Manual for Expanded Polystyrene (EPS) Core Panel System and its field Application

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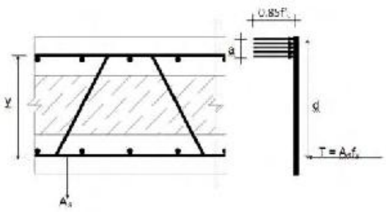

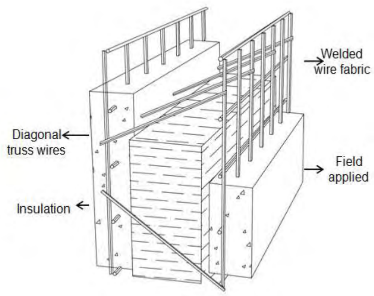

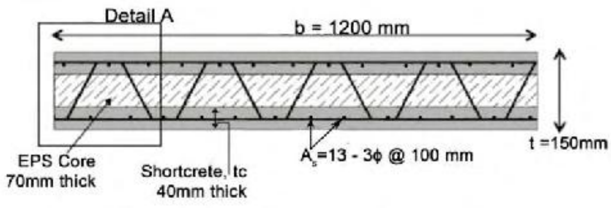

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EXPANDED POLYSTYRENE (EPS) CORE PANEL SYSTEM

CHAPTER -1

INTRODUCTION TO EPS CORE PANEL SYSTEM

1. Introduction

Expanded Polystyrene (EPS) core Panel system is a modern, efficient, safe and economic construction system for the construction of buildings. These panels can be used both as load bearing as well as non-load bearing elements.

EPS core panel is a 3D panel consisting of 3-dimensional welded wire space frame provided with the polystyrene insulation core. Panel is placed in position and shotcrete on both the sides.

The EPS panels consist of a 3-dimensional welded wire space frame utilizing a truss concept for stress transfer and stiffness as shown in Fig. 1.1.

EPS panel includes welded reinforcing meshes of high-strength wire, diagonal wire and self-extinguishing expanded polystyrene uncoated concrete, manufactured in the factory and shotcrete is applied to the panel assembled at the construction site, which gives the bearing capacity of the structure.

EPS panel after shotcrete has the following five components (as Fig. 1.1):

i. The outer layer of shotcrete.
ii. Welded reinforcing mesh of high wire.
iii. The core of expanded polystyrene sheet.
iv. Diagonal wire (stainless or galvanized wire).
v. The inner layer of shotcrete.

The welded mesh fabric connected piercing polystyrene with truss of steel wire, welded to the welded fabric at an angle. It gives a rigidity spatial structure, and simultaneously prevents polystyrene core shifting.

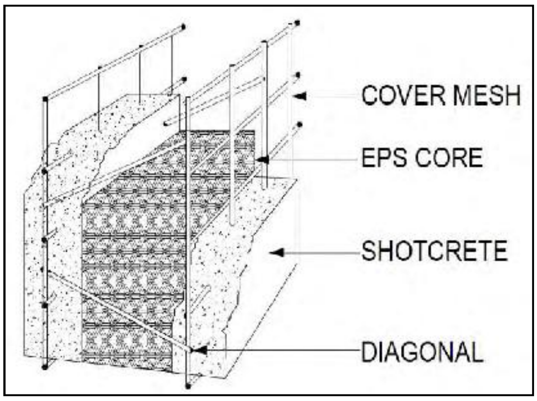


Fig 1.1: Typical cross section of wall panels

Individually welded internal strut wires or diagonals extend through the panel core between each surface. These galvanized strut wires are welded continuously in the required spacing so they form, with the welded wire fabric, into a triangulated truss system which greatly increases the panel strength.

EPS panel is a versatile structural element designed for floors, walls, partitions, roof and stairs. Fig. 1.2 & Fig. 1.3 shows the welded reinforcing mesh of the EPS panels at different cross-sections.

Fig 1.2: Reinforcing mesh expanded polystyrene core and diagonal wire.

Fig 1.3: Welded reinforcing mesh 3-D panel without expanded polystyrene core.

The typical EPS panel is generally manufactured with dimensions of 1200 m width, 3000 mm length and over all thickness range of 80-230 mm.

