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Examination of the Properties of Insulated Concrete Form Blocks and Study of Finishing System with Polypropylene Sheet

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Abstract

The construction industry is growing at a fast pace and it has caused a crisis of materials' shortage. Insulating concrete from wall system of building construction is an emerging technique to address this issue. This technique has numerous advantages over traditional brick wall and RCC construction. It enables construction of an energy saving and energy efficient building, that needs no special form works, is cost-effective, the fastest way of construction, sound proof, requires little maintenance, and is disaster resistance. Insulating Concrete Forms (ICFs) have been successfully used in the United States, Canada and Europe for over twenty years. Lack of knowledge and experience, and non-availability of required materials are the barriers in developing this technique in countries such as India. This paper presents experimental results carried out to study the behavior of ICF blocks. Results show increased compressive strength and ductile failure of the material of the yield point.

Keywords: *EPS Sheet, Insulated Concrete form, Load-Deflection Curve, Compressive Strength*

INTRODUCTION

Growth of population leads to an increase in construction of residential and commercial buildings. India is facing the problems of shortage of construction building materials. Hence, the challenge faced by civil engineers is to develop new materials for the future. EPS (Expanded

Polystyrene) sheets made from expandable polystyrene, which is a rigid cellular plastic containing an expansion agent, need to be developed to solve this problem. It has been tested by many researchers as an allowable light material for wall construction.

Insulating Concrete Forms (ICFs) are hollow molds with a center cavity (Figure 1) that is filled with reinforced concrete. The forms are usually made of rigid polystyrene or polyurethane insulation, and are produced as either pre-formed interlocking blocks, or as separate panels connected with plastic or steel rods and ties.

ICF structures are built by fitting together the insulating forms, adding steel reinforcing bars (rebar) for strength, and then filling the central cavity with concrete. The insulating forms, rebar, and concrete walls stay in place as a permanent part of the wall. The outer surface of the walls creates a supportive backing for most conventional finishing materials, such as stucco.

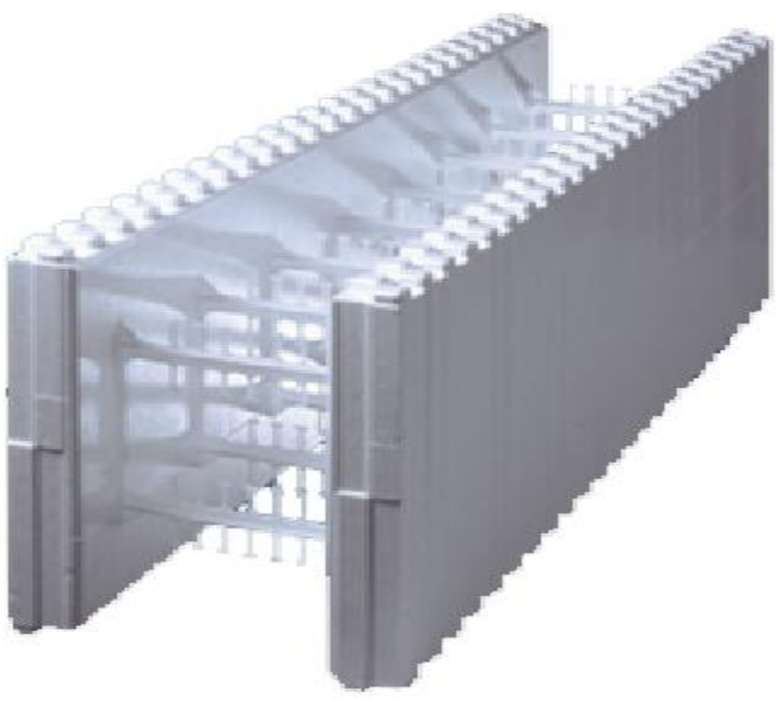

Figure 1: Typical ICF

Andreea-Terezia Mircea(2010) carried his research in ICF wall with parameters of ground acceleration (0.08g, 0.20g and 0.32g), the normalized axial force (0.05, 0.20 and 0.40), the quality of concrete (classes M 16/20 and M 20/25), the effective thickness of the walls (i.e., 150 mm and 200 mm), and the longitudinal reinforcing ratio at the ends of the wall (0.005, 0.020 and 0.040). The three observed thicknesses of shear wall were casted and tested for cyclic loading to find the seismic performance. It was concluded that ICF wall provides energy efficient green building that is highly durable, comes with increased strength, and maximizes resistance to natural disasters while minimizing temperature fluctuations by absorbing and storing heat.

Peter Dusicka (2010) studied the behavior of ICF wall under seismic loading. 4ft, 12 ft ICF wall and conventional wall are casted and tested under cyclic loading. It was found that failure occurred near the bottom of the wall at the point where the foundation rebar splices into the wall reinforcement. The 4ft wall exhibited ductile behavior where strength degradation did not occur till drift cycles were observed to be greater than 2%. The 12 ft wall showed a peak strength at 0.5% drift and significant strength degradation beyond 1% drift. It was concluded that ICF grid wall system potential exists for the seismically active regions.

Afshin Hatami (2011) studied the challenges in ICF system, like high initial cost and difficulties of pouring concrete at higher elevation. Final remarks made was, usages of flowable concrete (SCC) for walls up to 8ft height will reduce pouring difficulties and reduce construction time.

