Optimization of flexible structure for vertical base isolation

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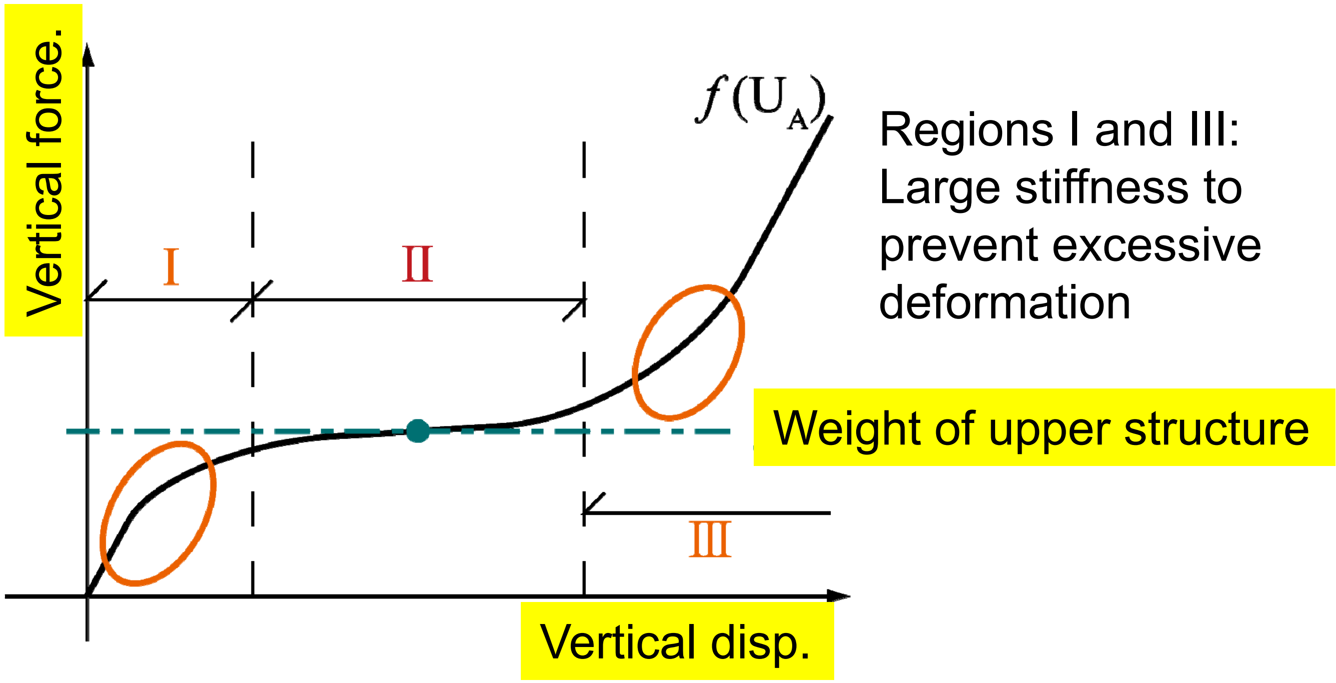


Regions I and III:
Large stiffness to prevent excessive deformation

Region II:
Support upper structure with small stiffness

Problem formulation

Minimize error from specified path

minimize $\quad e(\boldsymbol{X},\boldsymbol{A}) = \sum_{\mathrm{i=1}}^{\mathrm{m}} \left(f(U_A^{(i)}) - \overline{f}_i \right)^2$

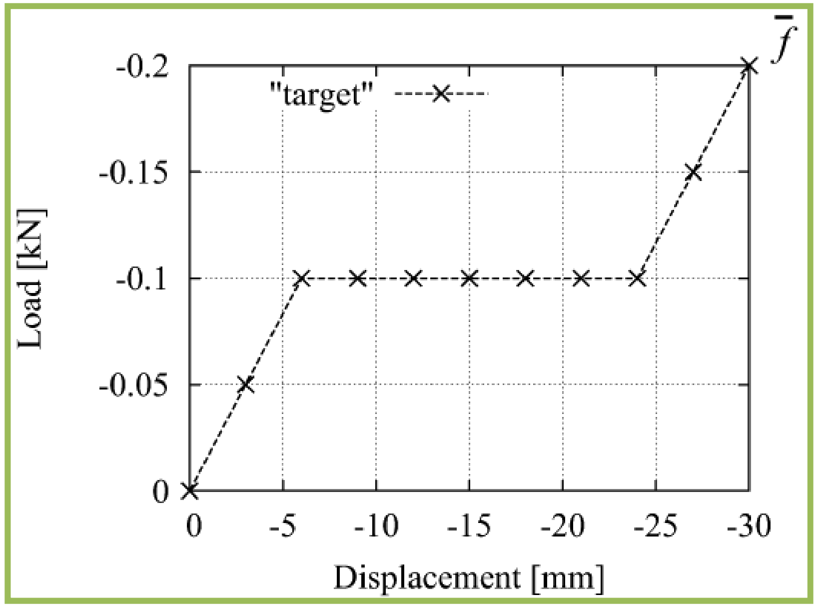
subject to $\quad f(U_A^{(i)}) \leq f(U_A^{(i+1)})$

