Experimental Investigation of Insulated Concrete Form (ICF) Wall Panels under Quasi Static Cyclic Load

Arun Solomon.A, Hemalatha.G

Abstract**: *Insulated Concrete Form (ICF) is a promising construction technique that provides fast construction, energy efficient, cost effective, sound proof and disaster resistant building. ICF is made from expanded polystyrene (EPS) and reinforced concrete. EPS occupies permanent position on the surface of concrete wall that offers insulation and structural benefits to the building. In this study, quasi-static cyclic load behavior of ICF wall panels were examined and test results were reported. ICF wall panels were made with 60 mm thick core concrete and 100 mm thick of 12, 20 kg/m^3 density EPS provided as a facesheet. The specimens were tested in 100 T capacity loading frame under horizontal quasi-static cyclic load. The experimental results were analyzed with hysteresis loops and load-deflection curves. From the study of cyclic load behavior and literature, ICF wall panel is recommended for the construction of seismic resistant buildings.***

Index Terms: Energy Dissipation, EPS, ICF, Hysteresis Loops, Load-deflection Curve

I. INTRODUCTION

The advances in construction technique accomplishes low cost, flexible, acoustic resistance, energy efficient, and minimum installation times of low rise residential building worldwide [1]. Insulated concrete form (ICF) is one of the new construction technique which composed of expanded polystyrene (EPS) and concrete makes the structure light weight. ICF provides high insulation and increases ductile property to the building. The composite action of EPS and concrete enables the structure to obtain maximum structural, thermal and acoustic benefits. In ICF, the expected load carrying capacity is provided by traditional concrete and the thermal insulation and acoustic resistant behavior is exhibited by light weight EPS. Natural calamities like earthquake, cyclone, and flood are challenges in civil engineering design and construction. Adequate strength and stiffness is necessary to prevent structural and non-structural damage against unexpected natural forces[2].

Seyed et al.,[3] have proposed JK wall which is a kind of shear wall made with super-lightweight expanded polystyrene concrete and reinforced by JK panel. From quasi-static cyclic loading test, it was concluded that JK walls can sustain large ductility demands. Peter et al., [4] studied seismic evaluation of ICF grid wall where ICF grid wall was developed using recycled foam materials. Based on the preliminary cyclic test experimental results, it was concluded that this system has potential to implement in the areas of high seismicity. Also Peter et al.,[5] examined in-plane lateral cyclic behavior of insulated concrete form grid walls. After conducting thirteen full scale experiments of wall made from recycled polystyrene, it was concluded that individual element failure governs overall wall failure and wall's drift capacity and ductility depends on the wall aspect ratio.

EPS has the property of high elasticity that regains its original shape even after reaches its full compression. In addition to that small scale ICF specimens exhibits high ductility as compared to plain concrete specimens. The ductile property of EPS helps ICF to resist lateral loads such as earthquake, cyclone, flood etc.,[6]. The objective of this study is to assess the horizontal quasi-static cyclic load behavior of ICF wall panel. For the purpose real-scale two ICF wall specimens were cast and tested under quasi-static horizontal cyclic loading in 100 T capacity loading frame.

II. MATERIAL PROPERTIES

A. Concrete

Concrete design mix ratio of 1:1.2:2.4 and water-cement ratio 0.45 has been used to cast ICF specimens. Ordinary Portland cement of grade 43 has been used for the preparation of concrete which is commonly available and employed for the construction. Concrete mix was designed for a characteristics compressive strength of 25 MPa. Concrete has been cast with 10 mm size aggregate. The nominal compressive strength of designed mix was tested by cast of three cube samples and tested at 28 days and found the compressive strength of concrete is 30.5 MPa. Similarly reinforcement also tested under tensile test and found the tensile strength of reinforcement is 420 MPa. The basic material properties were examined by conducting the fundamental tests and ensured the same has been used for specimen preparation.

B. Expanded Polystyrene

The material properties of EPS were examined under compressive, tensile and flexure test.

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The experimental results has presented in the previous research article [6]. In this study, ICF panels were prepared with EPS of 12 and 20 kg/m3 density with the thickness of 100 mm.

