Analysis and Design of Multi-Storey Buildings with Dampers for Improved Earthquake Resistance

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Abstract — The project investigates advanced seismic protection for medium-rise structures, specifically a G+5 Reinforced Concrete (RC) building, situated in high-risk zones such as Seismic Zone IV of the Indian Standard IS 1893. Traditional seismic design methods, which increase stiffness and strength, often lead to heavier members, higher costs, and increased seismic forces. This research focuses on utilizing Fluid Viscous Dampers (FVDs), a passive energy dissipation technology, to enhance seismic resilience. These dampers convert earthquake-induced kinetic energy into heat, providing substantial supplemental damping. The study employs the software ETABS to create a detailed analytical model, performing comparative analysis of the building's seismic performance with and without viscous dampers under design-level earthquake loads. Key engineering demand parameters (EDPs) such as inter-storey drift, base shear, storey displacement, and energy dissipation will be evaluated. The research aims to quantify the reduction in structural demands and establish a practical methodology for integrating dampers into medium-rise buildings in high-seismic region.

Keywords: Fluid Viscous Dampers, Seismic Performance, Reinforced Concrete Buildings, Passive Energy Dissipation, Inter-Storey Drift, Seismic Zone IV

I. INTRODUCTION

A. Earthquake Hazard and Limitation of Conventional Seismic Design

Earthquakes remain one of the most unpredictable and destructive natural hazards, capable of causing widespread damage to the built environment. In regions classified under Seismic Zone IV of the Indian Standard IS 1893, the expected ground shaking is severe, and structures are subjected to high levels of dynamic loading. Buildings in these regions require careful engineering consideration to ensure that they not only prevent collapse but also maintain adequate performance during and after earthquake events. This has led to growing interest in advanced seismic protection systems that go beyond conventional design approaches.

A G+5 reinforced concrete (RC) building is considered a medium-rise structure with flexible dynamic characteristics. During strong ground motions, such buildings tend to sway significantly, resulting in large inter-storey drifts, structural cracking, damage to infill walls, and in extreme cases, failure at critical weak points. Traditional seismic design involves increasing the strength and stiffness of structural members; however, this method often leads to heavier sections, increased project cost, and larger seismic forces due to added mass. Additionally, stiffness-based design alone is often insufficient to control dynamic responses such as drift and accelerations.

B. Passive Damper Systems (VISCOUS DAMPER)

To enhance seismic resilience without excessively increasing weight and stiffness, modern structural engineering focuses on energy dissipation technologies. Passive damper systems are crucial structural control devices that operate without external power to mitigate the dynamic response of buildings subjected to seismic events. They are integral to advanced seismic protection systems that seek to overcome the limitations of traditional design methods.

Among these, viscous dampers have emerged as one of the most effective passive energy dissipation devices. These dampers operate by converting kinetic energy induced during earthquakes into heat through fluid movement inside a cylinder. The force generated by a viscous damper is directly related to the relative velocity between floors, enabling the device to quickly counteract sudden movements and reduce overall vibration.

Viscous dampers offer numerous advantages:

1) They significantly reduce peak structural responses such as roof displacement, storey drift, and base shear.
2) They improve occupant comfort by minimizing floor accelerations.
3) They help protect non-structural components, which are often more vulnerable than structural frames.
4) They require no external power, have high reliability, and demand minimal maintenance.

These qualities make viscous dampers particularly beneficial for medium-rise buildings like the G+5 RC structure considered in this study, especially in high-risk seismic zones.

C. Analytical Methodology and Scope of Evaluation

Accurate assessment of damper performance requires advanced analytical tools capable of capturing both structural dynamics and damper behaviour. ETABS, developed by CSI, provides a comprehensive platform for modelling, analyzing, and designing multi-storey buildings subjected to dynamic loads. It features specialized non-linear link elements for simulating viscous damper properties, enabling engineers to incorporate velocity-dependent damping forces directly into the analysis model. ETABS also supports various seismic analysis procedures, including response spectrum analysis and time-history analysis, which are essential for evaluating the real behaviour of buildings equipped with dampers.

In this study, ETABS is utilized to develop a detailed analytical model of a G+5 RC framed building located in Seismic Zone IV, both with and without viscous dampers. By comparing the seismic performance under design-level earthquake loads, the research aims to quantify the improvements provided by supplemental damping. Key parameters such as inter-storey drift, base shear, storey displacement, modal characteristics, and energy dissipation are thoroughly evaluated.