$$(i = l,..,u-1)$$

$$V(\boldsymbol{A},\boldsymbol{X}) \leq V^{\max}$$

$$\boldsymbol{A}^L \leq \boldsymbol{A} \leq \boldsymbol{A}^U$$

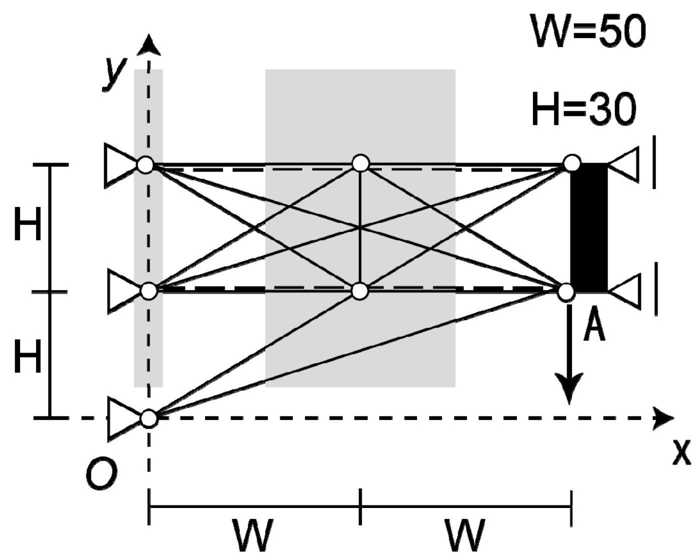
$$\boldsymbol{X}^L \leq \boldsymbol{X} \leq \boldsymbol{X}^U$$



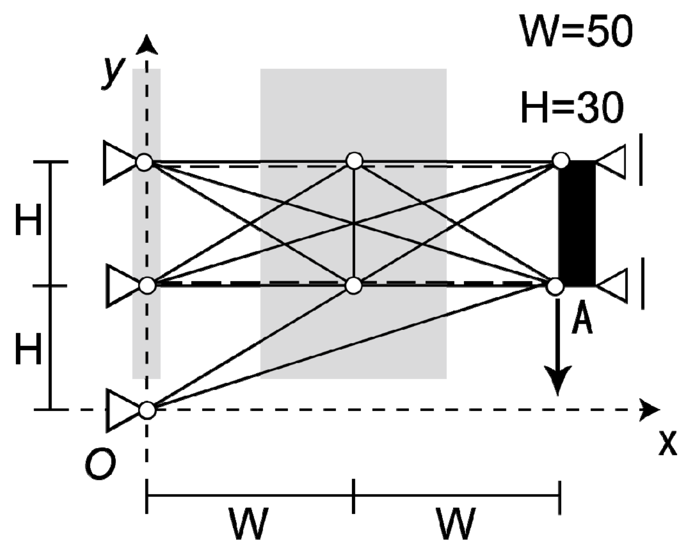
Specified path

Truss model

- Models 1 and 2
  - Ground structure with truss elements
  - Add rigid element at right supports to represent upper structure
  - Optimize from several random initial solutions



