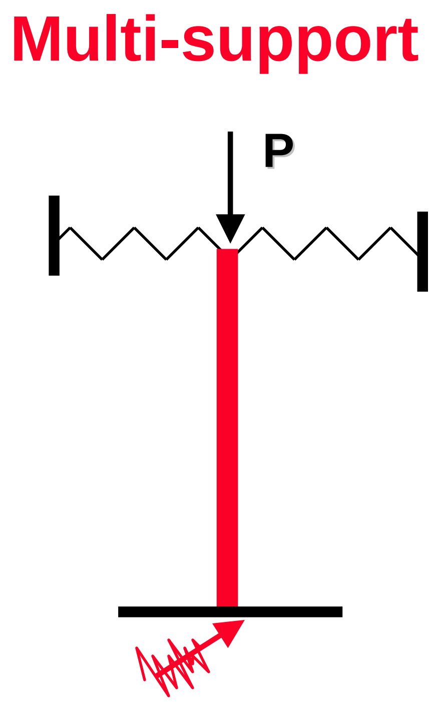
Support Motions due to earthquake





Outlines

- **Why this research ?**
- **How to solve the problems ?**
- **What are the results ?**
- **Conclusions.**

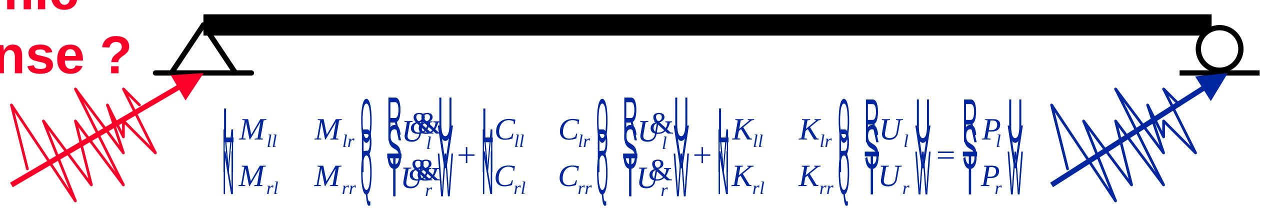
Why this research ?

- **How many modes are necessary in the modal analysis ?**
- **To meet the requirement of code (UBC).**
- **To save CPU time in computation.**
- **To provide a guide for engineers.**

Why Modal Participation Factor so Important?

$$\rho \ddot{u}(x,t) + \left(2\alpha\rho - \beta G \frac{\partial^2}{\partial x^2}\right) \dot{u}(x,t) - G \frac{\partial^2 u(x,t)}{\partial x^2} = 0$$

dynamic response ?



random response ?

$$\begin{bmatrix} M_{ll} & M_{lr} \\ M_{rl} & M_{rr} \end{bmatrix} \begin{Bmatrix} \ddot{U}_l \\ \ddot{U}_r \end{Bmatrix} + \begin{bmatrix} C_{ll} & C_{lr} \\ C_{rl} & C_{rr} \end{bmatrix} \begin{Bmatrix} \dot{U}_l \\ \dot{U}_r \end{Bmatrix} + \begin{bmatrix} K_{ll} & K_{lr} \\ K_{rl} & K_{rr} \end{bmatrix} \begin{Bmatrix} U_l \\ U_r \end{Bmatrix} = \begin{Bmatrix} P_l \\ P_r \end{Bmatrix}$$

How to Calculate the Modal Participation Factor

- **Free Vibration:**

$$-\omega_i^2 \; M_{ll} \; \phi_i \; + \; K_{ll} \; \phi_i = 0$$

- **Full Set:**

$$-\omega_i^2 \begin{bmatrix} M_{ll} & M_{lr} \\ M_{rl} & M_{rr} \end{bmatrix} \begin{Bmatrix} \phi_i \\ 0 \end{Bmatrix} + \begin{bmatrix} K_{ll} & K_{lr} \\ K_{rl} & K_{rr} \end{bmatrix} \begin{Bmatrix} \phi_i \\ 0 \end{Bmatrix} = \begin{Bmatrix} 0 \\ R_i \end{Bmatrix}$$