The panels are finished at the site using minimum 30 mm thick shotcreting of cement & coarse sand in the ratio of 1:4 applied under pressure. The shotcreting coat encases the EPS Core with centrally placed steel welded wire mesh.

Some of the advantages of the EPS Core panel systems are as follows:

i. Reduce the cost of construction
ii. Reduce Construction period
iii. Reduce transport cost. Light weight panels: do not requires cranes and other heavy construction equipment. *(A Standard panel of size (1.2×3) m without shotcrete weighs 20 kg).*
iv. The installation does not need heavy construction equipment.
v. Ensure high levels of thermal insulation, sound insulation, as well as sanitary and fire safety.
vi. EPS 3-D panels allow no additional cost to erect buildings in areas with moving soil, especially heaving, subsidence, frozen ground, and remote areas.
vii. Strength and durability - used extruded polystyrene virtually inert and does not absorb moisture, is durable and resistant to decay.

Some of the Limitations of the EPS Core Panel System:

i. EPS Panel construction system may only be used in the construction of foundation walls supporting 4 storeys or less, unless designed by a professional engineer.
ii. Concrete must be applied by either the "shotcrete dry" or "shotcrete wet" process in accordance with ACI 506 R-85, "Guide to Shotcrete," by the American Concrete Institute.
iii. Compressive strength of concrete shall not be less than 20 MPa.
iv. The steel reinforcement shall have a minimum allowable stress (f_y) of 415 MPa.

The EPS Core panel system is environment friendly and aesthetically appealing. It can be constructed quickly resulting in savings in construction time and money. The technology has been in use successfully in many African as well as European countries with involvement of different agencies.

CHAPTER – 2

DESIGN PHILOSOPHY AND METHODOLOGY

This chapter discusses about the structural design of non – load bearing wall panel, load bearing wall panel , Floor Panel along with a User friendly interactive software, for the design of EPS panels.

2.1General Requirements

- The design shall satisfy the standards of IS 456, IS 1905, IS 11447, IS 875 (Part 1-5), IS 1893 (Part 1), IS 4326, IS 13920.
- Cutting drawings shall be prepared with clarity to facilitate the cutting at the manufacturing plant of the various wall or floor panels to appropriate sizes. In case of wall panels opening for doors, windows etc. shall be suitably marked in the respective panels.
- When the panels are to be cut at the factory in accordance with the cutting joints, these shall be suitably marked on the surfaces beforehand to facilitate correct identification for proper placement during erection at the construction site.
- In construction using EPS panels as load-bearing structural walling, the walls in the ground floor shall be typically founded on the reinforced concrete (RC) plinth beam.
- Appropriate starter bars shall be embedded at the locations in a staggered way to a minimum specified distance. This ensures the connections of the super structure with the foundation spread over the entire wall length over the network of RC plinth beams.
- Plinth beams shall be supported on appropriate foundations, typically comprising spread footings or raft foundations suitably designed.
- In the case of multi-storey buildings in high seismic zone, the design and detailing shall ensure proper transfer of base shear at the interface of the foundation and the super structure.
- EPS panels used as walls or floors shall be shotcrete with a concrete of grade not less than M20 using aggregate of size less than 5mm.
- The insulation core of expanded polystyrene (EPS) must comply with ASTM C578 and IS 4671: 1984.

- With 40 mm of shotcrete applied to both sides, each panel achieves a fire rating of 90 minutes [EVG].
- Reinforcement mesh with steel wires shall be used in accordance with ASTM A185 [EVG].
- The diagonal truss wires, as well as the wire used in the manufacture of welded wire fabric, must be in conformity with ASTM A82 [EVG].
- In case of cantilever projections such as balconies, suitable RC beams (Concealed within EPS forms) may be designed and detailed as required.
- Special care shall be taken during construction to ensure proper connections at the junction such as plinth to wall panels, wall panel to wall panel, wall panels to slab panel etc.

2.2 Properties of EPS

Expanded Polystyrene, often referred to as EPS, is a kind of rigid, closed cell foam plastic. EPS properties have a low thermal conductivity, high compressive strength, is light weight, inert. It can be used as a building material or a design element, and can be molded into many shapes for a number of household uses as well.