III. SPECIMEN PREPARATION

Two ICF wall panels were prepared with EPS of 12 and 20 kg/m^3 density with the thickness of 100 mm. Normally EPS sheets are available in the market of size 1000 x 500 mm. Hence ICF wall panels also prepared with the size of 1000 mm x 500 mm. Fig 1 shows the typical cast specimens of ICF and Table I provides the specimen details. The thickness of center core concrete is 60 mm which plays a predominant role against horizontal loads. The concrete core was reinforced with reinforcement mesh which was prepared with 8 mm diameter MS rod. The center to center distance between horizontal and vertical reinforcement was taken as 200 mm. The concrete core were cast with M25 grade concrete and this concrete core extended up to 300 mm on both sides of size 60 x 60 mm in order to fix the wall panel into the loading frame. Specimens were cured for 28 days with sack cloths.

IV. EXPERIMENTAL SETUP AND INSTRUMENTATION

Fig 2 exemplifies the graphical and pictorial representation of experimental setup in the 100 T capacity loading frame. One side of loading frame has been used to set electro-hydraulic actuator for applying the horizontal cyclic

Fig 1. Typical Cast ICF wall Panel

Load to the specimens. The load cell is attached with actuator which records the applied load in the connected system. The top of the wall panel is enveloped by the channel section and fixed by high strength bolts. This setup has connected to the load cell in order to provide cyclic motion to the top of the specimen. The horizontal cyclic lateral load has been applied to the wall panel by the actuator of capacity 15 ton. The bottom of wall panels were firmly fixed with the rigid steel beam of the loading frame by channel and high strength bolts in order to restrict the plane movement. The loading frame specially designed to apply either horizontal or vertical load. This paper focus of examining the behavior of insulated concrete form wall panel under quasi static cyclic horizontal load.

Displacements were recorded by linear variable differential transducers (LVDT). Two LVDTs has been used to document displacement history while applying horizontal cyclic load. LVDT were positioned on top and bottom of the wall panel which is indicated in the fig 2. The load cell and LVDT were connected to the system through digital load cell indicator and digital displacement indicator. By this experimental setup the loading and corresponding displacement history data has been obtained from the system, simultaneously manual observation data also noted through digital load and displacement indicator. The cracks were observed and marked in the sample at every load cycle, the type and number of cracks also noted at every cycle

A. Loading History

The in-plane quasi-static horizontal cyclic load were applied at the top of the wall panel. The cyclic load test were conducted by load controlled mode. The load cycles started from ±1 kN and every cycles repeated three times. Load cycles increased step by step by increment of 1kN and the experiment extended till the failure of the specimen. Fig 3 represents loading history of ICF12100 and ICF 20100. Total eighteen cycles of load has been applied in both of the specimen till the increment of load 7 kN.

Every cycle corresponding displacement recorded manually and complete load-displacement data obtained from the system. The experiments were carried out in the structural engineering laboratory of Karunya Institute of Technology and Sciences.

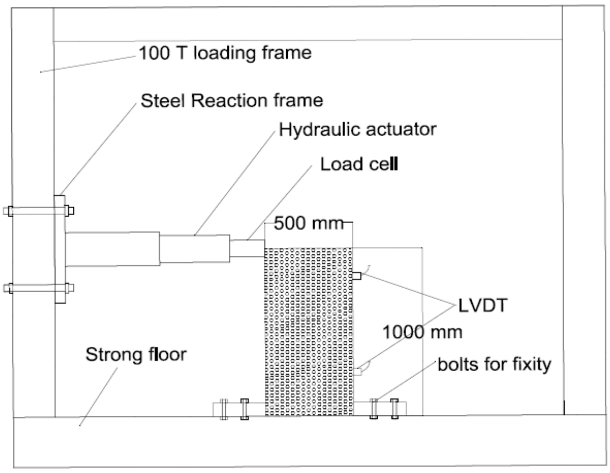

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Fig 2. (a) Schematic and (b) Pictorial Representation of Experimental Setup

