NUMERICAL ANALYSIS OF RC SHEAR WALL SUBJECTED TO MONOTONIC LOADING

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ABSTRACT

Earthquakes are one of nature's greatest hazards on our planet and have taken a heavy toll on human life and property since ancient times. They are also one of the most common natural disasters. People are not killed by earthquakes; instead, dangerous structures are to blame for the widespread destruction. Structures collapse when they are unable to withstand seismic forces. In addition to the significant loss of human life, it becomes difficult to dispose of the debris left behind when buildings fall, and the construction of new buildings also pollutes the environment. The most efficient way to lessen earthquake damage is to plan and construct structures that are earthquake-resistant from the start. Shear walls resist lateral and horizontal pressures, and dynamic loads. Our goal is to prevent structural deformation brought on by dynamic loading. A building's reinforced concrete shear walls may be able to withstand lateral loads from wind or earthquakes. Using ABAQUS software, this study examines the non-linear behaviour of reinforced concrete Shear wall under monotonic loading. Deformed shape, crack pattern, principal stresses, displacement contour and load versus deflection behaviour of reinforced concrete shear wall are investigated. And the comparison is made for the results obtained from our present study with the results shown in the literature G.V. Rama Rao (2016) [4].

Keywords: Shear wall, Abaqus, Non-linear, monotonic loading.

INTRODUCTION

According to Fintel (1991), a renowned consulting engineer in the United States, "We cannot afford to design concrete buildings built to endure severe earthquakes without shear walls." Building structures with shear walls are referred to as structural walls are made to withstand lateral forces that an earthquake, wind, or other lateral force can cause in the wall's plane. Because these walls act more like flexural members at large aspect ratios, the term "shear wall" (SW) is somewhat misleading. They are typically present in tall structures and have been discovered to be of great assistance in preventing the complete collapse of structures under seismic stresses. While planning shear walls, one shall try to reduce the bending stresses due to lateral loads on columns by transferring the lateral loads to shear walls of large stiffness.