Expanded Polystyrene (EPS) is processed from its resin form. The resin contains a pentane gas which is safely released during the expansion process. With the addition of steam, the EPS resin expands up to 40% of its original size. The expanded pellets are then transferred into a block molder.

2.2.1 Density

EPS density can be considered the main index in most of its properties. Compression strength, shear strength, tension strength, flexural strength, stiffness and other mechanical properties depend on the density. The cost of manufacturing an EPS is considered linearly proportional to its density. Non-mechanical properties like insulation coefficients are also density dependent.

Density of EPS shall be 15, 20, 25, 30 or 35 kg/m^3 according to IS 4671: 1984.
Table 2.1 shows types of EPS used in USA, which are categorized by ASTM C 578-95.

Table 2.1 ASTM C 578-95 EPS Densities

Type	XI	I	VIII	II	IX
Density (kg/m^3)	12	15	18	22	29

2.2.2 Compressive Strength and Stress-Strain Characteristics

Figure 2.1 shows the uniaxial compression stress-strain curve of EPS for two different densities. The two densities shown are considered the extreme values for most engineering applications done so far. Specimens are 0.05m cubes tested at a displacement rate of 0.005m/min. From the figure the stress-strain curve can be simply divided into two main straight lines connected with a curved portion. The slope of the straight-line portions increase with density. The stress at any strain level increases also with the density. The bead size has no important effect on the compressibility of cut specimens (BASF Corp., 1968)

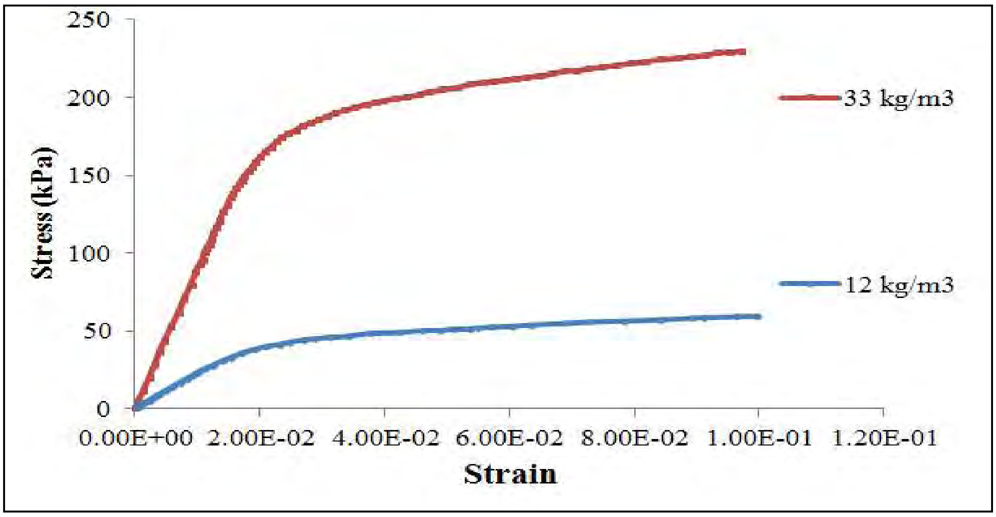


Fig.2.1: EPS Uniaxial Compression Stress Strain Curves (Negussey and Elragi, 2000)

2.2.3 Initial Elastic Modulus

The stress strain curve of EPS has an initial linear portion. The value of the slope of this initial portion is defined as the initial tangent modulus. It is known as Young's Modulus as well as the modulus of elasticity. EPS initial modulus is a function of the density as shown from Fig 2.2. For EPS, as shown from the same figure, there is no agreement from the researchers on a constant value for each density. For a 20kg/m^3 density the initial modulus ranges between 5MPa and 7.75MPa, which means a 55% difference. The relation is linear for some researchers (Horvath, 1995b and Miki, H., 1996) while it's nonlinear for others (Duskov, 1997 and Eriksson and Trank, 1991).

