ISSN: 0974-5823 Vol. 6 No. 3 October-December, 2021

International Journal of Mechanical Engineering

Pushover Analysis of RC Frame with Shear Wall and Openings

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Abstract- **Earthquake preparedness includes set of estimates process at the discrete, administrative and societal level to curtail the effects of earthquake. Preparedness measures can cover from designing earthquake proof structures, protecting heavy objects, structural modifications, and repository to having insurance, an emergency kit, and evacuation plans. Geographical statistics of India shows that almost 54% of the land is vulnerable to earthquakes. In the field of Civil engineering, this phenomenon plays a vital role. Consequently, structures are made earthquake resistant by incorporating shear walls, cross braces, diaphragms, and moment-resisting frames. Installation of Shear walls are a useful building technology helps to transfer earthquake forces. Made of panels, these walls help a building keep its original shape during ground movement without undergoing deformations. In recent times, shear walls are used for all high- rise buildings (which is over 35 to 100 meters tall) subject to lateral wind and seismic forces. Various research studies have been conducted on the design of shear wall and its performance to seismic forces. The present study is on the non-linear static performance of shear wall, with door and window openings and without openings on it. This paper compiles the evaluation of seismic performance of shear wall. The behavior, design models and application of RC shear walls were pellucid by studying copious number of literatures. It is planned to perform non- linear static pushover analysis in ETABS, with and without installing the openings to analyze both the uncontrolled and controlled non-linear performance of the structure. Substantiation was carried out to compare the numerical simulation with the analytical study performed in ETABS. The structure was modeled and non-linear static analysis for the structure was performed for soil type 2. The structure was analyzed without openings to determine the uncontrolled response of the building. The entire process of validation is yet to be performed and studied.**

Keywords: Base Shear, Base moment, Shear Wall, Etabs, Non- linear Static Method, Openings, Capacity curve.

INTRODUCTION

Earthquake is one of the most devastating natural calamities which cause sudden shaking of the earth surface. It majorly causes damage to buildings and other structures. Further, Indian buildings built over past two decades are seismically deficient because of lack of awareness regarding seismic behavior of the structures. Designing structures as earthquake resistant is one of the challenges for most of the engineers of the construction industry. Thus, structures to resist seismic forces is indispensable. Generally, buildings possess masonry walls which are easily susceptible to lateral wind and seismic forces but buildings with shear walls which are properly designed and detailed ave shown very good performance in past earthquakes. These walls are more important in seismically active zones when shear forces on the structure increases due to earthquakes. Due to sudden slip on a fault. The tectonic plates are always slowly moving, but they get stuck at their edges due to friction. When the stress on the edge overcomes the friction, there is an earthquake that releases energy in the form of waves that travel through the earth's crust and cause the shaking of ground. These complex shaking results in horizontal and vertical vibrations in structures called as responses such as displacements, velocities and accelerations. There has been an increase in the number of tall buildings, for commercial and residential purposes, under construction throughout the world. This increase has illuminated the necessity for knowledge of the behavior of these structures, and, in particular, the necessity for producing methods of analysis capable of giving rapid and accurate assessments of their overall strength and stiffness. As buildings increase in height, it becomes important to ensure adequate lateral stiffness to resist loads that might arise because of wind, seismic or blast effects. ETABS can perform static or dynamic, linear or nonlinear analysis of structural systems. To performs pushover analyses in ETABS, users can either automatically assign hinge or hinge properties are defined from moment-curvature analysis. ETABS is fully equipped with US, Canadian and International Design standards and codes like ACI concrete code, AISC building codes and AASHTO specifications. The employment of Nonlinear Static Procedures in the seismic assessment of existing structures (or design verification of new ones) has gained considerable popularity in the recent years. Pushover analysis gives better understanding about behavior of the building by identifying weak elements and realistic prediction of element demands. When existing buildings are retrofitted, the process becomes easier by providing shear walls initially. This is more advantageous only when the shear wall is placed symmetrically to the plan of the building.