MATERIAL DATA

The main drawback in the construction using ICF is non availability of the required thickness and density of EPS sheets in Indian scenario. The manufacturer of EPS sheets produce only, if the requirement is mass and due to this the cost is comparatively high. The figure 3 shows two EPS sheets of thickness are 60 mm and 100 mm used in this project. The size of the sheet is 1000 x 500 mm. The physical properties of this material are given below:

- Density: 6.37 kg/m3 for 60 mm thick EPS Sheet
  11.81 kg/m3 for 100 mm thick EPS Sheet
- EPS sheets absorbed more than 80 % of water, when the sample is immersed

in water for 24 hours, but it regains its property immediately after drying.

- Compressive Strength: 0.8-1.6 Kg/cm
- Cross breaking Strength: 1.4-2.0 Kg/cm
- Tensile Strength: 3-6 kg/cm
- Self ignition point: 300^{o} C

Figure 3: Typical 100 mm (60 mm thick) EPS sheets

MODEL'S PREPARATION

The EPS Sheets are cut into specified sizes. The specified size for the ICF model is 200 x 150 mm. Two pieces of such a material is interconnected by 6 mm tor steel rods, as shown in figure 4a. The steel was penetrated into the EPS Sheets by 40 mm and a gap of 60 mm was created between the two EPS sheets. In this cavity, M20 grade concrete was poured. For comparison, normal concrete without EPS was also prepared. The size of concrete model is 200 x 150 x 60 mm, as shown in figure 4b.

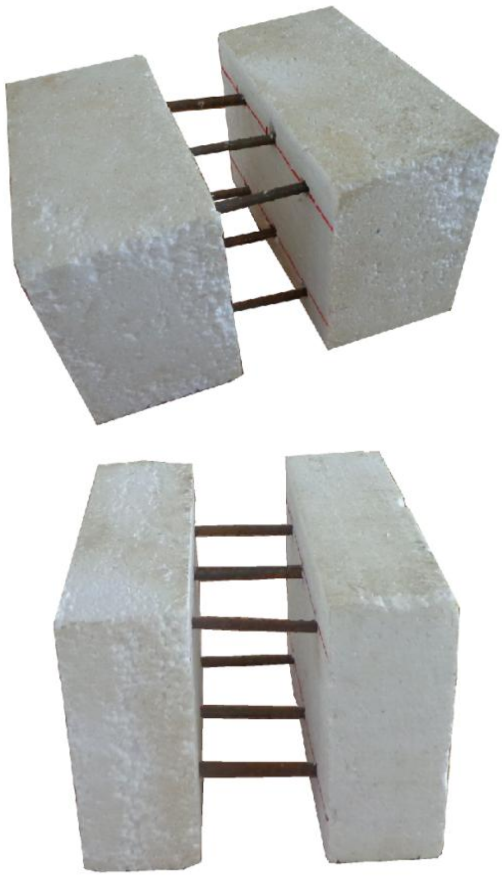

Figure 4a: Typical ICF model before Casting

Figure 4b: Typical ICF model after casting and plain concrete

TESTING THE MODELS

After the ICF models are casted, the samples are placed for curing. Because of huge water absorption property of EPS sheets, immersed curing method is not adopted. Instead of immersed curing, moist curing by gunny bags is adopted. After 7 and 28 days, compressive test was conducted in the universal testing machine. The deflection curve was plotted directly in the UTM machine. The figure 5 shows the testing equipment of ICF model.

Figure 5: Test carried out in the UTM

EXPERIMENTAL OBSERVATION

The figure 6a and 6b shows the typical failure of ICF models. From the figure it can be seen that even after the complete failure of concrete core part, the EPS sheets remains in an undisturbed condition. It does not exhibit any cracks or any sort of disintegration. This phenomenon implies that the formwork that does not fail during peak load is very important in the construction industry, because this type of technology may be used in the seismic prone areas and other important structures to avoid spilling of concrete.

Figure 6a: Test Specimen using 100 mm EPS Sheet

Figure 6b: Test Specimen using 60 mm EPS Sheet

Table 1 shows the values obtained from tests conducted on the two samples of ICF models and plain concrete model.

Table 1: Test Results

Sl. No.	Description of Sample	Peak Load		Deflection at Peak Load		Maximum Deflection		Compressive Strength		Reference figure No.
		7 Days kN	28 Days kN	7 Days mm	28 Days mm	7 Days mm	28 Days mm	7 Days N/mm^2	28 Days N/mm^2	
1	Plain concrete Model	161.10	204.70	5.60	2.60	6.00	3.00	13.43	17.06	7
2	60 mm thickness of EPS sheet on both sides of concrete	198.90	215.90	7.90	2.80	9.30	9.50	16.58	17.99	8
3	100 mm thickness of EPS sheet on both sides of concrete	196.50	216.00	3.10	7.90	16.00	19.10	16.69	18.00	9
4	60 mm thickness of EPS sheet alone	3.10		9.80		9.80		0.26		10a
5	100 mm thickness of EPS sheet alone	4.70		11.30		11.30		0.24		10b

The graph shown in figures 7 to 10, obtained from digital universal testing machine, explains the behavior of ICF model and plain concrete model.