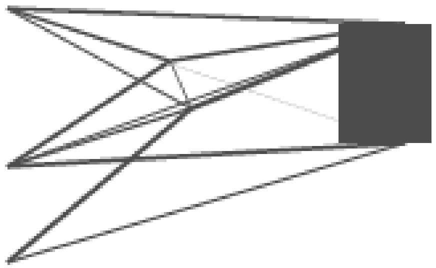
Model-1



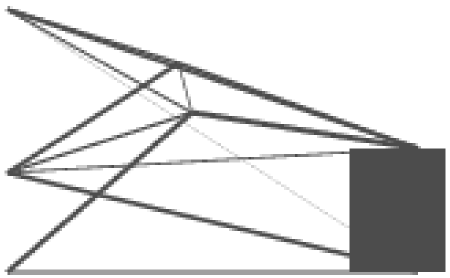
Model-2

Optimization results

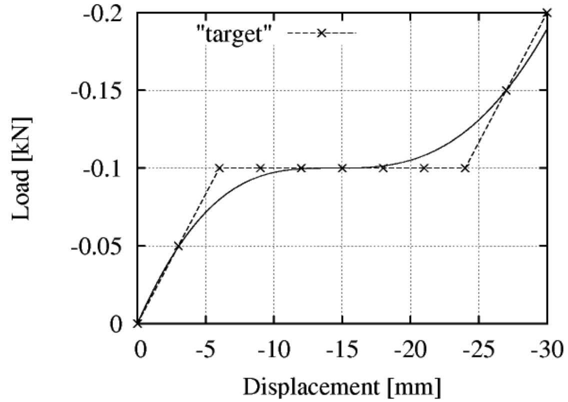
Model-1



Initial

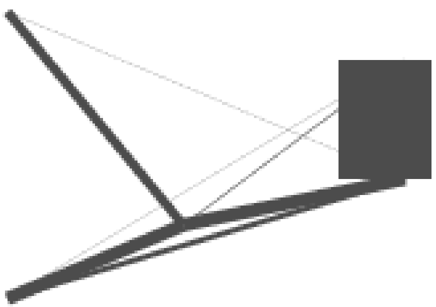


Deformed

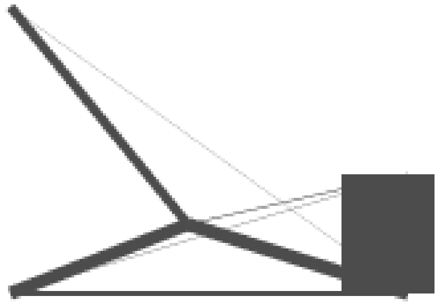


Equilibrium path

Model-2



Initial



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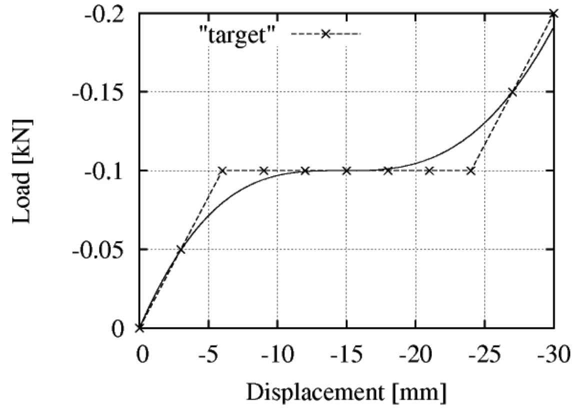
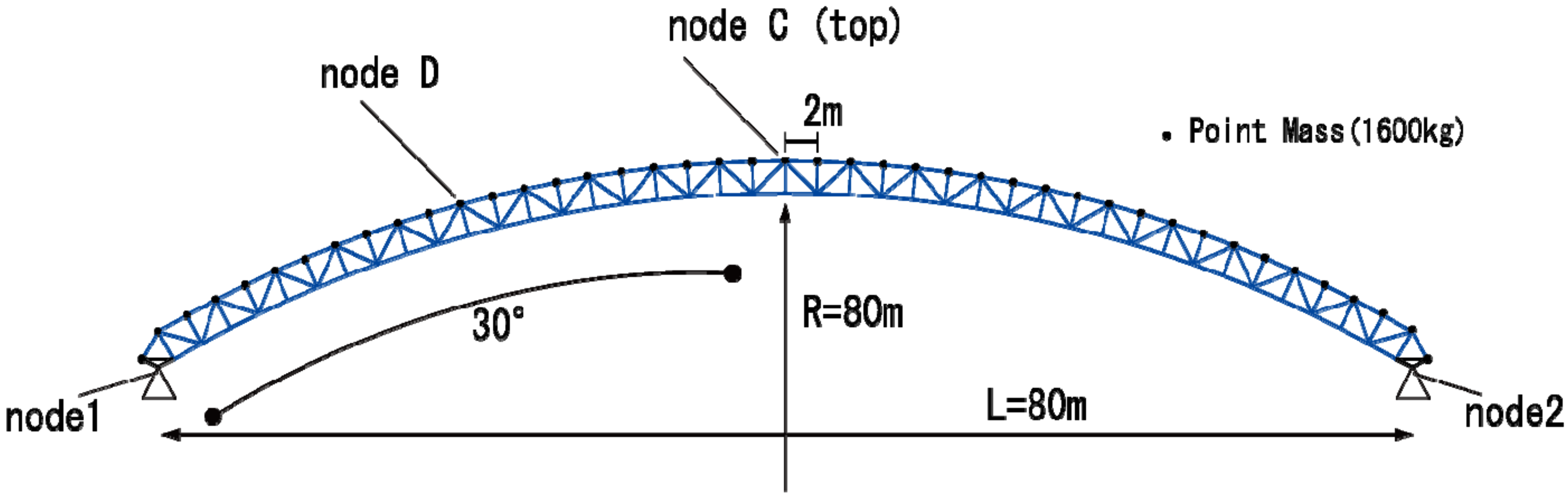