The introduction of viscous dampers is expected to significantly enhance the seismic performance of the building by reducing demand on structural members and improving overall stability. This study not only demonstrates the effectiveness of dampers but also provides a practical methodology for incorporating them in medium-rise buildings located in high-seismic regions. The outcomes of this research can serve as a valuable reference for engineers, designers, and researchers aiming to adopt modern seismic protection systems in building design.

D. Optimisation Of Dampers

Optimization of viscous dampers involves identifying the most effective number of dampers, their optimal locations, and the ideal mechanical properties such as damping coefficient (C) and velocity exponent (α) to achieve maximum reduction in seismic response with minimum cost. The goal is to enhance performance while ensuring that the structure remains economical, practical to construct, and free from torsional irregularities. Optimized dampers help achieve better control of storey drifts, uniform distribution of seismic forces, and improved energy dissipation throughout the building height.

To evaluate the optimized performance of the damped structure, Time History Analysis (THA) is employed in this study. THA provides a detailed, time-dependent assessment of how the building responds to real or synthetic earthquake ground motions. This method is particularly suited for damping devices because it accurately captures the nonlinear and velocity-dependent behaviour of viscous dampers. By applying dynamic ground motion records, the seismic performance of the G+5 RC building is analysed both with and without optimized dampers, enabling a clear comparison of the reduction in displacement, drift, base shear, and energy dissipation.

II. LITERATURE REVIEW

The application of Fluid Viscous Dampers (FVDs) as a passive energy dissipation system has been extensively studied and validated across the globe as an advanced seismic mitigation strategy. The literature strongly supports the use of FVDs to enhance the seismic performance of buildings by providing supplementary damping, thereby protecting the primary structural members from damage. This review summarizes key findings related to the principles, performance, modeling, and optimal design of FVDs, with a focus on structural analysis using software like ETABS.

A. "Analysis of efficiency of passive dampers in multistorey buildings",

Ersin Aydin, Baki Oztruck, Maciej Dutkiewicz, 11 September 2018:

The usage of the passive energy dissipative system is increasing nowadays in the high seismic risk zones, particularly in the important buildings. In this report, the effectiveness of the nonlinear fluid viscous dampers (FVDs) in the seismic performance enhancement of RC buildings is analysed in this study. This research compares the engineering response parameters such as total displacement, drift ratio, residual displacement and the floor acceleration between bare frame only model and the same with the addition of nonlinear fluid viscous dampers for Design Basis Earthquake (DBE) and Maximum Considered Earthquake (MCE). The study is done in three categories of regular buildings from the perspective of Nepalese cities; five-storeyed, ten-storeyed and fifteen-storeyed buildings as this covers the typical high-rise buildings in Nepal. The building is modelled in the 3-D finite element analysis software SAP2000 developed by Computers and Structures Inc. The results show that nonlinear fluid viscous dampers are highly effective in reducing the storey displacement, drift and residual displacement whereas less effective in reducing floor acceleration as compared to the others and the efficacy of the dampers reduces with increasing building height.

B. "Mitigating the seismic pounding of multi-story buildings in series using linear and nonlinear fluid viscous dampers" Hytham Elwardany1 · Robert Jankowski · Ayman Seleemah, 15 May 2021:

Seismic-induced pounding between adjacent buildings may have serious consequences, ranging from minor damage up to total collapse. Therefore, researchers try to mitigate the pounding problem using different methods, such as coupling the adjacent buildings with stiff beams, connecting them using viscoelastic links, and installing damping devices in each building individually. In the current paper, the effect of using linear and nonlinear fluid viscous dampers to mitigate the mutual pounding between a series of structures is investigated. Nonlinear finite-element analysis of a series of adjacent steel buildings equipped with damping devices was conducted. Contact surfaces with both contactor and target were used to model the mutual pounding. The results indicate that the use of linear or nonlinear dampers leads to the significant reduction in the response of adjacent buildings in series. Moreover, the substantial improvement of the performance of buildings has been observed for almost all stories. From the design point of view, it is concluded that dampers implemented in adjacent buildings should be designed to resist maximum force of 6.20 or 1.90 times the design independent force in the case of using linear or nonlinear fluid viscous dampers, respectively. Also, designers should pay attention to the design of the structural elements surrounding dampers, because considerable forces due to pounding may occur in the dampers at the maximum displaced position of the structure.

