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Study on the Effect of Swimming Pool as Tuned Mass Damper

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***Abstract*— The ever-increasing height of the high-rise structure poses considerable challenges for structural engineers and researchers. Among the many difficult technical problems involved in design, the effects of wind and earthquakes on these structures are definitely the most critical issues. The control of structural vibrations produced by earthquake or wind can be done by various means. Tuned mass dampers (TMD) have been widely used for vibration control in mechanical engineering systems.**

This paper presents the study carried out to find the feasibility of implementing swimming pool as passive TMD using SAP2000. Multi-storey concrete structures without swimming pool and with swimming pool were taken for the study. The swimming pool was placed at the roof. The mass and frequency of the swimming pool including its water were tuned to the optimized values. The behaviour of the pool was studied under various conditions, such as different shape. The results show if the pool is tuned properly it can reduce the peak response of structures subjected to seismic forces.

Keywords: Tuned Mass Damper (TMD), swimming pool, SAP2000

I. INTRODUCTION

Vibration control is having its roots primarily in aerospace related problems such as tracking and pointing, and in flexible space structures, the technology quickly moved into civil engineering and infrastructure-related issues, such as the protection of buildings and bridges from extreme loads of earthquakes and winds.

The number of tall buildings being built is increasing day by day. Today we cannot have a count of number of low-rise or medium rise and high rise buildings existing in the world. Mostly these structures are having low natural damping. So increasing damping capacity of a structural system, or considering the need for other mechanical means to increase the damping capacity of a building, has become increasingly common in the new generation of tall and super tall buildings. But, it should be made a routine design practice to design the damping capacity into a structural system while designing the structural system. The control of structural vibrations produced by earthquake or wind can be done by various means such as modifying rigidities, masses, damping, or shape, and by providing passive or active counter forces. To date, some methods of structural control have been used successfully and newly proposed methods offer the possibility of extending applications and improving efficiency. The selection of a particular type of vibration control device is governed by a number of factors which include efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety.

Tuned mass dampers (TMD) have been widely used for vibration control in mechanical engineering systems. In recent years, TMD theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures. Dynamic absorbers and tuned mass dampers are the realizations of tuned absorbers and tuned dampers for structural vibration control applications. The inertial, resilient, and dissipative elements in such devices are: mass, spring and dashpot (or material damping) for linear applications and their rotary counterparts in rotational applications. Depending on the application, these devices are sized from a few ounces (grams) to many tons. Other configurations such as pendulum absorbers / dampers, and sloshing liquid absorbers/dampers have also been realized for vibration mitigation applications.

TMD is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the damper is tuned to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. The mass is usually attached to the building via a spring-dashpot system and energy is dissipated by the dashpot as relative motion develops between the mass and the structure.

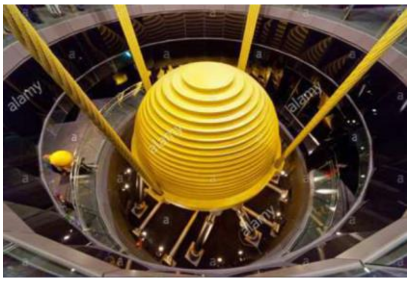

Fig.1 TMD installed in Taipei 101tower

II. OBJECTIVES

- To find out whether swimming pool as tuned mass damper is effective
- To find out whether providing a damper or swimming pool as damper is more effective

III. METHODOLOGY

Methodology employed is modal analysis.

A. Modelling of Building

Here the study is carried out for the behaviour of G+20 storied building with 2%, 4%, 6% and 8% mass for TMD and without TMD. The modeling of buildings was created in SAP2000 software.

B. Building with and without TMD

A building of plan 16m x 16m (i.e. 256m^2) is considered with G+20storey in zone V. A medium soil stratum is considered at the location.

