I-489 TUNED MASS DAMPERS FOR NARROW-BANDED EARTHQUAKE GROUND MOTIONS

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ABSTRACT.- This paper deals with application of a tuned mass damper (TMD) for earthquake response reduction of multistory structures. Highly resonant response due to the narrow-banded strong ground motion record of the 1985 Mexico earthquake is reduced significantly when TMDs are included into the structures. On the other hand, response to wide-banded strong motion records is reduced only moderately.

GENERAL DESCRIPTION.- The 1985 Mexico earthquake caused collapse or severe damage to many multistory buildings in Mexico City. The double resonance phenomenon (earthquake-ground, ground-structure) is considered as a main reason of the intensity of damage [1]. The strong ground motion recorded at SCT station, on the soft soil zone of the city, exhibits strong oscillations with 2-second period. Most of the buildings that collapsed or suffered the greatest damage were 7 to 15 stories tall. During the strong vibration caused by the earthquake, these structures lengthen their period and entered the range of resonance with the ground. This behavior can be identified as a narrow-band problem, in which the response associated with a period of 2 seconds should be suppressed. In recent years, several high-rise structures have included TMD systems in their design to reduce oscillations related to a natural mode of vibration [2]. The TMD is a device especially suited to improve situations in resonant vibratory systems. Earthquake response of multistory structures is usually governed by the first mode, and for a building having a fundamental period similar to that of the ground motion, high response amplitudes will develop. For these cases, addition of a TMD to the structure can make significant reduction of the response.

STRUCTURAL MODEL AND TMD DESIGN.- Fig.1 shows a schematic representation of a multistory structure equipped with a TMD on the top of the building; u_g denotes the ground displacement, and u_i denotes the displacement of mass m_i (story "i") relative to the ground. For this analysis, a 15-story frame building is idealized as a shear beam structure, considering one degree-of-freedom per floor. Mass and stiffness characteristics of the building model used are presented in table 1. The fundamental period for this model is calculated as 1.99 seconds. A TMD is simulated as an extra story in the model and designed according to Den Hartog's optimum tuning considerations [3]. Several sizes of TMD are analyzed, with different values of total mass ratio R (TMD mass / building's total mass). Dynamic characteristics of TMDs are obtained using the original building's effective mass for the first mode.

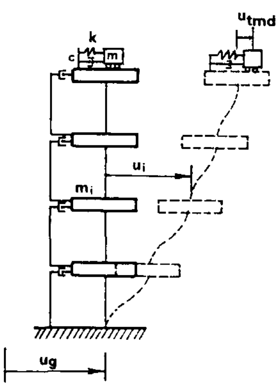

Fig.1. Multistory structure with TMD.

SEISMIC RESPONSE ANALYSIS.- The response of the building models is computed in the linear range to the EW component of SCT record, Mexico, 1985 (fig. 2). Structural damping factor for all modes is taken as 2 %. The 15th floor displacements relative to the ground, for the original structure and for a structure having a TMD with R=0.03 are shown in fig. 3.

Table 1 Characteristics of building model

Floor	Weight (ton)	Mass ($ton\text{-}sec^2/m$)	Number of columns	Column cross section (m)
15	140	14.30	8	0.40 x 0.40
11-14	830	84.70	24	0.40 x 0.40
6-10	870	88.78	24	0.55 x 0.55
1- 5	920	93.88	24	0.70 x 0.70

Similar response amplitudes were obtained for other TMD sizes. It is seen that the response is greatly reduced by the effects of a TMD. Due to reduced displacement response, member internal forces will also be reduced with increased structural safety.

Global effectiveness of the TMD can be observed in fig. 4, which shows envelopes of maximum displacement response to SCT record, for the original building and for the building with TMD (two cases: R=0.005 and R=0.03). Concerning the TMD displacement relative to the building, better results are obtained for the case of R=0.03.

