Analysis on Non Linear Static Analysis of High Rise Structure Using Indian Earthquake Data

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Abstract

This paper is concerned with the investigation. The objective of the project is to carry out Non-linear static Aalysis of High Rise structure using Tuned Mass Damper (TMD). TMD has been found to be most effective for controlling the structural responses for harmonic and wind excitations. Innovative strategies driven toward improving the structural and nonstructural performance of existing buildings during large earthquakes are of paramount interest for researchers and practitioners of earthquake engineering. One such strategy is the use of a Nonlinear Rooftop Tuned Mass Damper Frame (NRTMDF). This technique utilizes a rooftop penthouse structure as a tuned mass damper with mass incorporated as the roof deck of the penthouse while targeted nonlinearity and energy dissipation are introduced into the system by virtue of buckling restrained braces which link the penthouse mass to the structure below. An analytical study of existing buildings, each modified with an NRTMDF, demonstrates the effectiveness of this approach for reducing seismic response. In this paper, Non-linear Dynamic Time History analysis is done considering R.C.C framed structure by using steel dampers as Tuned Mass Damping Device at top of the building with a damping ratio of 5% using ETABS. The study had been carried out approximately keeping the mass of TMD 4%-5% of mass of structure. With 5% mass of Tuned Mass Dampers the frequency of the Tuned Mass Dampers matches close to the fundamental mode of the structure. Due to this reason mass of the Tuned mass dampers is fixed close to 5% of the structural mass. For Symmetrical Buildings, using of Tuned mass dampers in the form of steel dampers, the amplitude of vibration could be brought down by 51%. Similarly for un-symmetrical buildings, the value of the amplitude of vibration could be brought down by 49% using steel dampers.

KEYWORDS–Tuned Mass Dampers(TMD), Non-linear Static Analysis, Displacement, Base Shear, IS: 1893:2002(Part-I)

I. Introduction:

Tuned mass dampers have been widely used for vibration control in mechanical engineering systems. In recent years, Tuned Mass Dampers 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, Tuned Mass Dampers 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.IS 1893 definition of Vertically Irregular structures:

I. I Classification of Control Methods

a) Active Control: An active control system is one in which an external power source the control actuators are used that apply forces to the structure in a prescribed manner. These forces can be used to both add and dissipate energy from the structure. In an active feedback control system, the signals sent to the control actuators are a function of the response of the system measured with physical sensors

b) Passive Control:A passive control system does not require an external power source. Passive control devices impart forces that are developed in response to the motion of the structure. Total energy (structure plus passive device) cannot increase, hence inherently stable

c) Hybrid Control-The term "hybrid control" implies the combined use of active and passive control systems. For example, a structure equipped with distributed viscoelastic damping supplemented with an active mass damper near the top of the structure, or a base isolated structure with actuators actively controlled to enhance performance.

d) Semi-Active control systems - Semi- active control systems are a class of active control systems for which the external energy requirements are less than typical active control systems. Typically, semi-active control devices do not add mechanical energy to the structural system (including the structure and the control actuators), therefore bounded-input bounded-output stability is guaranteed. Semi-active control devices are often viewed as controllable passive devices.

II. Objectives

The Primary objectives of undertaking the present study are as follows:

1. To study the seismic response of a reinforced cement concrete framed ten storied building in Zone IV with the help of ETABS using non-linear time history analysis.
2. To analyze framed structures using ETABS to ascertain the seismic load carrying capacity.

To study the different characteristic time periods, base shear in x-direction, base shear in y-direction and Amplitude

III. Methodology

A high-rise framed building has been modeled using ETABS package. The framed structure was analysed using dynamic analysis and the time period, magnitudes of displacements at critical locations were recorded. Thereafter, a suitable TMD system was designed. The weight of the TMD will be 3% to 5% of the total weight of the building. The TMD was first analyzed separately and its natural frequency was obtained. Keeping the TMD so designed on top of the building, the structure was once again analyzed using dynamic analysis and the time period, displacement at the corresponding locations was compared with the results obtained without TMD to illustrate the utility of the study

IV. Time History Analysis

Time history analysis techniques involve the stepwise solution in the time domain of the multi-degree-of-freedom equations of motion which represent the actual response of a building. It is the most sophisticated analysis method available to a structural engineer. Its solution is a direct function of the earthquake ground motion selected as an input parameter for a specific building. This analysis technique is usually limited to checking the suitability of assumptions made during the design of important structures rather than a method of assigning lateral forces themselves.