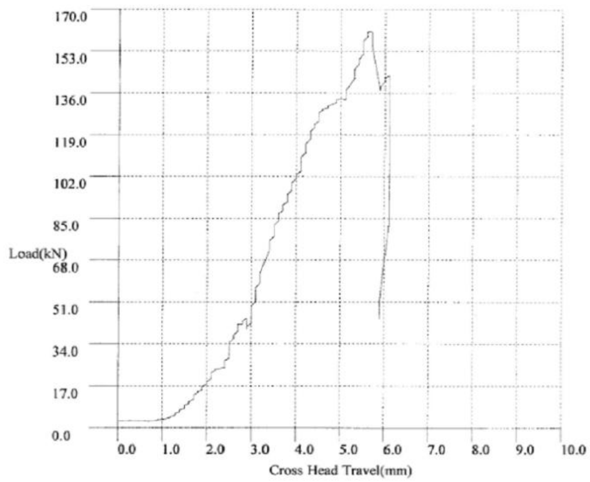

Figure 7a: 7 Days Load – Deflection curve for
Curve for Plain concrete model

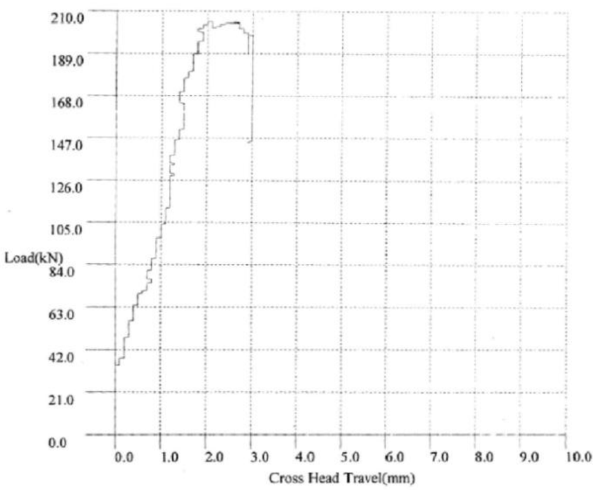

Figure 7b: 28 days Load - Deflection
Plain concrete model

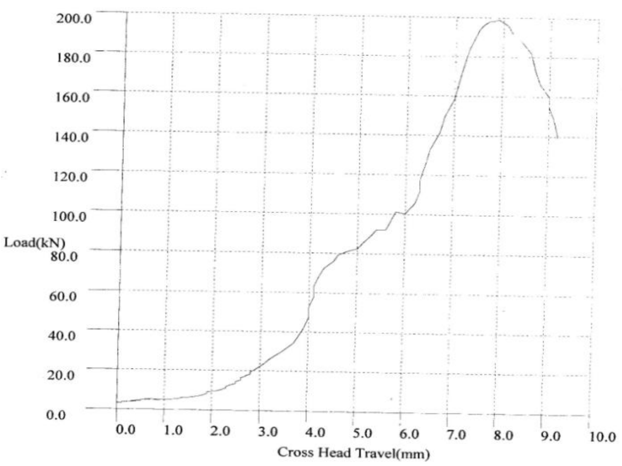

Figure 8a: 7 days Load-Deflection curve for
for 60 mm thick EPS sheet on both sides.

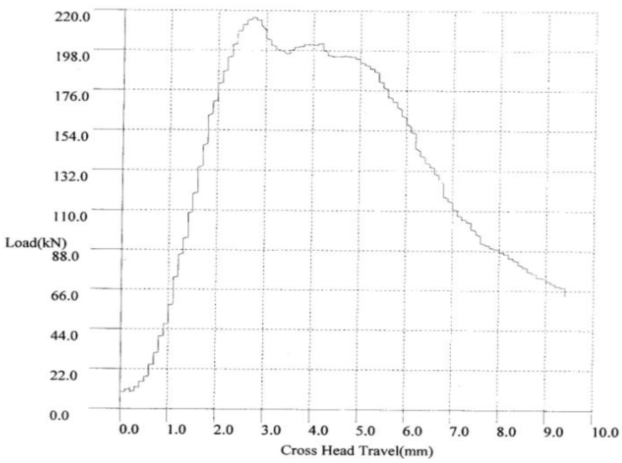

Figure 8b: 28 days Load-Deflection curve
60 mm thick EPS sheet on both sides.

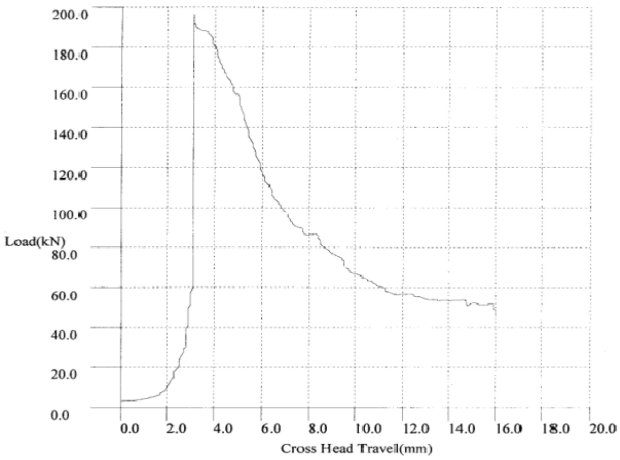

Figure 9a: 7 days Load-Deflection curve for 100mm for thick EPS sheet on both sides