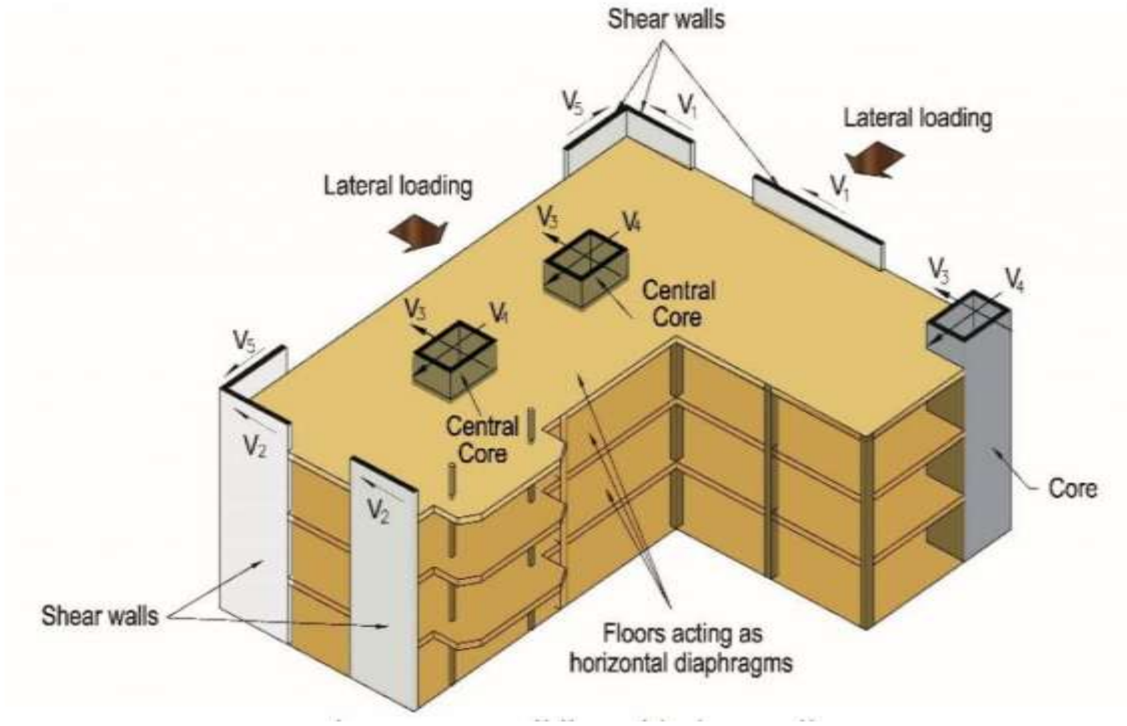

Fig. 1. 3D Structure with shear wall

Shear walls can be either (1) coupled shear walls (2) simple rectangular versions with or without boundary features. (3) Non rectangular T, C and (4) Box type. A simple rectangular shear wall that is being acted upon are susceptible to axial, bending, and shear forces as a result of in-plane vertical loads and horizontal shear along its length. Walls that are rectangular and have boundary elements tend to be stronger and more ductile. These walls should be designed in such a way that they never fail in shear but only by yielding of steel in bending, because shear failure is brittle and sudden. Due to this shear wall's rigidity, one of its drawbacks is that during an earthquake,it attracts and consumes a lot of energy by cracking, which is challenging to fix. Coupled shear walls have the ability to correct this flaw. The resultant wall will be more rigid if two structural walls are connected by relatively short spandrel beams, and the structure can release the majority of the energy without causing any structural damage to the primary walls by yielding the coupling beams. These connecting beams are simpler to replace than the walls. Elevators and other service spaces in some buildings may be arranged in a vertical core known as a box type shear wall, which may act as the primary structural component. Rajat et al., [7] made a research on the structural components of a multi-story structure, in which shear walls were among the most crucial and acceptable options. As a result, it would be a highly fascinating research to investigate the structural reaction and its systems in multi-storied buildings. Shear walls were frequently disregarded during the design of structures and construction because of their potential to contribute to the stiffness and strength during earthquakes. The results of this research demonstrate the influence of shear walls, which has a substantial impact on the structural vulnerability of buildings. Boria Anya and Tamal Ghosh[3] studied about the demand for tall buildings has greatly increased as a consequence of the rise in the urban population and the accompanying rise in the need for available space in Sikkim. In this article, a parametric research was presented in terms of storey drift, displacement, and base shear comparison for various locations of shear walls inside the structure. Their findings were distinctive and profitable for future attention. Deepna et al.,[6] explains about the implications of lateral loads, such as those caused by earthquakes, wind, and blast pressures, were becoming an increasing source of worry in today's world. One of the most difficult tasks that any designer must do was comes up with a way to provide a structure the strength and stability so that it can withstand lateral stresses. Using the ETABS programme, the building with an RCC shear wall, a steel plate shear wall, and a composite shear wall was designed, and its analysis was carried out. They also gave a brief comparison of the outcomes of tale drift and story shear as well as the effect of adjusting the thickness of the shear panels. G.V. Rama Rao[4] studies on the shear walls' ductility. Aspect ratio, axial stress on the shear wall, the proportion of vertical reinforcement, and the proportion of reinforcement in the boundary element are some of the variables that affect the ductility of shear walls. Using ABAQUS finite element software, a parametric investigation of the nonlinear ductile behavior of shear walls had been completed. To represent the nonlinearity, the Concrete Damaged Plasticity (CDP) model is employed. The experimental results are used to validate the model. The legal requirements for shear walls are thoroughly examined, and suitable suggestions are made to increase the ductility of shear walls. The parametric investigation came to the conclusion that the design of the shear wall section must ensure the axial load in order to achieve ductile response during intense seismic shaking. The design of shear wall section needs to ensure the axial load to be not more than about 30% of the ultimate axial compression capacity. G.V. Rama Rao et al.,[5]Studies on Nonlinear Behaviour of Shear Walls of Medium Aspect Ratio under Monotonic and Cyclic Loading. Shear walls are the ideal choice to resist lateral loads in multistorey RC buildings. Nonlinear performance of medium aspect ratio shear wall specimens are studied on three identical shear wall specimens through application of monotonic and cyclic loading. In order to study the effect of axial load on the flexural behaviour and ductility of shear wall, a parametric study is conducted using a layer-based approach, which is used to generate the analytical pushover curve for the shear wall and validated with the experimentally evaluated pushover curve of the tested shear wall. A comparison is made between monotonic and cyclic load behaviour. Stiffness and strength degradation and pinching parameters are evaluated from cyclic tests. Plastic rotation limits and ductility capacities under monotonic and cyclic loading conditions are compared with recommended values.

BEHAVIOUR OF SHEAR WALL

The following generic descriptions apply to the failure modes of the walls: Flexure failure (often seen in slender shear walls) is characterized by vertical steel yielding, steel fracture, and crushing of the surrounding material Concrete first, then buckles in steel. Shear failure, which is typically seen in squat shear walls, can result in either diagonal crushing (between tension cracks) or diagonal tension (steel yielding and fracture at crack Sliding shear failure is another prominent mode of failure that can be seen in slender walls. When horizontal fissures are widened by the cyclic moment following flexural yielding, slide failure can occasionally occur. These opening fractures experience in sliding shear lose the ability to transfer shear strength across horizontal cracks. Squat and slender walls are the two main categories for shear walls based on behaviour. A squat wall (low-rise or short shear wall) is one in which shear regulates deflection and strength. A slender (high rise) wall or tall shear wall) is one in which flexure regulates deflection and strength. In general, the walls with an aspect ratio (height to width ratio) less than unity are squat shear wall, while ratios more than 2 are defined as slender walls. The failure is governed by both flexure and shear in intermediate walls, which have an aspect ratio in transition between 1 and 2.

