Comparison between seismic performance of G+5 building with and without Fluid Viscous Dampers

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Abstract

Earthquake causes numerous loss of lives and damage to property. On 18 September 2011, Sikkim also experienced a major earthquake of magnitude 6.9 resulting in large-scale destruction. Therefore, as an attempt to prevent such scenarios, there are various techniques available to manage this problem one of which is by using dampers on building structures. The main objective of this study is to compare the seismic performance of G+5 building with and without dampers. The modelling and analysis in this study are done using “ETABs” software for G+5 story building as the maximum no. of floors allowed in Sikkim is six. The proposed model showed a drastic reduction in the displacement of the building using FVDs.

Keywords: Earthquake; Seismic Response; FVDs; Response spectrum analysis; ETABs

1. Introduction

Earthquake is a natural phenomenon which leads to numerous losses of lives and properties [1] [15]. The energy which is released from the ground shaking gets transferred to the structure and causes failure of the structure [15]. There are various studies over the past decades for disaster management for seismic response [1]. The structures can be made earthquake-resistant to minimize the damage [1]. One of the methods for building earthquake-resistant structures is by using dampers as it reduces the vibrations caused by the earthquake [1] [2] [3]. Using “Fluid viscous dampers (FVDs)” with other damping devices and isolators is often used for building structures that can minimize the seismic demand [11]. Hence the “Fluid Viscous Damper (FVD)” [1] [2] is used in this study to compare the seismic behavior of G+5 building. The analysis is carried out by the “Response spectrum” method using ETABs software [1]. The plan dimensions of the building are 20m×20m with each storey height of 3m. The main objective of this study is to compare the seismic behavior of the G+5 building with and without FVD in seismic zone IV.

1.1. FVD’S

FVD is a device that can minimize structural damage by absorbing the energy released from ground shaking due to earthquakes [1]. They dissipate the energy via orifices generating a force that reduces the earthquake force [1][16]. The damping force of an FVD is represented as [1] [3] [4].

\[ F = C.V^\alpha \quad \ldots \ldots \quad (i) \]

Where, ‘F’ is the Damping force in kN, ‘C’ is the Damping Coefficient in kNm/s, ‘V’ is the Relative Velocity in m/s and ‘\alpha’ is the Velocity Exponent.
2. Related study

The recent studies on the disaster management system that uses the FVD for building an earthquake-resistant structure are as follows- Shayza et al. [1] according to this paper damping can help in designing an earthquake-resistant building. Fluid viscous dampers (FVD) is a device used to dissipate energy caused during an earthquake that can operate between −40 to +70 °C [1]. In this paper, response spectrum analysis is done using the “ETABS software”, “IS 456-2000” [5] and “IS 875-1987” [6] for load combinations and “IS 1893-2002” [7] for earthquake loads [1]. This study uses “250 kN force and 44 kg weight” for FVDs link as per “standard dimensions by the Taylor Devices” [4] [1]. The modelling of the building is carried out in seismic zones IV and V [1]. This study states that “the purposed model with FVDs was able to reduce displacements up to 90% compared to a model without using the FVDs” [1]. Bisht et al, [2] this study analyses the seismic behaviour with and without viscous dampers on a soft-story building. Palermo et al, [8] this study uses the “fluid viscous dampers” for dynamic analysis of a multi-story frame building. Ahiwale et al, [9] this study used “fluid viscous dampers” in G+30 Steel building for reducing seismic response by using ETABs software, and time history analysis is used for analysing the building. The proposed study states that the displacement of the building decreases when “fluid viscous dampers” are used [9]. De et al, [14] in this study, “fluid viscous dampers” are used for designing earthquake-resistant buildings to reduce the displacements and floor accelerations of the buildings. According to this study, compared to buildings without FVDs, the proposed model was able to reduce displacements up to 50% and floor accelerations up to 80 % [14]. Del et al, [13] in this study, “fluid viscous dampers” are used on retrofit building for improving seismic response. According to this study, “the proposed model was able to minimize the structural damage ultimately leading to low repair costs” [13]. Fang et al, [10] this study used “fluid viscous dampers” for reducing the displacement and torsional effects of the structures during an earthquake. The analysis is done using SAP2000 [10]. Wang et al, [12] this study used “fluid viscous dampers” in an existing 35 story steel frame building to enhance the seismic behaviour of buildings.

