"Analysis Of High Rise Building By Using Viscoelastic Dampers"

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ABSTRACT

An earthquake directly affects structures by increasing the energy within the structural systems. A significance of this energy can be dissipated by the introduction of structural control systems. Several structural control systems such as passive, active and semi-active control systems are gaining importance now a days in the earthquake resistance design of structures. Viscoelastic damper is a type of passive energy dissipation device, which operates on principle of fluid flow through orifices. This type of damper has found numerous applications in military and aerospace industry from many years. Recently in the civil engineering field,high capacity visco-elastic dampers have found commercial applications on the buildings and bridges subjected to seismic and wind storm inputs.VE dampers are uses inertial flow, where oil is force through small orifices at high speed, in turn generating high damping force. In the present study the effectiveness of fluid viscous dampers in reducing the responses of the structures under seismic excitation has evaluated analytically using non-linear time history analysis. Twenty stories reinforced concrete analysis with the square plan is consider in this study. Acceleration, time history of Indian seismic zone III and IV are used for analysis. This analysis is carried by using software package ETABS 2015 as well as by manual analysis by using linear method. This analysis results confirmed that a significance reduction in the responses such as displacement and other forces is possible with the introduction of fluid viscous dampers and hence it can be used as an alternative to the conventional ductility based design method of earthquake.

Keywords-Viscoelastic Dampers, Nonlinear analysis, Energy dissipation, displacements, damping force seismic analysis.

1. INTRODUCTION

An earthquake is shaking of earth surface by waves emerging from the source of disturbance in the earth by virtue of release of energy in the earth's crest. The earthquake waves induce a large amount of lateral load on the structures. Due to this, the structures may suffer large deformation or complete collapse depending upon the type of structure, magnitude of earthquake and several other factors. The collapse of structures leads to loss of life and property damage, causing a large amount of financial losses and social sufferings. Hence it is necessary to design the structures to resist the earthquakes. Over many decades, the earthquake resistant design of structures was dependent on material ductility to dissipate the seismic energy induced into the structural systems. The ductility based design may provide life safety, as the structure gives enough warning before absolute collapse, but the damage control cannot be achieved to the required level. Because of the drawbacks of ductility based design, many structural control techniques have been developed over the years and are gaining importance now days. By installing some devices, mechanisms, substructures in the structure, the dynamic performance of the structure is adjusted. The structural control systems dissipate the major portion of the seismic energy and reduce the forces on the primary structure, thereby limiting the structural deformations. Thus, the introduction of structural control systems ensures life safety, as well as damage control to the required level.

II.TERMINOLOGY

Earthquake loads: Earthquake loads are causes more damage than wind loads. It is occurs frequently in certain regions. It is a sudden lateral movement in ground under a structure that may shift in any direction and the horizontal components of this movement generates a wave action which usually transferred vertically to a structural. The variations in earthquake load are almost consistence than the wind load. The magnitude earthquake load changes with change in the stiffness, mass of the structure, and the motion of the earth surface because of seismic forces. These lateral forces can be resisting by any structure by modifying location of building, importance factor, type of soil, and achieving good construction practices.

Story Displacement: A floor displacement profile is maximum with the maximum story drift ratio depending upon the height, the time period, and the column-to-beam strength ratio. It is measured in terms of mean coefficient of variation. The parameters under which displacement is study are sections and variations in of reinforcement. This term is proportional with the mechanism of formation of plastic hinges in structural members.

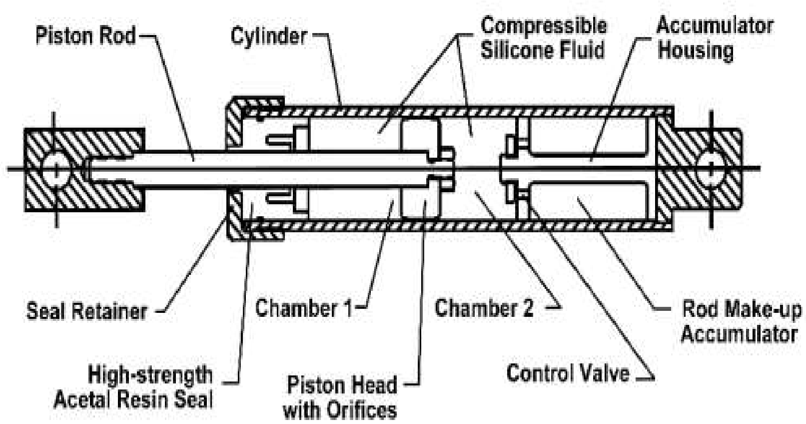
Response spectrum analysis: For determine the peak value of ground acceleration in case of seismic analysis of structure. The curve is plotted between ground motion and frequency. For which different damping ratios were considered and the mean peak response of displacement, velocity, acceleration of structure with time period is then calculated from different curves (i.e. .spectrums). Different factors that will affect the response spectrum analysis are energy release mechanism, soil condition, Richter magnitude, damping in the system, time period of the system.

