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On the Performance of Passivr TMDs in Reducing the Damage in 2-D Concrete Structural Models

F. R. ROFOOEI [1a], P. ABTAHI[2b]

[1] *Department of Civil Engineering, Sharif University of Technology, Iran*
[2]*Department of Civil Engineering, Sharif University of Technology-International branch, Kish Island, Iran*

Abstract

Pozzolanic materials, either naturally occurring or artificially made, have long been in practice since the early civilization. In recent years, the utilisation of pozzolanic materials in concrete construction has become increasingly widespread, and this trend is expected to continue in the years ahead because of technological, economical and ecological advantages of the materials. One of the latest additions to the ash family is palm oil fuel ash, a waste material obtained on burning of palm oil husk and palm kernel shell as fuel in palm oil mill boilers, which has been identified as a good pozzolanic material. This paper highlights test results on the performance behavior of palm oil fuel ash (POFA) in reducing the heat of hydration of concrete. Two concrete mixes namely OPC concrete i.e. concrete with 100% OPC as control, and POFA concrete i.e. concrete with 30% POFA and 70% OPC were prepared, and the temperature rise due to heat of hydration in both the mixes was recorded. It has been found that palm oil fuel ash not only reduced the total temperature rise but also delayed the time at which the peak temperature occurred. The results obtained and the observation made clearly demonstrate that the partial replacement of cement by palm oil fuel ash is advantageous, particularly for mass concrete where thermal cracking due to excessive heat rise is of great concern.

Keywords: Portland cement; pozzolan; palm oil fuel ash; temperature; heat of hydration.

1. INTRODUCTION

TMD are known as an efficient vibration control damper for both new and existing building structures, to improve their behavior against lateral forces such as winds and earthquakes. Extensive researches conducted in the last couple of decades indicate that for ground motions with narrow band frequency

[a] Corresponding author: Email: rofooei@sharif.edu
[b] Presenter: Email: abtahi_pooya@hotmail.com

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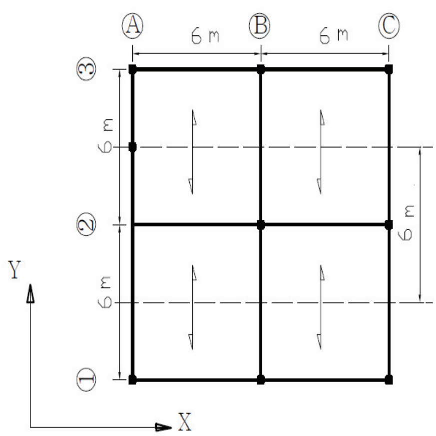
content and long duration, TMD, can perform up to the expectations. Villaverde and Koyoama investigated the efficiency of TMD in controlling the seismic response of a ten-story building that led to about 40% reduction in the peak roof displacement of the building. However, under high intensity ground motions, the effect of TMD would be totally changed due to nonlinear structural behavior.

Soto-Brito and Ruiz studied the effect of ground motion intensity on the effectiveness of TMD in the response of a 22-story frame, that behaved nonlinearly under moderate and high intensities of SCT accelerograms. Their investigations showed that due to nonlinear behavior of the building, which mostly happens under high intensity ground motions, the efficiency of TMD in lowering the peak responses of the structure can be reduced considerably. In general and unlike the linear systems, evaluating the efficiency of TMD using maximum displacement reduction seems to be inadequate. Clearly, this type of assessment cannot explain the effects of accumulated damages caused by low cycle fatigue. Therefore, in these situations, TMD is expected to effectively reduce not only the maximum displacement of the structure but also the overall damage of the structure.

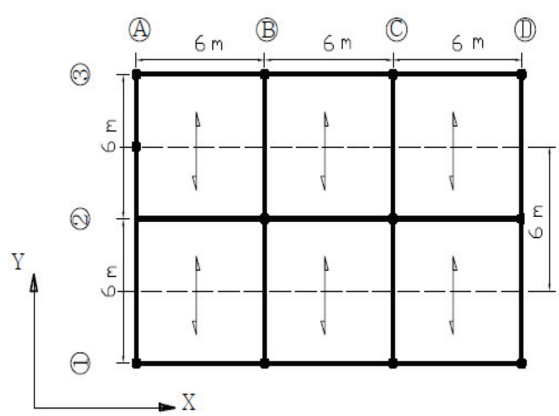
In this work, a damage index is used as an indicator to quantify the effectiveness of TMD in reducing the seismic response of inelastic structures. Various numerical simulations for the controlled and uncontrolled structural models are carried out. Comparison of damage indices obtained for the structural models with and without TMD, would determine its efficiency in suppressing the unwanted vibration of those structures. Seven records of far field ground motions are used. The structural models are shown to behave nonlinearly with increasing the peak ground acceleration of the ground motions. The TMDs can also be considered as an option for retrofitting purposes.