C. "Seismic mitigation performance of structures with viscous dampers under near-fault pulse-type earthquakes",

Gaoxing Hua, Yanan Wangb, Wei Huanga, Bin Lic, Bin Luod,30 October 2019 :

This study is aimed at clarifying the seismic mitigation performance of structures with fluid viscous dampers (FVDs) as a function of the characteristics of the near-fault pulse-type (NP) ground motion and the structural dynamic properties. For this purpose, the response spectra and energy response of single-degree-of-freedom (SDOF) structures with FVDs subjected to 20 NP ground motions with different pulse periods T_p are discussed. The seismic response and energy dissipation distribution of multi-degree-of-freedom (MDOF) structures with FVDs are also investigated and compared with those of SDOF structures. The results revealed that although the presence of FVDs produces significant improvements in the seismic response of the structures, the structure may still experience large plastic deformation, which always occurs when T/Tp is less than ‘1’ and $T1/Tp$ is greater than ‘1’, T and $T1$ being pre-earthquake and post-earthquake structural periods. For short period structures (multi-storey) with FVDs, the plastic deformation can be further slightly reduced by making T/Tp and $T1/Tp$ less than ‘1’ at the same time, so that the structure can be basically kept within the elastic range. However, the intermediate and long period structures (mid-rise and high-rise) with FVDs are more likely to experience large plastic deformation when T/Tp is less than ‘1’, and the floor shear forces may be slightly reduced or even obviously amplified. Furthermore, the current research findings on SDOF structures with FVDs may not be extended directly to MDOF structures with FVDs due to the more complex dynamic properties of MDOF structures.

D. “Seismic performance of building structures based on improved viscous damper seismic design”

Yingfei Guo, Sen Wang, Shuyuan Zhang,6th June 2024:
Earthquakes have serious destructive effects on building structures, and effective seismic design is the key to building design. In order to reduce the damage of earthquakes to building structures, seismic design of buildings is based on improved viscous dampers. First, the displacement seismic design was studied and a displacement-based structural seismic model was constructed. In addition, analyzing traditional viscous dampers, an improved viscous damper is adopted based on it. Through equivalent damping expression, a displacement seismic model based on the improved viscous damper is constructed. Finally, two targets, frequent and rare earthquakes, were selected for experimental analysis. In frequent earthquake experiments, the improved viscous damper structure increased the shock absorption rate by 35.65 % compared to the no-structure design. In the shear force comparison, the maximum shear force of the improved viscous damper structure in the HB wave X direction is 2186 KN, which is the smallest shear force among the three structural designs. In a rare earthquake experiment, the maximum value of the floor shear force in the X-direction of the Humbolt Bay wave of the proposed improved viscous damper structure was 8696 KN. Compared with other structures, the floor shear force was the smallest. In the comparison of floor displacements, the maximum inter-story displacement in the Humbolt Bay wave Y-direction of the proposed improved viscous damper structure is 162 mm, which is the smallest inter-story displacement compared with other structures. In addition, the structure apex displacement was also compared. The structure apex displacement value of the improved viscous damper structure was lower than that of other structures and was in the slight damage range. The overall seismic effect was significantly better than other structural designs.

The research content is conducive to optimizing the application effect of viscous dampers and provides technical reference for the seismic design of building structures.

E. “The efficiency of fluid viscous dampers (FVDs) in enhancing a low-rise Construction Domestic Reinforced-concrete Building's Seismic Performance”

Ahosan Habib, Abdul Salam, Md. Farid Hasan, Syed Ali Haider, Sakibul Hasan, IMM Seraj Haque,11 November 2024:
This study investigate the efficiency of fluid viscous dampers (FVDs) in enhancing a low-rise construction domestic reinforced-concrete building's seismic performance. The research, conducted in Bangladesh (June 2023 to June 2024), sought to understand the operation, design specifications, and effectiveness of FVDs for mitigating seismic activity.

The study used a real-world example of a building retrofit project and used E-Tabs software to create a detailed 3D FEA model of a 10-story structure. The study aimed to assess the ways in which fluid viscous damping systems can improve a structure's seismic resilience, potentially leading to more efficient building techniques in seismically active areas.

Fluid Viscous Dampers (FVDs) are considered highly effective and reliable, as they generate a damping force proportional to the velocity, leading to significant reductions in displacement and inter-storey drift. Optimal placement is key, with methods like the Modal Strain Energy (MSE) method often employed. FVDs are a practical choice for both new and existing structures due to their low cost, ease of installation, and minimal need for structural modification.