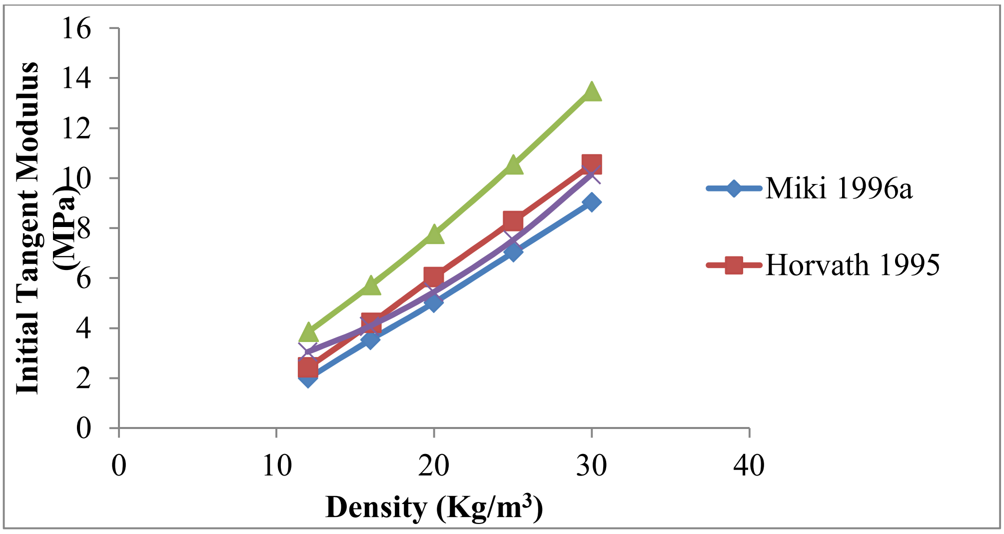


Fig. 2.2 Initial Tangent Modulus for EPS

2.2.4 Poisson's Ratio

Poisson's ratio is an index of the lateral pressure of EPS on adjacent structural elements, in contact, for a certain applied vertical load on the EPS mass. Value range between 0.05 and 0.5 are found in the literature for EPS as shown in Table 2.2.

Table 2.2 Poisson's ratio of different types of EPS (Sanders, 1996)

Reference	Yamanaka, et al. (1991)	Negussey and Sun (1996)	GeoTech (1999a)	Duskov et al. (1998)	Ooe, et al. (1996)	Sanders (1996)	Momoi and Kokusyo (1996)
Poisson's Ratio	0.075	0.09 and 0.33	0.05	0.1	0.08	0.05 up to 0.2	0.5

2.2.5 Water Absorption

The water absorption of expanded polystyrene is low. Although water absorption decreases as density increases as shown in Table 2.3. Fusion is the most important factor influencing the moisture resistance of expanded polystyrene. Good fusion reduces the amount of water absorption. For 9–12 years of service, equilibrium values of 8-9 % volume have been found in EPS fills below the ground water table (van Dorp, 1988).

Table 2.3 % Volume of Water Absorption
(German Specifications, after van Dorp, 1988)

Density, kg/m^3	After 7 Days	After 1 Year
15	3.0	5.0
20	2.3	4.0
25	2.2	3.8
30	2.0	3.5
35	1.9	3.3

2.2.6 Durability

No deficiency effects are to be expected from EPS fills for a normal life cycle of 100 years [Aabøe, R. (2000)].

2.2.7 Thermal Conductivity

The thermal conductivity at 0°C and 10°C, respectively of the material shall not exceed the values given below according to IS:4671-1984, determined in accordance with the method prescribed in IS : 3346-1980.

Table 2.4 Bulk Density and thermal conductivity of EPS

Bulk Density (kg/m^3)	Thermal conductivity mW/cm °C	
	0°C	**10°C**
15	0.34	0.37
20	0.32	0.35
25	0.30	0.33
30	0.29	0.32
35	0.28	0.31

2.2.8 Acoustical Properties

Expanded polystyrene, when used in combination with other building materials effectively reduces the transmission of airborne sound through partitioned walls, ceilings and floors (Huntsman, 1999g). EPS has the advantage of being lightweight and effective in thicknesses as low as 0.625 cm it can replace thicker, heavier materials.