As study conducted by Rahul Leslie., [3] gives basic understanding about the SA and PA, where as in conventional seismic analysis the lateral load is distributed either parabolically or proportional to modal combination; in PA the distribution is proportional to either the first mode shape or combination of modes. In both SA and PA, the maximum lateral load estimated for the structure is calculated based on the fundamental time period of the structure. The initial time period is taken to be a constant and uses elastic model in SA; whereas the initial time period continuously re-calculated as the analysis progresses and uses nonlinear model.One of the fundamental simplifications underlying the concept of PA is that it considers the structure as a single degree of freedom system. In SA, the lateral load of a calculated intensity is applied in whole – in one shot. In PA, structure model is gently 'pushed over' by a monotonically increasing lateral load, applied in steps up to a predetermined value or state. Capacity Spectrum Method of ATC-40, where the load is incremented and checked at each stage, until what is called the 'Performance Point' condition is reached. Finally, the study conducted by Sarosh Hashmat Lodi et al., [18] for the evaluation of a RC frame building with exterior and interior walls of block masonry infill panels. ASCE 41 is used for providing hinge properties in the model for beam columns and struts. After the performance of analysis on this structure it was clearly known that the building has few deficiencies which need to be retrofitted for improving the strength for future usage. This study demonstrates the power of nonlinear analysis; firstly, one can easily estimate the capacity of new and existing structure and check it against the demand. Secondly, can be used to assess the effectiveness of various types of low cost and innovative retrofitting schemes, such as the rocking spine concept used in this paper for particular structure.

SHEAR WALL

Shear walls are used in the construction of tall buildings both residential, commercial and the modern trend is towards more tall structures. This could minimize the effects of lateral loads like wind loads, earthquake loads and blast forces. Almost every designer is faced with the problems of providing adequate strength and stability against lateral loads. Shear walls are providing all the lateral support for the high-rise buildings in the form of external box, which helps in reducing the lateral sway of the building. Along the direction of its orientation, it provides more strength and stiffness. It is also called rigid vertical diaphragms which transfers loads to the foundations below. The shear walls are classified into various types. They include:

1. Column supported shear wall
2. Core type shear wall
3. Rigid frame shear wall
4. Framed walls with in-filled frames
5. Simple rectangular type and flanged wall
6. Coupled shear wall
7. Cantilever shear wall

In Column supported shear wall, the shear wall and column lie in its response to the load acting on it and functionality. Thus, primary function of column is to transfer vertical load applied on it from top to bottom; whereas the shear wall is to resist horizontal forces acting on the building. In core type shear wall, the shear wall is placed in the Centre of the building, typically encasing a stair wall or lift shaft. In rigid frame shear wall, it is either straight or curved members which is interconnected using rigid connections mostly. These infilled frames are non-load bearing frames, these types of frames can also be used as internal separating walls for the purpose such as providing acoustic insulation and enhancing fire resistance. And majorly it provides support for the cladding system. In simple rectangular type and flanged wall is also called as Bare bell type wall. Examples are the reinforced concrete wall or vertical truss. In coupled shear wall, the external loads are resisted by creating couple at the base. Thereby coupling discrete flexural walls overturning moments can be resisted partially by axial compression- tension couple across the wall system rather than individual walls flexural action. This possesses higher strength, stiffness and energy dissipation than single shear wall. Where cantilever shear wall act as a cantilever beam and its design is governed by flexural behaviour.