F. “High-performance computer-aided optimization of viscous dampers for improving the seismic performance of a tall building”

Shanshan Wang, Stephen A. Mahin ,9th June 2018:
Fluid Viscous Dampers (FVDs) are effective for improving the seismic performance of both new and existing buildings. However, engineering design for these dampers often relies on a laborious and repetitive trial-and-error process. This paper proposes a more formal and automated approach to optimization design by leveraging modern software for nonlinear dynamic analysis, the Performance Based Earthquake Engineering (PBEE) framework, workflow management, and the computational power of high-performance, parallel processing computers.
Optimization strategies fall into two main categories:

1) Direct Optimization: Using algorithms (e.g., Genetic Algorithms, Simulated Annealing) to search for the best damper properties directly.
2) Indirect Optimization: Calculating optimal supplemental damping based on modal properties and then determining the required damper properties.

III. RESEARCH GAP FROM LITERATURE

The literature review confirms the significant advantages and proven effectiveness of Fluid Viscous Dampers (FVDs) in mitigating seismic response parameters like story drift, displacement, and base shear across various building types and seismic scenarios.

However, a review of the current research highlights several areas that require further investigation, forming the basis of the research gap for this project:

A. Advanced Optimization Methodology for Nonlinear Dampers

While the necessity of optimal design and placement is acknowledged, and a methodology for linear FVDs exists, a consistent and easily implemented optimization methodology for nonlinear viscous dampers ($\alpha < 1$) is still lacking.

– The Gap: There is a need for a clear, performance-based design procedure that provides the optimum distribution of the damping coefficient (C) and the velocity exponent (α) for nonlinear FVDs across different stories in high-rise buildings. This procedure should be easily adaptable to structural analysis software like ETABS for diverse building typologies and seismic zones.
– The Focus: Current studies often use fixed or predetermined damper properties. The practical challenge lies in developing a routine or algorithm that systematically optimizes these two nonlinear parameters simultaneously to achieve target performance levels (e.g., drift ratio reduction) with minimal damper cost/size.

B. Insufficient cost–benefit and lifecycle performance evaluation for mid-rise buildings

A few studies consider repair-cost optimization (e.g., minimizing total damping coefficient or life-cycle losses), but these analyses are performed for specific structures and are not representative of typical RC residential buildings. There is a clear gap in life-cycle performance assessment that evaluates damper cost, installation complexity, maintenance, and long-term repair cost savings for mid-rise buildings. Without such data, optimal economic damping levels are difficult to recommend.

C. Inadequate studies of damper performance in closely spaced residential blocks (pounding conditions)

Urban Indian and Nepalese residential areas often feature narrow seismic gaps, making pounding a real concern. While a few numerical studies examine pounding between idealized steel frames, there is minimal research on pounding behaviour between RC residential buildings, especially when viscous dampers are used to mitigate impacts. The interaction between infill walls, nonstructural elements, and dampers during pounding in structure configurations remains largely unexplored.

D. Integrated Validation of Nonlinear FVDs Under Regional Seismic Hazard

– Established Gap: The nonlinearity of FVDs and the critical nature of near-fault ground motions are known.
– The Missing Link: There is a gap in studies that integrate the following three specific elements simultaneously for a typical residential building in a defined hazard area (e.g., Earthquake Zone 4 /5):
    1) Design based on the specific Regional Response Spectrum (e.g., IS 1893).
    2) Accurate modeling of the nonlinear FVD link element (e.g., in ETABS).
    3) Validation using Nonlinear Time History Analysis (NLTHA) with records scaled to Zone 4/5 intensity that also possess relevant near-fault pulse characteristics.

IV. OBJECTIVES

The primary objective of this project is to evaluate and enhance the seismic performance of a G+5 Reinforced Concrete (RC) multi-storey building using Fluid Viscous Dampers (FVDs) as a supplemental energy dissipation system. The following specific objectives have been formulated to achieve the overall aim of the study:

A. To develop a detailed analytical model of a G+5 RC building using ETABS

This objective focuses on creating an accurate structural model of the selected building, incorporating all relevant structural elements such as beams, columns, slabs, and load-bearing components. The modelling is performed in accordance with the seismic design requirements specified by the Indian Standard IS 1893 for structures located in Seismic Zone IV. The intent is to establish a realistic baseline model that reflects the actual behaviour of the structure under dynamic loading.