2. DESCRIPTION OF STRUCTURAL MODELS AND TMD SPICIFICATIONS

In the present study, three reinforced concrete building structures of 8, 12 and 15 stories are considered with each floor 3 meters high. The 8-story model has 2 bays and the 12 and 15-story models have 3 bays as illustrated in Fig 1. Gravity dead and live loads are considered to be 500 [illegible] and 150 [illegible] according to the Iranian regulation No. 519 respectively. The Rayleigh damping is used for the primary models with 2% damping for the first 2 modes of vibration. Four different mass ratios, e.g., 0% 2.0% 3.5% and 5.0% are considered for the TMD to evaluate its variation on the performance of TMD. The specifications of TMD for different structural models are provided in Tables(1),(2) and (3). In IDARC 2-D program, the TMD can only be modeled as an additional floor with its own mass, stiffness and damping properties.



(a) 8-Story Model



(b) 12 & 15-Story Models

Figure1: Structural Models with TMD

Table 1: TMD Specifications in 8 story model

Mass ratio	Mass (kgf-s^2/cm)	Stiffness (kgf/cm)	Damping Coefficient (kgf.sec/cm)
1.0%	2.71	54.20	2.40
2.0%	5.43	108.5	4.76
3.5%	9.49	189.6	8.19
5.0%	13.6	271.1	11.5

Table 2: TMD Specification in 12-story model

Mass ratio	Mass (kgf-s^2/cm)	Stiffness (kgf/cm)	Damping Coefficient(kgf.sec/cm)
1.0%	6.22	90.80	4.71
2.0%	12.4	181.6	9.31
3.5%	21.8	317.9	16.3
5.0%	31.1	544.1	22.6

Table 3: TMD Specification in 15-story model

Mass ratio	Mass (kgf-s^2/cm)	Stiffness (kgf/cm)	Damping Coefficient(kgf.sec/cm)
1.0%	7.92	80.59	5.00
2.0%	15.8	161.2	9.90
3.5%	27.7	282.1	17.3
5.0%	39.6	402.0	24.0

Seven earthquake records are considered for evaluating the performance of TMD in controlling the seismic response of structural models. In each case, the larger component is scaled to 0.4g and the smaller component is multiplied by the same scale factor. In the next step, and as a parametric study, the records are scaled to 0.3g; 0.5g and 0.6g respectively to investigate the effect of ground motion intensity on the performance of TMDs. The selected ground motions records cover a variety of different parameters such as frequency content, peak ground acceleration and velocity, duration, and earthquake intensity.

3. DAMAGE QUANTIFICATION

To evaluate the efficiency of TMDs in decreasing damages of the structures induced by ground excitation, Park and Ang' damage model is considered. This damage index for structural elements can be globally described by:

$$DI_{P\&A} = \frac{\delta_m}{\delta_u} + \frac{\beta}{\delta_u P_y} \int dEh \quad (1)$$

Where:
δ_m = Maximum experienced deformation
δ_u = Ultimate deformation of element
P_y = Yield strength of element
$\int dEh$= Hysteretic energy absorbed by the element during response history
β = A model constant parameter
For the parameter β, a value of 0.1 has been suggested for nominal strength deterioration. The Park and Ang damage model accounts for damage due to the history of deformations. The value of damage index (DI) can vary from 0 to 1.0, which corresponds to the damage level of the structure from no damage level to total collapse, respectively.

4. NUMERICAL RESULTS

Three structural models were subjected to seven earthquake records with different intensities. Nonlinear time history analyses were carried out for these models with and without TMDs. The peak ground acceleration of the earthquake records was scaled to .3g, .4g, .5g, and .6g respectively to study the ground intensity on the performance of the TMDs. As Figs 2-4 indicates, TMD has efficiently reduced the damage index for the 8-story model for PGAs 0.3g and 0.4g. However, for larger intensities, the TMD does not show any performance due to detuning. For the 12 and 15-story models, TMD is effective in damage reduction even at PGAs equal to 0.5g and 0.6 g. That is mainly due to the larger period of the primary structures, and that the damage caused period elongation for these models are not very noticeable compared to the primary periods of the system. In general, one should observe that the frequency content of the earthquake records has a very decisive effect on the performance of the TMDs in all these parametric studies.

