Seismic Response Control of Irregular Shaped RCC Buildings by using Nonlinear Viscous Damper

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***Abstract*— Structures with irregularities are constructed to provide better architectural appearance. But it is noted that irregular buildings show poor seismic performance compared to regular buildings. So it is essential to study the seismic response of these irregular shaped buildings to reduce the seismic potential damages. The current study focuses on the effect of viscous damper on irregular shaped buildings such as symmetrical rectangular and L shaped buildings. Diagonal nonlinear viscous dampers are provided for dissipating the effect of earthquake. The methodology includes modal analysis and calculation of lateral displacement for each model. The study concludes that a considerable reduction in seismic response can be achieved for each configuration.**

Keywords*— *Irregularities, Ordinary moment resisting frame, El centro earthquake, Non-linear Viscous damper, Nonlinear time history analysis.

I. INTRODUCTION

A. General

Ground motions due to earthquake induces a large amount of energy to structures and thus make them more susceptible to sudden damage. The design of structures to reduce vibrations due to earthquakes has been a major concern of engineers for many years. Also the behavior of a building during earthquake depends critically on its overall shape, size and geometry in addition to how the earthquake forces are shaking the ground. Hence at the planning stage itself, architects and structural engineers must work together to ensure that the unfavorable features are avoided and a good building configuration is chosen. Nowadays most of the structures are involved with architectural importance and hence it is impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under dynamic loads. Conventional methods of seismic design rely on ductile behavior of structural members for energy dissipation. But retrofitting of structures is difficult in certain cases. In order to overcome this drawback, the current design practices use some special damping systems to reduce the response of the structure. Besides reducing damage, these methods have been successful in increasing safety of the structure. There are mainly three types of protective systems such as passive, active and semi active control systems [1]. The basic function of the passive devices is to absorb a part of input energy, reducing energy dissipation on structural members and minimizing the damage on structures. Several different types of energy dissipation systems such as Viscous dampers, Visco-elastic dampers, Friction dampers, and Yielding metallic dampers etc were used. This study aims to enhance the seismic response of symmetrical rectangular shaped building and L shaped building by using various orientations of diagonally braced viscous damper.

B. Viscous damper

Fluid viscous damper is one type of passive energy dissipation systems that is used in the absorption and dissipation of the earthquake input energy.

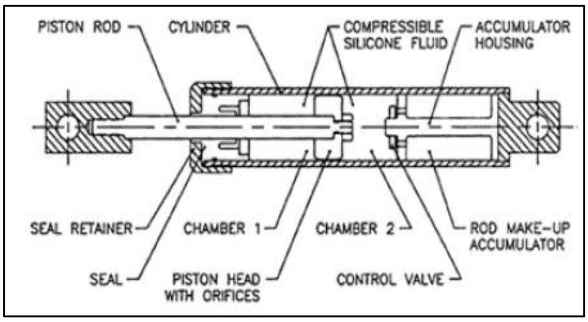

Fig. 1. Components of Viscous damper [2]

Viscous dampers are made up of a cylinder and a stainless-steel piston [2].The cylinder is filled with incompressible silicone fluid that is divided into two compartments by a piston. The damper is activated by the stream of silicone fluid between the chambers at the opposite ends of the unit through small orifices. When the fluid viscous damper strokes in compression, fluid flows from chamber 2 to 1. When the fluid viscous damper strokes in tension, fluid flows from one chamber to another. The high pressure drop across the annular orifice produces a pressure differential across the piston head, which creates the damping force. Fluid viscous dampers have the unique ability to simultaneously reduce both stress and deflection within a structure subjected to a ground motion. This is because a fluid viscous damper varies its force only with velocity, which provides a response that is inherently out of phase with stresses due to flexing of the structure [4]. The addition of fluid viscous dampers to a structure can provide damping as high as 30% of critical, and sometimes even more. This provides a significant decrease in earthquake excitation [4]. The addition of fluid dampers to a structure can reduce horizontal floor accelerations and lateral deformations by 50%.

