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A Review on the Effect of Openings in RC Shear Walls and EPS Sandwich Core Wall under Cyclic Load

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Abstract: *Nowadays many residential and commercial buildings are constructed by MIVAN technology with reinforced concrete walls which act as shear walls in Higher seismic zones. Due to advancements in research and ecofriendly way of construction, the EPS sandwich core walls are becoming popular. The EPS walls reduce carbon emission, cut down the construction cost and tend to act as shear walls when lateral loads are applied. The above study compares the strength of the EPS sandwich wall with that of RC shear wall. When openings are provided in an RC Shear wall, the opening portions tend to deflect more. Much research has been carried out with different lengths and width, placement of the openings, change in concrete properties and different shapes were analyzed using Finite Element (FE) Software's under monotonic, cyclic and reversed cyclic loading and were validated by the lab tests. EPS walls being cost efficient, CSIR have released the design considerations to be followed and research shows that the performance increases, self-weight of the structure decreases, and the construction time decreases with better insulation properties. When the EPS sandwich walls are combined with the frame of RC structure the performance of the sandwich wall increases when applied with lateral load.*

Keywords: RC shear wall, EPS sandwich walls, Openings, Properties, Performance, Analysis

I. INTRODUCTION

The construction of the high-rise buildings is done in a fast phase manner. To complement such type of construction without compromising the performance of the structure, MIVAN type of construction is carried out. In MIVAN type construction, the structure is fully constructed with concrete walls and slabs, and they are cast monolithically. The MIVAN construction walls are Fully RC, and they also take lateral loads when earthquake hits. These types of walls act as RC shear wall and has all the properties of RC shear wall. Scaffolding and staging are done after the rebars, plumbing lines, electrical conduits and fire lines are placed in place. MIVAN is aluminum developed by a European company. The MIVAN construction can be done in a fast phased manner but requires skilled workforce, alterations are limited, since the whole structure is concrete the self-weight of the structure increases, and the construction of the MIVAN structure is costly. The planning by using the MIVAN type of construction should be made in similar type so that the formworks can be used for different projects. A typical MIVAN residential building and its cross section are given in Figures 1 and 2 which are referred from [14] and [15].

Nowadays due to exposure to people, even the construction of the small residential buildings is carried out in MIVAN type. The engineers carrying such construction are pushed to construct different projects in the same design. The cost of construction for such type of construction is very high and the alterations cannot be made. The residential sites cannot be same size and same area as compared to that of the high-rise buildings. To create a structure with same properties of strength, reduce the carbon emissions, reduce the cost many recent advancements in are made. EPS sandwich core wall is one such invention. Figures 3 and 4 represent a building with EPS Panels and the cross section of an EPS panel respectively. Figure 4 is referred from [5]. Due to the cost-effective way of the construction and easy way of handling the panels these are becoming more popular among peoples. Many design considerations for different element are put forward by **CSIR** – (Council of Scientific & Industrial Research). Even these structures are constructed as load bearing structures.

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We know that the concrete structures perform well during earthquake. Even in those concrete structures the openings are the weakest link. To prevent the structure from failing IS codes have given specific guidelines. But in the case of the EPS core wall there are no such guidelines given for openings. There are not many research papers on the study on the behavior of openings on the EPS core walls as compared to that of RC shear wall. The present study provides a review on the behavior of the RC shear wall and EPS core wall in Ansys.

Figure 1- MIVAN Residential Building

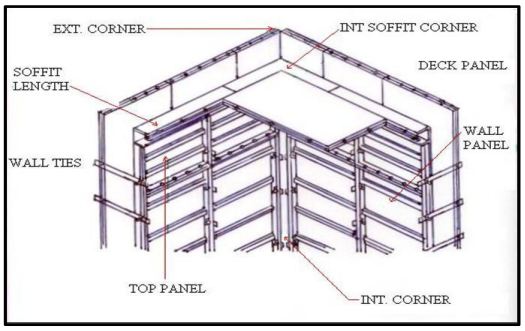

Figure 2- C/S of MIVAN Panel

Figure 3- EPS Panel Building

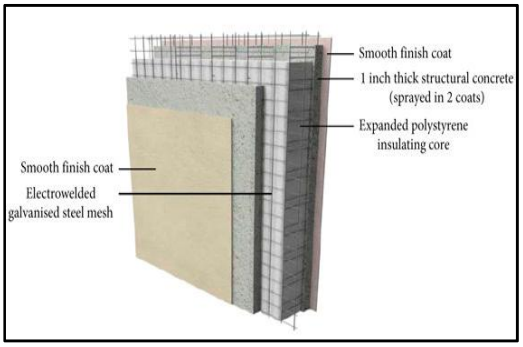

Figure 4- C/S of EPS Panel

II. LITERATURE STUDY

[1] Musmar, M. A. (2013). Analysis of shear wall with openings using solid65 element. Jordan journal of civil engineering, 7(2), 164-173.