B. To perform seismic analysis of the building with and without dampers

The purpose of this objective is to conduct a comprehensive seismic analysis using Time History Analysis (THA). The comparison between undamped and damped models will help determine the degree of improvement achieved by incorporating viscous dampers. This analysis also allows identification of changes in building behaviour due to added damping mechanisms.

C. To evaluate structural response parameters under seismic loading

This objective involves assessing key seismic performance indicators that govern structural safety and serviceability. These include:

– Storey displacement
– Inter-storey drift ratio
– Storey shear and base shear
– Modal properties such as natural period and mode shapes
– Energy dissipation capacity

By evaluating these parameters, the project aims to quantitatively assess the impact of dampers on the seismic resilience of the structure.

D. To determine the effectiveness of viscous dampers in enhancing seismic performance

The objective here is to identify the extent to which FVDs can reduce earthquake-induced forces, drifts, and overall structural deformation. This includes evaluating improvements in occupant comfort, reduction of non-structural damage, and enhanced structural stability. The comparative results from analyses with and without dampers will help validate the practical benefits of FVDs in medium-rise RC structures.

V. METHODOLOGY

A. Analysis Of Building

This is a G+5 Residential Building. With the given plan, the work started with the grid numbering, identifying the columns and other structural parameters and the beam, column layout is provided with the help of which different slabs were identified as one way, and two- way.

1) *Project Details – Residential Building*

- Property Type: Residential Building
- Location: Delhi
- No. of Stories: G+5
- Floor to Floor Height: 3.05m floor height

B. *Method Of Analysis In Etabs*

1) *Modelling Approach*

a) Structural Modelling

- A full three-dimensional RC building model was created using ETABS.
- Structural components such as beams, columns, slabs, and shear walls (if applicable) were defined using appropriate section properties.
- Material properties (M25 concrete, Fe500 steel) were assigned based on IS code provisions.
- Floor diaphragms were modelled as rigid to simulate realistic in-plane action.

2) *Load Definitions*

- Dead loads and live loads were assigned as per IS 875 (Part 1&2).
- Seismic loads were defined according to IS 1893 (Part 1): Response Spectrum Method.
- Mass source was defined using self-weight + appropriate percentage of live loads.

3) *Type of Analysis Used*

ETABS allows different types of structural analysis. For this study, the THA(Time History Analysis) is performed:

Time History Analysis (THA) is a powerful dynamic analysis method used to determine the seismic response of structures under actual or synthetic ground-motion records. For this project, THA is selected to accurately evaluate the performance of a G+5 RC building equipped with Fluid Viscous Dampers (FVDs), since it captures the nonlinear, velocity-dependent behaviour of dampers more precisely than the Response Spectrum Method.

a) Purpose of Time History Analysis

The key reasons for adopting THA in this project include:

- To capture real-time dynamic behaviour of the structure under earthquake shaking.
- To accurately evaluate the nonlinear behaviour of viscous dampers.
- To study peak responses, including displacement, drift, base shear, and damper forces.
- To observe energy dissipation and the effectiveness of dampers over the duration of the earthquake.

b) Selection of Ground Motion Records

The following procedure is used for selecting appropriate ground motions:

- Earthquake records are chosen based on similarity to the seismic characteristics of IS 1893 Zone IV.
- The ground motions must match the target response spectrum of the region.
- Records are scaled so that their spectral acceleration matches the design spectrum at the fundamental period of the structure.
- Multiple (3 to 7) earthquake records are recommended for accuracy and statistical averaging.

c) Preprocessing of Ground Motion Data

Before importing into ETABS:

- The acceleration time histories are filtered to remove noise.
- Units are converted into m/s² or g according to ETABS requirements.
- Baseline correction is performed to ensure zero residual displacement.
- Time step compatibility is checked with the program's numerical integration requirements.

d) Modelling of Fluid Viscous Dampers in ETABS

For THA, nonlinear damper modelling is crucial. Dampers are defined using:

- Nonlinear Link Element – Damper (Viscous)
- Force–velocity relationship:

$$F = C \cdot v^{\alpha}$$

- Parameters assigned:
  - Damping coefficient (C)
  - Velocity exponent (α) (typically 0.1 to 1.0)
  - Max/min deformation limits
  - Orientation (global X/Y) depending on frame direction