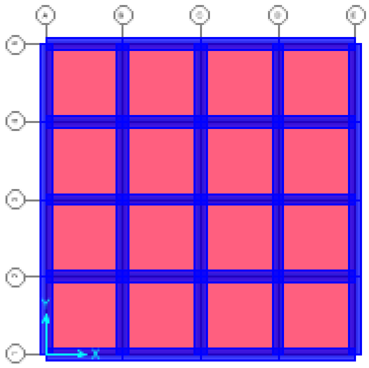

Fig.2 Plan of building without TMD

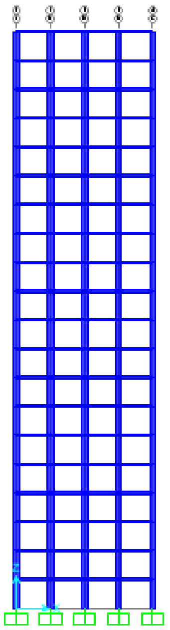

Fig.3 Elevation of building without TMD

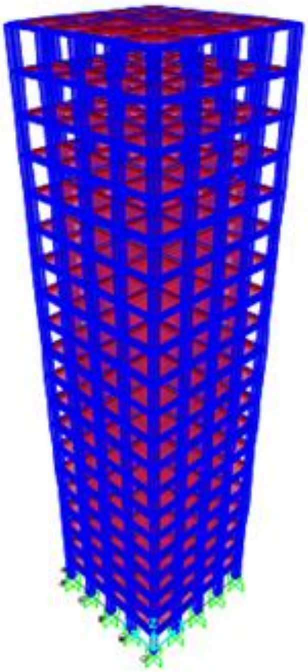

Fig.4 3D view of building without TMD

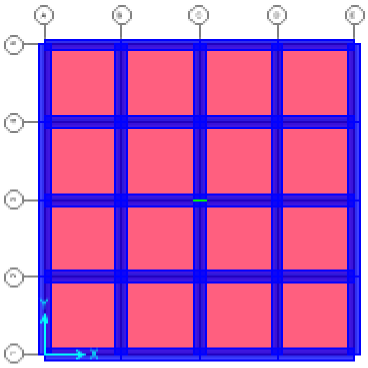

Fig.5 Plan of building with TMD

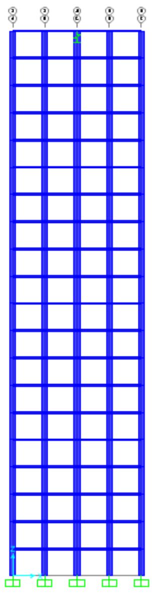

Fig.6 Elevation of building with TMD

C. Loads considered

The loads considered for the present study is given in Tables

Table 1
Dead load and live load data

Live Load	3 kN/m^2
Roof Live Load	1.5 kN/m^2
Floor Finish	1 kN/m^2

Table 2
Earthquake load data

Seismic zone	V
Soil Type	Medium (Type -2)
Zone Factor ,Z	0.36
Importance factor ,I	1
Response reduction factor, R	5
Damping Ratio	5%

D. Building with swimming pool on top floor

A building of plan 16m x 16m (i.e. 256m^2) is considered with G+20 storey in zone V. A medium soil stratum is considered at the location. The top floor of the building contains swimming pools of various positions. Modal analysis is conducted and result is obtained.

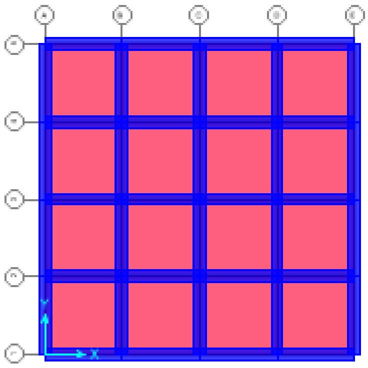

Fig.7 Plan of building

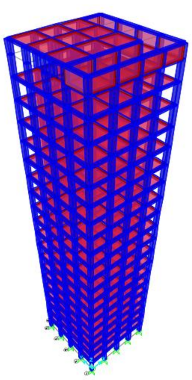

Fig.8 Elevation of building with swimming pool at two sides

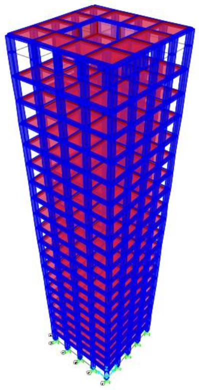

Fig.9 Elevation of building with swimming pool at centre

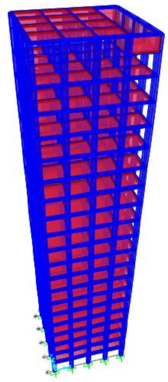

Fig.10 Elevation of building with swimming pool at one side

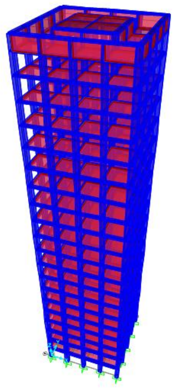

Fig.11 Elevation of building with swimming pool at four sides

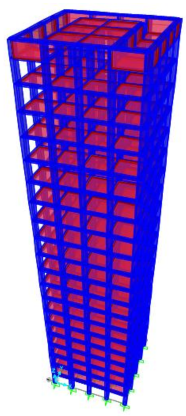

Fig.12 Elevation of building with swimming pool at three sides

IV. RESULTS

After analyzing the models the natural frequency and time period is obtained.