2.3 Design philosophy

The design capacities given in these guidelines are based on limit state design procedures considering the ultimate limit state for strength design, treating the 1.2m wide and 3m high EPS building panel as the unit building material.

The design should be such that the structure should withstand safely all loads (as per relevant Indian Standards) likely to add from the structure during its lifetime. It shall also satisfy serviceability requirements such as limitations of deflection and cracking. In general the structure shall be designed on the basics of most critical limit state and shall be checked for other limit state design.

2.3.1 Design basis

The design of EPS Panels is based on the below mentioned standards, codes and engineering practices.

List of Codes (National & International)

National Codes

IS 875-1: 1987	Code of Practice For Design Loads (Other. Than Earthquake) For Buildings And Structures, *Part 1*: Dead. Loads - Unit Weights of Building Materials and Stored Materials
IS 875-2: 1987	Code of Practice For Design Loads (Other. Than Earthquake) For Buildings And Structures, *Part 2*: Imposed Loads
IS 875-3: 1987	Code of Practice For Design Loads (Other. Than Earthquake) For Buildings And Structures, *Part 3*: Wind Loads
IS 1893-1: 2002	Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings
BS 13163: 2001	Thermal Insulation Products for Buildings- Factory made products of expanded polystyrene (EPS) - Specification
IS 9012: 1978	Recommended Practices for Shotcreting.

International Codes

ACI 318-08	Building Code Requirements for Structural Concrete and Commentary
ASTM E 72-15	Standard Test Methods of Conducting Strength Tests of Panels for Building Construction
ASTM C578 - 15b	Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation
ASTM E695	Standard Test Method of Measuring Relative Resistance of Wall, Floor, and Roof Construction to Impact Loading
ASTM C578	Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation
ASTM E84 − 15b	Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM C1141/C1141M – 08	Standard Specification for Admixtures for Shotcrete
ASTM C1436 – 13	Standard Specification for Materials for Shotcrete
ASTM B606/B606M – 08	Standard Specification for High-Strength Zinc-Coated (Galvanized) Steel Core Wire for Aluminum and Aluminum-Alloy Conductors, Steel Reinforced1.
ASTM A185	Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement

2.3.2 Load calculations

2.3.2.1 Dead load

Dead load has to be calculated based on the unit weight provided in IS 875 Part-1 1987 for each work. Even though total weight of wall highly depends on the type of finish material/ Shot Crete/ other finishes, normally it varies from 0.5 kN/m^2 to 2.5 kN/m^2.

Weight of the floor normally varies from 2 kN/m^2 to 3 kN/m^2.

Load for Roof normally varies from 0.4 kN/m^2 to 0.75 kN/m^2 for GI Sheet and 2.4kN/m^2 to 3 kN/m^2 for R.C.C Slab.

These are indicative values.

2.3.2.2 Live load

Live load for different occupancies may be taken from Table 1 of IS 875 Part-2: 1987. Live load for dwelling units is considered 2.0 kN/m^2 except corridors and balconies. Extra load of 0.5 kN/m^2 shall be considered for service and false sealing.

2.3.2.3 Wind load

Wind loads apply on face of elevations of the buildings. The face loads are transferred from the cladding outer leaf by the wall ties to the stud sections, which span vertically between horizontal floor diaphragms. The floor diaphragm spans horizontally between each of cross walls, which can be internal load bearing, or external walls.

2.3.2.3.1 Wind load analysis

Wind load analysis conduct as per IS875-Part3. The 90-degree case acts on the side elevation and 0° wind load case acts on the front or back elevation. Each elevation will be analyzed separately and the highest calculated load will be applied throughout the entire structure. Therefore, this technique is deemed to be conservative.

Overturning (global stability) and holding down analysis is conducted for the widest cases. Comprehensive explanation of the global stability analysis follows.