Equilibrium path

Upper structure

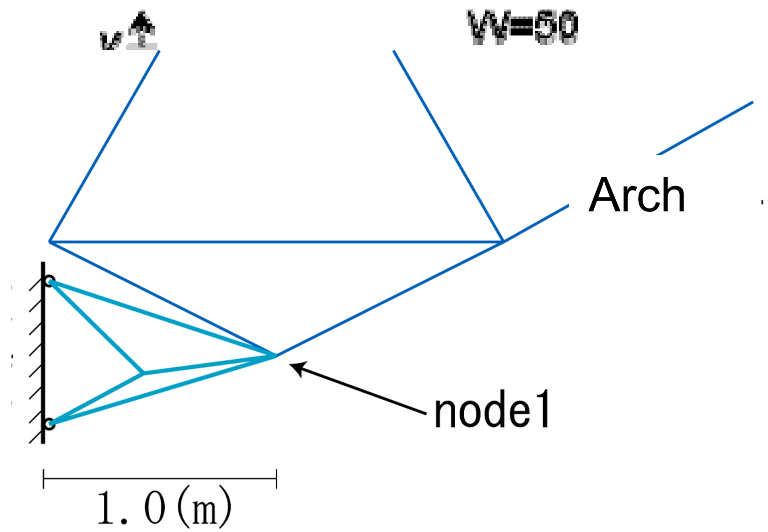
Arch model

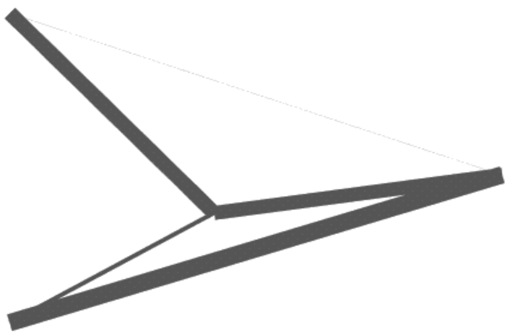
$T_1 = 1.21 \ , T_2 = 2.27 \ , T_3 = 3.88 \ , T_4 = 4.52$

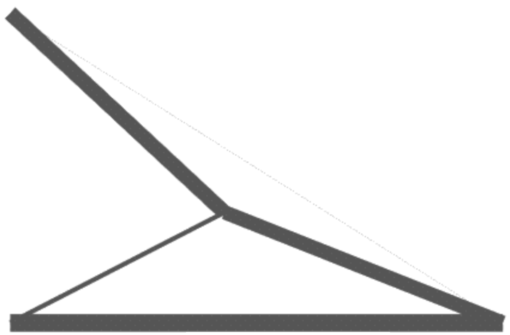


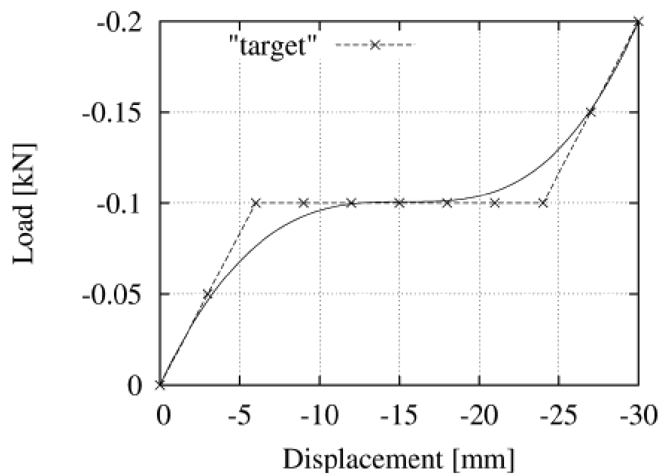
Base isolation model

- Specification
  - Width 1.0 (m)
  - Young's modulus 2.0×10^4 (N/mm^2)
  - Cross–sectional area: multiply 3.21×10^2 so that the self–weight is supported at the center of Region II