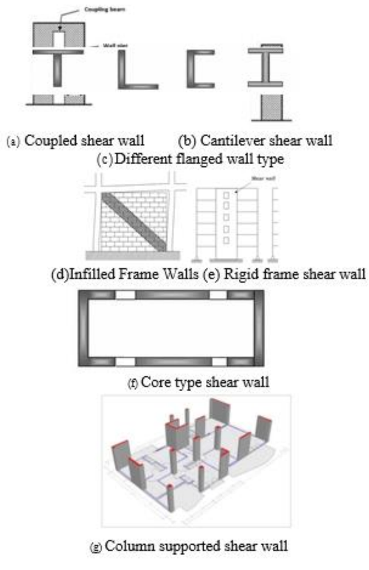

Fig.1 Types of Shear Wall

TABLE I DESCRIPTION OF THE MODEL

No. of Storey	G+9
Plan dimension	20 m x 17 m
Typical Floor height	3m
Ground Floor height	3m
Beam size	300x600 mm
Column size	700x700 mm
Thickness of slab	125 mm
Thickness of Shear wall	200 mm
Mid opening	1m x 1m
Zigzag opening	1m x 1.5m
Concrete grade	M 30
Rebar Grade	Fe 415

available in the structure. Gravity load bearing elements function. No out of plane failure of walls and some drift can be observed with some failure to the partition walls and the building is beyond economical repair. **Collapse Prevention Level** (CP): Buildings meeting this performance level are expected to have little residual strength and stiffness, but the load bearing structural elements function. **Point C** represents the ultimate capacity for pushover analysis. **Point D** represents a residual strength limit in the structure. **Point E** represents total failure of the structure. After this point hinges break down. A hinge property is a set of non-linear properties that can be assigned to points along the length of one or more frame elements. Assigning hinge starts from 0(Starting point) of member to 1(End Point) of that members. In this chapter, the building performance level has been distinctly presented.

MODELING AND ANALYSIS OF RC SHEAR WALL

The modeling of RC frame with shear wall is done based on codal requirements.

HINGE MECHANISM

Point of Inelastic action of the structural member is called as Plastic hinge. In this state structural member starts its plastic behavior. We assign hinges to Model for observing the structural behavior of sequential loss of strength in different performance level of the structure due to seismic effect.

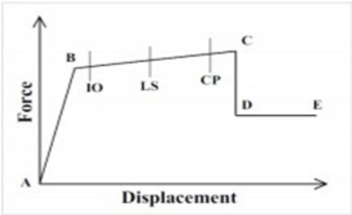

Fig.2 Force - Displacement curve of a Hinge.

Point A is the original state of Structure. **Point B** represents yielding. No deformation occurs in the hinge up to point B. **Operational level** (OL) at B: As per this performance level building are expected to sustain no permanent damages. Structure retains original strength and stiffness. Minor cracking is seen in partition walls and ceilings as well as in the structural elements. **Immediate occupancy level** (IO): Buildings meeting this performance level are expected to sustain no drift and structure retains original strength and stiffness. Major cracking in partition walls and structural elements is observed. **Life Safety Level** (LS): This level is indicated when some residual strength and stiffness is left

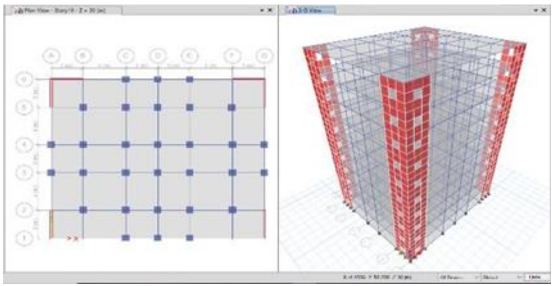

Fig.3 Plan and 3D view of model with corner shear walls with mid openings

ALGORITHM TO MODEL AND DO EQUIVALENT STATIC ANALYSIS OF RC FRAME IN ETABS

Set unit to metric and customize grid data. Make 3-D frame with required storey height. Define material, Frame and Shell properties. Quick draw beam, column, floor and wall sections. For openings, edit> edit shell data>apply. Assign support condition (fixed support). (Assign> joint> restraints> fixed> apply). Define floor load both dead and live load. Define load pattern (choose code IS 1893:2002) and define load combination as per IS 456:2000. Analyse the shear wall and display results.