3. Methodology

In this study, the modelling and analysis are done using the software ETABs [1]. For design purposes, “IS 456-2000” [5] and “IS 875:1987 (Part 3)” [6] are used and for the earthquake loads “IS 1893:2002 (Part 1)” [7] is used [1]. For FVDs link this study uses 500 kN force with 98 kg weight as per standard dimensions given by the “Taylor Devices” [1] [4].

3.1. Building model details

The building structure for this study is taken as a G+5 storey as the maximum no. of floors allowed in Sikkim is six. The dimension of 20m×20m is considered with each story height of 3m resulting in the overall elevation of the building as 18m. The total number of columns in each storey is 36 with both x and y direction having six columns, with 4m distance between each column. The columns are considered with the dimension of 400mm × 400mm and beams with 250mm × 400mm and the thickness of the slab is taken as 150mm. The material used for columns is M25 grade concrete [5], and for slab and beam, M20 grade concrete [5] is considered. The materials considered for rebar are HYSD500 and HYSD415 [5] for longitudinal bar and confinement bar respectively. For this study, the dead load is taken as 1 kN/m², live load as 2 kN/m² and wall load is considered as 5.25 kN/m on each beam.

3.2. Response Spectrum Analysis (RSA)

RSA is a method used for statical analyses that are used to measures seismic response [1] [17]. This analysis is done using the software “ETABs” in this study and “IS 1893:2002” [7] is used for seismic zone IV with a damping ratio of 0.5 for defining response spectrum function [17].
4. Results

The parameters considered for the analysis are maximum storey displacement, required stiffness and storey drifts according to response spectrum analysis (RS). After the analysis, the obtained results are compared between building models with and without FVDs. The obtained result is shown in Table 1 and Table 2.

| Story | Elevation (m) | Displacement (mm) | Required stiffness (kN/m) | Drift Ratio |
|-------|---------------|-------------------|---------------------------|-------------|
|       | WO FVD | W FVD | WO FVD | W FVD | WO FVD | W FVD |
| Story6| 18 | 14.621 | 9.458 | 102805.683 | 122854.014 | 0.000504 | 0.000784 |
| Story5| 15 | 13.372 | 7.11 | 108548.18 | 87012.822 | 0.000758 | 0.000771 |
| Story4| 12 | 11.367 | 4.801 | 106486.055 | 96892.82 | 0.000959 | 0.000705 |
| Story3| 9 | 8.666 | 2.689 | 107538.5 | 95443.615 | 0.001106 | 0.000564 |
| Story2| 6 | 5.418 | 0.997 | 119729.905 | 129346.39 | 0.001132 | 0.000332 |
| Story1| 3 | 2.035 | 0 | 216545.925 | 0 | 0.000678 | 0 |
| Base | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 2. Reduction in Displacement using FVD.

| Story | Without FVD | With FVD | Reduction in (%) |
|-------|-------------|----------|------------------|
|       | Displacement (mm) | Displacement (mm) |          |
| Story6| 14.621 | 9.458 | 64.68777785 |
| Story5| 13.372 | 7.11 | 53.17080467 |
| Story4| 11.367 | 4.801 | 42.23629806 |
| Story3| 8.666 | 2.689 | 31.02930995 |
| Story2| 5.418 | 0.997 | 18.40162422 |

According to this study, the model with FVDs can minimize the displacement by about 64 %, 53%, 42%, 31%, and 18% in Story6, Story5, Story4, Story3, and Story2 respectively compared to the model without FVDs. The obtained results may vary in a different system with different parameters as the study is using some parameters based on an assumption like wall load.
Fig 1: Displacement according to Response spectrum analysis (RS).

Fig 2: Required Stiffness according to Response spectrum analysis (RS).
Fig 1, Fig 2, and Fig 3 represent the Displacement, Required stiffness, and Storey Drift Ratio according to Response spectrum analysis (RS) respectively.

5. Conclusion

Earthquake is a natural phenomenon that causes numerous losses of lives and damage to property. Various techniques are available to manage this problem one of which is using “Fluid viscous dampers (FVDs)” with other damping devices and isolators that can minimize the seismic demand. The main objective of this study is to analyse the seismic performance of buildings with and without “Fluid Viscous Dampers (FVDs)” using the response spectrum analysis method. This study used “ETABs” software for modelling G+5 story building and analysing. The proposed model in this study was able to minimize the displacement by about 64%, 53%, 42%, 31%, and 18% in story6, Story5, Story4, Story3, and Story2 respectively compared to the model without FVDs.

Future work Unsymmetrical building can be considered for the analysis. Also, the position of the dampers can be changed accordingly with different parameters of the damper.

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