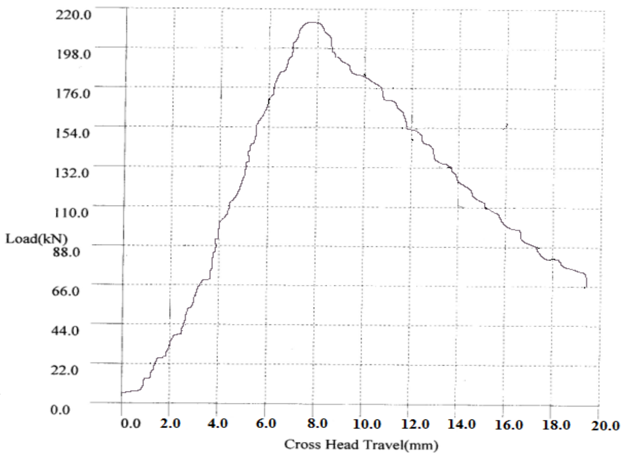

Figure 9b: 28 days Load-Deflection curve 100mm thick EPS sheet on both sides

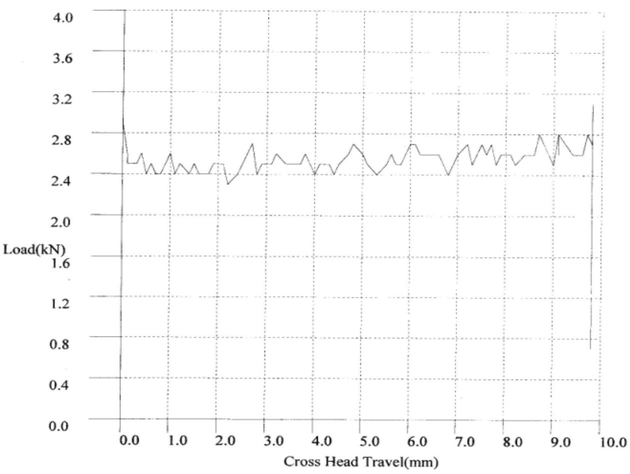

Figure10a: Load-Deflection curve for 60mm Thick EPS sheet of size 200 x 150 x 60

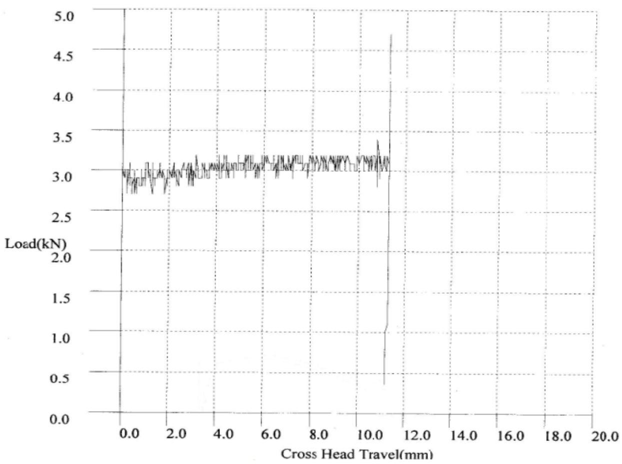

Figure 10b: Load-Def. curve for EPS sheet of size 200 x 150 x 100

RESULT & DISCUSSION

The figure 11 shows, the comparison of compressive strength between plain concrete with EPS sheets. It indicates increase in compressive strength for specimen with the EPS sheet on both sides of concrete. It also shows that, the difference of compressive strength of three models is not increasing significantly, but as the load increases plain concrete fails and it was observed that, the EPS sheets have not failed and in position. No single crack was observed in the sheets, indicates a ductile behavior.

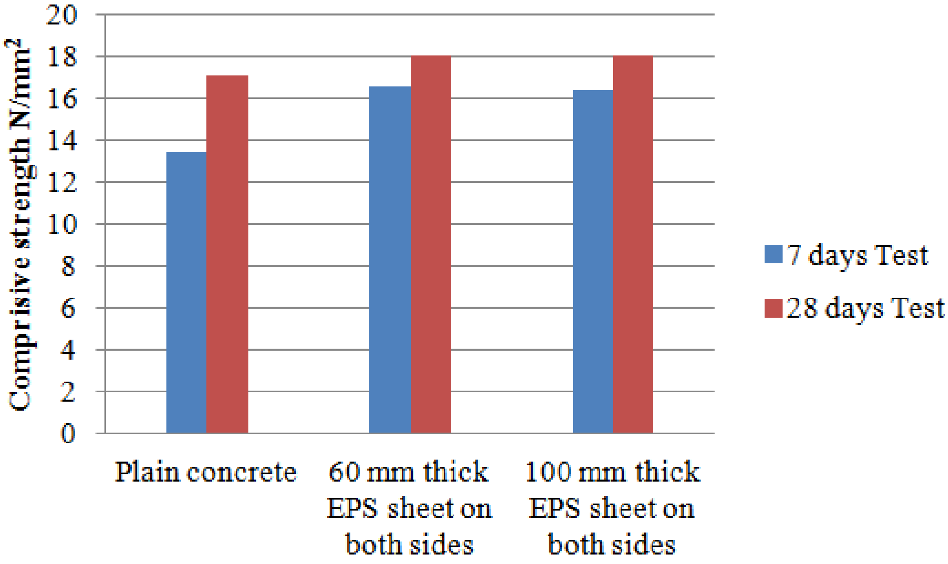

Figure 11: Compressive strength comparison chart

The figure 12 plotted between maximum deflection and respective concrete model explains that at ultimate load for plain concrete behavior was brittle whereas the specimen with EPS sheets shows prolonged yielding without failure.