Table 4
Frequency and time period obtained from analysis of building with and without TMD

MASS RATIO	FREQUENCY	TIME PERIOD
0%	0.2273905	4.420033
2%	0.22517309	4.441028
4%	0.22215846	4.501292
6%	0.21923276	4.561362
8%	0.21639378	4.621205

Table 5
Frequency and time period obtained from analysis of building with swimming pool

POSITION OF SWIMMING POOL	FREQUENCY	TIME PERIOD
4 side	0.21109729	4.737152
3 sides	0.21164858	4.724813
2 sides	0.20774612	4.813567
1 side	0.21069070	4.746294
center	0.21412554	4.670157

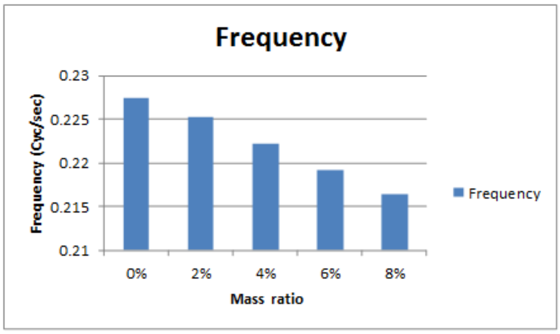

Fig.13 Frequency of building with various percentage of mass ratio for TMD

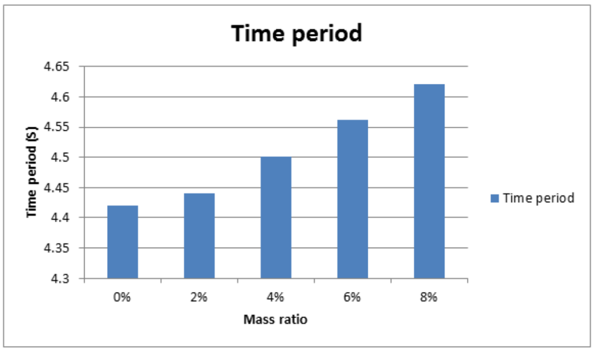

Fig.14 Time period of building with various percentage of mass ratio for TMD

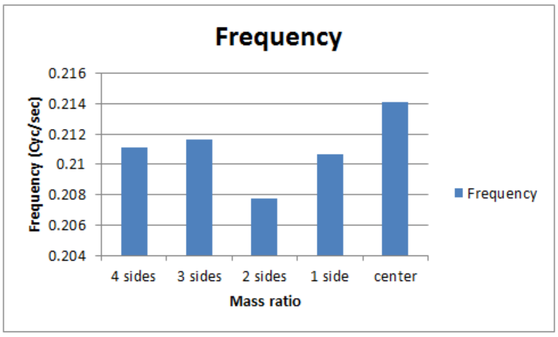

Fig.15 Frequency of building with swimming pool at various positions

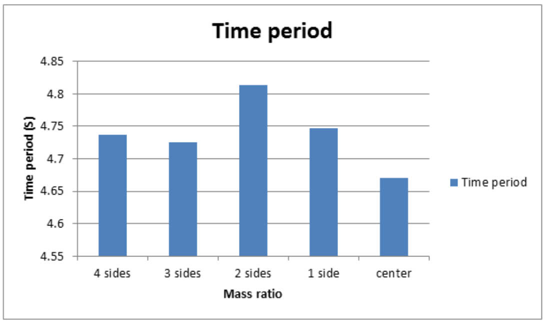

Fig.16 Time period of building with swimming pool at various positions

VI. CONCLUSIONS

Analytical study has been conducted to understand the behavior of TMD with various mass percentages and swimming pool at various positions on buildings. From the modal analysis we obtained that the building without TMD has high value of frequency and low value of time period. When TMD is provided the frequency of the building is reduced. Mass of the TMD has direct influence on frequency and time period of the building. As the mass of the TMD increases frequency decreases and time period of building increases.

When swimming pools are provided on top of the building, we can see that the frequency of building is less than that without a swimming pool on top. From this it is clear that swimming pools act as TMD in buildings.

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