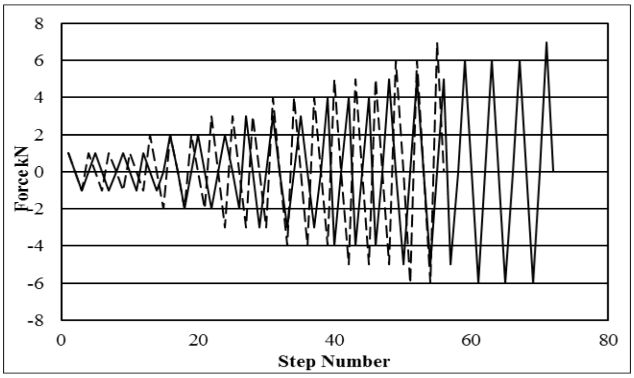
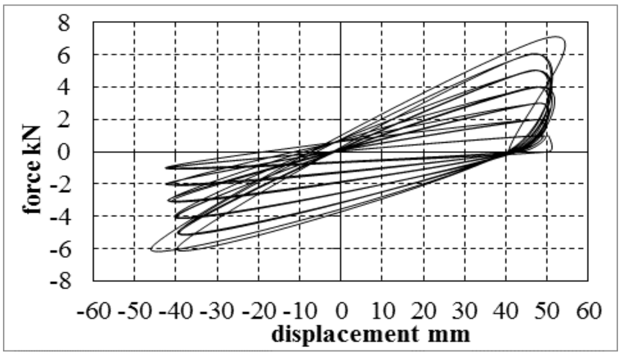


Fig 3: Loading History

V. RESULTS AND DISCUSSION

In this section, Quasi-static cyclic horizontal test results were analyzed by hysteresis loops and load-deflection curve. Eighteen full cycles were applied in each specimen and first shear crack was observed in 3.5 kN and 3.8 kN for ICF 12100 and ICF 20100 respectively. The displacement at shear crack is 9.2 mm and 9.8 mm respectively. Both the specimens first crack was observed in 300 mm from the bottom of the wall panel. After 10th cycle the reinforcement started to yield and it was observed in the displacement of 11.2 mm. Energy dissipation, strength and stiffness reduction was happened in every cycle which were indicated in the hysteretic loops. Flexural strength is also governing factor in order to resist the seismic shear force. The vertical reinforcement present in the wall provides flexural nature to the wall as well as step by step stiffness deterioration happens due this vertical reinforcement. And primarily horizontal shear is transferred through this vertical reinforcement. Fig 4 shows hysteresis loops developed based on applied horizontal force and corresponding displacement measured at top and bottom of ICF specimens using LVDT.



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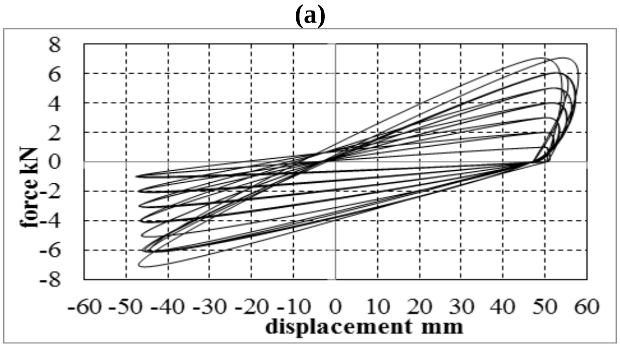

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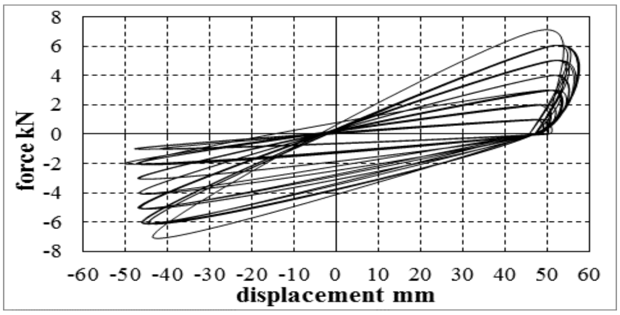