III.VISCOELASTIC DAMPERS

Among the various energy dissipation devices, fluid viscous dampers have been widely used in the vibration control of various structural and mechanical systems. These dampers were widely being used in the military and aerospace industry for many years and recently been adapted for structural applications in civil engineering. VEs have the unique ability of simultaneously reducing both deflection and stresses within a structure subjected to a transient. This is because a Viscoelastic damper varies its force only with velocity, which delivers a response that is essentially out of phase with stresses. A modern fluid viscous damper functions at a fluid pressure level of significant magnitude, thus making the damper small, compact and easy to install. This type of damper is generally less expensive to purchase, install and maintain compared to other types of dampers.

Components:

VD consists of a stainless steel piston rod with a bronze orifice head and a self-contained piston displacement accumulator. The damper cylinder is filled with a compressible viscous fluid (silicone oil) which is generally non-toxic, non-flammable, thermally stable and environmentally safe. A typical longitudinal section of fluid viscous damper is shown in figure.



` IV.WORKING METHOD

Viscoelastic damper work on the principle of fluid flow through orifices. These devices resemble the common shock absorber such as those found in vehicles. VEs consist of a stainless steel piston that travels through chambers filled with silicone oil. The silicone oil is inert, non-toxic, non-flammable and stable for extremely long periods of time. The silicone oil flows through an orifice in the piston head due to the pressure difference between two chambers and the seismic energy is transformed into heat, which dissipates into the atmosphere. When the VE is subjected to external excitations, the piston rod with piston will make reciprocating motion in the cylinder to force the damping medium move back and forth between the two chambers separated by the piston. In this process, the friction occurred between the molecules of the damping medium, the medium and the shaft and piston, the damping medium and the cylinder, and the throttling damping force produced by the damping medium through the piston, all these action work together constitute the damping force. The role of VE is to transform mechanical energy caused by the winds, earthquakes or other structural vibrations into the inner energy of the damping medium. The dampers use the increasing temperature of damping medium to store energy temporarily. The heat is eventually consumed by natural cooling. In this way, the fluid viscous dampers protect the structure from damage. VEs can operate over temperature fluctuations ranging from minus forty to plus seventy degree celcius.The ideal damping force of a fluid viscous damper is given by,

$F = C.V^{\alpha}$

Where, F is the damping force, C is the damping co-efficient, V is the velocity of piston relative to the cylinder and α is the damping exponent.

V.LITERATURE REVIEW

A. Ri-Hui Zhang1, and T. T. Soong (1992)

A design procedure is presented by which damper dimensions, number, and locations needed to achieve desired level of additional damping can be determined. Once the optimal location indices are found, the optimal location of the first damper is determined as the story with the maximum index value. Adding one VE damper to that story means an increase in stiffness and equivalent viscous damping. Therefore, to find the best location of the next damper, the response is recalculated accounting for the increased stiffness and damping coefficient due to the addition of the first VE damper. The location for the next VE damper is then found from the newly calculated indices

For the 10-story example structure, a saving of two to five dampers by optimal placing can be realized if story drift is taken as the criterion of response reduction. The optimality of locations found by this procedure is also supported by experimental results. Reduction in top displacement in case one damper is 83% and with the addition of two or three damper at optimal locations drift reductions are 73% to 78%.

B. Kazuhiko Kasai1, Member ASCE, Yaomin Fu, and Atsushi Wantanabe

The analysis methods are also different between the VE (visco-elastic) and EP (Elasto-plastic) systems; these make direct comparison of the two types of passive systems difficult. A 14-story steel MRF having insufficient stiffness and strength at lower stories was retrofitted to achieve the optimized response by using either VE or EP dampers. Both VE and EP systems performed excellently for the major earthquakes considered.