The steps involved in time history analysis are as follows:

1. Calculation of Modal matrix and effective force vector
2. Obtaining of Displacement response in normal and physical coordinate

V. Literature Review

There has been considerable research work done on different control system of Tuned mass damping for multistoried building. The prime importance of the review was to develop basic understanding of Tuned mass damping and how to incorporate the same in the structures.

Clark [2]. The concept of multiple tuned mass dampers (MTMDs) together with an optimization procedure was proposed by Clark. The first mode response of a structure with TMD tuned to the fundamentalfrequency of the structure can be substantially reduced but, in general, the higher modal responses may only be marginally suppressed or even amplified. To overcome the frequency-related limitations of TMDs, more than one TMD in a given structure, each tuned to a different dominant frequency, can be used., then, a number of studies have been conducted on the behavior of MTMDs a doubly tuned mass damper (DTMD), consisting of two masses connected in series to the structure was proposed (Setareh 1994). In this case, two different loading conditions were considered: harmonic excitation and zero-mean white-noise random excitation, and the efficiency of DTMDs on response reduction was evaluated. Analytical results show that DTMDs are more efficient than the conventional single mass TMDs over the whole range of total mass ratios, but are only slightly more efficient than TMDs over the practical range of mass ratios (0.01-0.05).

Villaverde. Recently, numerical and experimental studies have been carried out on the effectiveness of TMDs in reducing seismic response of structures [for instance, Villaverde(1994)]. In three different structures were studied, in which the first one is a 2D two story shear building the second is a three-dimensional (3D) one-story frame building, and the third is a 3D cable-stayed bridge, using nine different kinds of earthquake records. Numerical and experimental results show that the effectiveness of TMDs on reducing the response of the same structure during different earthquakes, or of different structures during the same earthquake is significantly different; some cases give good performance and some have little or even no effect. This implies that there is a dependency of the attained reduction in response on the characteristics of the ground motion that excites the structure. This response reduction is large for resonant ground motions and diminishes as the dominant frequency of the ground motion gets further away from the structure's natural frequency to which the TMD is tuned. Also, TMDs are of limited effectiveness under pulse-like seismic loading.

FahimSadek et al [8]. A method of estimating the parameters of tuned mass dampers for seismic applications. In this paper the optimum parameters of TMD that result in considerable reduction in the response of structures to seismic loading has been presented. The criterion that has been used to obtain the optimum parameters is to select for a given mass ratio, the frequency and damping ratios that would result in equal and large modal damping in the first two modes of vibration. The parameters are used to compute the response of several single and multi-degree of freedom structures with TMDs to different earthquake excitations. The results show that the use of the proposed parameters reduces the displacement and acceleration responses significantly. The method can also be used for vibration control of tall buildings using the so-called ‗mega-substructure configuration', where substructures serve as vibration absorbers for the main structure.

G. W. Housner et al [9]. Structural control: past, present, and future This paper basically provides a concise point of departure for those researchers and practitioners who wishing to assess the current state of the art in the control and monitoring of civil engineering structures; and provides a link between structural control and other fields of control theory, pointing out both differences and similarities, and points out where future research and application efforts are likely to prove fruitful.

VI. Structural Modelling

Specifications

Live load	3.5 KN/ m3
Depth of Slab	150mm
Column Size	600X600
Beam Size	450X400
Density of infill	20KN/m3
Thickness of outside wall	230mm
Thickness of partitionwall	115mm
Height of each floor	3m
Earthquake zone	Zone IV
Damping ratio	5%
Type of soil	Rock
Type of structure	Multi-storied Rigid Frame
Time history	As per I.S 1893 (part I):2002.