The link element ensures correct force development during rapid velocity input from the earthquake ground motion.

e) Time History Load Case Setup

In ETABS, Time History load cases are defined with the following settings:

1) Analysis Type
   - Linear Time History (if dampers linear)
   - Nonlinear Direct Integration Time History (for nonlinear dampers)
2) Integration Method
   Common options:
   - Hilber–Hughes–Taylor (HHT)
   - Newmark-beta method

   These ensure numerical stability during nonlinear dynamic analysis.
3) Damping
   - Material (Rayleigh) damping is assigned for structural elements.
   - Additional damping is provided by dampers.
4) Scale Factors
   - Ground motions are scaled to match design-level earthquake intensities.

f) Running the Time History Analysis

Once set up:

- ETABS performs step-by-step integration of the structure's response for each time increment.
- Nonlinear force in dampers is computed at every time step based on instantaneous velocity.
- Structural deformations, accelerations, and internal forces are recorded throughout the earthquake duration.

g) Extraction of Results

From THA, the following essential results are extracted and compared:

1) Structural Response
   - Maximum storey displacement

- Inter-storey drift ratio
- Base shear
- Storey accelerations
- Time-dependent deflection curves

2) Damper Response
   - Damper force vs. time
   - Relative velocity at damper location
   - Energy dissipated by dampers (hysteresis loops)
3) Global Building Behaviour
   - Reduction in peak responses
   - Improved stability during shaking
   - Change in natural periods due to damper addition.

C. Structural System

The Project consists of proposed Wedding Hall. The Structural system consists of conventional beams & slabs. The building is designed for GROUND + 5 UPPER FLOORS + HEADROOM.

D. Material And Sectional Properties

The grade of concrete considered for all R.C. members is M25. The grade of reinforcing steel considered is Fe 500 conforming to IS 1786-2008.

The sectional properties of structural and non-structural member are as follows:

1) External Wall – 230mm thick
2) Internal Wall – 150 mm thick
3) Slab – 120 thick
4) Beam size – 230 x 450mm
5) Column Size – 230 x 450mm

E. Design Loads

Following individual load cases considered are defined and corresponding values / parameters have been considered in the modal:

1) Dead Load
2) Live Load
3) Earthquake Load

1) Dead Load

ETABS automatically calculates the self-weight of steel members and applies it as a uniform load across the member's length.

The dead load is assessed based on the occupancy classifications as per IS: 875 (Part – 1)
– 1987.

Wall load Calculations:

Wall loads per meter length:			
Internal Wall	150 mm thick Brick masonry wall 3.05 m floor to floor	Self-weight of wall including plaster (20 kN/m³ is density)	0.180 x 20.0 x (3.05-.45) = 9.36kN/m Say = 9.5 kN /m
External Wall	230 mm thick Brick masonry wall 3.05 m floor to floor	Self-weight of wall including plaster (20 kN/m³ is density)	0.260 x 20.0 x (3.05-.45) = 13.52 kN/m Say = 13.6 kN /m
Parapet Wall	150 mm thick Brick Masonry wall 1 m height	Self-weight of wall including plaster (20 kN/m³ is density)	0.180 x 20 x 1 = 3.6 kN/m Say = 4 kN /m

2) Live Load

The super-imposed load or otherwise live load will be assessed based on the occupancy classifications as per IS: 875 (Part –2) – 1987.

Rooms for general with separate storage	2.5 kN/m²
Rooms without separate storage	4 kN/m²
Business Computing machine rooms (with fixed computers or similar equipment)	3.5 kN/m²
Records/files store rooms and storage space	5 kN/m²
Bath and toilet rooms	2 kN/m²
Corridors, passage, lobbies and Staircase including fire escapes as per the floor serviced (Excluding stores) but not less then	4 kN/m²

3) Earthquake Loads

Earthquake/Seismic Loads corresponding to Zone IV of IS 1893 (Part 1): 2016 will be considered with the following parameters in ETABS. Analysis will be done using Time History Analysis method in built in ETABS program.

