Behaviour of Coupled Shear Walls in Multi-Storey Buildings

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***Abstract*— Finite element modeling is the order of the day for analyzing several of kinds of civil engineering problems. The present study dictates the behavior of coupled shear wall under a seismic event. In multi-storied buildings, shear walls are commonly used as vertical structural elements for resisting lateral loads induced by the effect of earthquake. Generally, shear walls are located at the sides of the building, or at the core of the building to counter the earthquake forces. If the building consists of either external shear walls or internal shear walls then it is necessary to provide openings in these walls. In order to accommodate these doors, windows in the shear walls it is necessary to pierce them. The size and location of the opening may vary from the architectural and functional point of view. This study is carried out for a 10-storied building using ETABS software. The obtained results disclose that the behaviour of the structure is definitely affected by the size of the openings. The stress concentration around the opening is completely based on the openings size. It was also noticed that the depth of the coupling beam is based on the size of the opening. If the depth varies there is an effect on the angle of inclination provided in the diagonal reinforcement.**

Keywords—Coupled shear walls, stress concentrations, angle of inclination and diagonal reinforcement.

I. INTRODUCTION

A coupled shear wall is a structure composed of two secluded or isolated shear walls that are connected by beams or slabs in height wise manner. Normally, shear walls are incorporated with openings, just to allocate elevator doors, windows, shafts, stairwells, service ducts in the buildings which are unavoidable. Thus the walls on each side of opening must be coupled either by beams or by floor slabs or by combination of both the elements. The beams used for coupling the isolated walls are called coupling beams. The overriding purpose of the coupling beams is to assemble the walls and make them act as a single composite cantilever unit. Consequently, the horizontal stiffness is also improved when compared to the uncoupled shear walls.

An extensive research from past shows that the coupled shear walls are the prolific systems and could outlast in any kind of circumstances just by the introduction of a coupling beam. This introduction of coupling beam effectively increases the axial forces, thereby reducing bending moments in the walls and also the lateral deflection in the structures. And the performance of the coupled shear wall is decided by the combined action of shear and flexure.

"Pierced shear walls", "shear wall with openings" and "rigid jointed frame consisting deep members" are the best synonyms for the coupled shear wall.

Fig.1 Coupled Shear Walls

The efficacy of coupled shear wall can be emphasized in terms of stiffness. Solid shear walls or shear wall without openings is the effective one among the other types which make their use more desirable. Though the efficiency of the solid shear walls make their use necessary and desirable, but equipping them may not meet functional necessity. Hence, the concept of a shear wall with openings or coupled shear walls or pierced shear walls came into the picture. The segment between the openings is named as pier, and the portion above the openings is named as spandrel or a coupling beam.

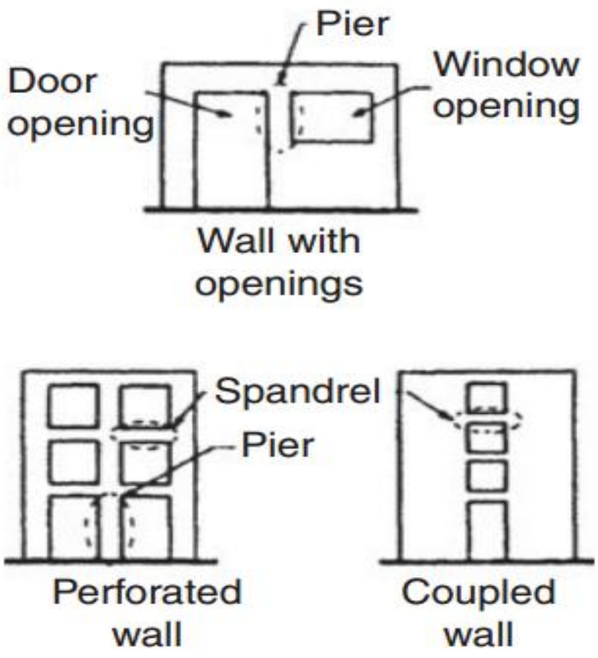

Fig.2 Picture describing Pier and Spandrel

II. COUPLING BEAMS

To intercept deterioration of the structure, the coupling beams should be designed to survive the soaring lateral loads and should also posses certain aspects like high ductility. In this kind of structure the axial forces in the walls obtained from the piled up shear in the beam are exemplarily stiffer, when compared to the wall piers.

In general, coupling beams need a colossal amount of shear reinforcement in the plane of coupling the shear walls and the coupling beams, to dispel the seismic energy produced by the earthquakes. To surpass this colossal amount of reinforcement an auxiliary technique is proposed, that is, diagonally reinforced coupling beams.

