Preliminary study on displacement-based design for seismic retrofit of existing building using tuned mass damper

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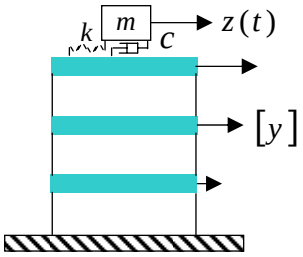
Summary: According to the equivalent linear system, this paper presents a preliminary displacement-based design (DBD) procedure for seismic retrofit of existing buildings using tuned mass damper (TMD) under the specified seismic loading. The design method is primarily controlling the roof displacement of the building to satisfy the objective. The design results are compared with those computed from the dynamic inelastic time history analyses. It is shown from nonlinear time history analyses that the maximum nonlinear responses of the retrofitted building with TMD can be reasonably captured by the presented method.

Mechanics of building with TMD: The motion equations of the multi-story building equipped with TMD are as follows:



$$[M][\ddot{y}]+[C][\dot{y}]+K[y]=-[M][L]\ddot{u}_g+[P]$$

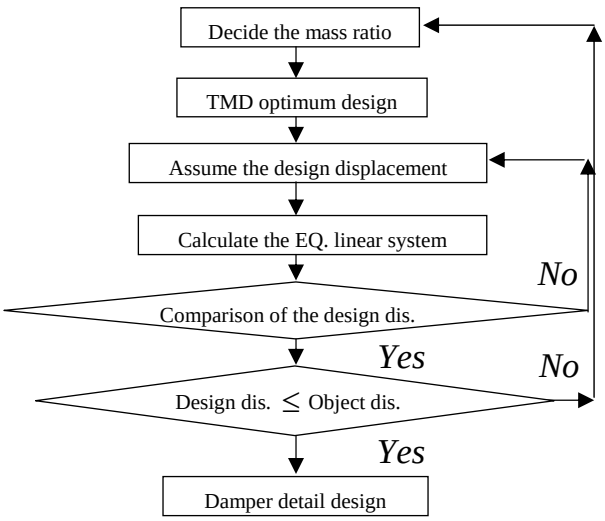
$$m\ddot{z}+c\dot{z}+kz=-m(\ddot{y}_N+\ddot{u}_g)$$

The simulation of the TMD by using the 3D nonlinear analysis programs can be combined with the stiffness and damping link elements. The stiffness and damping link elements are connected parallel to each other. The stiffness and damping parameters may be input linear or nonlinear according to the practice application.

Displacement-based design: Based on the equivalent linear system method, this study proposes the displacement-based design for seismic retrofit of the existing multi-story buildings equipped with TMD. The design object is the control of the displacement. The design procedure would repeat the steps until the design displacement being satisfied the object criteria. The pushover analysis and simple linear dynamics analyses will be substituted for nonlinear time history analyses.

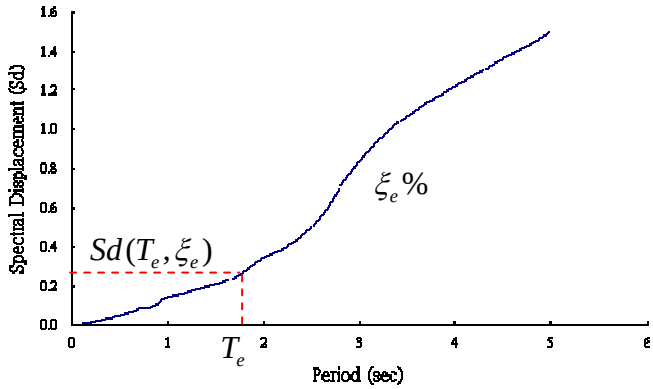
The equivalent period T_e and equivalent damping ratio ξ_e of the equivalent linear system for the building with TMD would be used to evaluate the maximum nonlinear responses by using the response spectrum.

When performing the pushover analysis, the lateral story forces distribution $[F]$ and the equivalent mode shape $[\bar{\phi}]$ are calculated as follows.



$$T_e=2\pi\sqrt{\frac{M_e}{K_e}}\qquad \xi_e=\xi_{e(inelasticity)}+\xi_{e(damper)}+\xi_{e(inherence)}$$

$$[F]=[K][\bar{\phi}]\qquad [\bar{\phi}]=\Gamma_1 S_d(\omega_1,\xi_1)[\phi]_1+\Gamma_2 S_d(\omega_2,\xi_2)[\phi_2]$$



Comparison between DBD and time history analysis

	EQ. Period T_e (sec)	Damping Ratio $\xi_{e(inelasticity)}$	Damping Ratio $\xi_{e(damper)}$	Damping Ratio $\xi_{e(inherence)}$	Maximum roof dis. (m)
EQ. Mode	1.052	0.097	0.0033	0.02	0.2
	Nonlinear Time History Analysis				0.218