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ANALYSIS OF SEISMIC BEHAVIOR OF HOLLOW CORE SHEARWALL WITH CHANNEL BOUNDARY ELEMENTS

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Abstract - *Shear wall is a structural member used to resist lateral forces i.e. parallel to the plane of the wall. For slender walls where the bending deformation is more, Shear wall resists the loads due to Cantilever Action Shear walls are especially important in high-rise buildings subject to lateral wind and seismic forces. Generally, they also provide adequate strength and stiffness to control lateral displacements. Structurally, the best position for the shear walls is in the center of each half of the building. This is rarely practical, since it also utilizes the space a lot, so they are positioned at the ends. So usually, the walls around lift shafts and stairwells are used. The barbell is one type of shear wall which having two columns at each end which called boundary elements. This provision has some advantages like stronger, more ductile and never fails in shear but yielding of steels occur in bending. The study is about the CFRP hollow core (vertical direction) shear wall with channel shaped boundary element. The advantages of both channel section and CFRP can be make shear wall stiffer and increasing durability and having more resistance to seismic loads like earthquake, wind etc. The obtained results are compared with the same shear wall without vertical reinforcement. The analysis of seismic behavior of hollow core shear wall with channel shaped boundary elements and CFRP hollow core without vertical reinforcement carried by Etabs17.The seismic performance can be improved by the additional materials and other configurations.*

Key words: Shear wall, Boundary element, hollow core wall, seismic resistance, CFRP tubes…

1. INTRODUCTION

Every structure consists of different types of loads such as vertical, horizontal and longitudinal loads etc. The vertical loads are dead load, live load and impact loads also the horizontal loads termed as wind load and earthquake loads. The design and construction of the structures are greatly depending on these and some is provision also considered regarding the type of loads. The earthquake load is one of the major load conditions, sometimes these loads are exceeding ability of structure to resist it without being broken partially or completely. The shear walls the vertical structural element which is used to resist the in plane lateral load (seismic loads). Shear wall are the structure which resist load parallel to the plane of wall rather than ordinary wall. Its location is greatly influencing the structural behavior of the structure. Sometimes it containing opening which will decrease the strength of shear wall, but it can be retard by the suitable provision of wall different configuration and materials. The Bar-bell types shear wall is one type of common shear wall (simple rectangle type and flanged). The bar well type of share wall is formed when a wall is provided monolithically between two columns, the column at the two end is called boundary element. The main advantages of this type are its more ductile never fails due to shear but subjecting yielding of steel in bending. The wall web of the barbell type shear wall is provided with hollow core concrete that will reduce the amount of concrete and increasing workability and also improving the strength, energy dissipation, durability and lateral force resistibility. Due to the provision of channel section as boundary element thereby it can increase the seismic capacity and overall capacity. The hollow core providing with CFRP tubes that will result in the better lateral resistance and failure by buckling of tubes. Due to this provision the use of vertical reinforcement can be reduced. In this paper the analysis of seismic behavior of CFRP hollow core shear wall with and without channel shaped boundary element carried out by ETAB Software.

2. LITERATURE REVIEW

Chen Xiong et al (2018) Conducted study on a new precast concrete shear wall system based on two-way hollow-core precast panels (TWHCPP) is proposed. First, pseudo-static tests were performed for one cast-in-place shear wall specimen and three TWHCPP shear wall specimens with different shear span to depth ratio. Three of them are casted with two ways hollow core slab (140 and 89mm). TWHCPP wall specimen starts from base block and boundary element also provided. The specimen was tested under axial and cyclic lateral load. The failure mod, load bearing capacity, energy dissipation capacity, deformation pattern is studied. From the results TWHCPP avoiding the brittle failure and sustain vertical and lateral loads more than ordinary shear walls also it avoiding the diagonal tension cracks, ductility is much better. The ordinary shear wall failed at displacement of 16.5mm but TWHCPP failed at 45mm which approximately 3 times that of cast-in place shear wall. Hysteretic energy consumption of TWHCPP shear wall is more than that of cast-in place shear wall.