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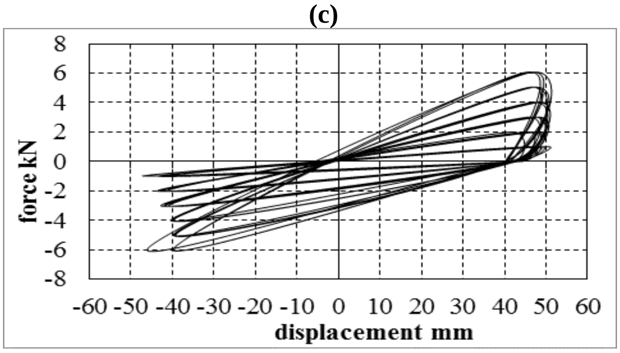

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Fig 4. Force vs displcament : (a)(b)Top and bottom LVDT of ICF12100 (c)(d) Top and bottom LVDT of ICF20100

Table I. Specimen Details

S. No	Reference Name	Grade of concrete	Height mm	Breadth mm	Density of EPS (kg/m^3)	Thickness of EPS (mm)	Thickness of core concrete (mm)	Total thickness (mm)
1	ICF12100	M25	1000	500	4	100	60	260
2	ICF20100	M25	1000	500	8	100	60	260

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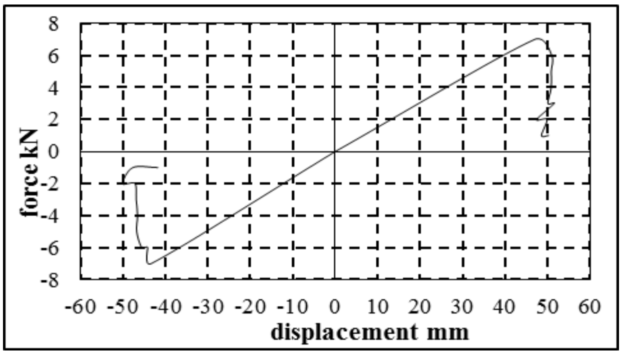
A. Lateral Strength

Construction of force-displcement envelope is the key to study the inelastic behavior of walls. Fig 5 presents force-displacement envelope which were developed by connecting peaks in force-displacement hysteresis loops (figure 3). The maximum value of lateral load carried by ICF 4100 is 7.2 kN and ICF 8100 is 7.4 kN with the displacement of 42 mm and 48 mm respectively. The degree of strength degradation is almost similar to both the specimens.



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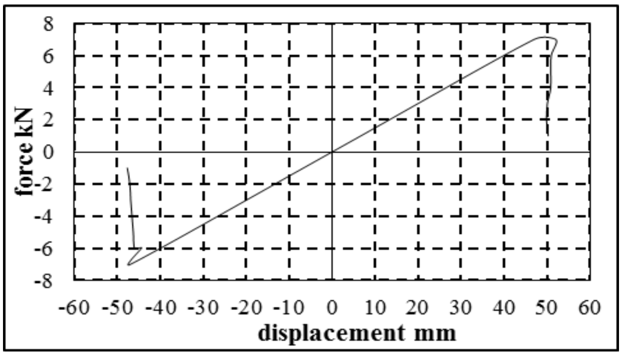

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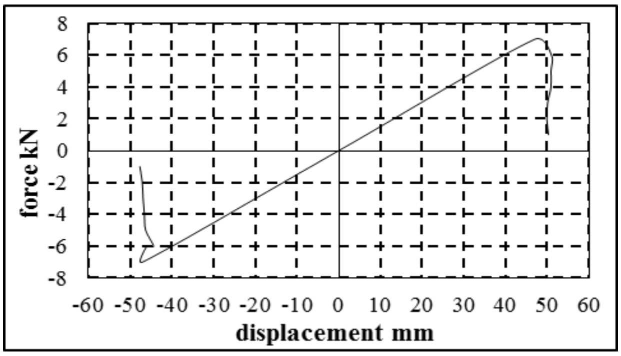

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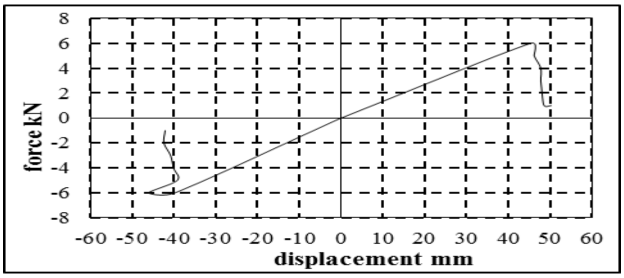