II. OBJECTIVES

The main objectives of this study are:

- To study the effect of diagonally braced viscous damper on symmetric rectangular and L shaped buildings
- To find the optimum number and location of viscous damper in these buildings

III. METHODOLOGY

A. Modelling

(a) Structure: The structure considered for the study was an G+8 storey hospital building with tower room at roof level. The plan area of the building is 24m x12m. All beams along longitudinal and transverse direction are assigned with geometrical properties of 0.23m x 0.5m. All sub beams are assigned with a property of 0.23m x 0.4m and the slab thickness was taken as 0.12m. All columns are of 0.3m x 0.6m dimension and the typical floor height was taken as 3m. The RCC frame was analyzed on the basis of IS 456 -2000. From IS 1893 (PART I) 2016, the response spectrum of medium soil condition was considered. The building was modeled by using SAP2000 by assigning its geometric properties. Live load was calculated as per IS 875 Part I and Part II.

(b) Viscous damper: Dampers are represented by an exponential Maxwell Damper model. Nlink was the element used for modelling damper in SAP2000. Viscous damper is a velocity dependent device in which the force in the damper is directly proportional to velocity [6].

$$F = Cv^{\alpha} \tag{1}$$

Where F is the damping force, C is the damping coefficient, v is the velocity of the piston and α is the damping exponent. For nonlinear damper α was taken as 0.7.

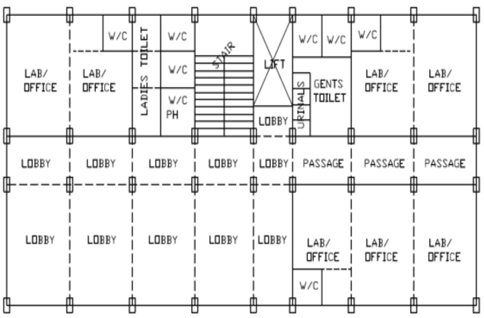

Fig. 2. Typical floor plan

TABLE I. DESIGNATIONS AND NOTATIONS USED

Designations	Notations
Longer face	X
Shorter face	Y
Alternate bays	1
Alternate floors	2
Diagonally braced damper	D