Design wind pressure (N/m^2) $P_z = 0.6 \times V_z^2$ (IS875-1987 Part-3; Clause: 5.4)

Design wind speed (m/s) $V_z = V_b \times K_1 \times K_2 \times K_3$ (IS875-1987 Part-3; Clause: 5.3)

Basic wind speed (m/s) V_b can be taken from IS 875(Part 3)-1987; (Fig 1)

Risk coefficient factor (K_1) can be considered from IS 875(part 3)-1987; Table: 1 Clause: 5.3.1)

Terrain, height and Structure factor (K_2) IS 875(part 3)-1987; Table 2; Clause: 5.3.2)

Topographic factor (K_3) (IS 875(part 3)-1987; Clause 5.3.3.1)

2.3.2.4 Seismic load

Seismic loads apply on the each floor and roof level of the buildings. The horizontal loads are transferred from the floor Panel to the walls tying or supporting the floors and roof.

By inspection, the seismic loads are critical for overall stability.

Total Design lateral Force or Seismic Base Shear V (KN) = $A_h \times W_{total}$ (As per IS1893-2002 ; Clause: 7.5.3)

Design Horizontal Seismic Coefficient A_h= ($Z \times I \times S_a/2 \times R_g$) (As per IS1893-2002 Clause: 6.4.2)

Zone Factor (Z) (As per Table2 IS1893-2002 (Clause: 6.4.2)

Seismic Zone (As per Seismic Zone map IS1893-2002)

Seismic Intensity (As per Table2 IS1893-2002 (Clause: 6.4.2)

Importance Factor (I) (As per Table6 IS1893-2002 Clause: 6.4.2)

Response Reduction Factor (R) (As per Table7 IS1893-2002 Clause: 6.4.2)

Average response acceleration coefficient factor (Sa/g) (As per IS1893-2002 Clause: 6.4.5).

Total weight of building (W, total) (kN) (As per IS1893-2002 ; Clause 7.3)

2.3.2.5 Serviceability requirements

Serviceability performance concerns the limits on deflections due to loading and the control of vibrations, due to regular activities. Appropriate limits are specified, depending on the application.

2.3.2.5.1 Deflection

The deflection under serviceability loads of a building or its members should not impair the strength or efficiency of the structure or its components or cause damage to the finishing. The recommended deflection limits for certain structural members shall be as per IS 456:2000 and IS 1893:2002.

2.3.2.5.2 Deflection criteria

Static criteria

a) The maximum deflection for a single panel subject to dead and imposed loads is limited to the smaller of span/350, or 15 mm.

b) The maximum deflection for a single Panel subject only to imposed load is limited to span/450.

Dynamic criteria

a) The natural frequency of the floor should be limited to 8Hz for the uniformly distributed load case of dead plus 0.3 KN/m^2, which represents the nominal load on lightly loaded floor. This is achieved by limiting the deflection of a single Panel to 5mm for this loading condition.

b) For the floor subjected to imposed loads in excess of 1.5 KN/m^2, the governing criterion is most likely to be (a) (Span/350 or a maximum of 15mm).

Deflection of uniformly distributed simply supported beam can calculate by 0

$$Deflection = \frac{5Wl^4}{384EI}$$

E is the modules of Elasticity 205000 N/mm^2.

I is the moment of inertia mm^4.

W is the total uniform load l Span length.

2.3.2.6 Robustness of EPS panels (Applicable to 5 floors and above)

The Building Regulations require that structures of 5 or more storeys should be designed to localize the effects of accidental damage. There is currently no published guidance on the 'robustness' of EPS Panels to accidental effects, within the context of the Building Regulations.

2.3.2.7 General anchorage provisions:

Minimum base fixity has to be provided based on the following:

i. All external perimeter walls and internal load bearing are secured to the sub-structure using suitable Rebar at regular centers to suit site specific lateral loading on individual panels.
ii. External Walls is to be fixed and the fixing type should be checked for wind loads.

2.4. Interaction Diagram

Interaction diagram represent the relationship for combination of axial load and bending moment on EPS walls and are used as a design aids to assist the designer with the selection of the various parameters such as reinforcement, thickness, width etc. Point located with the interaction curve and the reference axis represent the combination of axial load and bending moment that the wall can support.

For EPS walls, interaction diagram can be approximately constructed by connecting three basic points with straight line as shown in Figure.