Seismic zone co-efficient	0.24
RF (Response Reduction Factor)	5 Special moment-resisting frame
I (Importance factor)	1.0
SS (Rock or Soil factor)	2 for soil
ST (Type of structure)	1 for RC frame building
DM (Damping Ratio)	0.05

Table 5.5.1: Seismic Parameters considered

Viscous Damping Coefficient: $\zeta = \frac{c}{c_{critical}}$

where

C = actual damping coefficient of the system

$C_{critical}$ = critical damping coefficient (the minimum value required to bring the system to rest without oscillation)

The critical damping coefficient for a single-degree-of-freedom (SDOF) system is:

$$C_{critical} = 2\sqrt{km}$$

where

k = stiffness of the system

m = mass of the system

$$\text{So,} \quad \zeta = \frac{c}{\sqrt{2km}}$$

With Viscous damper,the damping ratio is 15 – 20 %.

☐ ζ_{struct} = inherent structural damping (0.05 for RC)

☐ ζ_{target} = desired total effective damping (taking,0.20 = 20%)

Inherent damping: $\zeta_{struct} = 0.05$ (5%).
Target total damping: $\zeta_{target} = 0.20$ (20%).
Therefore $\zeta_{damper} = 0.20 - 0.05 = 0.15$(15%)

F. Load Combinations

The various loads are combined in accordance with the stipulations in IS: 875 (Part 5)-1987. Following Load combinations have been defined by combining the 'Independent Load cases' given above.

- 1.5 x [DL+LL]
- 1.2 x [DL + LL + EQx]
- 1.2 x [DL + LL + EQz]
- 1.2 x [DL + LL - EQx]
- 1.2 x [DL + LL - EQz]
- 0.9(DL) + 1.5(EQx)
- 0.9(DL) + 1.5(EQz)
- 0.9(DL) - 1.5(EQx)
- 0.9(DL) - 1.5(EQz)
- DL + LL
- DL + (LL + EQX) x 0.8
- DL + (LL – EQX) x 0.8
- DL + (LL + EQZ) x 0.8
- DL + (LL – EQZ) x 0.8
- DL + EQX
- DL – EQX
- DL + EQZ
- DL – EQZ

where,
DL = Dead Load
LL = Live Load
(EQ+X) = Earth quake in +X-direction
(EQ-X) = Earth quake in -X-direction
(EQ+Z) = Earth quake in +Z-direction
(EQ-Z) = Earth quake in -Z-direction

G. Analysis

In this project, a complete ETABS model will be generated using the defined building data. All structural components—including beams, columns, slabs, and load-bearing elements—will be assigned appropriate material and section properties based on the project specifications. Gravity loads, lateral loads, and dynamic earthquake loads will be applied to the structure in accordance with the relevant IS codes. The base of the structure will be modelled with fixed support conditions by assigning full fixity to the bottom-most joints and nodes to accurately represent the foundation restraints.

After the modelling phase, the structure will undergo dynamic analysis as per Indian Standards, including IS 456 for concrete design and IS 1893 for seismic analysis. ETABS will compute internal forces, member stresses, storey displacements, storey drifts, and base shear values. These analytical results will be used to evaluate the seismic performance of the building and to design the structural members and viscous dampers incorporated in this study.

To quantify damper effectiveness:

$$\%\ \text{reduction} = \frac{\text{undamped peak} - \text{damped peakundamped peak}}{\text{undamped peak}} \times 100$$

H. Structural design

All structural members will be designed according to the Limit State Method as specified in IS: 456-2000. The Structural system consists of conventional beams & slabs. Appropriate loads and its combinations, as per relevant clauses in Code IS 456:2000 Code IS 875 (Part- 5) 1987, for the most unfavorable effects are chosen for design.