CODAL PROVISIONS

In India, codal provisions for shear wall are discussed in Indian standard code IS13920:2016, which deals with the ductile detailing of reinforced concrete structures subjected to seismic forces with several improvements in the design of shear walls. IS 13920: 1993 is silent about classification of wall as squat or slender based on aspect ratio. The revised IS 13920:2016 is classified shear wall according to aspect ratio i.e. ratio of height of the wall (hw) to horizontal length (Lw). If $hw/Lw < 1$,squat walls; $1 \leq hw/ Lw \leq 2$ intermediate walls and $hw/Lw > 2$ are termed as slender walls. The minimum thickness of any part of the wall shall preferably, not be less than150 mm.

NUMERICAL INVESTIGATIONOF SHEAR WALL

ABAQUS MODELLING

Reinforced concrete shear wall absorbs and dissipates considerable energy during an earthquake by concrete cracking and yielding of steel. All this phenomena occurred in inelastic range. Hence it is mandatory to study the behaviour of structures in inelastic range also. Nonlinear models for shear walls need improvement and refinements based on inputs from actual tests. The finite element analysis of shear wall using ABAQUS software is presented. And comparison made for the results obtained with the results shown in the literature G.V. Rama Rao (2016)[4]. The shear wall, having dimensions of 3 m in height, 1.56 m in width and 0.2 m in thickness is considered for validating the procedure. The shear wall is axially loaded with a super-imposed vertical load of 80 kN.

Table 1- Dimensions of shear wall

Description	Dimension in (mm)
Height	3000mm
Width	1560mm
Thickness	200mm
Slab	2500x2500x500mm
Raft	2500x2500x400mm
Clear Cover	30mm

Fig.1 Reinforcement details of the shear wall: (a) elevation; (b) cross section view along BB; (c) plan view along AA (all dimensions shown are in mm, Drawn not to a scale) from G.V. Rama Rao (2016)[4]

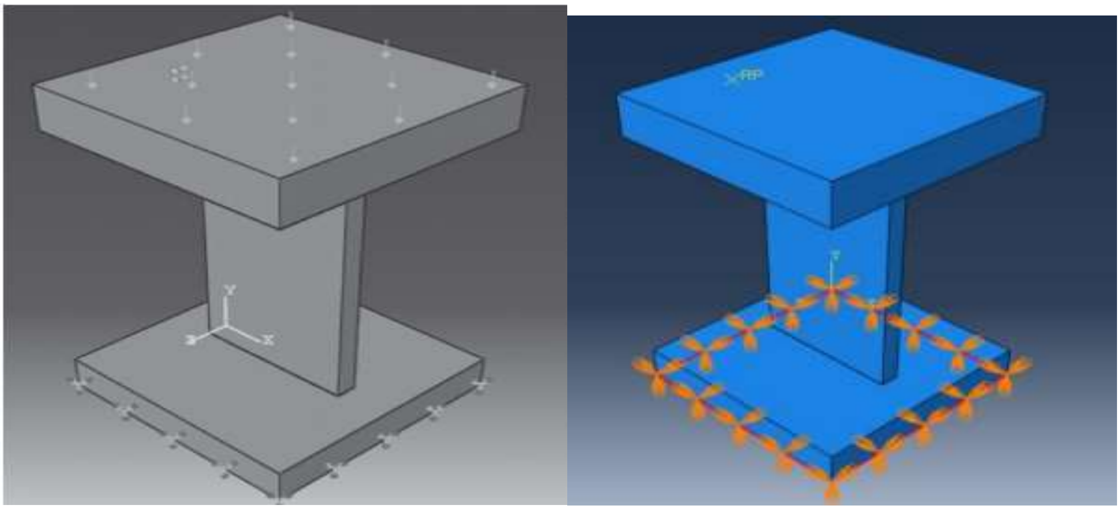

Fig. 2. FEA Model of Shear wall from literature and present study

REINFORCEMENT DETAILING OF SHEAR WALL IN ABAQUS

The shear wall has 16 - 10 mm diameter bars which are placed as longitudinal vertical reinforcement in two layers with a non-uniform spacing in plan. At both ends of shear wall, 3 bars in each layer are kept with a spacing of 150 mm c/c and remaining bars are spaced at distance of 300 mm c/c. Four vertical bars at the both ends are provided with special confining reinforcement in the form of hoops. This is towards simulating a concealed boundary element. 10 mm diameter bars are placed as horizontal reinforcement with spacing of 300 mm c/c at two layers. The grade of concrete is M30 and the grade of steel reinforcement is Fe415.

