TUNED MASS DAMPER FOR LOCAL SITE DEPENDENT EARTHQUAKE GROUND MOTIONS

YAMADA, Yoshikazu; Professor, Kyoto University
IEMURA, Hirokazu; Assoc.Professor, Kyoto University
QUIUN, Daniel; Graduate Student, Catholic Univ. of Peru

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 strong ground motion record of the 1985 Mexico earthquake is reduced significantly when a TMD is included into the structure. The relative displacement of TMD can be kept within reasonable amplitudes by using an appropriate size of TMD.

GENERAL DESCRIPTION.- Many multistory buildings collapsed or suffered severe damage in Mexico city during the 1985 earthquake. The double resonant effect (earthquake-ground, ground-structure) is considered as a reason of the intensity of damage [1]. The strong ground motion recorded at SCT station, on the old lake bed zone of the city having soft compressible soil, shows strong oscillations with 2-second period. Most of the buildings that collapsed or were severely damaged were 7 to 15 stories. Fundamental period of these structures, during the strong vibration caused by the earthquake, reached 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. TMD systems have been included in the design of several high-rise structures to reduce oscillations related to a natural mode of vibration [2]. Earthquake response of multistory structures is usually governed by the first mode, and for a building having a fundamental period similar to 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, TMD DESIGN AND MODAL ANALYSIS.- A 15-story frame building is idealized as a shear beam structure for this analysis, considering one degree-of-freedom per floor. The first two natural vibration modes (normalized), natural periods and corresponding modal effective mass for the original structure are given in fig. 1. A TMD is simulated as an extra story and designed according to Den Hartog's optimum tuning considerations [3]. Several sizes of TMD are analyzed. Modal analysis results obtained for a structure equipped with a TMD defined by a total mass ratio R of 0.03 are shown in fig. 2 for the first

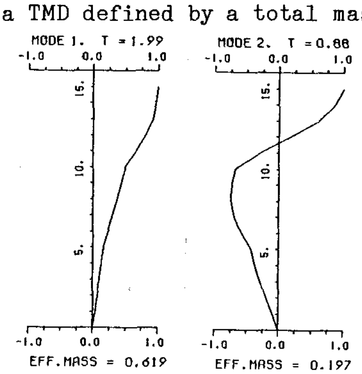

Fig.1. Modes of original structure

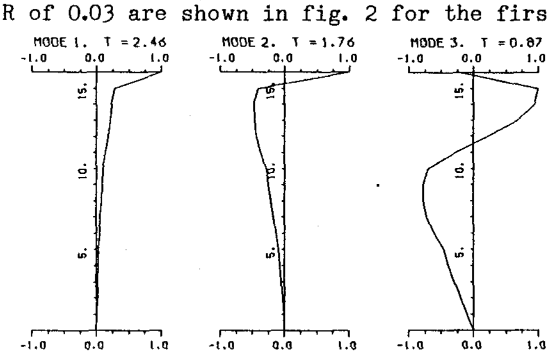

Fig.2. Modes of structure with TMD, R=0.03

3 modes. From fig. 2, the TMD has strong influence in the first two modes, reducing the oscillations of the main structure. The third mode corresponds to the second mode of the original structure. For other TMD sizes similar values are obtained.

SEISMIC RESPONSE ANALYSIS.- The response of the building models is computed in the linear range to the EW component of SCT, Mexico, 1985 (fig. 3). 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. 4. It is seen that the response is greatly reduced by the effects of a TMD. Similar response amplitudes were obtained for other TMD sizes having smaller R values. Due to reduced displacement response, member internal forces will also be reduced with increased structural safety.

The TMD displacement relative to the building is an important design consideration for this kind of system. Small TMD sizes (R=0.005) resulted in an excessive drift, but for a TMD with R=0.03, reasonable amplitudes are obtained. Fig. 5 shows these two cases.

CONCLUSIONS.- From this investigation, TMD systems seem to be effective in reducing earthquake resonant response of structures. Even with small TMD sizes, the response can be greatly reduced. To control the TMD relative displacement, a larger TMD should be used, but the TMD' mass can still be a small fraction of the buildings' total mass.

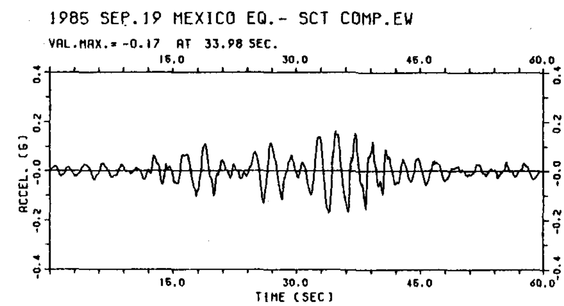

Fig.3. SCT ground motion record used in analysis

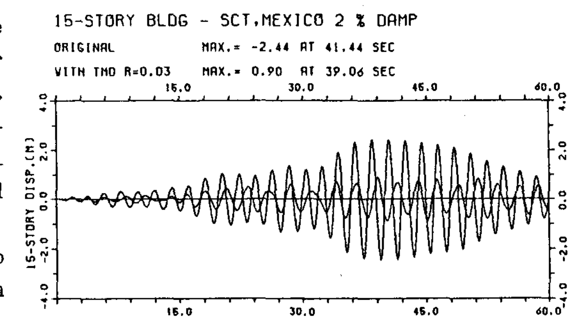

Fig.4. Displacement response of story 15

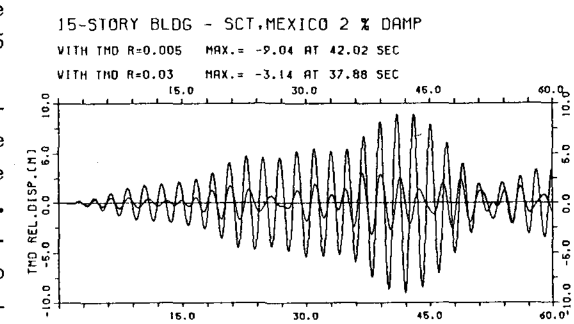

Fig.5. TMD displacement relative to the building

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