In this paper the shear walls are analyzed with different size of openings and at different places. The shear walls with small openings yields minor loads. Small openings in shear wall acts as coupled shear wall and larger the size of openings in shear wall causes disturbance to the stress flow of the shear wall. The cracking for solid shear walls takes place at discrete locations nearer to the base of the wall, and for shear walls with smaller openings cracking starts at base of the wall and shear wall with larger openings cracks occur at the side of the wall, upper lintel, and corner of the shear walls.

[2] Benbellil, B., Kebdani, S., Kettab, R. M., & Benbouras, M. A. (2019). Comparative modelling of seismic performance of l-shaped reinforced concrete shear walls. Urbanism. Arhitectura. Constructii, 10(1), 29-46. [1]

In this paper the structural behavior of the L- Shaped RC shear wall is analyzed in two phase. In first phase the RC shear wall is analyzed in Ansys and in second Phase the experimental tests are carried out for the model. The outcome of this paper is, base of the L-shaped RC shear wall deflects more and the base has adverse effects. It fails due to crushing and 80% of the total deflection in at base.

[3] Bhandari, P. (2016). Evaluating properties of lightweight sandwich wall panels. International Journal for Scientific Research & Development., 4, 175-178.

In this paper the EPS wall panel is studied for its physical properties with ferrocement made as cover for the panel. The EPS sandwich panels is found to give better results in flexural, vertical load carrying test, compressive strength, thermal

conductivity, and impact resistance than conventional brick mortar wall systems.

[4] Chen, W., Hao, H., Hughes, D., Shi, Y., Cui, J., & Li, Z. X. (2015). Static and dynamic mechanical properties of expanded polystyrene. Materials & Design, 69, 170-180.
In this paper the Expanded polystyrene (EPS) with different densities were tested for Quassi-Static Compressive and Tensile Strength and Dynamic compressive and Tensile Strength. From this paper it is studied that, the higher the density of the EPS the compressive Strength, Youngs Modulus and Energy absorption also increases. Due to increase in Strain rate the tensile strength and failure strain increasesduring dynamic test.

[5] Wibowo, A., Wijatmiko, I., & Nainggolan, C. R. (2018). Cyclic behaviour of expanded polystyrene (EPS) sandwich reinforced concrete walls. *Advances in Materials Science and Engineering*, *2018*, 1-9.
This paper assesses the cyclic behavior of EPS panels by developing and comparing the behaviour of two wall specimens: one with the expanded polystyrene panel and the other one with the wire mesh reinforcement. It was summarized that the wall with EPS panel showed a usual flexural behavior with a drift capacity of 1.3% whereas the wall with reinforced panel showed a drift capacity of 1% and was prone to penetration dur to thinner section.

[6] Dabbagh, H. (2005). Strength and ductility of high-strength concrete shear walls under reversed cyclic loading (Doctoral dissertation, University of New South Wales).
The RC shear walls with High Strength Concrete (HSC) are tested for reversed cyclic loading. Due to the brittle nature of the HSC the ductility of the element is found to be very low. So the analysis in FE software were carried out. From this Paper it is studied that HSC shear walls have good stability against the axial load but very poor stability to the ductility. When the Longitudinal reinforcements are increased the failure capacity of the RC Shear walls are increased.

[7] Husein, N. R., Agarwal, V. C., & Rawat, A. (2013). An experimental study on using lightweight web sandwich panel as a floor and a wall. International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN, 2278, 3075.
In this the paper the author has tested the physical properties of the Lightweight Sandwich Panel (LWSP) with Aerated core and EPS Core. From the above research it is found that the LWSP EPS performs better and reduces weight of the structure by 30%. The cost of the LWSP EPS core is cheap when compared with that of Aerated core.

[8] Musmar, M. A. (2013). Analysis of shear wall with openings using solid65 element. Jordan journal of civil engineering, 7(2), 164-173.
In this paper the shear walls are analyzed with different size of openings and at different places. The shear walls with small openings yields minor loads. Small openings in shear wall acts as coupled shear wall and larger the size of openings in shear wall causes disturbance to the stress flow of the shear wall. The cracking for solid shear walls takes place at discrete locations nearer to the base of the wall, and for shear walls with smaller openings cracking starts at base of the wall and shear wall with larger openings cracks occur at the side of the wall, upper lintel, and corner of the shear walls.