FengmingRen et al (2018) Conducted experimental study on composite shear wall consisting of a reinforced concrete (RC) wall web and two boundary columns, in the form of square concrete-filled steel tubes (CFST) incorporating with a carbon fiber–reinforced polymer (CFRP)–confined concrete core. The shear wall subjected to constant axial compression and lateral cyclic loading to evaluate the seismic performance of shear wall under large earthquake. To conduct the study three additional shear walls with different boundary column configurations were also casted and tested are of (i) an ordinary shear wall, (ii) a shear wall with CFST boundary columns, and (iii) a shear wall with double-skin CFST boundary columns. The failure mode, load-bearing capacity, ductility, energy dissipation capacity, stiffness degradation, strength degradation, and deformation mode of the four shear walls were thoroughly examined and compared. The results show that the deformation of the proposed shear wall was dominated by bending and that the distribution of axial strain generally satisfied the plane section assumption. The results also show that the seismic performance of the proposed shear wall was superior to that of ordinary shear wall and also the shear wall with CFST boundary columns. The proposed shear wall had the comparable load-bearing capacity as the shear wall with double-skin CFST columns, but it had better ductility and larger dissipation capacity. This pilot study illustrated that the composite shear wall has good potential for improving the seismic performance of buildings constructed in seismic regions.

G.Amaret al(2016) Conducted an analytical study of G+5 storey office building which situated in zone IV with shear wall analyzed by using STAAD PRO. The storey height chosen as storey height 3.35m, shear wall and slab thickness 250 mm, column and beam size 350 × 350 mm materials of M 30 & FE 415 are provided and number of shear walls 2 chosen for analysis. Earthquake loads are assigned to the structure in X and Z directions and concrete design is done for beams and columns. The result shows larger stiffness to the buildings there by reducing the damage to structure and its contents and maximum displacement at top stories is limited. In multi-storey structure if it is properly oriented it will reduce torsional effect and storey deflection overall resistance of the lateral forces more than 80% when compared to building without shear walls.

SamiullahQaziet al (2019) Study conducted on short RC shear wall to improve the strength and drift without deterioration in the wall energy dissipation capacity under seismic loading. Three specimens were casted and tested with same dimension and specification.one is ordinary shear wall and other two are strengthened with CFRP in different configuration. Test specimens where subjected to lateral cyclic loading and axial load were applied and deformation pattern noted. Test results shows Both the CFRP reinforcement pattern improved the ultimate shear strength, Stiffness, Deformability, Limited crack propagation, Improved the energy dissipation capacity and the control specimen failed under loading with deflection 83mm, horizontal configuration about 46mm and diagonal configuration about 21 mm.

M.Dakhelet al (2018) The study conducted on shear wall provided with FRP composite plate of 0.8mm thickness. The dimension of 125x70mm were chooses based on the restriction imposed by the testing machine. Specimen was categorized into two main groups, specimen fastened with 2 and 3 bolts. Applying additional GFRP strips using adhesive between steel plate and internal layer of GFRP as well as applying adhesive between clamping plate and FRP around and the bolted area. Application of adhesive around the bolted area results higher increase in ultimate load capacity. Additional layer of GFRP around the bolted area of specimen have beneficial effect for both 2 bottled and 3 bolted specimens. Increasing both ultimate load capacity and energy absorption. However ultimate capacity in 2 bolted is more prominent in two bolted specimens. This study indicates the effective approaches to increase the ultimate load carrying capacity and energy absorption for connections in hybrid and pure FRP shear wall system.