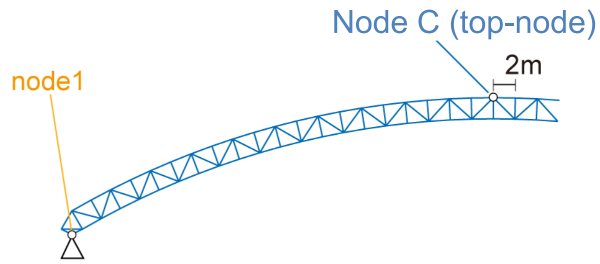

Initial

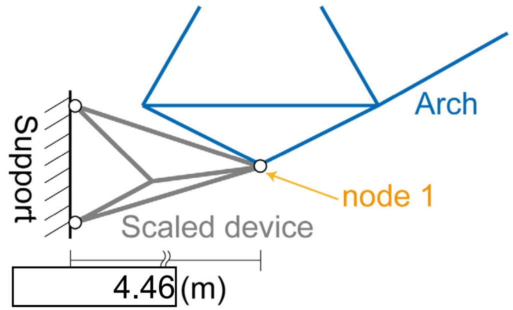

Deformed



Response against recorded ground motions

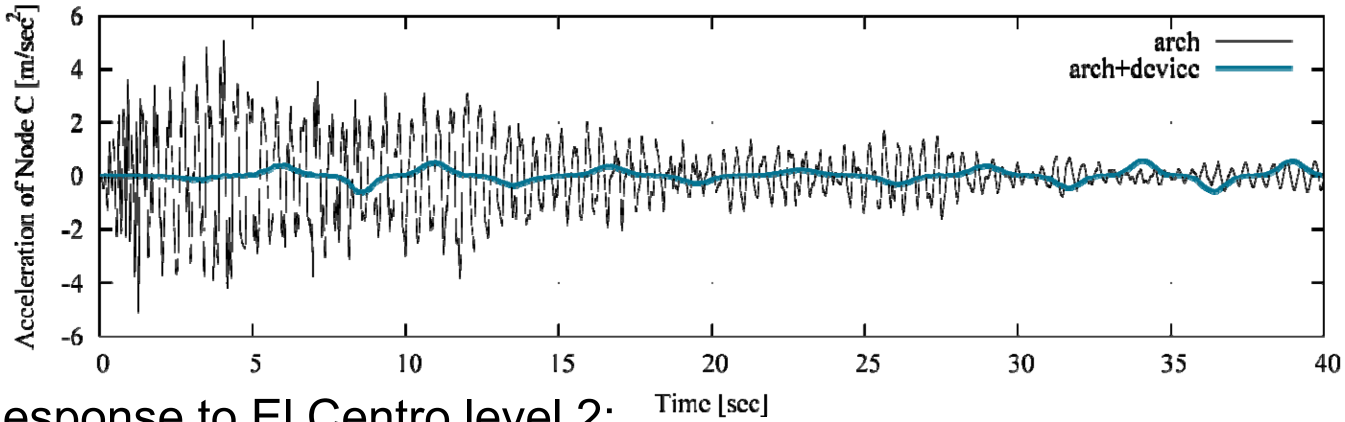
(i) El Centro UD (1940)
(ii) Hachinohe UD(1968)
(iii) Taft UD (1952)
} Levels 2 and 3
(iv) Takatori UD (1995) ... Original level





- Bar-spring model
  - Max. deformation of spring: 0.402 m
  - Scale of isolation device: $(2 \times 0.402)/0.18 = 4.46$
  - Size of device: width = 4.46 m, height = 2.68 m

Response against recorded ground motions



Response to El Centro level 2:
Blue: isolated, Black: pin-support

		Arch		Arch + Spring				Arch + Device			Response ratio
地震波	Acc_g^{max}	Acc_D^{max}	Acc_C^{max}	Δ^{max}	Acc_D^{max}	Acc_C^{max}	応答比	Δ^{max}	Acc_D^{max}	Acc_C^{max}	
(i)$_2$	3.084	6.004	5.109	0.236	0.580	0.594	0.116	0.290	0.613	0.627	0.123
(ii)$_2$	1.627	12.557	6.223	0.135	0.336	0.347	0.056	0.394	1.732	1.803	0.290
(iii)$_2$	2.906	12.186	9.524	0.402	0.989	1.010	0.106	0.327	1.039	1.132	0.119
(i)$_3$	4.626	8.989	7.651	0.285	0.708	0.706	0.092	0.489	2.977	3.139	0.410
(ii)$_3$	2.440	18.860	9.405	0.203	0.505	0.521	0.055	0.408	1.674	1.748	0.186
(iii)$_3$	4.359	18.222	14.213	0.473	1.217	1.234	0.087	0.387	1.417	1.464	0.103
(iv)	2.793	9.403	7.123	0.102	0.263	0.269	0.038	0.133	0.108	0.110	0.015