- **Modal Reaction:**

$$R_i = -\omega_i^2 \; M_{rl} \; \phi_i \; + K_{rl} \; \phi_i$$

- **ABAQUS: only available for single support case**

- **MSC/NASTRAN: conventional method by DMAP**
  modal reaction method by SPC force

Normalized quasi-static mass

- **Parseval's equality:**

$$\int_D \rho(x) f^2(x)dx = \sum_{i=1}^{\infty} a_n^2$$

- **Normalized quasi-static mass:**

$$\int_l \rho(x) U^2(x)dx = \sum_{i=1}^{\infty} \Gamma_{ij}^2 = M_j$$

- **Single support:**

$$\int_l \rho(x) U^2(x)dx = \sum_{i=1}^{\infty} \Gamma_{i1}^2 = M_1 = total\ \ strucure\ \ mass(\,j=1\ \ only)$$

- **Multiple support:**

$$\int_l \rho(x) U_j^2(x)dx = \sum_{i=1}^{\infty} \Gamma_{ij}^2 = M_j = normalized\ \ quasi-static\ \ mass$$

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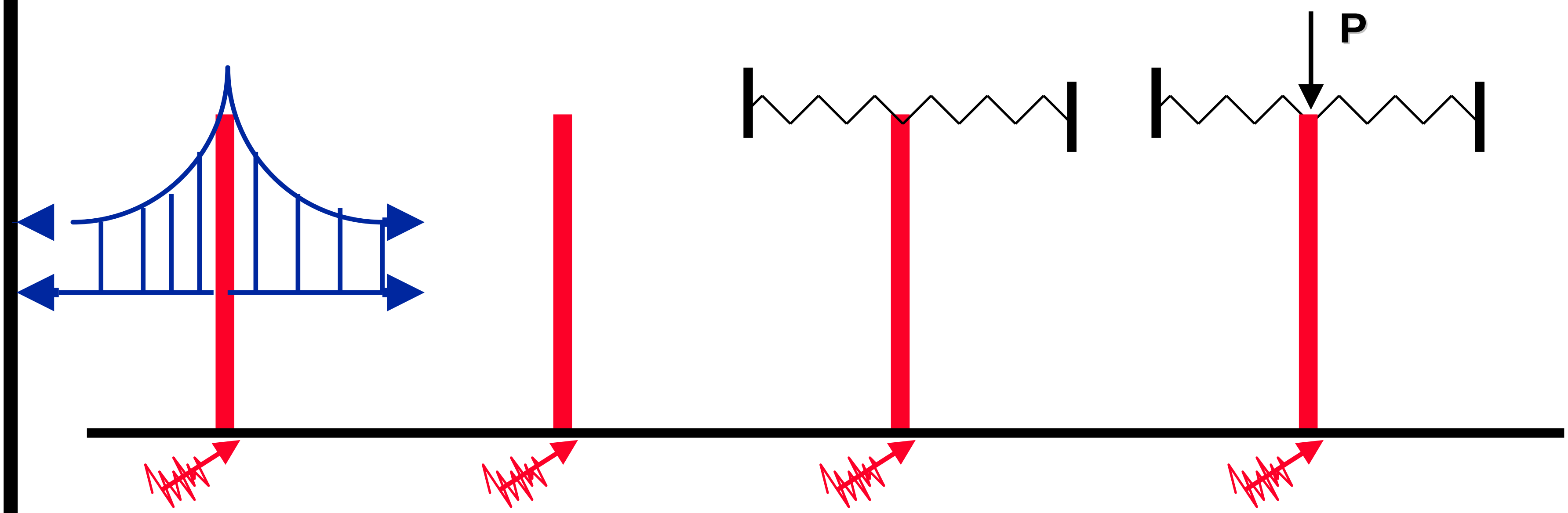
How Many Modes Are Necessary ?