(d)

Fig 5. Force vs Displacement Envelopes (a) (b) top and bottom LVDT of ICF12100 (c)(d) top and bottom LVDT of ICF20100

B. Energy Dissipation

Due to earthquake the building structures get sudden distortion energy and this energy has to be dissipated by the building components. Seismic performance of a structure or member depends on energy dissipation capacity which are measured in different ways. The total amount of energy dissipated are measured by calculating area under hysteresis loops [7]. Two specimens were tested and four hysteresis loops were plotted by two LVDT readings which were placed in top and bottom of the specimen. The experiments extended up to eighteen cycles of quasi static cyclic loads. Dissipated energy under each cycle are calculated by measuring the enclosed area of each hysteresis loops. Fig 6 shows the dissipated energy under each cycle of hysteresis loop. Fig 7 plots the total (cumulative) energy dissipated by the two specimen up to failure. The maximum energy dissipated by ICF12100 is 341.65 kN.mm and ICF20100 is 340.2 kN.mm. Cumulative energy dissipated by ICF12100 is 3055.162 kN.mm and ICF20100 is 2971.368 kN.mm. Similar results were observed in both specimens especially top and bottom LVDT results of both specimens exhibits identical results.

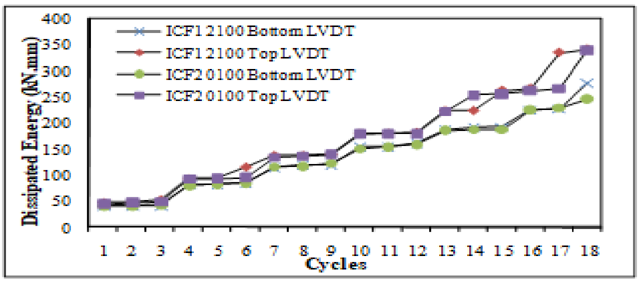

Fig 6. Energy Dissipation under Each Cycle of Hysteresis Loops

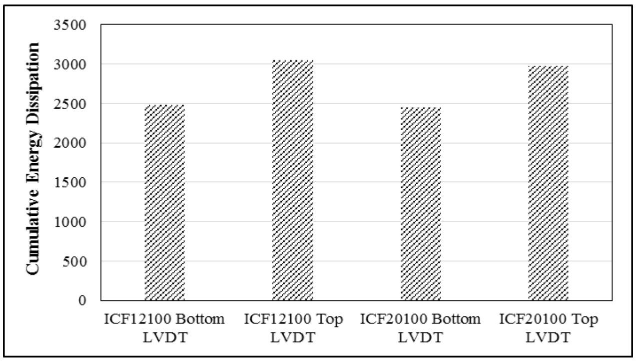

Fig 7. Total Energy Dissipation under Each Hysteresis Curve

VI. CONCLUSION

The quasi static cyclic load behavior of ICF wall panels were investigated with experiments. Two panels ICF 12100 and ICF 20100 were cast and tested under 100 T loading frame where ICF 12100 denotes wall panels cast with 60 mm thick core concrete and both

Side of concrete wall affixed with 100 mm thickness EPS having density 12 and 20 kg/m^3. The experiment were carried out in 100 T capacity loading frame. The cyclic loads were applied to the wall panel on increment basis from 1 kN up to failure load. Three cycle of load were applied on every scale of load. It was observed that, the wall specimens withstand up to eighteen cycles. Hysteresis loops were developed based on force-displacement data obtained from system.

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Load vs displacement graphs were derived from the hysteresis loops for analysis. It was found from graph that, the maximum peak load for ICF 12100 is 7.2 kN and ICF 20100 is 7.4 kN. The maximum displacement of ICF12100 is 42 mm and ICF 20100 is 48 mm. The maximum energy dissipated by ICF12100 is 341.65 kN.mm and ICF 20100 is 340.2 kN.mm. Cumulative energy dissipated by ICF4100 is 3055.162 kN.mm and ICF 20100 is 2971.368 kN.mm. This pilot experimental studies proved that the ICF wall panels resist lateral loads.

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