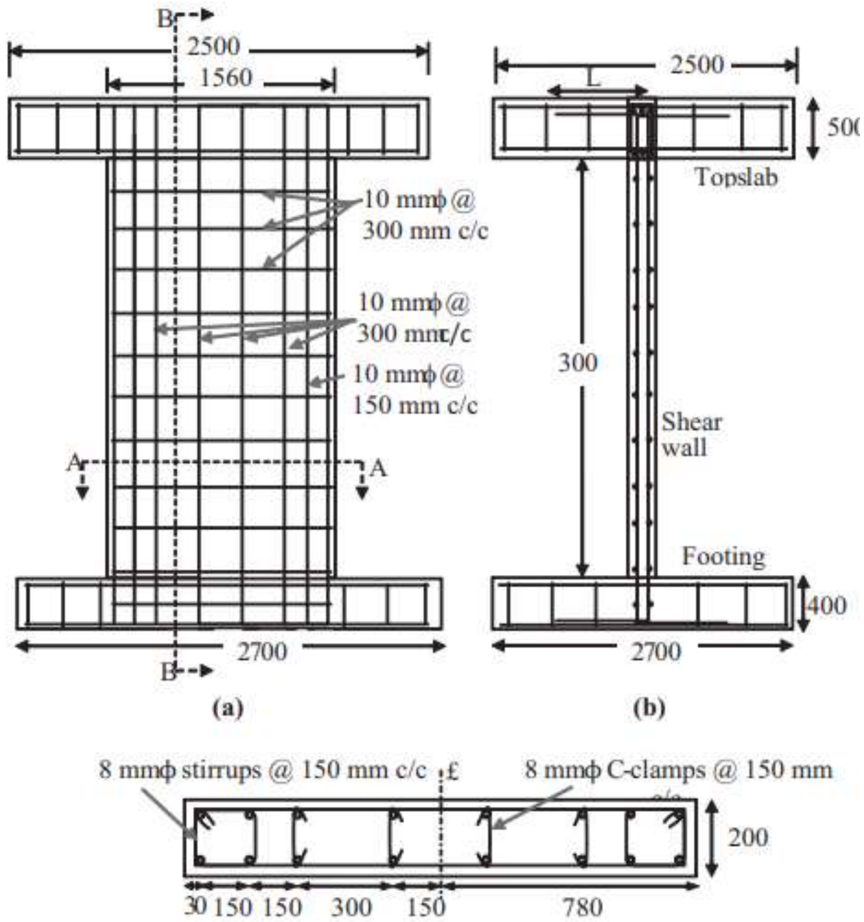

Fig.3. Reinforcement details of the shear wall: (a) elevation; (b) cross section view along BB; (c) plan view along AA (all dimensions shown are in mm, Drawn not to a scale) from G.V. Rama Rao (2016)[4]