Bridge tower subjected to support motion



Modal dynamics

$$u(x,t)=\sum_{k=0}^{k=n} \bar{q}_k(t)\, u_k(x)$$

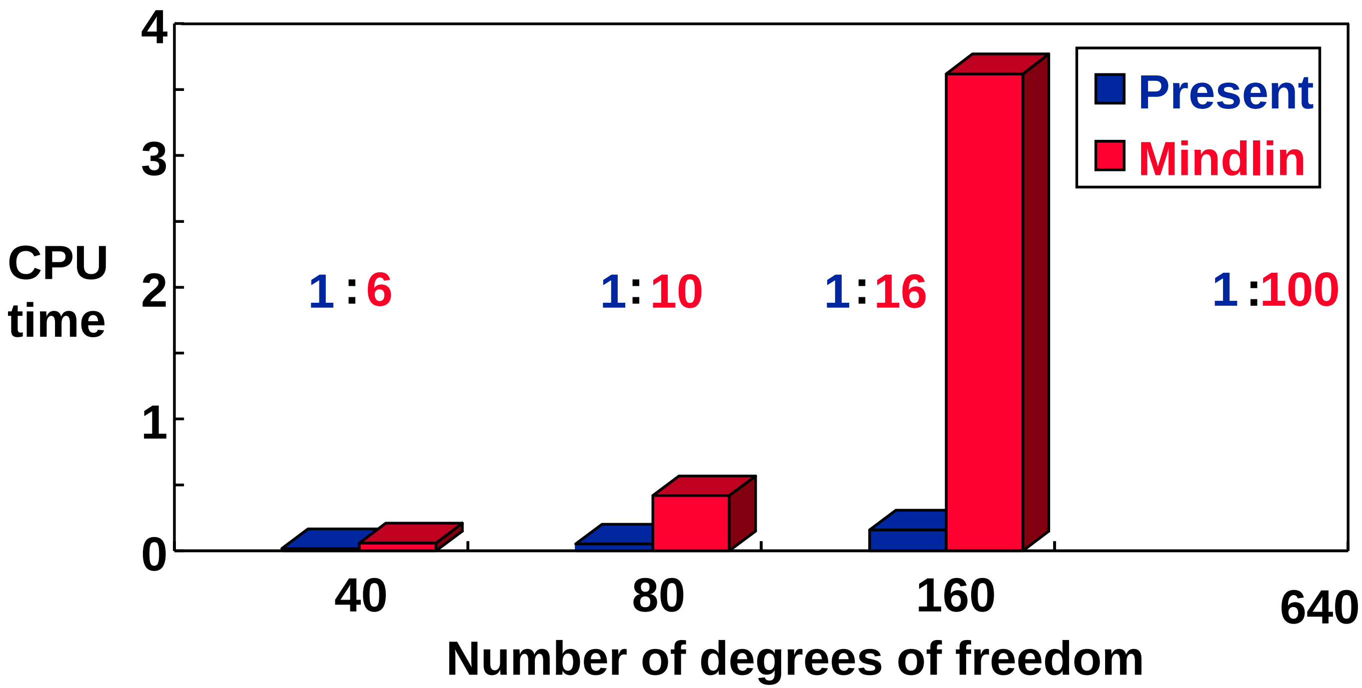
Comparisons of CPU Time to Calculate the Modal Participation Factor for Discrete System

$$\Gamma_{ij} = \frac{R_{ij}}{(-\omega_i^2)}$$ **Present**

R_{ij} : modal reaction

$$\Gamma_{ij} = \begin{Bmatrix} \phi_i \\ 0 \end{Bmatrix}^T [M] \{G_j\}$$ **Mindlin**

$\{G_j\}$: quasi - static solution



Conclusions

- **A new method for determining MPF has been proposed.**
- **Five typical structures have been demonstrated to check the validity.**
- **MSC/NASTRAN has been successfully implemented.**
- **The minimum number of modes to satisfy UBC code has been obtained.**
- **The effects of a restrain condition and an axial force have been discussed.**
- **A real structure of Golden Gate Bridge have been considered.**
- **The greater the stiffness is, the larger the number of modes are needed.**