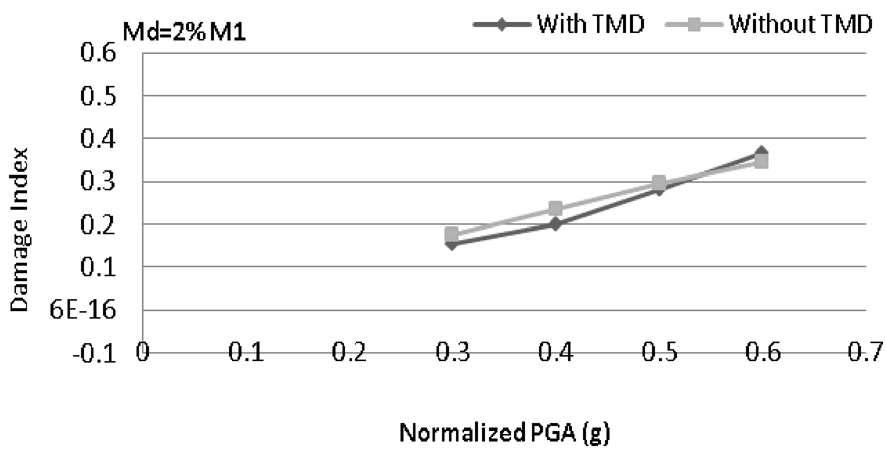


Figure 2: Damage index VS normalized PGA in 8-story model

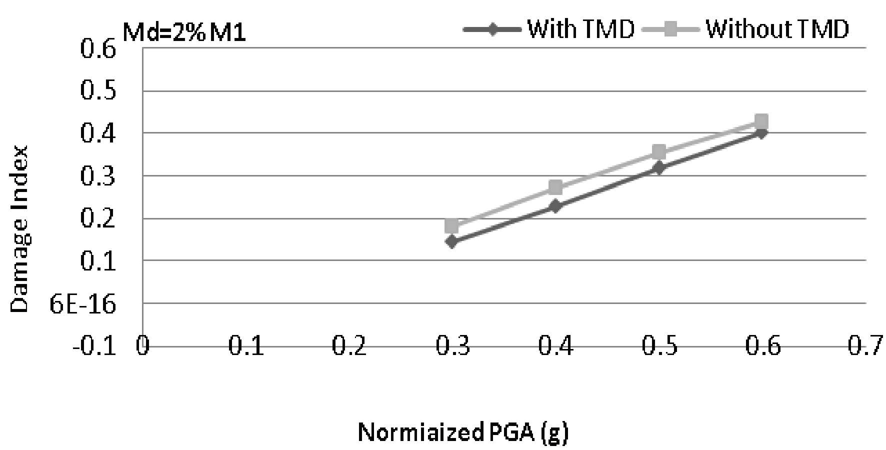


Figure 3: Damage index VS normalized PGA in 12-story model

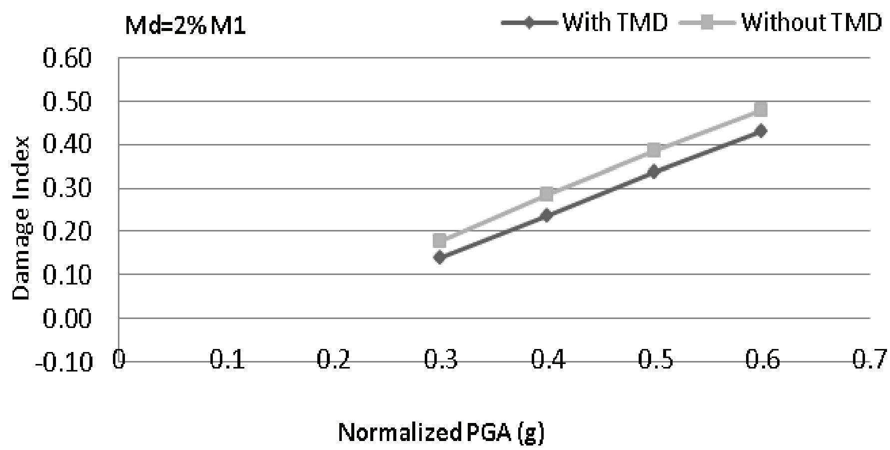


Figure 4: Damage index VS normalized PGA in 15-story model

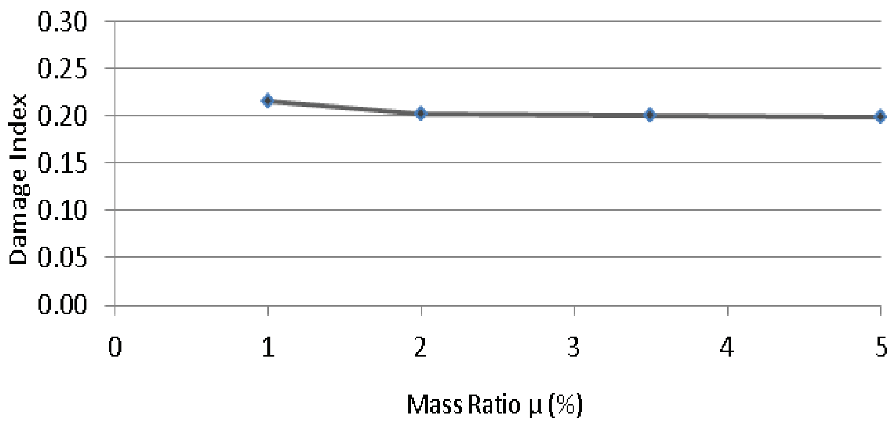


Figure 5: Damage index VS mass ratio in 8-story model

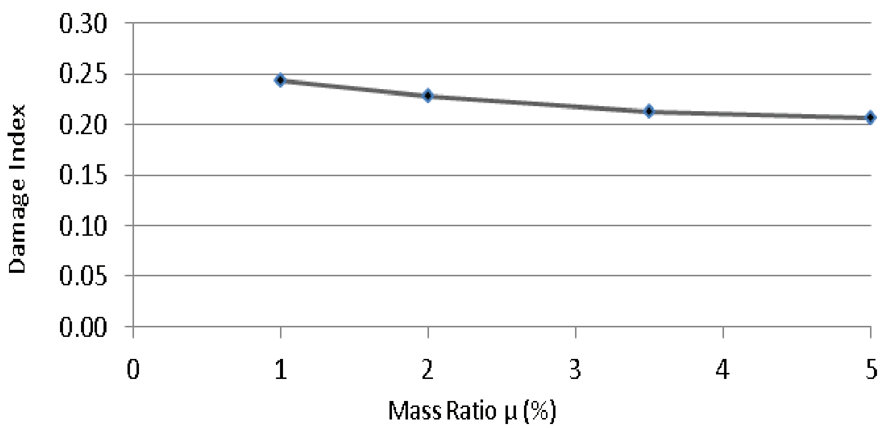


Figure 6: Damage index VS mass ratio in 12-story model

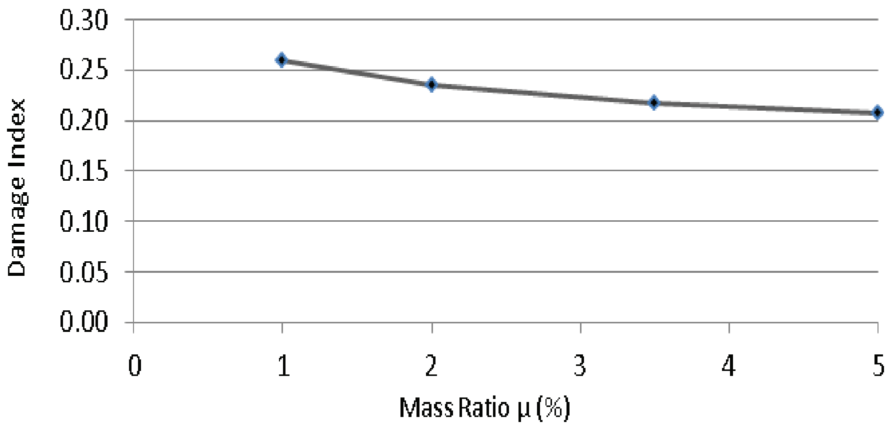


Figure 7: Damage index VS mass ratio in 15-story model

In order to evaluate the effect of TMD mass ratio on its performance, a number of mass ratios, e.g., 1.5%, 2%, 3.5% and 5% was considered. Using seven ground motions scaled to the PGA=0.4 g, the results are presented in Figs 5-7. As it can be seen, larger mass ratios leads to a better performance of TMD. On the other hand, using larger ground intensities does not change these results significantly.

5. CONCLUSIONS

Three 2-D concrete moment resisting frames with 8, 12, and 15 stories are considered. The mass of TMDs are varied from 1% to 5% of the first effective modal mass of the structural models. IDARC 2-D program is used for the numerical analyses. The Park-Ang damage index of the same program is used to determine the level of imposed damage to the structural models under earthquake excitation. In IDARC 2-D program, the TMD can only be modeled as an additional floor with its own mass, stiffness and damping properties. The results obtained indicate that depending on the frequency content of the earthquake accelerations, there is not a significant change in TMD's performance due to detuning caused by the nonlinear behavior of the structural systems. Also, as expected, application of TMD can in average reduce the inelastic deformation of the structural models in comparison to the case with structures without TMDs. Also, TMDs with larger mass ratios has better performance in reducing the damage index in structural models under moderate ground motions. The optimum mass ratio in this study is determined to be around 2-3.5 % of the first effective modal mass in all structural models.

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