LiweiWuaet al (2018) An experimental study conducted on precast structural wall system, concrete-filled steel tubes (CFSTs) were used to entirely replace the longitudinal reinforcement in the boundary elements of conventional reinforced concrete (RC) shear walls. At joints, the CFSTs and wall web reinforcement were connected by sleeves filled with high-strength mortar. To examine the seismic performance of the proposed system, seven 1/3-scale specimens were built and tested under quasi-static and dynamic cyclic lateral loading with a top displacement rate up to 20mm/s. Major test variables included axial force ratio ranging from 0.075 to 0.19 and loading rate. Result shows the damage pattern, hysteretic load deformation response, energy dissipation capacity, and connection performance of the test specimens. Under the considered axial force levels and loading rates, lateral loads were successfully resisted at the joints and the response of all specimens was dominated by flexure. The use of CFSTs increased lateral strength and deformation capacity. The highest axial force ratio caused drift capacity to be reduced from 2.5% to 2.0%. Although loading rate nearly had no influence on either lateral stiffness or strength, it reduced energy dissipation capacity. Finally, the effectiveness of proposed detailing of sleeve-mortar connections in load transfer was validated by the similar hysteric response, joint opening, and wall sliding between monolithic and precast CFST wall specimens.

Osman Hag-Elsafiet.al (2018) conducted study on seismic behavior of RC Square Columns strengthened with self-compacting concrete-filled CFRP-Steel Tubes. Eleven columns were tested under lateral cyclic load while simultaneously being subjected to constant axial load. The test parameters included the number of CFRP layers, the thickness of the steel tube, and the axial load level. The entire failure process, ultimate lateral load, and deformation capacity were analyzed. The experimental results indicated that the seismic bearing capacity of the RC columns could be improved significantly while the strengthening method was applied, because the ultimate lateral load strengthened columns were 7.36–9.67. Times that of the un strengthen column and the improvement ratio of ductility parameter reached 42.38–115.56%. As the number of CFRP layers increased, the ultimate bearing capacity, ductility, and energy-dissipation capacity of the CFCST-strengthened columns increased slightly. The CFCST-strengthened columns under a higher axial load level exhibited better ultimate bearing capacity and energy-dissipation capacity but worse ductility. With the increase of the thickness of the steel tube, all seismic performance indexes significantly improved.

3. SCOPE OF WORK

The following are the scope of works,

- Strength of shear wall can be improved by the provision of channel section boundary elements.
- Durability can be increase by the provision of CFRP tubes
- Hollow core will increase cost of concrete and also it makes concrete light weight
- Eliminating the vertical reinforcement by providing CFRP hollow core.

4. OBJECTIVES OF WORK

The following are the objectives of work,

- To Study the seismic behavior of hollow core shear wall with C shaped boundary elements.
- To study the ETAB Software for seismic analysis
- To study the analysis of shear wall with CFRP holes instead of vertical reinforcements.
- Comparing deflection of conventional with CFRP two-way hollow core (TWHC) shear wall (with channel boundary element and the same without boundary elements)

5. SEISMIC ANALYSIS

5.1 Specimen details

In this study, three specimens were compared, one specimen was controlled specimen (SW_0) and CFRP two-way hollow core shear wall without channel shaped boundary elements (SW_1) and the other one was CFRP hollow core shear wall with channel shaped boundary elements (SW_2). Seismic analysis was carried out using ETAB software. The Shear wall was subjected to seismic load according to IS 1893-2002 and live load of 250kN. The M70 grade of concrete and Fe415 steel is considered for the analysis. SW_0 is the cast-in-place benchmark specimen. SW_1 is the TWHC shear wall specimens without channel shaped boundary element which SW_1 and SW_2 has the same dimensions as the benchmark specimen SW_0.

5.2 Models

The reinforcement layouts of Conventional shear wall (SW_0), CFRP- TWHC Shear wall without channel shaped boundary elements (SW_1) and with boundary elements (SW_2) are shown in Fig.1 and Fig.2 and Fig.3 Respectively. Note that three specimens are made from the same batches and shear wall has same dimensions such as 1440mm x 180mm x 1700mm. The diameters of the vertical and horizontal hollow cores of the TWHCs are 140mm and 89mm, respectively, and the distance between adjacent vertical and horizontal hollow cores are 44mm and 110mm, respectively in both cases. The transverse and longitudinal reinforcements in the TWHCPP are ϕ 8@200 and ϕ 8@180, respectively. The construction of the TWHCPP shear wall specimens starts from the base block. The reinforcements of the boundary elements and dowel bars were embedded in the base block.