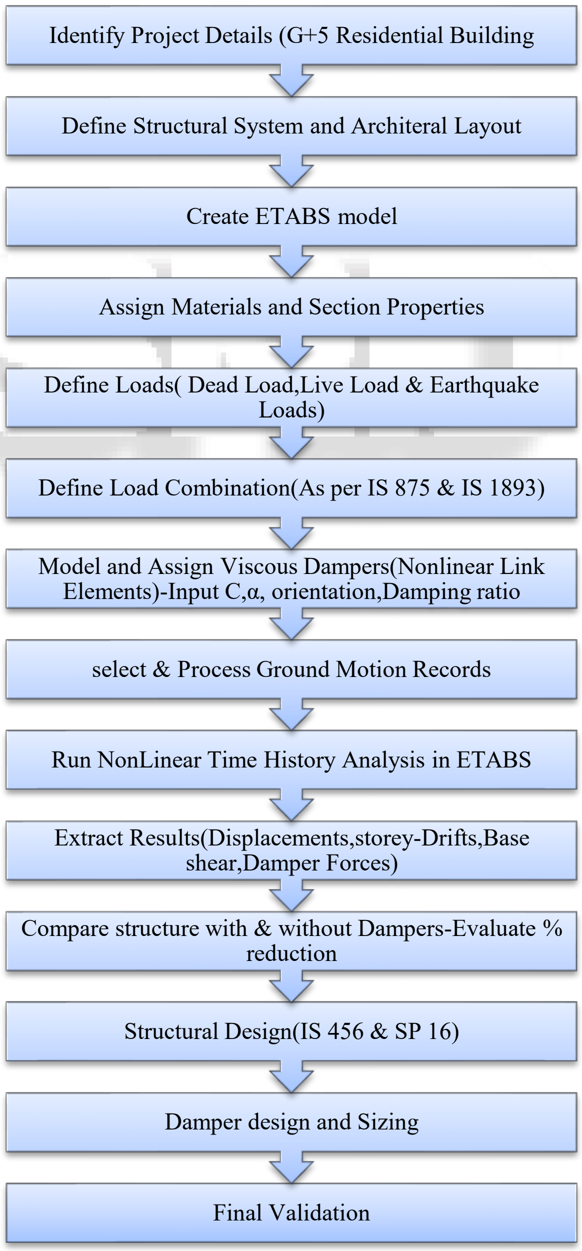
The detailed structural analysis of the building, using the finalized dimensions of the various members and as per the standards furnished in the Design Basis Report is carried out and the results are tabulated. As a preliminary requirement, the structure is checked for the stability and integrity requirements. The deflection limits under the gravity loads are first assured to be within the limits. Once the structural is conceptualized, a preliminary analysis of the building is carried to decide upon the sizes of the various structural components. For this purpose, the structure is modelled using "ETABS" software and the analysis results are to fix up the dimension of various structural elements.

1) Design and Verification of Viscous Dampers

The viscous dampers will be designed and verified as follows:

- Damper coefficient (C) will be chosen based on target damping ratio or required force–velocity response.
- Damper location and number will be optimized based on relative displacement patterns.
- THA results will be used to verify peak damper force, energy dissipation, and stroke capacity.
- Adjustments will be made to damper properties until performance objectives are met.

I. Flowchart Of the Methodology:



VI. EXPECTED OUTCOMES

The implementation of Fluid Viscous Dampers (FVDs) in a G+5 Reinforced Concrete (RC) building located in Seismic Zone-IV is expected to provide significant improvements in seismic performance. Based on the analytical approach adopted in ETABS, the following outcomes are anticipated:

A. Reduction in Storey Displacement

The building equipped with viscous dampers is expected to experience a substantial reduction in peak lateral displacements, particularly at the roof level. This reduction enhances structural stability and limits excessive sway during strong ground motion.

B. Reduction in Inter-storey Drift

Inter-storey drift ratios—one of the most critical performance indicators for seismic safety—are expected to decrease by 30–50%, helping protect structural and non-structural components such as partition walls, glazing, and architectural finishes.

C. Reduction in Base Shear

Due to increased damping and controlled dynamic response, the base shear forces induced in the structure will reduce significantly. This leads to lower demand on columns, beams, and foundations, enhancing overall safety margins.

D. Improved Energy Dissipation

FVDs provide supplemental damping of 15–20%, allowing the structure to dissipate a major portion of earthquake-induced kinetic energy. This results in reduced stress and deformation demands on primary structural members.

E. Enhanced Structural Performance in Time History Analysis

Time History Analysis is expected to show superior performance of the damped structure by demonstrating:

- Lower peak accelerations
- Reduced velocity response
- Minimal residual deformation after shaking
- More stable and controlled oscillation patterns

F. Effective Functionality of Nonlinear Dampers

The nonlinear viscous damper model ($F = C \cdot v^{\alpha}$) is expected to:

- Deliver high force output during large-velocity ground motion
- Maintain flexibility at low velocities
- Avoid adding unwanted stiffness to the building

G. Optimization Insights

The study is expected to provide practical recommendations regarding:

- Optimum damper placement
- Required damping coefficient (C)
- Suitable velocity exponent (α)
- Economic number of dampers

These findings support performance-based seismic design.

H. Contribution to Seismic Resilience

Overall, the project will demonstrate that FVDs are an effective, reliable, and economically viable method for improving seismic resilience of medium-rise residential buildings in high-risk seismic zones.

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