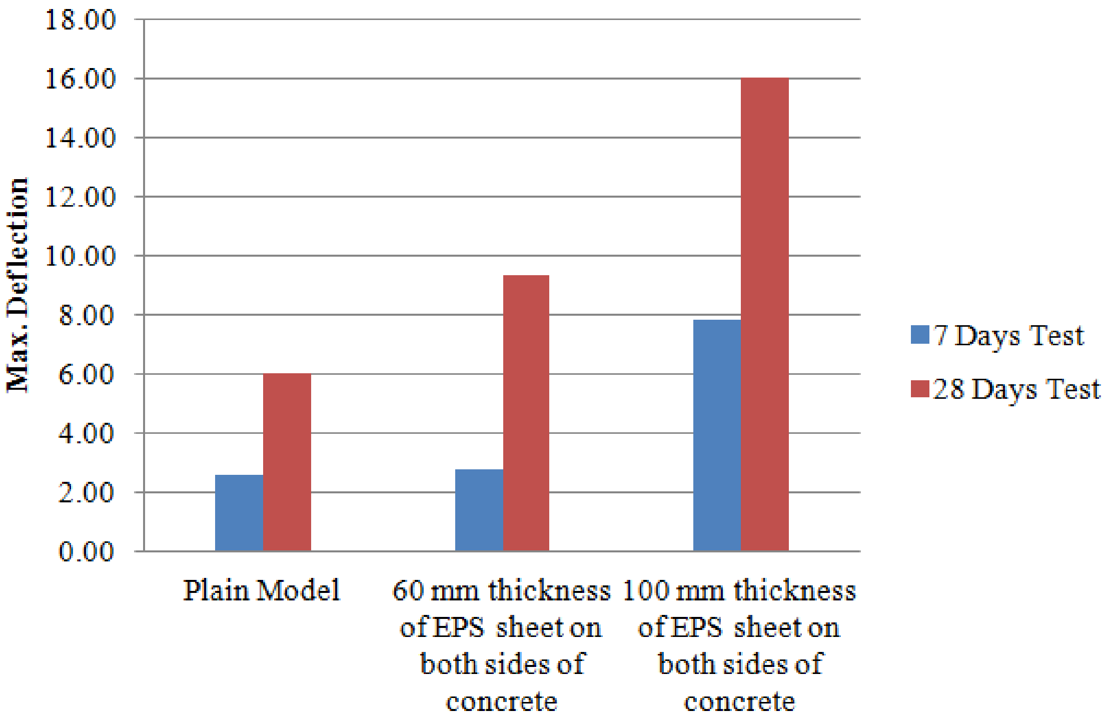

Figure 12: Maximum Deflection comparison chart

FINISHING OF ICF WALLS WITH POLYPROPYLENE SHEETS

In the ICF system of wall construction EPS sheet is an exposing material, hence it is required to protect the wall with suitable material to avoid disposing of EPS sheet. Consequently the second set of experimental observation carried out.

For a trial, Poly propylene sheets (High Density Plastic Sheets) have been used to finish the exposed EPS sheets.

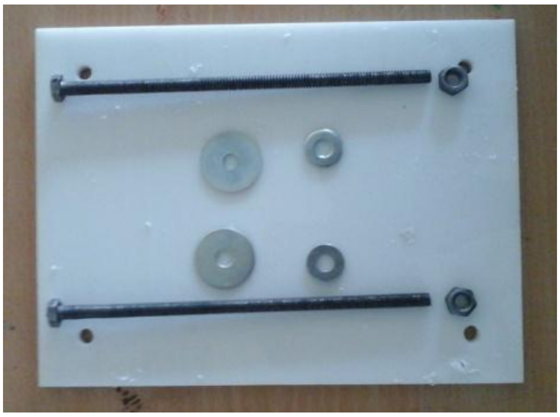

Figure 12: Polypropylene sheet with embedded bolt

i. Samples with Polypropylene sheets

EPS sheets are covered by polypropylene sheets with suitable bolts. The bolts are penetrated through concrete; hence the possibility of separation from EPS sheets will not happen. For experiment plain concrete, 50 mm, 100 mm thick EPS as well as 6 mm thick polypropylene sheets have been used. Three plain concrete samples have been casted for comparison, three 50 mm thick EPS on both sides of concrete and three 50 mm thick EPS in addition to 6 mm thick polypropylene sheets with embedded bolts also casted. It is also done for 100 mm thick EPS sheets.