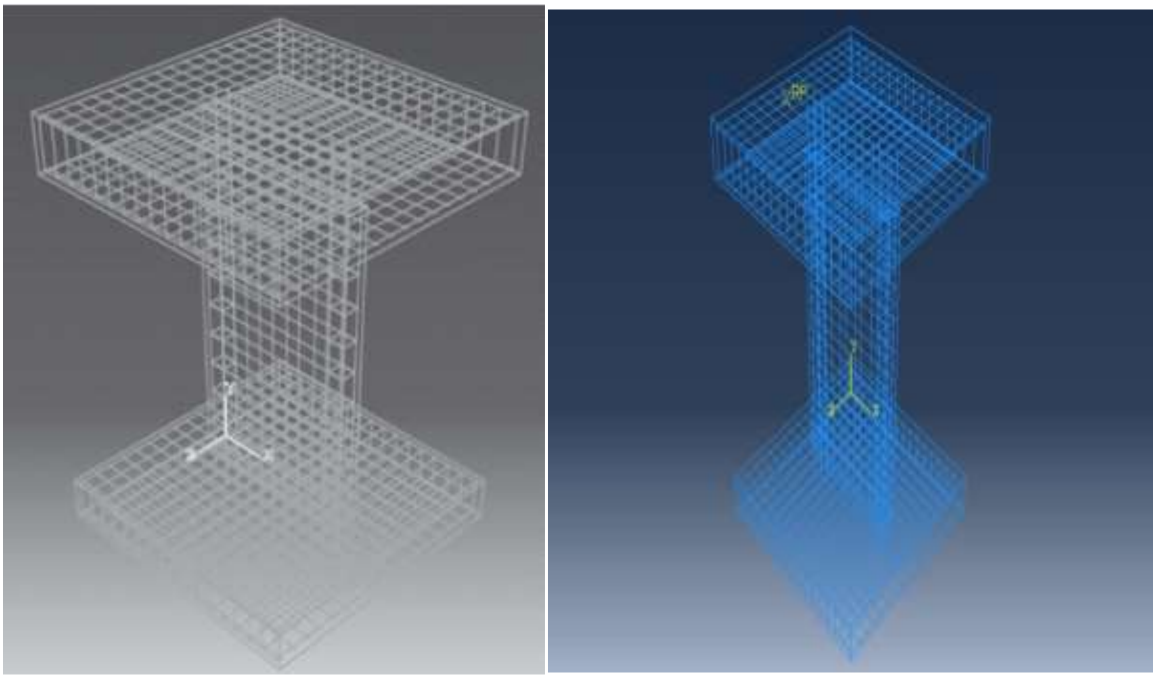

Fig.4. Reinforcement detail in the model from literature and present study

DEFORMED SHAPE OF SHEAR WALL

The top slab has been additionally given with pressure load (0.25Mpa) to create axial stress in the shear wall, in such way that the top slab and additional load together creates 160 kN axial load on the shear wall. Monotonic lateral loading is applied on the shear wall is simulated in analysis by giving a nodal displacement boundary condition applied at the mid-height of the top slab of 60mm. The corresponding deformed shape for the pressure load and lateral displacement is shown in Fig.5.

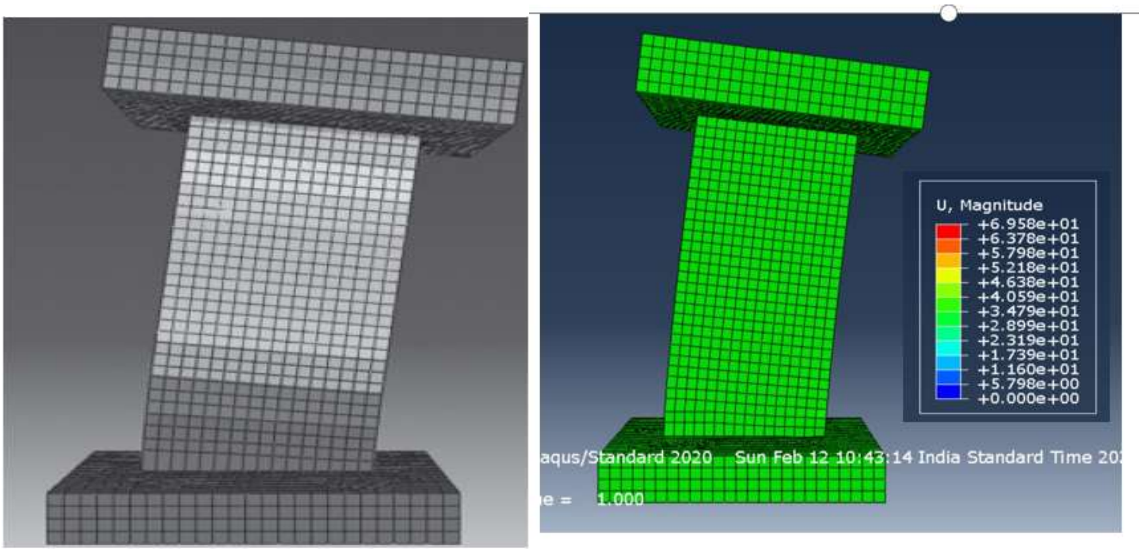

Fig. 5. Deformed shape of shear wall from literature and present study

CRACK PATTERN OF SHEAR WALL

The Plastic hinge is formed at the base of the shear wall i.e. at the junction of raft and shear wall.The same crack pattern is observed both in literature and in the present study. The Tension crack pattern is observed at the side of lateral loading (left). On the base of the shear wall i.e. above the foundation the tension crack is developed for a stress of magnitude 1.348Mpa.The Compression crack pattern is observed at the other side of the shear wall (right). On the base of the Shear wall i.e. above the foundation the compression crack is developed for a stress of magnitude 1.196Mpa.