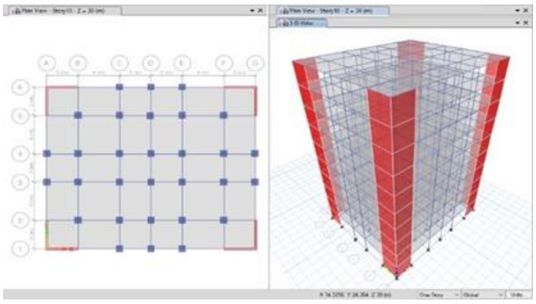

Fig.4 Plan and 3D view of model with corner shear walls without openings.

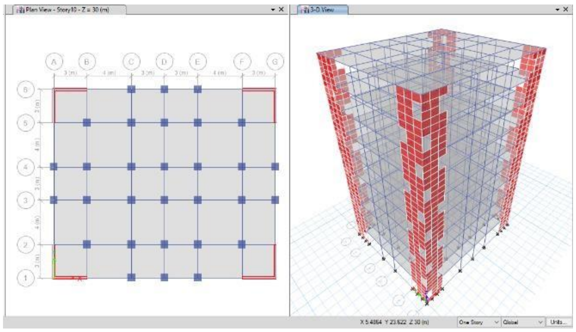

Fig.5 Plan and 3D view of model with corner shear walls with zigzag openings

The maximum deformations of all 3 modeled structures were found under the load combination of 1.5D. L+1.5EQx.

PUSHOVER ANALYSIS STEPS IN ETABS

- Finalize the structural members and unlock the model.
- Then decide push displacement value up to which we want to observe the nonlinear behavior of the structure. Push Displacement is kept as 1200mm (As per ATC 40, the buildings are pushed to a controlled displacement of 4% of the height of the structure).
- Consider the corner joint label of top floor for target displacement.
- Define Load Case: Convert Dead load to Nonlinear Static. Define > Load Case> Add New>Name-PAx > Type-NS>Mass Source > Initial Condition-Continue from State-Dead> Loads Applied-Add-Load type- Acceleration Ux-Factor1> Load Application> Displacement Control> Results Saved>Modify>Multiple Stage.

TABLE II JOINT DISPLACEMENT

Storey	Label	Load Case/Combo	UX	UY	UZ
			mm	mm	mm
WITHOUT OPENINGS IN SHEAR WALL:					
Story10	12	1.5DL+ 1.5eqx	18.902	0.26	-1.947
WITH MID OPENINGS IN SHEAR WALL:					
Storey10	7	1.5dl+1.5eqx	38.976	0.594	0.29
WITH ZIGZAG OPENINGS IN SHEAR WALL:					
Storey10	7	1.5dl+1.5eqx	73.456	1.074	3.681

- Assign Hinge Properties- Select All Beams>Assign>Frame>Hinges>AutoM3> Distance 0.1 to 0.9.Similar way Assign Hinge for Columns & Walls. Then select all beams & columns. Assign hinge overwrites > this will discretize the members & can give better result.
- Set the load cases to run analysis. Linear analysis is used to design the section sizes of the members & nonlinear analysis used to observe the designed structure's behavior. So, here run only nonlinear static analysis to observe proper structural behavior for defined push displacement.
- After running analysis see deformed shape for push along x direction & y direction and observe what hinges are formed OI>IO>LS>CP>C>D>E. Display static pushover curve- base shear vs. displacement also display maximum moment and shear force for pushover analysis.

V. RESULTS AND INTERPRETATION

The performance point for all the RC models is determined and the performance point diagrams are shown in the figure below.