Fig13: Sample of EPS Sheet with polypropylene sheet

Fig 14: Side view of sample after sheet testing

ii. Experimental Results

The compression test carried out for all the samples in the UTM meanwhile deflection chart also obtained. Table 2 gives the comparison of all the test samples.

Table 2: Test Results

Sl. No.	Description of Specimen	Peak Load	Deflection at Peak Load	Maximum Deflection	Compressive Strength (28 Days) N/mm^2	Ref-figure No.
1	60 mm Thick plain concrete	207.7	10.9	11.4	17.31	15
		102.2	13.5	15.8	8.52	
		255.3	5.1	5.3	21.28	
2	50 mm Thick EPS sheet on either side of 60mm thick concrete	323.8	9.5	12.3	26.98	16
		218.6	11.3	21.2	18.22	
		304.9	9.3	17.9	25.41	
3	50 mm Thick EPS and 6 mm thick Polypropylene sheet on either side of 60 mm thick concrete	294.8	1.9	8.8	24.57	17
		350.6	12.1	16.2	29.22	
		310.2	5.5	8.9	25.85	
4	100 mm Thick EPS sheet on either side of 60mm thick concrete	409.4	11	14.2	34.12	18
		264.1	6.7	10.3	22.01	
5	100 mm Thick EPS and 6 mm thick Polypropylene sheet on either side of 60 mm thick concrete	338.2	4.5	10.6	28.18	
		418.5	8.3	16.8	34.88	

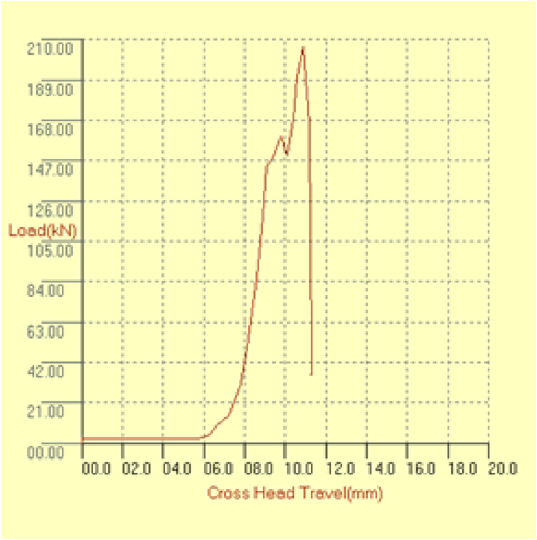

Fig15: 60mm Thick Plain Concrete

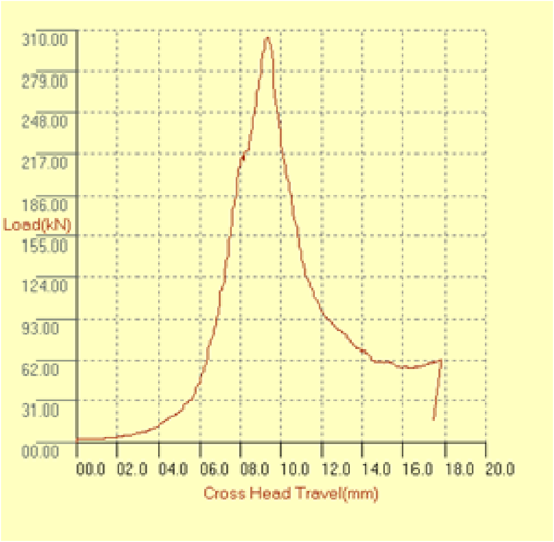

Fig16: 50 mm Thick EPS sheet on either side of 60mm thick concrete

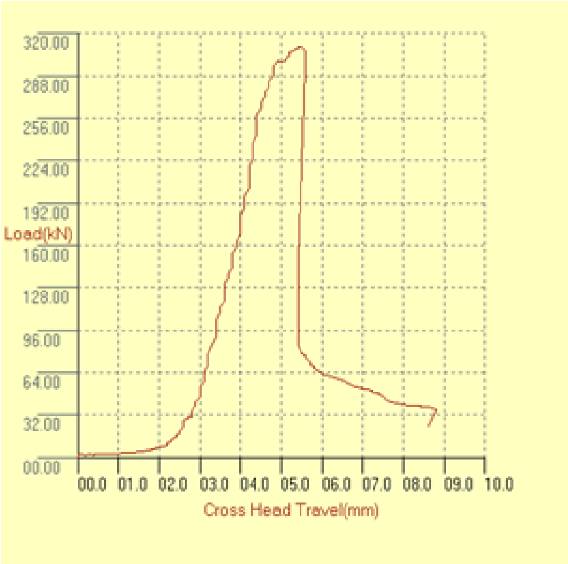

Fig 17 : 50 mm Thick EPS and 6 mm thick Polypropylene sheet on either side of 60 mm thick concrete