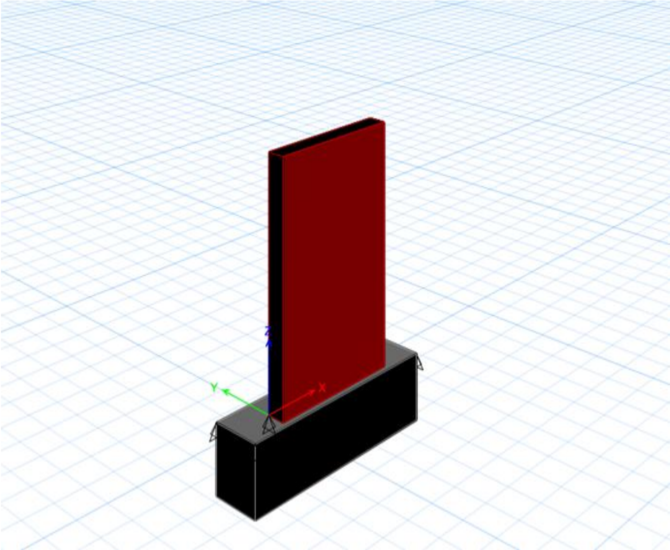

Fig-1 Conventional Shear wall (SW_0)

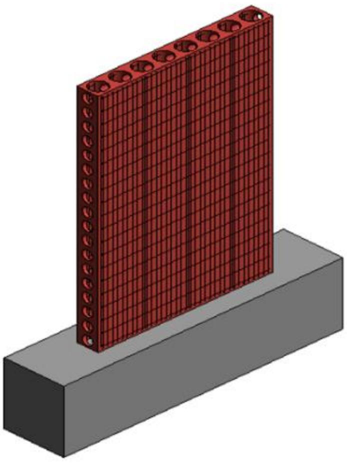

Fig-2 CFRP two-way Hollow core shear wall without Channel shaped boundary elements

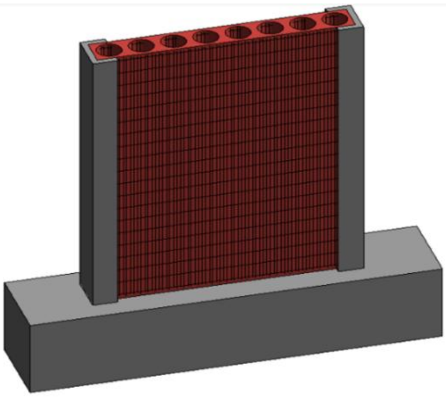

Fig-3 CFRP two-way Hollow core shear wall without Channel shaped boundary elements

5.3 Loading

Both shear wall was subjected to seismic load according to IS 1893-2002 and the live load of 250 kN. The loading diagrams of the SW_0, $SW_1$and SW_2 are shown in Fig.4 and Fig.5 and Fig.6.

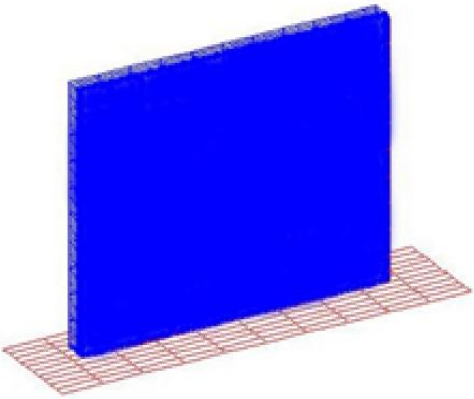

Fig-4 Loading diagram of CFRP two-way Hollow core shear wall without Channel shaped boundary elements