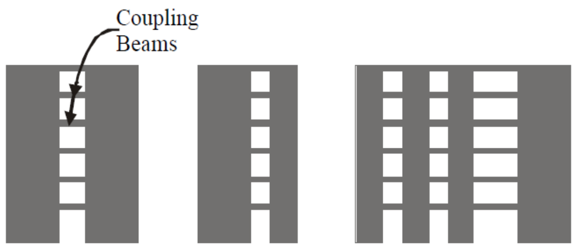

Fig.3 Coupling Beams

A. Types of Reinforcement In Coupling Beams

Based on the arrangement of reinforcement, coupling beams are classified into two types; they are coupling beams with conventional and diagonal reinforcements.

- Coupling beams with Conventional Reinforcement: In this kind of beam the arrangement of reinforcement is similar to that of a normal beam, where longitudinal reinforcement is composed of steel that is placed both at the top and bottom of the beam in the longitudinal axis of the beam and the transverse reinforcement is composed of ties. But when compared to regular beams this kind of beams do possess a colossal amount of shear reinforcement. The shear that is generated in between the connection of shear wall and coupling beam is endured by furnishing bulky amounts of transverse reinforcements in this area particularly. Fig.4 represents the geometry of the coupling beam with conventional reinforcement.

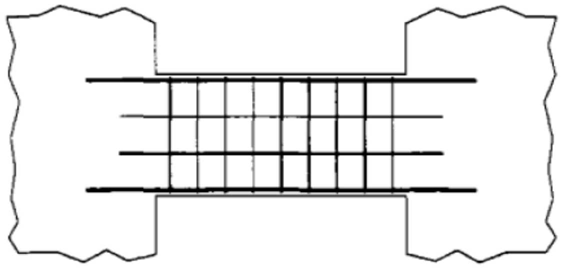

Fig.4 Typical Layout of Conventionally Reinforced Concrete Coupling Beam

- Coupling beams with Diagonal Reinforcement: In this model of coupling beams the arrangement of reinforcement is done with rebar's that bisect at an angle and display evenness about the mid span. Due to this angular arrangement of reinforcement, the large shear force is transformed into axial load. This variety of coupling beam can be fabricated either by using single bars or a set of bars. Fig.5 represents the geometry of the coupling beam with diagonal reinforcement.

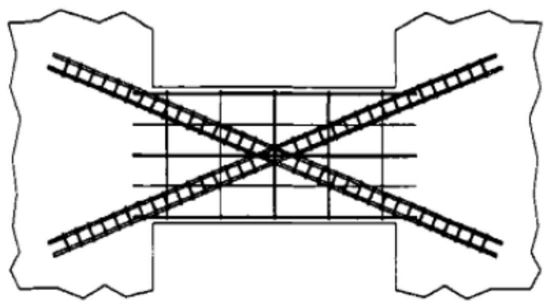

Fig.5 Typical Layout of Diagonally Reinforced Coupling Beam

B. Assumptions

If Shear stress exceeds $\frac{0.1ls\sqrt{fck}}{D}$ diagonal reinforcement is provided or when $\frac{l_s}{D}$ is less than or equal to 3.

The diagonally reinforced coupling beam design principle is based on the assumption that shear force itself is resolved into diagonal compression and diagonal tension forces.

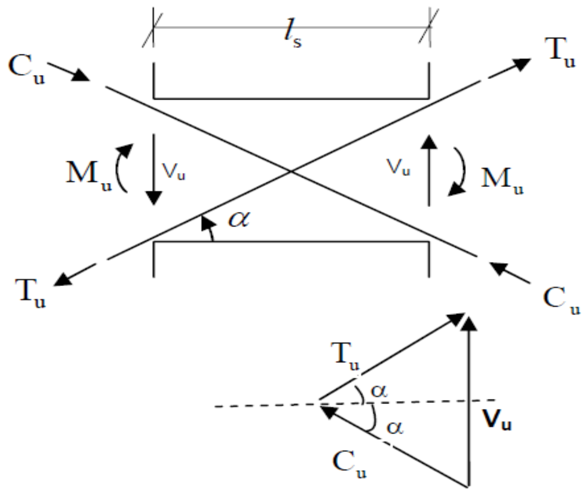

Fig.6 Diagonally Reinforced Coupling Beam

III. MODELING OF THE STRUCTURE

A ten storied building with external shear walls having a storey height of 3.1m is considered for this study with the help of finite element software ETABS under earthquake loads. The following dimensions 28.8m × 9.6m determine the floor plan of the building. The thickness of the shear walls and slab provided is 300mm and modeled them using shell element. The dimensions of the beam and columns are as follows 300mm × 600 mm. Fig.7 represents the plan of the building.