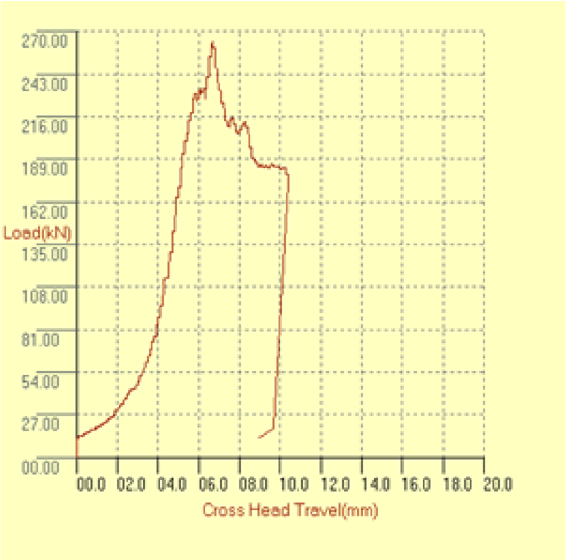

Fig 18: 100 mm Thick EPS sheet on either side of 60mm thick concrete

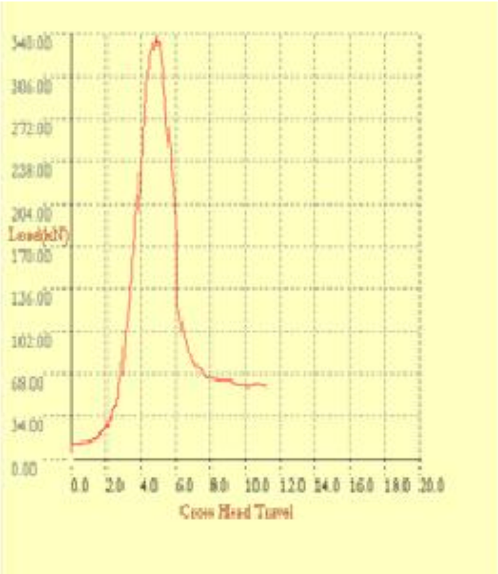

Fig 19: 100 mm Thick EPS sheet on thick either side of 60mm thick concrete

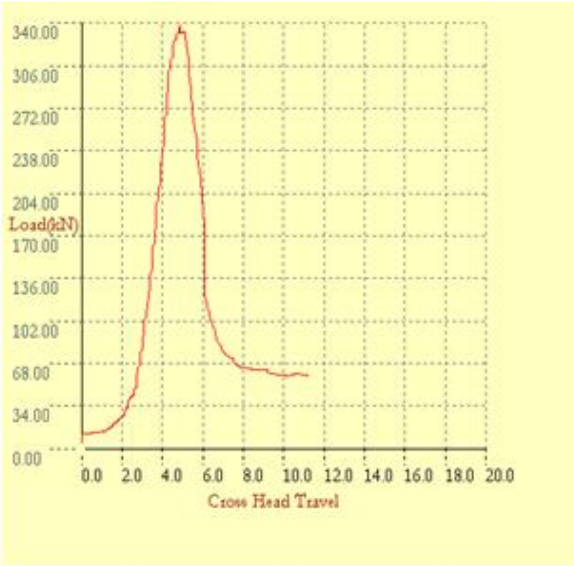

Fig 20: 100 mm Thick EPS and 6 mm Polypropylene sheet on either side of 60 mm thick concrete