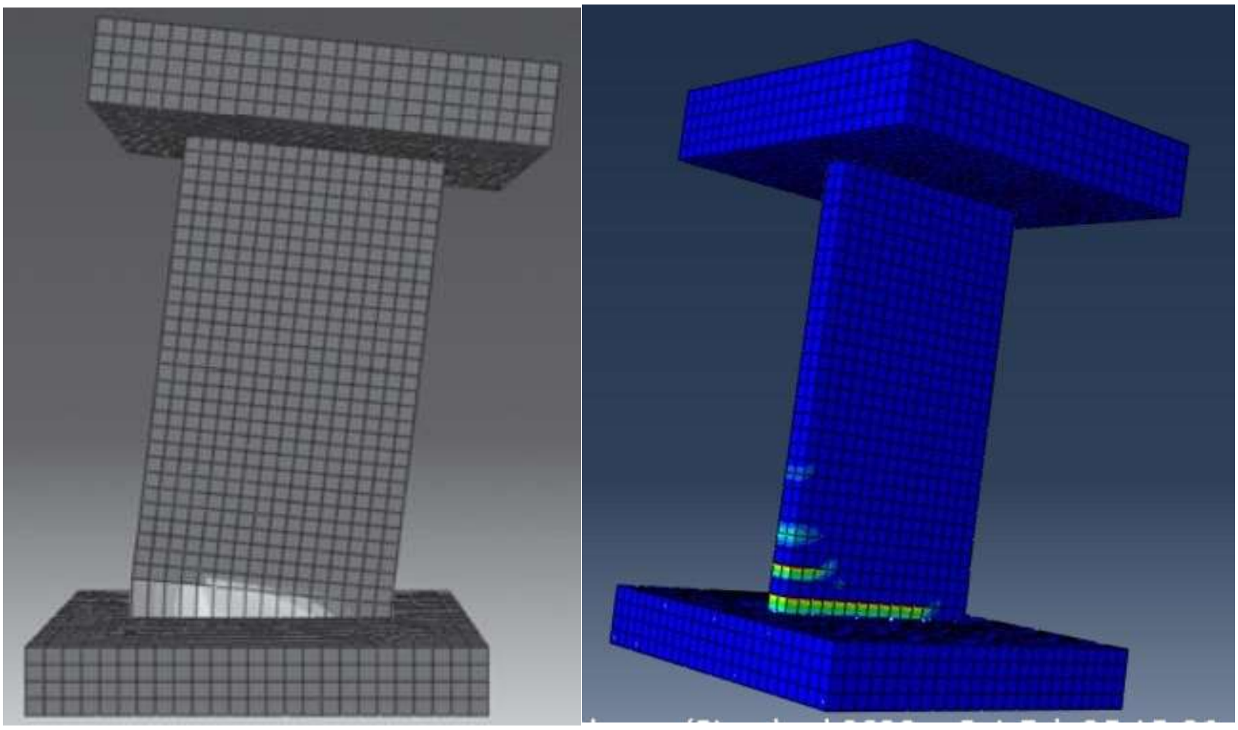

Fig. 6. Crack pattern obtained in analysis from literature and present study

PRINCIPAL STRESSES OBTAINED FROM ABAQUS

The Principal stresses were observed at the base of the shear wall with the magnitude of maximum principal stress as 0.2837Mpa.