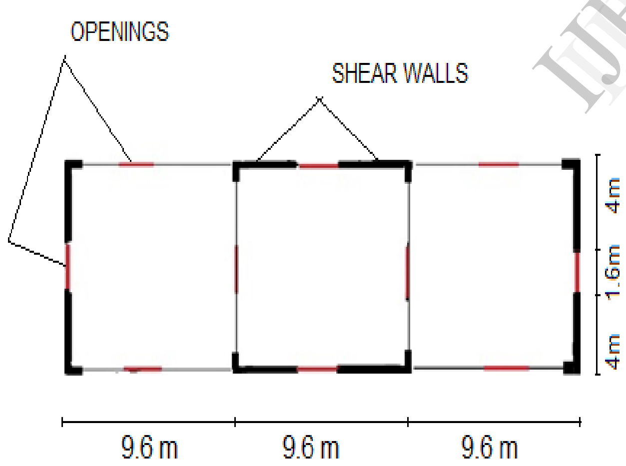

Fig.7 plan view of the building

IV. PROBLEM STATEMENT

In this study the ten storied building is modeled in ETABS for different sizes of openings in shear walls. Four cases were considered for door opening in the shear walls and the location of the opening is same in all the cases. The opening sizes of the door are as follows:

2.1m × 1.6m
2.0m × 1.6m
1.9m × 1.6m
1.8m × 1.6m

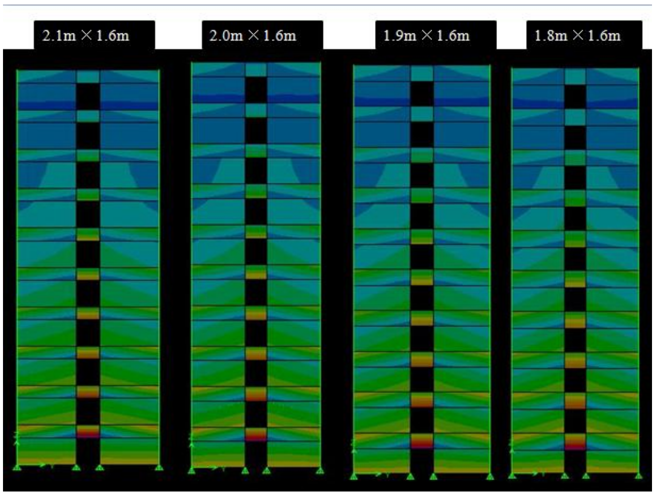

Fig. 8 Stress Representation for the above mentioned Opening Sizes

The figure below represents 3d view of the building modeled in ETABS.

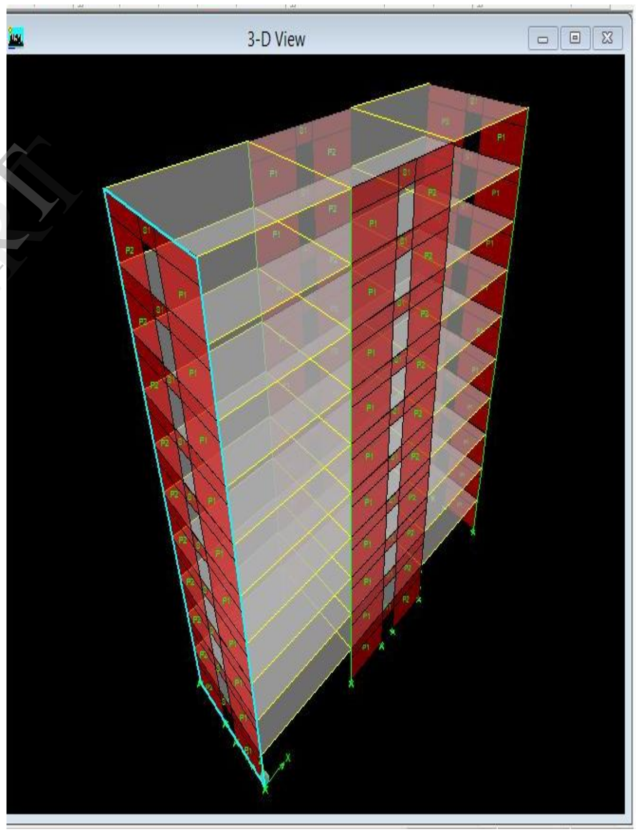

Fig.9 3D view modeled using ETABS

The main intent of this parametric study is to assess the behaviour of shear wall which is encompassed with varied opening sizes and stresses around the openings.