Drifts were very small and uniform; MRF member stresses were well below the yield limit; nonstructural components were protected; and foundation uplift forces were kept below capacity.

c. Marko, Julius and Thambiratnam, David P. and Perera, Nimal j (2006)

18-storey and 12-storey frame –shear wall structures with with embedded dampers was considered Three damping mechanisms (i) displacement-dependent friction dampers, (ii) velocity-dependent VE dampers and (iii) hybrid system which is a combination of friction and VE dampers were considered Friction and VE diagonal dampers, friction and VE chevron brace dampers, hybrid friction-VE dampers and VE lower toggle dampers Study of viscoelastic and friction damper configurations in the seismic mitigation of medium-rise structures Diagonal friction dampers performed better under the earthquakes which produced higher deflections of the structure Diagonal VE dampers was noticeably less sensitive to this aspect chevron brace dampers were effective in case of overall tip deflection reduction and even significantly more reliable than those of the diagonal dampers Both types of chevron brace dampers were clearly the least effective in terms of tip acceleration reduction The damping systems were embedded in six different locations (one at a time) within cut-outs of the shear wall in the structure In the 18-storey structure reductions of up to 36% in the peak values of tip deflections and 47% in the peak values of the tip accelerations were obtained while in the 12-storey structure the highest tip deflection reduction was 43% and the tip acceleration reduction 50% The friction dampers in the huge majority of cases surpassed the VE dampers in their ability to reduce the intensity of the initial strong strikes In contrast, the VE dampers gradually decreased the deflection and acceleration of the structure The performance of the friction dampers increased with higher inter story drift, while the best performance of VE dampers was achieved when placed in the lowest stories.

VII. METHODOLOGY

Among finite element method software's, ETABS is known as "Extended 3D Analysis of Building Structure" Software in industry and university researches. It is used for static as well as dynamic analysis of structures.In the present study three dimensional analyses with the help present study three dimensional analyses with the help of ETABS (Non-linear version) is used for modelling and analysis of the structure.

Analysis of the structure.

Type of structure: RCC building structure

No of storeys: B+P+20 storeys

Plan dimensions: 35m x 36m

Floor to floor Height: 3 m

Damping mechanism: Viscoelastic damper

Damper location: Installations of Viscoelastic dampers at different locations along the height and width of the building.

SECTION DETAILS

Column: 300 x 1600 mm – base to 9 Storey
Column: 300 x 1500 mm – 9 to 11 Storeys
Column: 300 x 1200 mm – 11 to 20 Storeys
Slab = 150 mm
Beam = 200 x 600 mm
Linear Damper Properties: As per design Taylor's Device criteria.

SEISMIC ANALYSIS ACCORDING TO IS 1893-2016 2016

Seismic Zone = 0.16
Soil Type = II
Importance Factor = 1.5
Response Reduction = 5

FOR WIND ANALYSIS ACCORDING TO ACCORDING TO IS 875 (PART3):1987

Windward Coefficient = 0.8
Leeward Coefficient = 0.5
Wind Speed = 39 m/s
Terrain Category = 4
Structure Class = B
Coefficient (K1 Factor) = 1.07
Topography (K3 Factor) =1
Parapet Height =1.5 m
Dead Load = 2 kN
Live Load = 5 kN for podium lvl and 2 KN for typical

MATERIAL PROPERTIES

Grade of concrete: M30
Grade of steel: Fe500
Unit weight of RCC: 25 KN/m^3
Unit weight of masonry: 20 KN/m^3

Gravity loads

Dead loads according to IS 875: Part I
Live loads according to IS 875: Part II

Wind load

Wind loads have been calculated in accordance with IS 875: Part 3.
Basic wind speed is taken as 39 m/s (Pune).
Risk coefficient and topography factor are taken as unity.
Code refers following load combinations for wind analysis.
1.5 (DL + LL)
1.2 (DL + LL ± WL)
1.5 (DL ± WL)
0.9 DL ± 1.5 WL

Seismic Loads

Criteria as per IS 1893: 2016 As per this code, Pune has been designated to Zone III
Soil type: Medium
Code refers following load combinations for seismic load analysis.
1.5 (DL + LL)
1.2 (DL + LL ± EQ)
1.5 (DL ± EQ) 0.9 DL ± 1.5 E