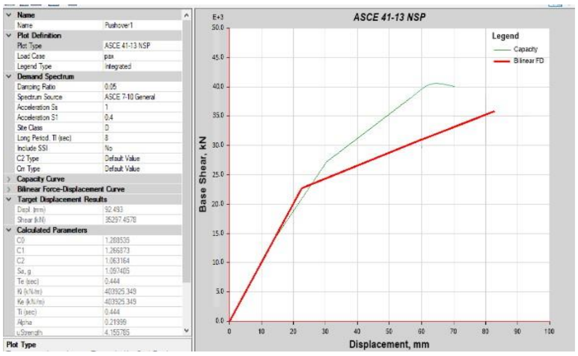

Fig.6 Pushover curve in X direction

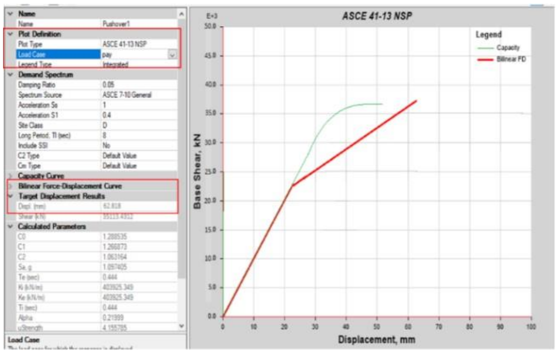

Fig.7 Pushover curve in Y direction

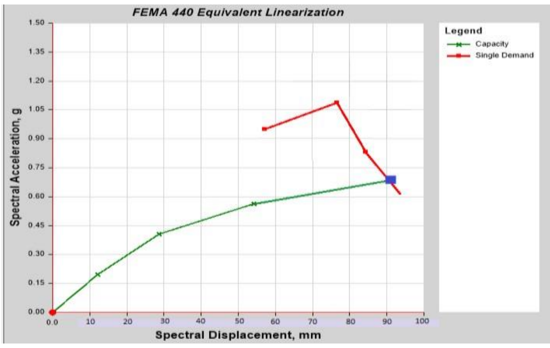

Fig.8 Capacity spectrum in X direction

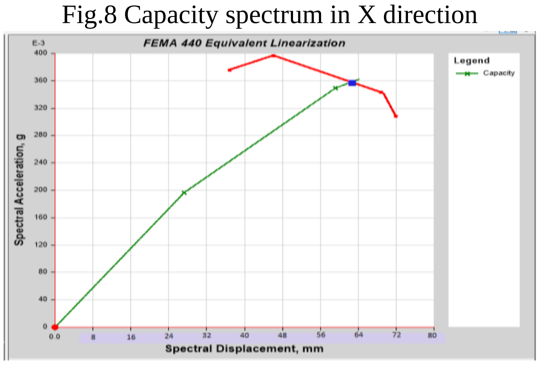

Fig.9 Capacity spectrum in Y direction

CONCLUSION

Parishith J et al., carried out RC frame with different locations of shear wall to study the behavior of the structure. To validate the investigation the modeling (case 1) was done and the nonlinear static analysis was conducted in ETABS software, for the given earthquake ground motion. The ultimate aim of analysis is to derive maximum base shear and top displacement value for push forces in X and Y direction for each case. From the below graph it is inferred that RC frame with corner shear walls and without openings has base shear capacity 73% and 77% more along X direction in comparison with case 2 and 3 respectively. Likewise, along Y direction base shear capacity is 81% and 82% more in comparison with case 2 and 3 respectively. From the comparative study it is founded that the occurrence of base shear capacity in structure with shear wall having openings arranged in zigzag manner is approximately 4% lesser as compared to mid arrangement of openings, whereas displacement demand is found to be approximately 40% more in zigzag manner openings than mid openings. It is very clear that, case 1 shows more significant seismic performance than case 2 and 3. From the results discussed , it is concluded that the performance based design concepts provides a systematic design approach for evaluating the seismic capacity of the RC frame designed for earthquake loading.

ACKNOWLEDGEMENT

The authors wish to record their sincere and heartfelt thanks to Dr K Prakasan, Principal, Dr M Palanikumar, Head of the Department, Department of Civil Engineering, PSG College of Technology, Coimbatore.

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