V. RESULTS AND DISCUSSIONS

If the opening is undersized then the depth of coupling beam gets increased and if the opening is oversized opening then coupling beams depth gets decreased, thereby the reinforcement in the coupling beam is effected. In the case of undersized opening the depth of the coupling beam is more so, the angle of inclination α to be provided in the diagonal reinforcement is high, thereby the beams performance is improvized. But for the case of oversized opening the depth of the coupling beam is less so, the angle of inclination α to be provided in diagonal reinforcement is less, thereby the performance of the beam gets deteriorated. Futhermore, in the case of oversized opening, coupling beam depth is less which signifies that furnishing diagonal reinforcement becomes a herculean task.

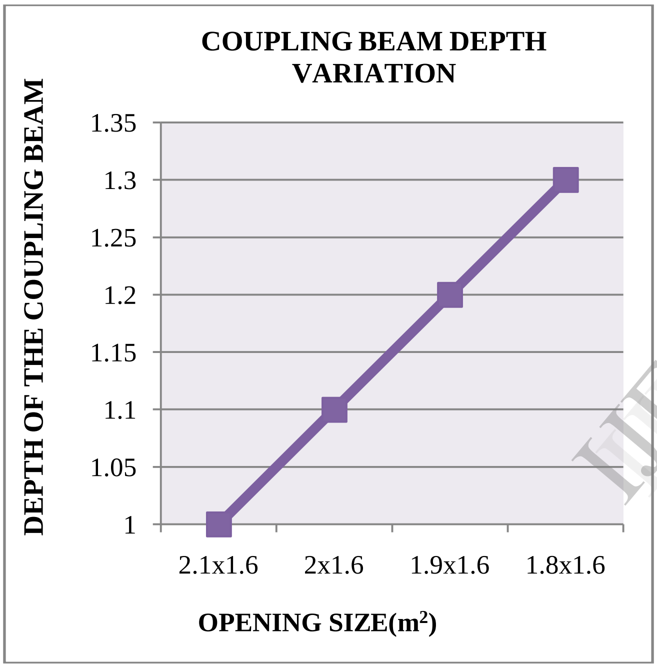

Fig. 10 Graph representing coupling beam depth to opening size

The overriding peculiarity is, if the opening is undersized then a weak beam mechanism is exhibited. And for oversized a strong beam meachanism is turned out. Another influential triat is, if the opening is undersized the stress around its periphery is less and if the opening is oversized the stress concentrations are shooted up.

The coupled shear walls are further classified on the basis of the magnitude of the parameter. According to the Albiges and Goulet(1960), coupled shear walls are classified based on the magnitude of parameter that,

- If the wall has undersized openings (i.e. with bulky coupling beams) then the shear deformations can be ignored.
- If the wall openings are oversized the involvement of the coupling beam can be ignored completely.
- A special analysis is necessary for the walls with openings in the middle of the walls where coupling beams are efficient of bearing the shear, and are subjected to deformations.

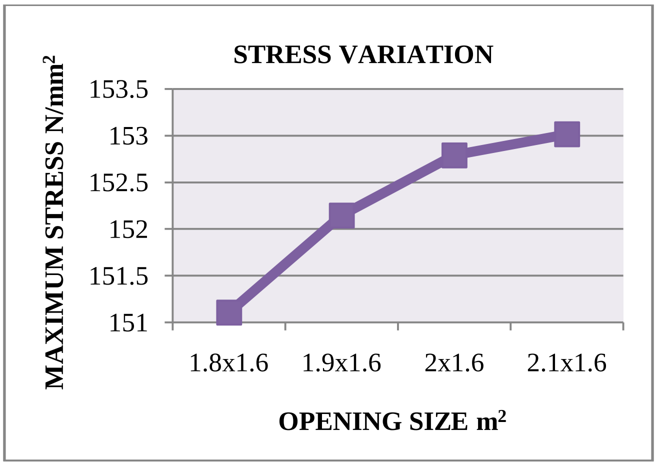

Fig.11 Stress variation around the openings

VI. CONCLUSIONS

When the size of the opening is increased the coupled shear wall system behaves as a single wall unit. There is less participation of coupling beam if the opening is oversized and vice versa. It is clearly evident that there is effect on the depth of the coupling beam for undersized and oversized openings. Getting down to the nitty-gritty, whatever the sizes of the opening, may it be an undersized opening or an oversized opening, the concentration of stresses are compulsory. The basic verity observed about coupled shear walls is if the opening is oversized then the concentration of stress is more and if the opening is undersized then the concentration of stress is less. The study reveals that the stress concentration wholly depends on the size of the opening.

VII. REFERENCES

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