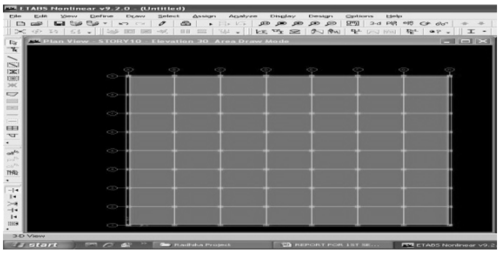

Fig shows: plan of regular structure (10 storey's)

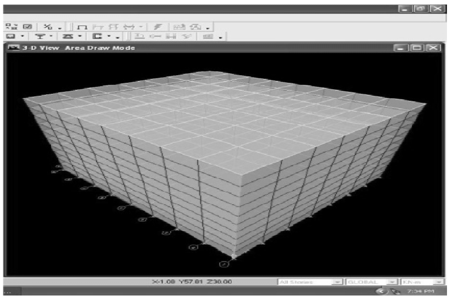

Fig shows: 3D view of regular structure (10 storey's)

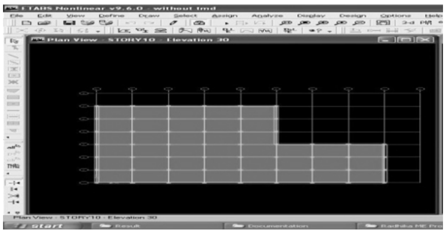

Fig shows: plan of irregular structure (10 storey's)

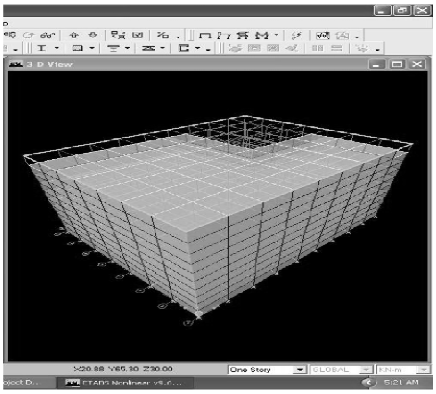

Fig shows:3D view of irregular structure (10storey's)

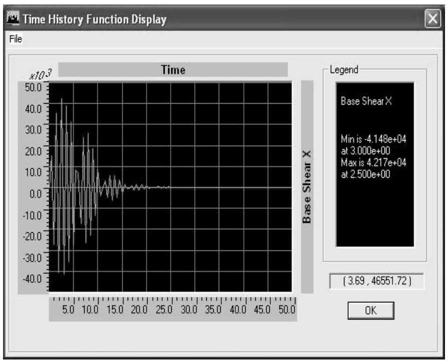

Fig: 5.2 The Graph Showing betweenTimeVs Base shear X (Without TMD)

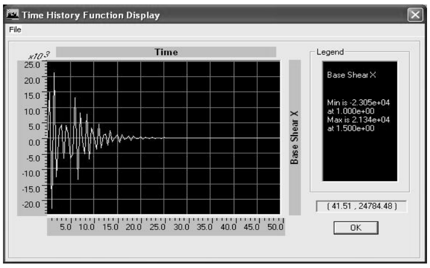

Fig: 5.3 The Graph Showing betweenTimeVs Base shear X (With TMD)

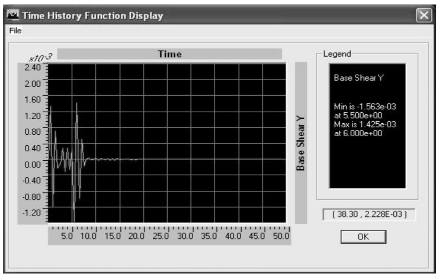

Fig: 5.4 The Graph Showing betweenTimeVs Base shear y (With out TMD)

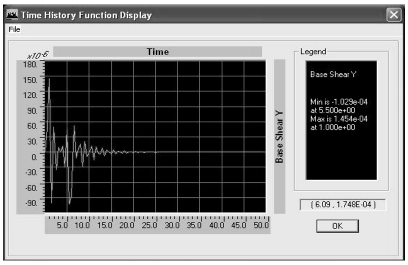

Fig: 5.5 The Graph Showing betweenTimeVs Base shear y (With TMD)

Storey Number Vs Max Displacement

Table 5.3 Storey Number Vs Maximum Displacement (without & with TMD).