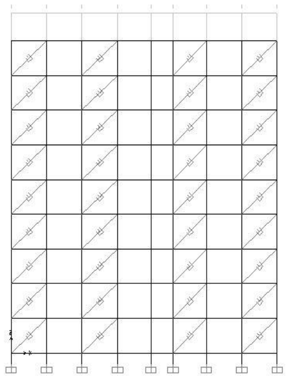

Fig. 3. DX1 configuration

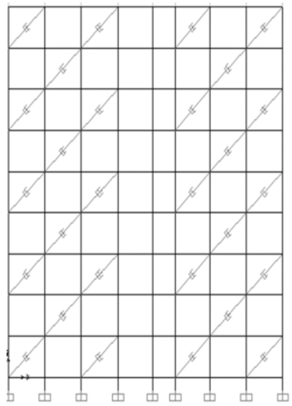

Fig. 4. DX2 configuration

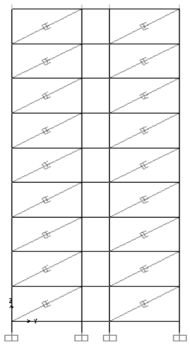

Fig. 5. DY1 configuration

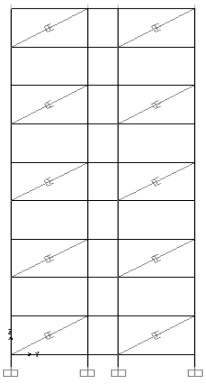

Fig. 6. DY2 configuration

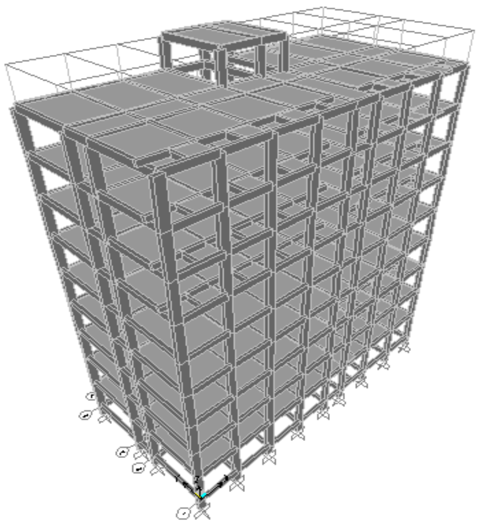

Fig. 7. Rectangular shaped building

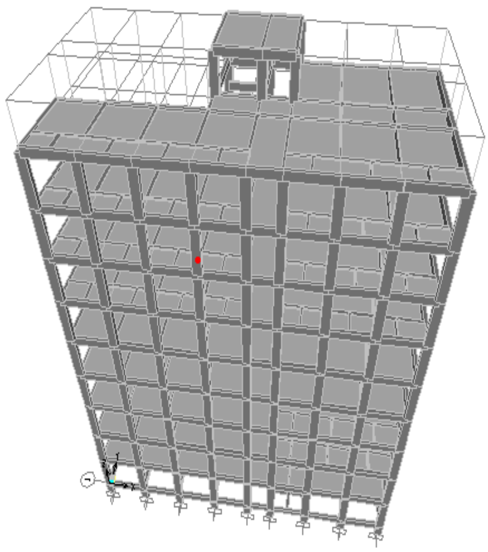

Fig. 8. L shaped building

B. Validation

Modeled structure is validated by using the base shear value. Base shear value of regular building is calculated theoretically by using Equivalent lateral force method on the basis of IS 1893 PART I 2016 code provisions and analytically by using non-linear time history analysis method.

C. Modal analysis

Modal analysis was carried out to study the variation in natural frequency and natural period for each mode in a system. It is used to understand the vibration modes of a structure and was carried out by means of Eigen value method according to IS 1893 (Part 1) 2016.

D. Nonlinear time history analysis

Nonlinear time history analysis (NL-TH) is considered for the study. SAP 2000 uses Hilber Hughes Taylor method for NL-THA. Iteration procedure used for NL-TH is double integration method. For analysis, the building will be subjected to El Centro earthquake. Damping coefficient (C) is calculated for each damper [6].

$$C=2\xi m\omega \tag{2}$$

Where ξ is the damping ratio which is taken as 5%, m is the lumped mass on each floor, ω is the fundamental frequency of the structure.

IV. RESULTS AND DISCUSSIONS

Base shear and maximum roof top displacement were calculated by using nonlinear time history analysis and the obtained results were compared with results of buildings with and without damper. Fundamental natural frequency of rectangular shaped building without damper is 5.78 rad/sec ,L shaped building is obtained as 5.32 rad/sec.

TABLE II. TIME PERIOD VALUES

Model	Time period values (Sec)				
	Without damper	With damper			
		DX1	DX2	DY1	DY2
Rectangular	1.086	0.692	0.919	0.944	0.985
L shape	1.181	0.668	1.054	0.952	1.103

From the above table it has been observed that, when dampers are arranged in longer faces time period value gets reduced. When dampers are arranged in alternate bays on longer faces the time period gets reduced. Hence the flexibility of the structure also gets reduced.

TABLE III. BASE SHEAR VALUES

Model	Base shear values (kN)				
	Without damper	With damper			
		DX1	DX2	DY1	DY2
Rectangular	1576.95	961.48	1083.93	1555.72	1557.9
L shape	1382.08	788.50	820.24	1357.88	1379.13

Table III shows the variation of base shear values in rectangular and L shaped building. It has been observed that building with dampers arranged in alternative bays on longer faces shows less base shear value.

TABLE IV. ROOF TOP DISPLACEMENT VALUES

Model	Roof top displacement values m)				
	Without damper	With damper			
		DX1	DX2	DY1	DY2
Rectangular	0.0168	0.0095	0.0110	0.0162	0.0166
L shape	0.0225	0.0116	0.0127	0.0196	0.0205

Table III shows the variation of roof top displacement when dampers are arranged in different configuration. DX1 arrangement shows reduction in roof top displacement in case of rectangular and L shaped building.

V. CONCLUSIONS

From the results obtained from the nonlinear time history analysis it has been observed that when viscous dampers are arranged in longer sides the base shear value and roof top displacement values decreases.

- Dampers arranged in longer faces shows better performance in case of irregular shaped buildings
- Dampers arranged in alternate bays gives better seismic response in rectangular and L shaped building
- DX1 arrangement shows better seismic performance in terms of lateral displacement in case of L and rectangular shaped building
- DX1 arrangement shows 40% reduction in base shear in case of rectangular building and 43% reduction in case of L shaped building
- DX1 gives 48% reduction in lateral displacement in case of regular and L shaped building

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