[9] Morsy, A., & Ibrahim, Y. (2019). Parametric Study for Performance of RC Wall with Opening Using Analytical FE Model. Athens Journal of Technology and Engineering, 6(1), 31-62.
Here in this paper, the RC shear wall is analyzed with different shapes with different sizes in Ansys. The FE approach is statistically verified with other papers. From this paper it is studied that rectangle opening RC shear wall have highest load carrying capacity compared square and circular opening. The orientation, aspect ratio, wall thickness place's vital role in the ductility and axial load carrying capacity of the wall. The RC walls with small openings (Area 7% less than area), its effect can be neglected.

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[10] Adly, A. K. (2018). FINITE ELEMENT MODELING OF RC SHEAR WALLS STRENGTHENED WITH CFRP SUBJECTED TO CYCLIC LOADING (Doctoral dissertation, Faculty of Engineering at Cairo University in Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE in STRUCTURAL ENGINEERING FACULTY OF ENGINEERING, CAIRO UNIVERSITY GIZA).

The RC shear Walls are provided to resist the sudden load and give structural stability to the building. The RC shear walls are strengthened with CFRP (Carbon Fiber Reinforced Polymer) and its behavior during cyclic loading and inverted loading is carried out. Seven specimens were modelled in the Ansys and they were validated with two experimental programs under monotonic and inverted cyclic loading. The tests conducted on the two specimens showed the same results with that of Ansys model.

he Shear walls were modelled in Ansys with five different types of compressive strength of concrete. As the compressive strength of the concrete is increased the lateral displacement also increases. Adding the CFRP sheets in multiple layers increases the ultimate load and increases the maximum displacement. By increasing the thickness of the CFRP sheets the ultimate lateral load increases.

[11] SIVAGURU, V., & RAO, G. A. Behavior of Reinforced Concrete Squat Shear Walls with Utility Openings.

In shear walls it becomes inevitable if openings are provided for the MEP purposes, since it reduces the ductility, the cracks might arise at the corners of the opening. The specimens are modelled with openings and the corners of the openings are smeared with steel fibers. it increases shear strength by 60% and increases the ductility of the shear wall when compared to the shear wall with opening that does not have steel fibers smeared.

[12] Chen, W., & Hao, H. (2014). Experimental and numerical study of composite lightweight structural insulated panel with expanded polystyrene core against windborne debris impacts. *Materials & Design*, *60*, 409-423.

This paper speaks about the effects of windborne debris on Structural Insulated panels with expanded polystyrene. Eight model specimens of size 1200x762mm were developed and impacted using pneumatic cannon testing system. The specimen was placed at a distance of 3m from the cannon which had a timber projectile. The projectile was launched with different velocities and its effects were studied experimentally. The specimens with damage in the front skin alone were designated as 'Pass' and the remaining were designated as either 'Fail+stay' or 'Fail+through' based on the results. Also, numerical models were developed using ANSYS and LS PREPOST. On the whole, it was observed that out of the eight specimens, four specimens fell under 'Pass' category and the remaining specimens failed either by tearing action or punching shear.

III. RESULTS AND DICUSSION

The results of the above reviewed papers are summarized and discussed

- The EPS panel for smaller construction which has minimum loads are safe for construction.
- The compressive strength of the EPS sandwich core increases with an increase in the density of the EPS core.
- By use of double panel EPS core wall, the structure can withstand heavy loads.
- When providing the openings, necessary guidelines should be followed as per the Code books and CSIR for EPS core wall.
- The EPS panel takes the lateral load and acts as shear wall.

As mentioned in [13],

- The design of these panels should be carried out as per the Indian Standards (IS 456:2000, IS 11447:1985, IS 875 (Parts 1-5), IS 1905:1987, IS 4326:1993, IS 1893 –Part 1: 2016 and IS 13920:1993.
- Proper distribution of Base shear should be ensured in case of multi-storey buildings that are located in high seismic zones.
- The concrete grade used for these panels should not be less than M20 with which shotcreting should be done for 40mm on both the sides. It should have a fire rating value of 90 minutes.
- The insulation core and the reinforcement mesh shall comply with the American Standards.

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IV. CONCLUSION

From the literature review, the behavior of EPS Sandwich core wall is analyzed for cyclic loading, reversed cyclic loading and when the density of the EPS core wall increases the lateral load capacity of the shear wall increase. It also acts as shear wall which can be used in the construction of low-cost houses in a fast phase manner and effectively. The general requirements for the design of an EPS panels are presented in [13] which follows Indian and American standards. Therefore, EPS panels exhibit a better performance since they conduct less heat, are light in weight and also have higher compressive strength when compared to the usual wall panels as per [13]. Currently, many studies are in progress to assess the effect of various parameters on these EPS Panels.

V. ACKNOWLEDGEMENT

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