Optimization of flexible base for reduction of seismic response of buildings

> Makoto Ohsaki Osamu Iwatsuki Hidekazu Watanabe

Rocking mechanism

Dissipate seismic energy using rocking of frame and plastic dissipation at column base



Purpose

Optimize flexible base to control mode shape and reduce response displacement of building frame

Rotate opposite direction against horizontal input



Details of flexible base



Truss members (cm ²)				
Α	(members 1-4,3-5)	200.0		
В	(members 2-4,2-5)	50.0		
С	(members 1-2,2-3)	1.0		

Material: steel

Manufacture member C using a spring

Optimization problem

Design variables: nodal coordinate X cross-sectional area A Objective function: roof displacement $|y|_{max}$ minimize

Response spectrum approach (SRSS rule)

$$|y|_{\max} = \sqrt{\sum_{i=1}^{3} |\beta_i \cdot u_i \cdot S_{D_i}|^2}$$

Constraint : lowest natural period $T_1 \leq 1.0$

Optimization result



- Damping factor 2%
- Young's modulus: 200kN/mm²
- Story mass: 8000kg

	Beam section (SN400B)	
2~R	$H - 400 \times 200 \times 8 \times 13$	
	Column section (BCR295)	
1~4	$1 \sim 4 \qquad \Box - 350 \times 350 \times 16$	

-Base beam (points 4,5) 45000kg



Optimization result



Maximum responses



Maximum responses



Interstory drift angle (rad)

Story shear (kN)

Column axial force (kN)



Rocking response is enhanced



Trajectory of drift angle and rotation of base



Eigenvalue analysis

Optimal model

Eigenmode

	Doriod	Participation	Effective
	Periou	factor	mass ratio
	T(s)	β	X-dir. (%)
1st	0.712	16.53	0.22
2nd	0.379	287.77	67.88
3rd	0.155	13.75	0.15





Stiff model

	Period	Participati	Effective
		on factor	mass ratio
	T(s)	β	X-dir. (%)
1st	0.556	157.30	20.28
2nd	0.160	90.66	6.74
3rd	0.107	186.00	28.36



2nd





Frequency response



Base with viscous damper



Red: with damper, Blue: without damper

Conclusions

- Flexibility of supports can be effectively utilized for reduction of seismic responses of structures.
- Two-stage procedure:
 - 1st stage: static optimization maximization of vertical displacement: minimization of structural volume:
- 2nd stage: dynamic optimization seismic response reduction variable: cross-sectional area