Storey Number	With out TMD	With TMD
Base	0	0
1	0.018	0.0093
2	0.0389	0.021
3	0.0596	0.0309
4	0.0792	0.0413
5	0.0969	0.0509
6	0.113	0.0595
7	0.1253	0.0671
8	0.1352	0.0735
9	0.1421	0.0786
10	0.1461	0.0825
11	-	0.0917

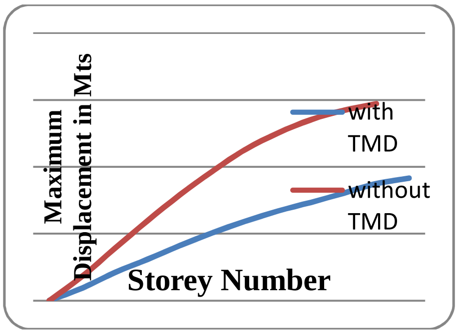

Fig: 5.6 The Graph Showing betweenStorey number Vs Max Displacement

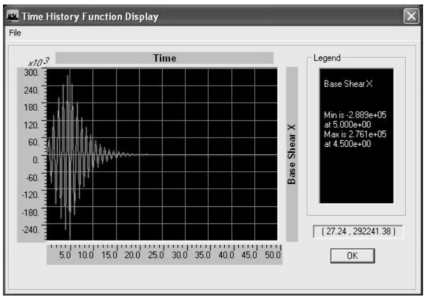

Fig: 5.8The Graph Showing betweenTimeVs Base shear x (Without TMD)

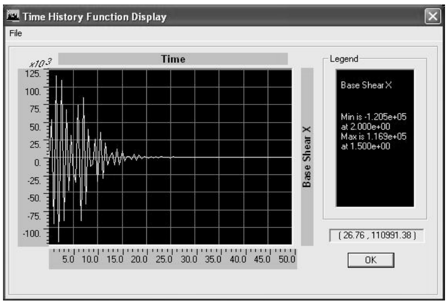

Fig: 5.9 The Graph Showing betweenTimeVs Base shear x (WithTMD)

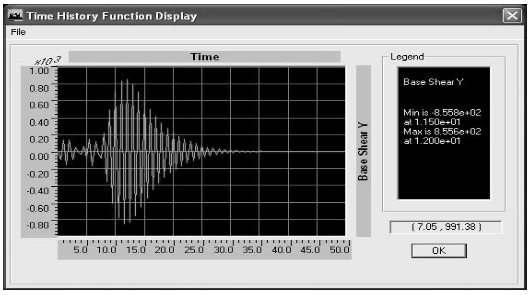

Fig: 5.10 The Graph Showing betweenTimeVs Base shear y (Without TMD)

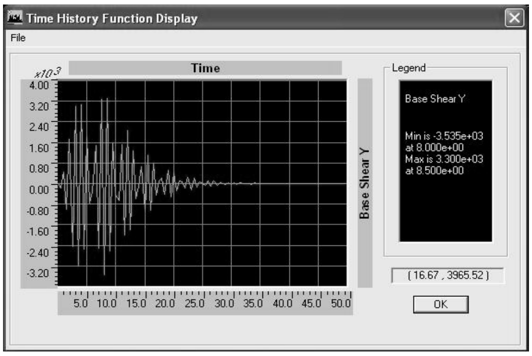

Fig: 5.11 The Graph Showing betweenTimeVs Base shear y (with TMD)

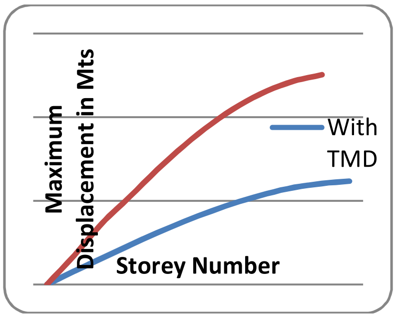

Fig: 5.12 The Graph Showing betweenStorey Number Vs Max displacements

VII. Conclusion

Based on the outputs obtained from the ETABS package as per IS: 1893:2002 (part-I) with 5% of structural damping following conclusions are made.

- With 5% mass of Tuned Mass Dampers the frequency of the Tuned Mass Dampers matches close to the fundamental mode of the structure. Due to this reason mass of the Tuned mass dampers is fixed close to 5% of the structural mass.
- For Symmetrical Buildings, using of Tuned mass dampers in the form of steel dampers, the amplitude of vibration could be brought down by 51% (page 50).
- Similarly for un-symmetrical buildings, the value of the amplitude of vibration could be brought down by 49% (page 58) using steel dampers.
- Similarly for symmetrical Buildings, the value of the base shear is brought down by 56% (page 45 & 46) using steel dampers.
- For un-symmetrical Buildings, the value of the base shear is brought down by 42% (page 54) using steel dampers.

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