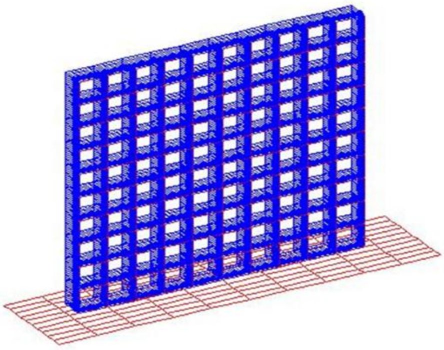

Fig-5 Loading diagram of CFRP two-way Hollow core shear wall without Channel shaped boundary elements

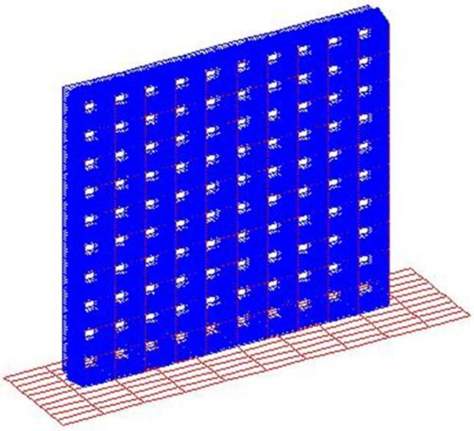

Fig-6 Loading diagram of CFRP two-way Hollow core shear wall with Channel shaped boundary elements

6. RESULT AND DISCUSSION

6.1 Resultant Stress Diagram

The Result Stress diagram of hollow core with horizontal and vertical reinforcement are graphically represented in Fig 7 and the shame shear wall without vertical reinforcement also graphically represented in Fig 8.

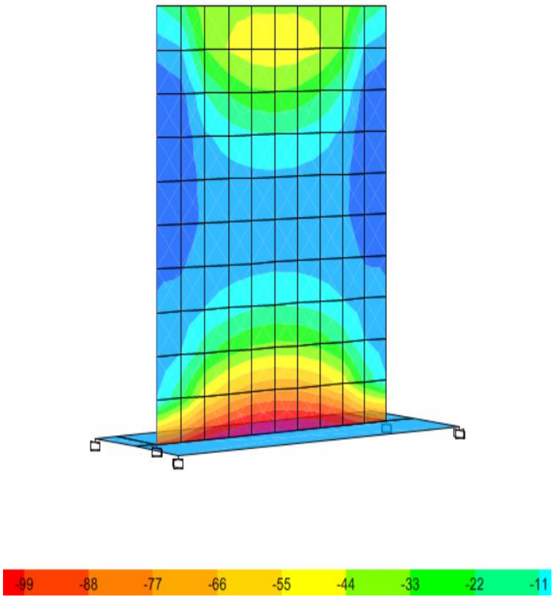

Fig-7 Resultant Stress Diagram of CFRP two-way Hollow core shear wall without Channel shaped boundary elements

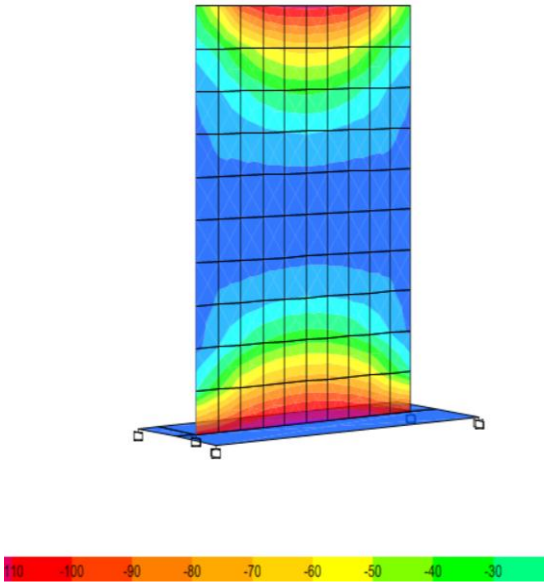

Fig-8 Resultant Stress Diagram of CFRP two-way Hollow core shear wall with Channel shaped boundary elements

The resultant stress showing at a peak level in the shear wall without Channel shaped boundary elements as compared to with channel shaped boundary elements. This additional provision can be reduced.

