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Analysis of A Tall Structure Considering Opening Wall Conditions Using ETABS Varsha Ahirwar¹, Rahul Sathbhiya²

P.G. Scholar¹, Assistant Professor²

Department of Civil Engineering, Infinity Management and Engineering College Sagar, Madhya Pradesh, India

| ARTICLEINFO | ABSTRACT |
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| Article History: Accepted: 30 Sep 2023 Published: 20 Oct 2023 | Shear walls are structural systems which provide stability to structures from lateral loads like wind, seismic loads. An attempt is made to apply the finite element modelling in analyzing and exploring the behavior of shear wall with opening under seismic load actions. Shear walls are generally located at the sides of buildings or arranged in the form of core that houses |
| Publication Issue Volume 7, Issue 5 September-October-2023 Page Number 138-153 | stairs and lifts. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the shear walls appropriately. Due to functional requirements such as doors, windows, and other openings, a shear wall in a building contains many openings In this research, the main focus is to determine effectiveness of shear wall with vertical opening and staggered opening in regular and irregular buildings under earthquake loads with the help of finite element software, ETABS. using the Response Spectrum method. The comparative results showed that the time period, displacement, base shear and stress distribution around the openings depend on the arrangement of openings. Finally, the staggered arrangement of openings in shear walls is suggested to be applied in practice, since it satisfies both the architectural and the seismic requirements. Keywords : ETABS, Seismic behavior, Storey drift, Shear Wall, Staggered Openings, Seismic Loads, Finite Element Analysis and Response Spectrum Method |
| | |

I. INTRODUCTION

Shear walls are vertical structural elements for resisting the lateral loads that may be induced by the effect of wind and earthquakes. Shear wall is a structure considered to be one, whose resistance to horizontal loading is provided entirely by them. Introduction of shear walls in a building is a structurally efficient solution to stiffen the building because they provide the necessary lateral strength and stiffness to resist horizontal forces. Shear walls generally start at the foundation level and are continuous throughout the building height. They are generally provided along both length and width of



the building and are located at the sides of the buildings or arranged in the form of core. Shear walls may have one or more openings for functional reasons.

The size and location of shear walls is extremely critical. They must be symmetrically located in plan to reduce the effect of twisting in buildings. Properly designed and detailed buildings with shear walls have shown good performance in past earthquakes. Also the strong earthquakes recorded worldwide in the past have shown that the damages and certain failure mechanisms of shear walls depend on a series of factors such as, the shape in plan, dimensions of the walls and openings, reinforcement and the openings layout, site condition, type of earthquake and strain rates. Even if failure modes have been extensively researched, there are still certain failure modes which have to be investigated further. One such is the case of shear walls with staggered openings.

Irregularity of Building

Many buildings in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. In case, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. Structures experience lateral deflections under earthquake loads. Magnitude of these lateral deflections is related to many variables such as structural system, mass of the structure and mechanical properties of the structural materials. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. The current version of the IS: 1893 (part I) -2002 requires that practically all multistoried buildings be analyzed as threedimensional systems. This is due to the irregularities in plan or elevation or in both. The paper discusses the performance evaluation of RC (Reinforced Concrete) Buildings with irregularity. Structural

irregularities are important factors which decrease the seismic performance of the structures.

Types of Irregularity



Fig 1 : Vertical Irregularities

II. Objectives of the Research

- To determine the effect of vertical and staggered openings in RC shear wall in a regular building under seismic loads
- To study the behavior of vertical and staggered openings in RC shear wall in a irregular building under seismic loading
- Comparison of effect of openings in regular and irregular building

III. Review of Literature Survey

Akash Malika et.al (2023) objective of the research paper was to determine the seismic behaviour of staggered shear wall models and staggered X bracing models when subjected to historical earthquake data with the assistance of nonlinear time history analysis carried out by ETABS software.

Results stated that base shear of the structure with staggered X bracing is 37% lower than the base shear of the structure with staggered shear walls. When



compared to staggered X bracing structures, staggered shear walls have a fundamental time period that is 62% shorter. However, because the values are lower, the structure with staggered shear walls is stiffer. Therefore, the structure with the staggered X bracing can perform better than the structure with the staggered shear wall because of the higher value of time period. When compared to the staggered X bracing structure, staggered shear walls have a frequency that is 62% higher. When compared to the structure with staggered X bracing, the overall dynamic performance of the structure that has staggered shear walls is superior.