Manual Calculation and software results:P+20 storiey buiding

Column No.s .	Manually Calculated axial load(kn)	ETABS software axial loads(kn)
1	3520	4000
2	8500	8951
3	4200	5800
4	3591	6100
5	4715	4810
6	3591	3610
7	4200	4500
8	8500	8951
9	3520	3522
10	960	1000
11	110403	11568
12	6972	7200
13	9429	10200
14	6973	7412
15	11000	11561
16	960	1100
17	1265	1285
18	1410	1516
19	1324	1345
20	1384	1395
21	1302	1355
22	1384	1390
23	1413	1455
24	960	1000
25	11000	11545
26	6972	7450
27	9429	9540
28	6973	7400
29	11000	11045
30	960	1000
31	3520	3585
32	8500	8592
33	4250	4298
34	3592	3600
35	4715	4781
36	3590	3600
37	4252	4298
38	8500	8590
39	3520	3582

VIII. DETERMINATION OF THE OPTIMAL PROPERTIES OF DAMPERS

The modelling and analysis of the bare frame and structure with fluid viscoelastic dampers are using the ETABS 2015 computer program. The modelling of fluid viscous dampers varies with the type of bracing used to mount the damper to the frame. Link element called Damper – Exponential should use to model fluid viscous dampers. The mass and weight of the damper element along with the bracing connected should be calculate. The fluid viscous dampers should mount in single diagonal bracings are active only in the local axial direction. Therefore, only one active degree of freedom U1 is select in the directional properties and since its behaviour is non-linear, the non-linear option is marked. As there will be no provision for rotation, rotational inertia R1, R2 and R3 will be entered zero. After defining the directional properties (U1), the non-linear properties of the damper in that particular direction have to be specifing.The values of stiffness, damping co-efficient and damping exponent should be enter in the non-linear properties window.

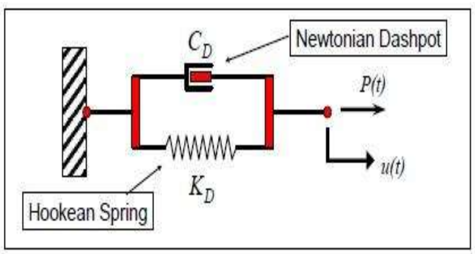
It is important to determine the optimal properties of viscous dampers in order to reduce the response of the structure by a considerable amount. The optimal damper properties are nothing but the values of damping coefficient (C) and damping exponent (α) corresponding to minimum response of the structure and maximum seismic energy dissipation. A simple procedure for the determination of damping co-efficient is used.

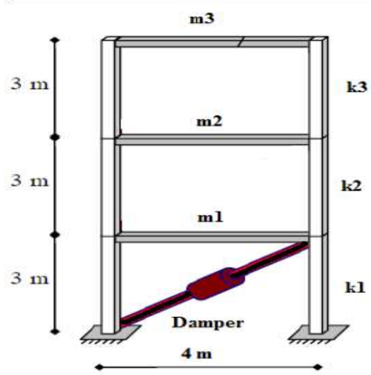
$$C = 2.m.\omega.\xi$$

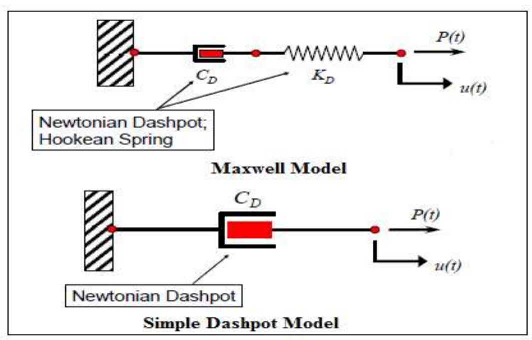
Where ξ is the damping ratio, m is the seismic weight of the structure and ω is the natural frequency which is given by

$\omega = 2\pi/T$. Here, T is the fundamental time period, which is obtain from modal analysis. Knowing the value of natural frequency ω, the co-efficient of damping is calculate by assuming suitable value of damping ratio ξ and is used in analysis. The value of damping exponent varies in the range of 0.2 to 1.0 for typical viscous dampers used in structural applications. The seismic weight of the structure (m) and fundamental time period (T) obtain from modal analysis are kN and sec.respectively.