6.2 Deflection Diagram

The Deflection diagram of hollow core with horizontal and vertical reinforcement are graphically represented in Fig 9 and the shame shear wall without vertical reinforcement also graphically represented in Fig 10.

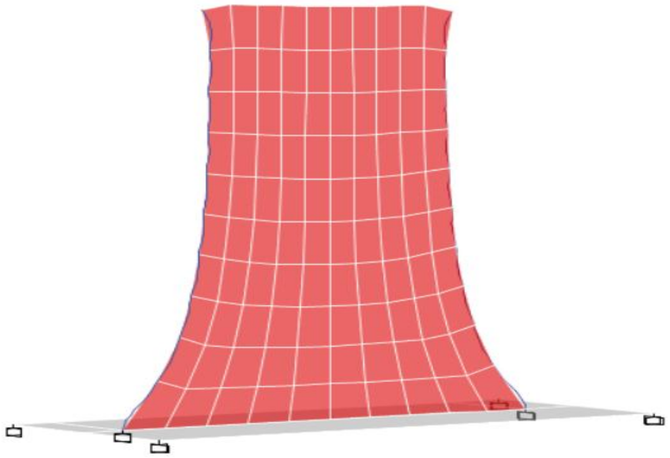

Fig-9 Deflection Diagram of CFRP two-way Hollow core shear wall without Channel shaped boundary elements

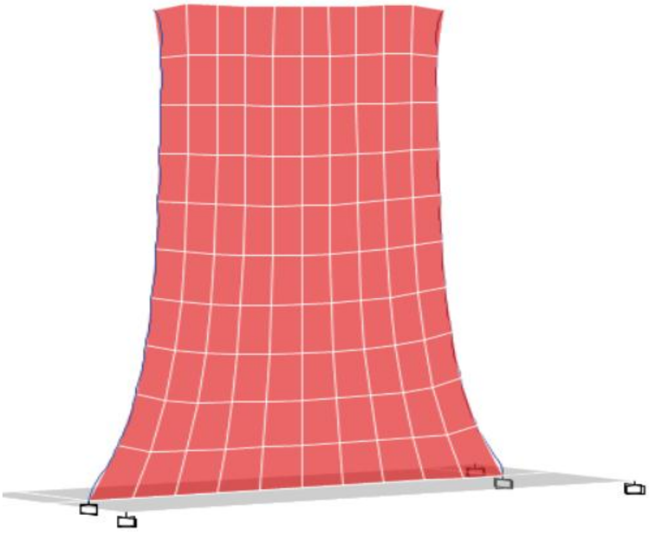

Fig-10 Deflection Diagram of CFRP two-way Hollow core shear wall with Channel shaped boundary elements.