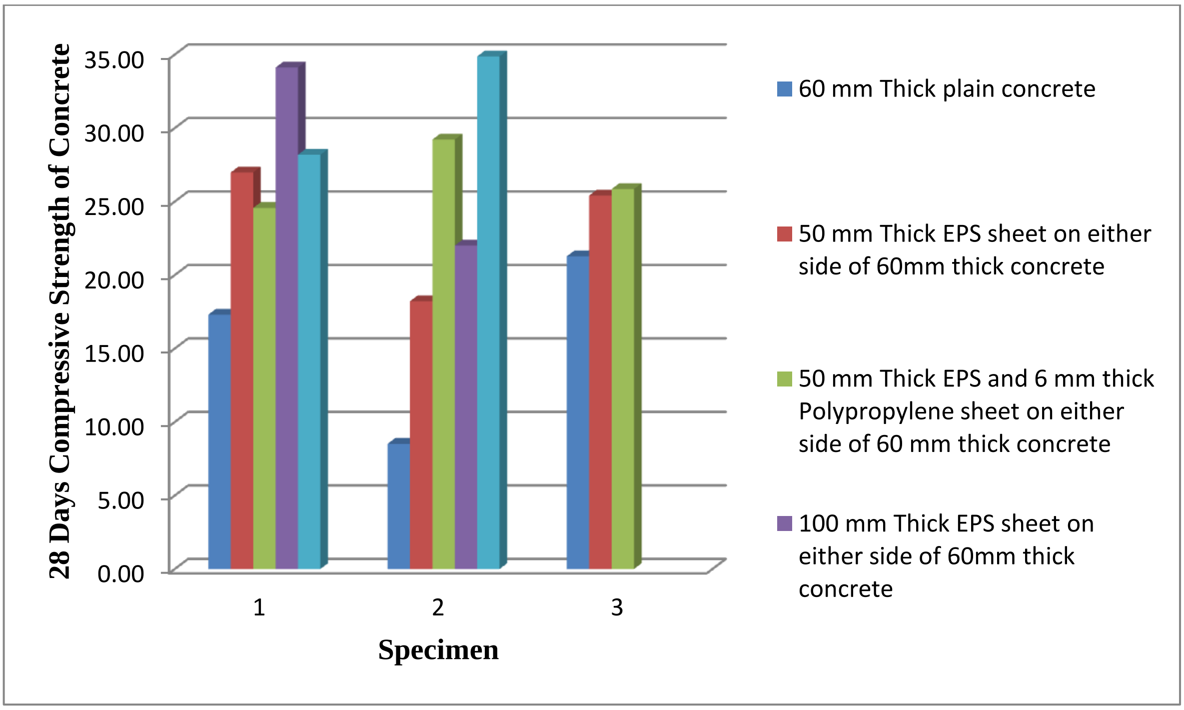

Fig 21: Compressive strength comparison chart

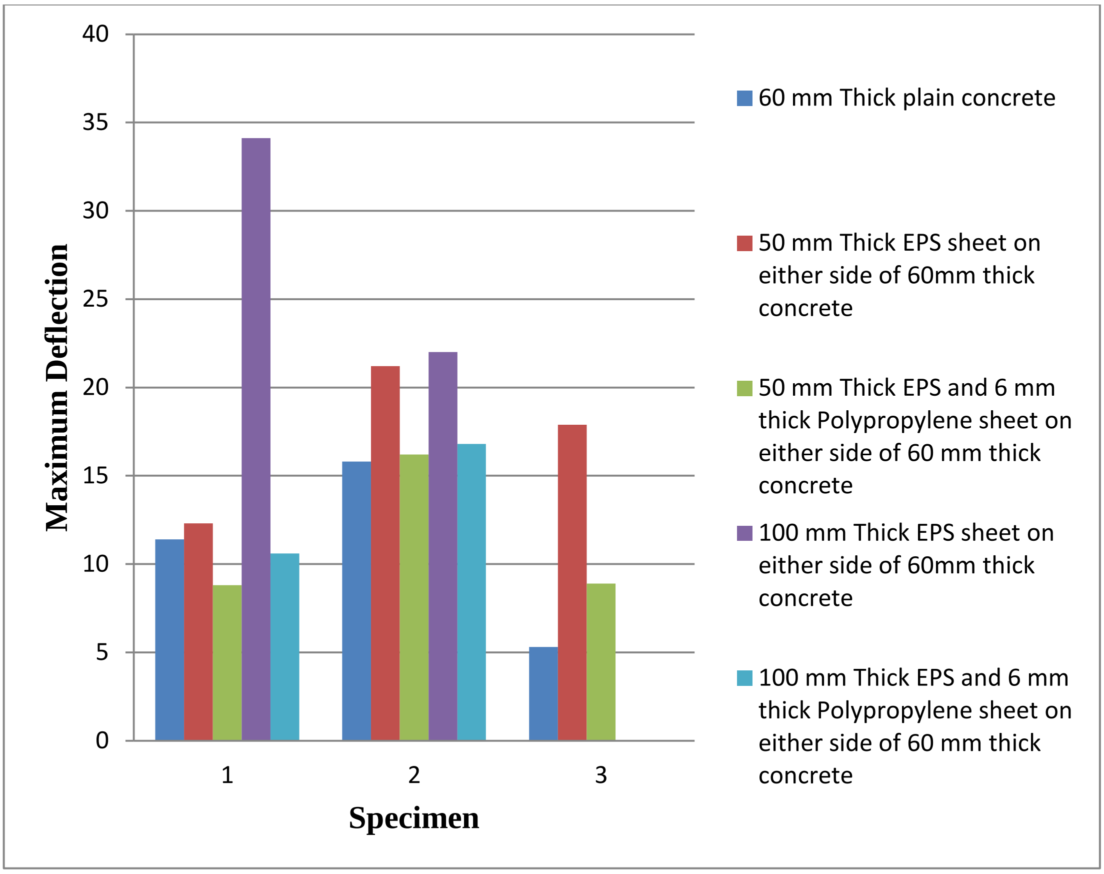

Fig 22: Maximum Deflection comparison chart

iii. Results and Discussion

The figure 21 and 22 shows comparison of compressive strength and maximum deflection between various samples. It indicates that the addition of 6 mm polypropylene sheet on either side of EPS sheet has increased compressive strength, but in the case of maximum deflection, polypropylene sheet does not have much of an impact to the specimen. This is the case despite the polypropylene sheet suggested in the ICF system because of its water resistance, durability, ease in adoption, and low cost.

CONCLUSION

- Concrete specimen with EPS sheets exhibit no cracking or zero disintegration of EPS sheets even after complete failure of concrete core. This means if walls are constructed with this method, the walls stand and deflect largely, even though the load carrying concrete has failed.
- When compared to normal plain concrete and ICF model, there is not much change in the load carrying capacity, but after

attaining peak load, sudden failure occurs in the normal plain concrete but ICF shows ductile failure.

- Because of usage of EPS sheets, formwork is not necessary during construction; hence project time schedule will be reduced. And it requires minimum skilled labors, leading to reduction in labor cost.
- Curing process is not required, since the concrete is covered by EPS sheets.
- Initial cost of ICF building is high because of non-availability of required EPS sheets and the fact that concrete corer is the entire wall. The building requires lesser amenities for heating and cooling, which may reduce the electric bill and it requires low maintenance.
- Due to ductile behavior, its use may protect the structure from natural disasters such as earthquake.

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