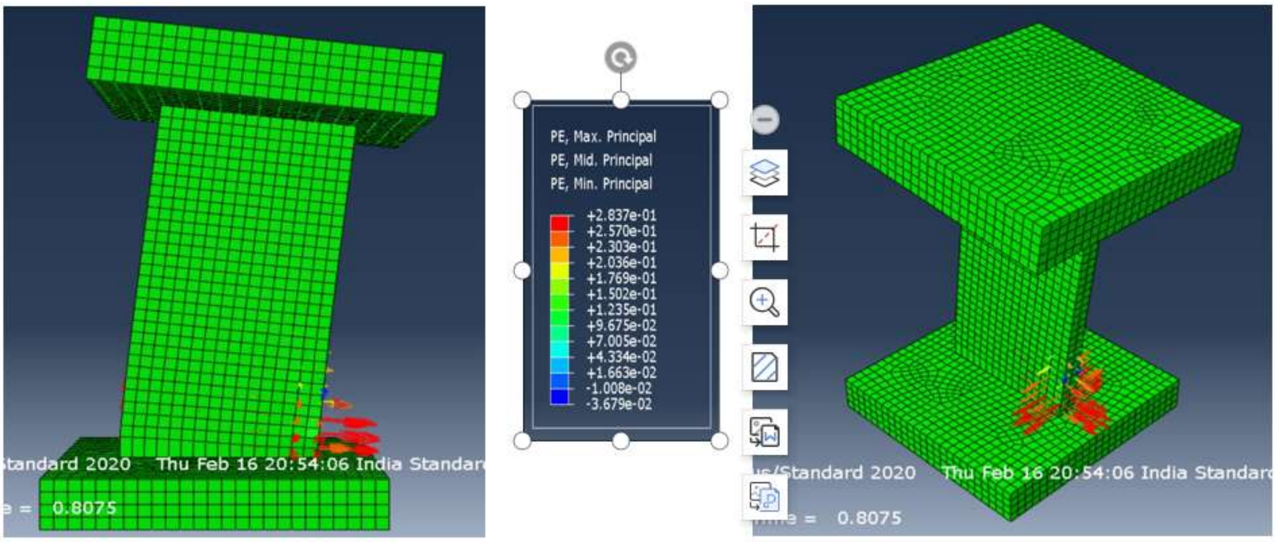

Fig.7. Principal stresses obtained in present study

DISPLACEMENT CONTOUR

The displacement in the top slab is more than that of wall and raft slab. Next to the top slab, the wall get displaced more than raft slab.

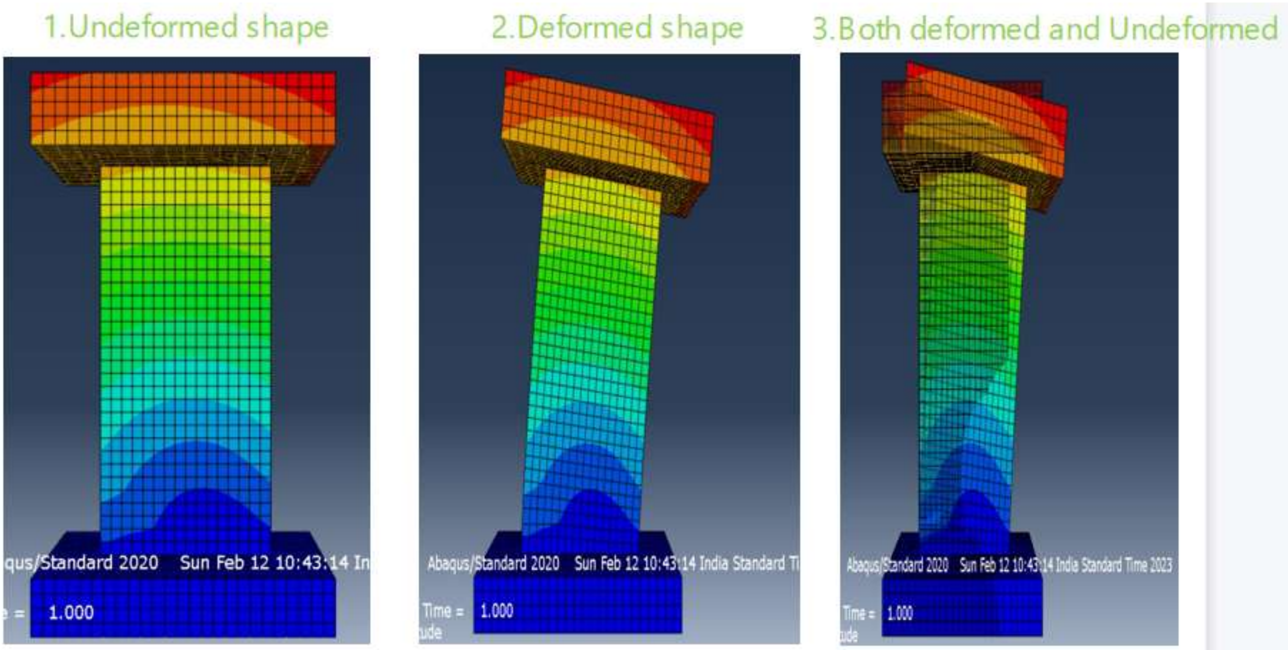

Fig. 8. Displacement contour obtained in present study

LOAD VERSUS DISPLACEMENT BEHAVIOUR

In the present study the additional axial load given on the top slab is 80kN. Whereas in G.V. Rama Rao (2016) [4] the additional axial load given on the top slab is also 80kN. The lateral displacement given on the side of the wall in the present study is 60mm.

Whereas in G.V. Rama Rao (2016) [4] lateral displacement given on the side of the wall is also 60mm. The maximum lateral load carrying capacity from his experimental study is about 210kN with maximum displacement of 65mm and from analytical study is about 180kN with maximum lateral displacement of 60mm.The maximum lateral load carrying capacity as per the present study is about 140kN with maximum lateral displacement of 60mm. This difference may because of different version of ABAQUS software and different mesh size,etc. Fig.9 shows the comparison of FEA result versus experimental results obtained from pushover analysis.