Similar analyses are done using wide-banded strong motion records: El Centro NS, 1940, and Hachinohe NS, 1968. Envelopes of maximum displacement response, for the original building and for the building with the most effective TMD are given in figs. 5 and 6, respectively. The TMDs in these cases reduce only moderately the response, and this effect is mostly concentrated on the upper floors.

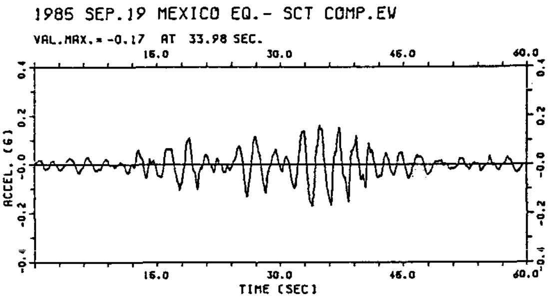

Fig.2. SCT ground motion record used in analysis.

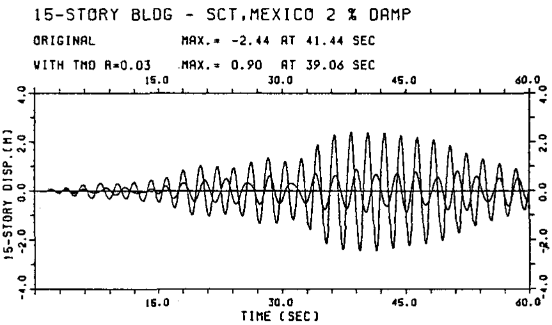

Fig.3. Displacement response of story 15.

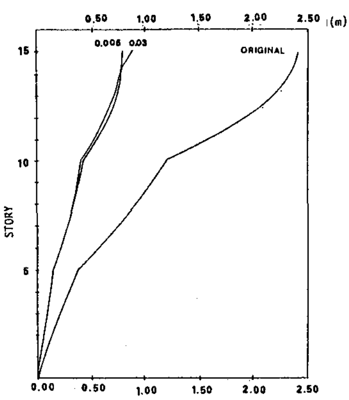

Fig.4. Envelope of maximum displacements, for original building and for building with TMD, R=0.005 and R=0.03, SCT record.

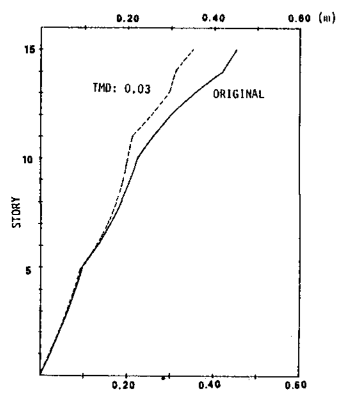

Fig.5. Envelope of maximum displacements, for original building and for building with TMD, R=0.03, El Centro record.

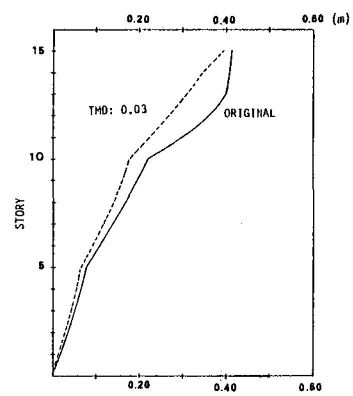

Fig.6. Envelope of maximum displacements, for original building and for building with TMD, R=0.03, Hachinohe record.

CONCLUSIONS.- From this investigation, TMD systems seem to be effective in reducing earthquake response of structures in resonant conditions (narrow-banded ground motion combined with structures having similar natural periods). Great reduction of response is achieved even with small TMD sizes. When wide-banded records are used, TMD systems are found to be less effective.

REFERENCES

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[2] Wiesner, K. "Taming Lively Buildings", Civil Engineering, ASCE, Jun.1986.

[3] Den Hartog, J.P. "Mechanical Vibrations", McGraw-Hill Book Co., 1947.