6.3 DISPLACEMENT V/S HYSTERETIC ENERGY

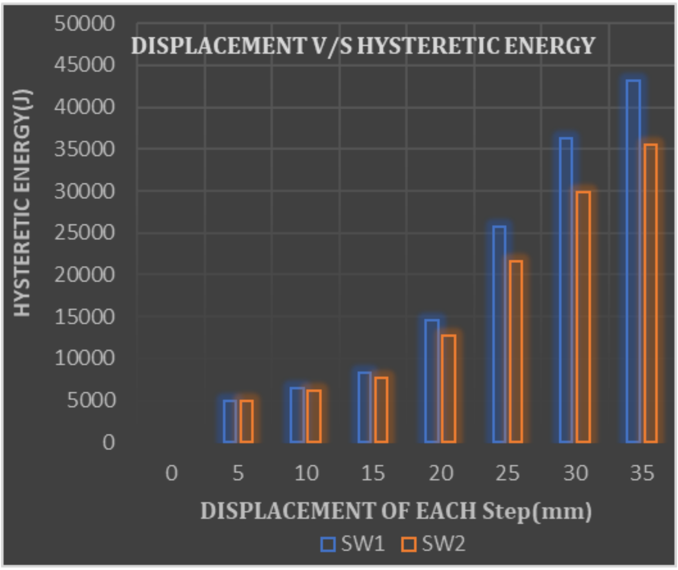

Fig-11 Graph of Displacement V/S Hysteretic Energy

The Graph of Displacement v/s hysteric energy of hollow core with horizontal and vertical reinforcement are graphically represented in Graph 11. From Graph the hysteretic energy is increase with displacement. The peak value obtained at 35 mm displacement.

Table-1 Displacement V/S Hysteretic Energy

DISPLACEMENT (mm)	HYSTERETIC ENERGY (J)	
	SW$_1$	SW$_2$
5	5100	4989
10	6500	6145
15	8324	7653
20	14509	12765
25	25764	21670
30	36327	29876
35	43216	35479

6.4 DISPLACEMENT V/S HEIGHT

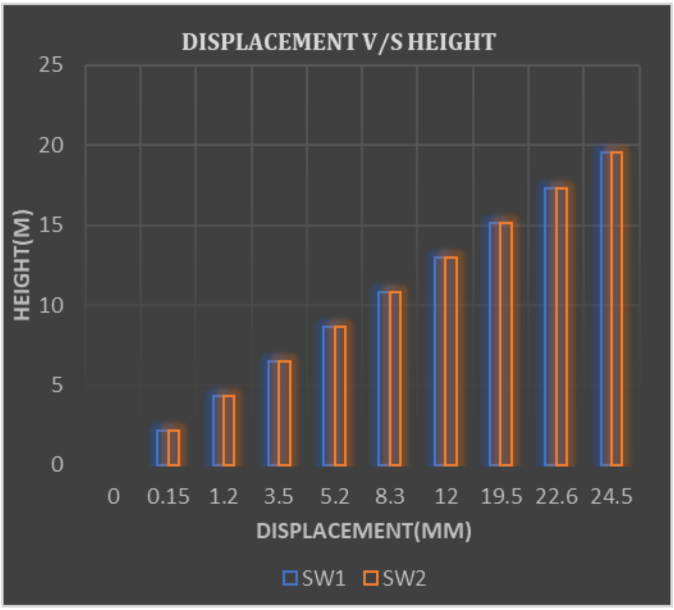

Fig-12 Graph of Displacement V/S Height

The Graph of Displacement V/S Height of hollow core with horizontal and vertical reinforcement are graphically represented in Graph 12. From Graph Displacement is increase with height. The peak value obtained at 20 m height.

Table-2 Displacement V/S Height

HEIGHT (mm)	DISPLACEMENT (mm)	
	SW$_1$	SW$_2$
5	2.352	1.47
7.5	4.704	3.525
10	7.35	6.468
12.5	11.76	9.112
15	19.58	15.00

Obtained value from analyses the displacement is increased with increase in the height. displacement for shear wall without horizontal hollow core having lower value compared to shear wall with two-way hollow core. The maximum value of displacement obtained corresponding to peak height.

7. CONCLUSIONS

The seismic performance of CFRP Two-way hollow core with and without Channel shaped boundary element were analyzed using ETAB software. The analysis concluded by Shear walls are basically constructing in multi-storied building in order to resist the lateral forces. The analytical study showing that Hollow core shear wall with boundary element is much superior to Conventional shear walls.

- The new set-up of hollow core shear wall having boundary elements and the same with CFRP hollow core analyzed by using ETABS.
- The results showing that CFRP two-way hollow core shear walls with channel shaped boundary element (SW_2) has very lesser deflection than the Normal hollow core shear walls (SW_1).
- The seismic resistance of SW_2 is higher than SW_0 due to the provision of two side boundary elements.
- Use of M_{70} Grade concrete gives superior strength even though two-way hollow core is provided.

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