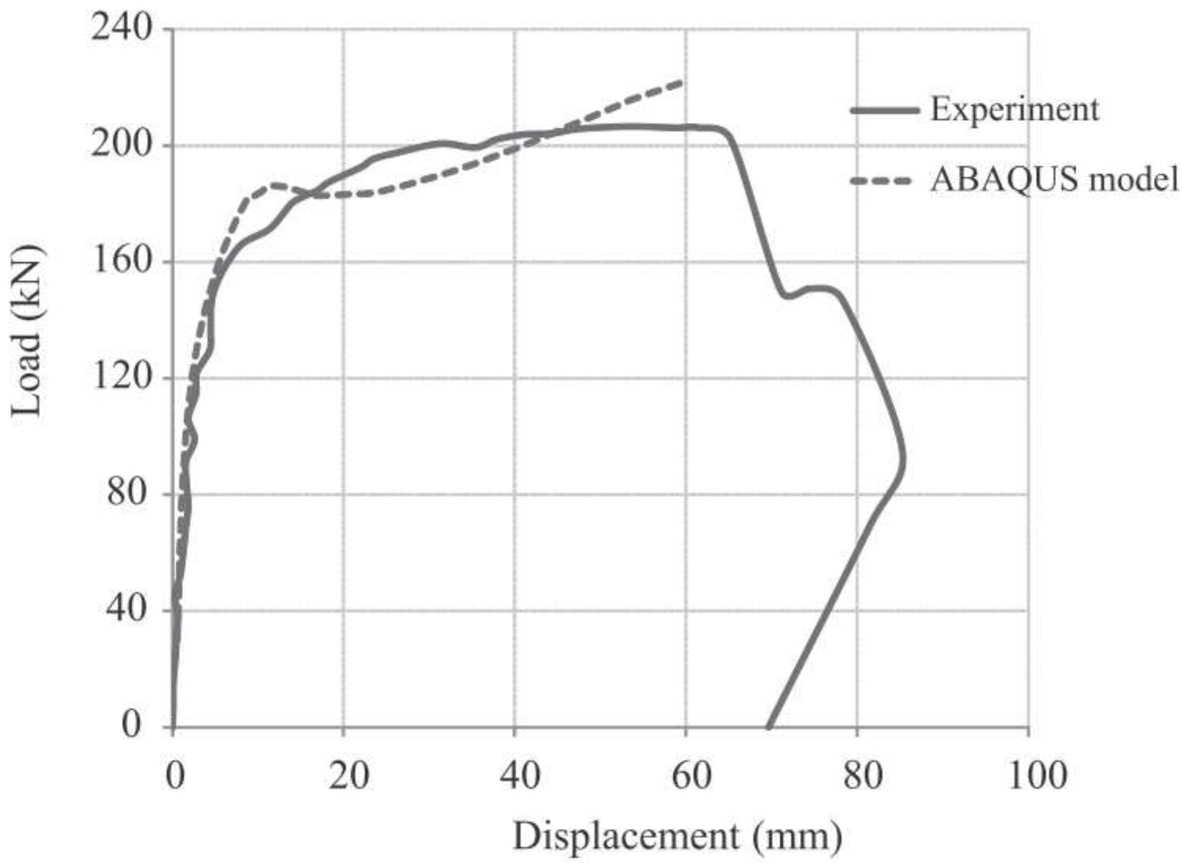

Fig.9. Load versus Displacement curve obtained from literature

Fig.10 Load versus Displacement curve obtained from present study

CONCLUSION

1. The Plastic hinge is formed at the base of the shear wall i.e. at the junction of raft and shear wall both in literature and present study.
2. The same crack pattern is observed both in literature and in the present study. The Tension crack pattern is observed at the side of lateral loading (left). On the base of the shear wall i.e. above the foundation the tension crack is developed for a stress of magnitude 1.348Mpa.
3. The Compression crack pattern is observed at the other side of the shear wall (right). On the base of the Shear wall i.e. above the foundation the compression crack is developed for a stress of magnitude 1.196Mpa.
4. The Principal stresses were observed at the base of the shear wall with the magnitude of maximum principal stress as 0.2837Mpa.
5. According to G.V. Rama Rao (2016) [4], the maximum lateral load carrying capacity of the shear wall is about 180kN and with maximum lateral displacement of 60mm(from ABAQUS).
6. According to G.V. Rama Rao (2016) [4], the maximum lateral load carrying capacity of the shear wall is about 210kN and with maximum lateral displacement of 65mm (from experimental study).
7. According to present study The maximum lateral load carrying capacity of the shear wall is about 140kN and with maximum lateral displacement of 60mm.

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