Vinodkumar S A et.al (2023) objective of the research paper was to identify the optimum location of shear wall in irregular buildings with different irregular ratios by comparing structures with shear walls at various locations like, at the edges, at the corners and at both the corner and the edges. Further the dynamic analysis was carried out by considering optimum location of shear wall and replacing it with staggered shear wall. The effectiveness of staggered shear wall was analyzed by comparing the results with the shear wall structure having regular openings considering same percentage of openings in both the models using ETABS v18 software.

Model with shear wall at edges of the structure shows 70% less displacement in regular structure and up to 50% less displacements in irregular structure models. Staggered shear wall structure shows 1.5% variation in storey displacement and 2.8% variation in storey drift ratio in comparison with the structure having no openings in the shear wall. Shear wall structure having regular openings in shear wall shows 49 % variation in storey displacements and 40 % variation in storey drift ratio in comparison with the structure having no openings in the shear wall. Hence results confirmed that staggered shear walls

are more effective than the shear walls with regular openings. Staggered shear wall performs very well under seismic activity without affecting the stiffness of the building largely.

Steps involved in Modelling and Analysis

Step 1: Research paper from different authors was summarized in this section who have focused towards analyzing multi storey high rise structures considering seismic loads with different zones and soil condition.

Step 2: In order to initiate the modelling of the case study, firstly their's need to initialize the model on the basis of defining display units on metric SI on region India as ETABS supports the building codes of different nations. The steel code was considered as per IS 800:2007 and concrete design code as per IS 456:2000.

| alization Options | | |
|----------------------------------|-------------|--------|
| Use Saved User Default Settings | | 0 |
| O Use Settings from a Model File | | 0 |
| O Use Built-in Settings With: | | |
| Display Units | Metric SI | \sim |
| Region for Default Materials | India | \sim |
| Steel Section Database | Indian | ÷ |
| Steel Design Code | IS 800:2007 | ~ |
| Concrete Design Code | IS 456:2000 | ~ |

Fig 2 Model Initialization

Step 3: ETABS provides the option of modelling the structure with an easy option of Quick Template where the grids can be defined in X, Y and Z direction. Here in this case, 7 bays in X direction and 5 bays in Y direction with a constant spacing of 3.5m in both X and Y direction making the model symmetrical in nature. G+12 storey structure is considered with typical storey height of 3.2 m and Bottom storey height of 2.5 m.



| Grid Dimensions (Plan) | | Story Dimensions | |
|-------------------------------------|----------------|---------------------------|-----------------|
| Uniform Grid Spacing | | Simple Story Data | |
| Number of Grid Lines in X Direction | 7 | Number of Stories | 13 |
| Number of Grid Lines in Y Direction | 5 | Typical Story Height | 3.2 m |
| Spacing of Grids in X Direction | 3.5 m | Bottom Story Height | 2.5 m |
| Spacing of Grids in Y Direction | 3.5 m | | |
| Specify Grid Labeling Options | Grid Labels | | |
| O Custom Grid Spacing | | O Custom Story Data | |
| Specify Data for Grid Lines | Edit Grid Data | Specify Custom Story Data | Edit Story Data |
| Add Structural Objects | | | |

Fig 3 New Model Quick Template



Fig 4 Grid Plan of the Structure

Step 4: Next step is to define the material properties of concrete and steel. Here in this case study, green concrete and rebar HYSD 550 is considered and its predefined properties are available in the ETABS application.



| enals | Click to: |
|-------------------|----------------------|
| Fe345 | Add New Material |
| HYSD415 Tendon | Add Copy of Material |
| Masonry | Modify/Show Material |
| | Delete Material |
| | ок |

Fig 5 Defining Materials

| Material Name | M30 | | |
|--|-------------------|--------------------|-----------|
| Material Type | Concrete | | ~ |
| Directional Symmetry Type | Isotropic | | |
| Material Display Color | | Change | |
| Material Notes | Modi | fy/Show Notes | |
| Material Weight and Mass | | | |
| Specify Weight Density | O Spe | ecify Mass Density | |
| Weight per Unit Volume | | 24.9926 | kN/m³ |
| Mass per Unit Volume | | 2548.538 | kg/m³ |
| lechanical Property Data | | | |
| Modulus of Elasticity, E | | 27386.13 | MPa |
| Poisson's Ratio, U | | 0.2 | |
| Coefficient of Thermal Expansion, A | | 0.000013 | 1/C |
| Shear Modulus, G | | 11410.89 | MPa |
| Design Property Data | | | |
| Modify/Show M | laterial Property | y Design Data | |
| Advanced Material Property Data | | | |
| Nonlinear Material Data | | Material Damping P | roperties |
| Time D | ependent Prop | erties | |
| Nodulus of Rupture for Cracked Deflect | ions | | |
| Program Default (Based on Cond | crete Slab Des | ign Code) | |
| User Specified | | | |