Mathematical Model and Behaviour-







In this model, the spring attached in parallel to the dash-spot

The force displacement relation for the model is $P_d(t)=k_d(w)\,\Delta_d(t)+c_d\,\Delta_d(t)$

Where k_d and c_d stiffness and damping coefficient of model. The main VD properties used the designing VE damper as storage modulus .G′ provide with the actual elastic shear stiffness of material The stress strain relation expressed as

τ (t) = G ″C)+G ″Y″(t)/ f .

IX. TEST AND VALIDATION

A. Example

Type of structure: RCC building structure

No of storeys: G+3 storeys

Grade of concrete and steel: M20 & Fe500

Zone : IV

Unit weight of brick : 14 KN/m^3

Beam size: 230x 600 mm

Column size :300x300 mm

Thickness of slab:150mm

Live load : 2 KN/m^2

Dead load :1.5 KN/m^2

Floor finish:1.25 KN/m^2

Plan dimensions: 15m x 15 m

Floor to floor Height: 3 m

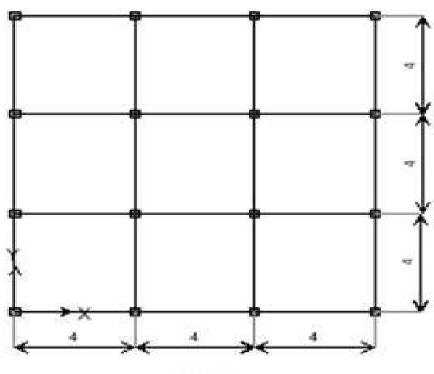
Damping mechanism: Viscoelastic damper

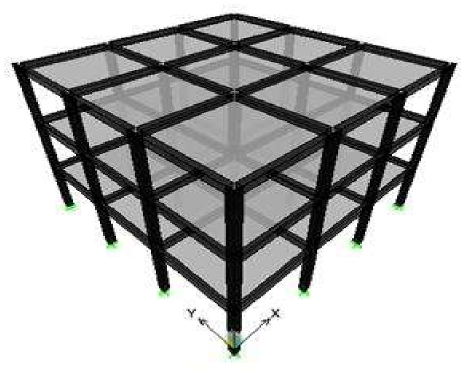
Damper location: Installations of viscous damper in outer and inner frame with diagonally attached.

It should be performed nonlinear dynamics analysis, to validate the solution and the method under study. The analysis of the studied situations always considers that the building's structure remains in the linear regime.

The viscous dampers are modeled as a Maxwell element, which is a nonlinear damper in series with a nonlinear spring (CSI).

The design parameters for this model of viscoelastic dampers are: K (spring stiffness), C (damping coefficient) and α (characteristic of fluid).





Manual calculate axial load =747 KN (factored)

Etabs axial load =755 KN, Mx=58.68KN,My= 42.56 KN. Firstly doing static and dynamic analysis deciding scale factor it is 1.42 analysis and get dynamic result. so the manual and software results are matched.

Total 18 Nos fluid viscous dampers in each story in X and Y direction.

Finding stiffness : The stiffness will be calculated based on the cross sectional area of the steel section used for bracing and the length of bracing.

Seismic weight of building of structure from analysis=11212 KN

Damping=0.05, steel plate 200 mm size of plate attached at the concrete frame.

$F = C.V^{\alpha}$

K is the stiffness of damper device.

K=200X200XE/3200=2500 kN/m

The value of stiffness is taken as 2500 kN/m in this model analysis from force displacement curve.

$C=2.m.w.\xi$

where ξ is the damping ratio, m is the seismic weight of the structure and ω is the natural frequency which is given by $\omega = 2\pi/T$. T is the fundamental time period.

$W=2\pi/T= 2\pi/0.5=13, \alpha=0.2$

C=2x6392x0.05x13=8309.06 KN

Taylor device model ISM110 is considered as extender to mount the fluid viscous damper in the frame.
After run analysis of model the damper and without damper should be cheeked following variations are obtained. From above observation viscoelastic damper reduced the base shear, storey displacement, shears, axial load, column moments, base reactions.

	Without Damper	With Damper
Base shear	38.42	32.53
displacement	0.55	0.35
Storey shear	40.33	38.26
Column axial load	752	567
Column moments	45.56	42.77
Base reaction	58.98	42.56

CONCLUSION

1.Viscoelastic dampers are effective for reducing structural response of structures.
2.The effectiveness of viscoelastic dampers is reduced seismic response (drift, displacement, story shear. Moments of structures.)
3.Also time period of structures reduced when placement of dampers.

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