Fig 6 Defining Properties of Concrete M30.

| General Data | | | |
|--|-------------------|--------------------------|-----------|
| Material Name | HYSD550 | | |
| Material Type Rebar Directional Symmetry Type Uniaxial Material Display Color Image: Color Material Notes Modify | | ~ I | |
| | | | |
| | | dify/Show Notes | |
| | | Material Weight and Mass | |
| Specify Weight Density | ⊖ Spe | cify Mass Density | |
| Weight per Unit Volume | | 76.9729 | kN/m³ |
| Mass per Unit Volume | | 7849.047 | kg/m³ |
| Mechanical Property Data | | | |
| Modulus of Elasticity, E | | 200000 | MPa |
| Coefficient of Thermal Expansion, A | | 0.0000117 | 1/C |
| Design Property Data | | | |
| Modify/Show M | laterial Property | / Design Data | |
| Advanced Material Property Data | | | |
| Nonlinear Material Data | | Material Damping P | roperties |
| Time De | ependent Prop | erties | |
| | | | |

Fig 7 Defining Properties of Rebar HYSD 550

| Material Name | Fe345 | | |
|---------------------------------|--------------------------------|--------------------|-------------------|
| Material Type Steel | | | \sim |
| Directional Symmetry Type | Isotropic | | ~ |
| Material Display Color | | Change | |
| Material Notes | | Modify/Show Notes | |
| aterial Weight and Mass | | | |
| Specify Weight Density | O Sp | ecify Mass Density | |
| Weight per Unit Volume | | 76.9729 | kN/m ³ |
| Mass per Unit Volume | | 7849.047 | kg/m³ |
| echanical Property Data | | | |
| Modulus of Elasticity, E | | 210000 | MPa |
| Poisson's Ratio, U | | 0.3 | |
| Coefficient of Thermal Expansio | n, A | 0.0000117 | 1/C |
| Shear Modulus, G | | 80769.23 | MPa |
| esign Property Data | | | |
| Modify/Sh | ow Material Proper | ty Design Data | |
| dvanced Material Property Data | | | |
| Nonlinear Material Data | | Material Damping P | roperties |
| Tir | me Depende <mark>nt</mark> Pro | perties | |
| | | | |

Fig 8 Properties of Steel

| Property Name | SLAB GREEN | _ |
|-------------------------------|---------------------------|--------|
| Slab Material | GREEN | ~ |
| Notional Size Data | Modify/Show Notional Size | |
| Modeling Type | Shell-Thin | ~ |
| Modifiers (Currently Default) | Modify/Show | |
| Display Color | Change | |
| Property Notes | Modify/Show | |
| Туре | Slab | \sim |
| operty Data | | |
| Thickness | 125 | mm |
| | | |
| | | |
| | | |
| | | |
| | | |

Fig 9 Properties of Slab

Step 5: Defining section properties for Beam, Column. Beam size of 350x300mm, Column size of 400x400mm and Slab size of 125 mm is considered in the study.

| General Data | | | | |
|-------------------------|-------------------------|------------------|----|-----------------------|
| Property Name | beam | | | |
| Material | M30 | | · | • 2 * • |
| Notional Size Data | Modify/Sh | ow Notional Size | 1 | 3 0 |
| Display Color | | Change | | |
| Notes | Modify | /Show Notes | | • • |
| Shape | | | | • • • |
| Section Shape | Concrete Rect | angular 🗸 | / | |
| Section Property Source | | | | |
| Source: User Defined | | | | Property Modifiers |
| Section Dimensions | | | | Modify/Show Modifiers |
| Depth | | 350 | mm | Currently Default |
| Model | | 200 |] | Reinforcement |
| width | | 300 | mm | Modify/Show Rebar |
| | | | | ОК |
| | Show Section Properties | | | Cancel |

Fig 10 Defining the section properties of Beam

| General Data | | | |
|-------------------------|-------------------------|------|-----------------------|
| Property Name | column | | |
| Material | M30 | × | 2 |
| Notional Size Data | Modify/Show Notional | Size | • • |
| Display Color | Chang | ie | • |
| Notes | Modify/Show Note: | s | • • |
| Shape | | | • • • |
| Section Shape | Concrete Rectangular | ~ | |
| Section Property Source | | | |
| Source: User Defined | | | Property Modifiers |
| Section Dimensions | | | Modify/Show Modifiers |
| Depth | 400 | mm | Currently Derault |
| Width | 400 | mm | Modify/Show Rebar |
| | | | |
| | | | |
| | | | ок |
| | Show Section Properties | | Cancel |

Fig 11 Defining Properties of Column

| | - | | |
|-------------------------------|---------------|---------------|----|
| Property Name | Slab1 | | |
| Slab Material | M30 | ~ | |
| Notional Size Data | Modify/Show N | lotional Size | |
| Modeling Type | Shell-Thin | ~ | |
| Modifiers (Currently Default) | Modify/S | šhow | |
| Display Color | | Change | |
| Property Notes | Modify/S | Show | |
| Туре | Slab | ~ | |
| Inickness | | <u>40</u> | mm |
| | | | |

Fig 12 Defining the Properties of slab

| aerierai Data | | |
|-------------------------------|---------------------------|----|
| Property Name | Wall1 | |
| Property Type | Specified 🗸 | |
| Wall Material | Masonry 🗸 | |
| Notional Size Data | Modify/Show Notional Size | |
| Modeling Type | Shell-Thin 🗸 | |
| Modifiers (Currently Default) | Modify/Show | |
| Display Color | Change | |
| Property Notes | Modify/Show | |
| roperty Data | | |
| Thickness | 200 | mm |
| Include Automatic Rigid Zone | Area Over Wall | |

Fig 13 Properties of Masonry Wall

Step 6: Assigning Fixed Support at bottom of the structure in X, Y and Z direction in both the considered cases.



Fig 14 Assigning Fixed Support

Step 7: Defining Load cases for dead load, live load and seismic analysis for X and Y Direction.



Fig 15 Defining Load Cases

Step 8 Defining Seismic Loading as per IS 1893: 2016 Part I.

| Direction and Eccentricity | | Seismic Coefficients | | |
|----------------------------|----------------------|------------------------|------|-----|
| 🗹 X Dir | Y Dir | Seismic Zone Factor, Z | | |
| X Dir + Eccentricity | Y Dir + Eccentricity | Per Code | 0.24 | ~ |
| X Dir - Eccentricity | Y Dir - Eccentricity | User Defined | | |
| Ecc. Ratio (All Diaph.) | 0.05 |] Site Type | Ш | ~ |
| Overwrite Eccentricities | Overwrite | Importance Factor, I | 1.5 | |
| Story Range | | Time Period | | |
| Top Story | Story13 V | Approximate Ct (n | n) = | |
| Bottom Story | Base ~ | Program Calculated | | |
| | | O User Defined | T = | sec |
| Factors | | | | |

Fig 16 Seismic Loading





Fig 17 Model Check

Step 10: Analyzing the structure for dead load, stress analysis and displacement.



Fig 18 Stress Analysis for Dead Load

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Fig 19 Storey Drift

39428 00020



Fig 20 Storey Displacement





Model I

Fig Model II Model III



Fig Model III

IV. RESULTS AND DISCUSSION





Shear Force in kN/Storey No.

V. CONCLUSION

With the assistance of nonlinear time history analysis carried out by ETABS software, the focus of this study is on determining the seismic behaviour of staggered shear wall considering three different cases when subjected to historical earthquake data. The following conclusions follow from the analysis study that was presented earlier:

Time Period

The results show that for all of the models, the time period is greatest for mode-1. The time period for a shear wall structure without an opening is 0.531 seconds, 0.585 seconds for a vertical opening, and 0.591 seconds for a staggered opening, indicating that the time period increases when a shear wall is provided with an opening. When compared to shear wall structures with staggered opening, the time period for shear wall structures with staggered opening is longer with vertical opening and also without opening.

Storey Displacement

Storey displacement is the lateral movement of the structure caused by lateral force. It is observed that



due to the presence of staggered opened shear wall, it has less displacement compared to regular opened shear wall. By comparing the position of shear wall, the staggered opened shear wall at corner will shows the less displacement compared to shear wall at periphery for all models. The results shows that staggered frame have higher displacement compared to other models.

Shear Force

The variation of storey shear in the staggered shear wallconsidering three different models were tabulated respectively. The storey shear for staggered building in model III was found to be least by more than 48% in comparison to model I and 21% less than Model II.

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