1. Pure compression with zero bending moment (concrete compression failure).
2. Tension steel is yielding; the compression steel is also yielding (balanced failure).
3. Pure bending with zero axial loads (under reinforced with the ductile reinforcement tensile failure)

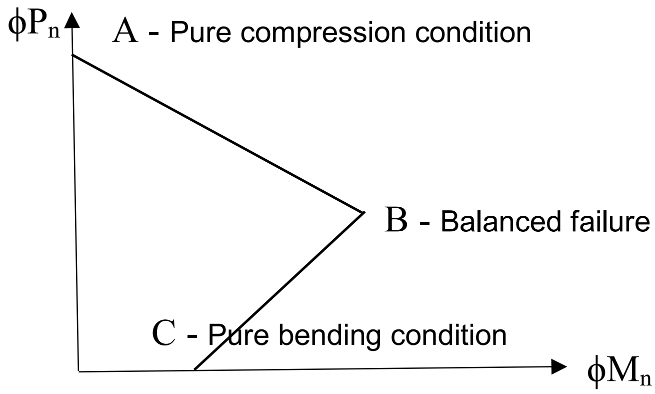


Fig. 2.3 – Interaction Diagram for EPS Walls

2.4.1 Validation of the analytical method for derivation of the interaction curve

In the calculations shown below, an approach has been made to evaluate the Interaction curve of an EPS panel discussed in "Structural Engineering Handbook on Structural Analysis of ICS 3-D Wall Panels". The design procedure for generating P-M Interaction Diagram according to ACI 318.

Details of the Panel have been given below:

b (Width of the Panel)	304.80mm
T (Total Panel thickness)	139.70mm
T_c(Depth of the Shotcrete on one side)	38.10mm
y(Distance between Compression and Tension Reinforcement)	101.60mm
T (Thickness of EPS core)	63.50mm
f_y(Yield Strength of Steel Wires)	386.11MPa
E_s(Elastic Modulus of Steel)	199947.96 MPa
f_{ck}(Compressive Strength of Concrete)	17.23MPa
β_1 Factor for fc $\leq$ 30 MPa	0.85
d Distance from the extreme compression fiber to the centroid	120.65mm

of tension reinforcement	
d' Distance from the extreme compression fiber to the centroid of compression reinforcement	19.05mm
d" Distance from the plastic centroid to the centroid of the tension steel of the wall panel when eccentrically loaded.	50.8mm
a_b Depth of the equivalent rectangular concrete stress block	62.39mm
Density of Shotcrete	25kN/m^3
Density of EPS	0.15kN/m^3
Area of tension and compression steel, A_s	42.39mm^2 (6-3 ϕ@ 50mm)

Pure compression with zero bending moment (concrete compression failure)

Compression in Concrete, $C_c = 0.85 f_{ck}\left(\left(\left(T - T_{EPScore}\right)\times b\right) - \left(2\times A_s\right)\right)$

[EB – 212. Appendix-D]

$$C_c = 0.85\times 17.23\left(\left(\left(139.70 - 63.50\right)\times 304.80\right) - \left(2\times 42.39\right)\right)$$

$$C_c = 338911.22kN$$

Compression in Reinforcement, $C_s = 2\times A_s \times f_y$ [EB – 212. Appendix-D]

$$C_s = 2\times 42.39\times 386.11$$

$$C_s = 32734.40kN$$

Strength of Reduction Factor, $\phi = 0.85$

Axial Load carrying capacity, $\phi P_n = \phi(C_c + C_s)$

$$\phi P_n = 0.85\times(32734.40 + 338911.22)$$

$$\phi P_n = 315898.76N$$

$$\phi P_n = 315.89kN$$

$$\phi M_n = 0$$

Maximum Axial Load carrying capacity,

$$\phi P_{n,\max} = 0.8P_n$$

$$\phi P_{n,\max} = 0.8\times 315.89$$

$$\phi P_{n,\max} = 252.71kN$$

Coordinates of point A in the interaction diagram is (0, 252.71)

<u>Balanced Failure</u>

The tension steel is yielding f_c = f_y. Assume that the compression steel is also yielding from we have,

Depth of the equivalent rectangular concrete stress block, $a_b = \dfrac{0.003E_s}{f_y + 0.003E_s}\beta_1 d$

[Eq. 5.13 Park, R., & Paulay, T. (1975)]

$$a_b = \frac{0.003\times199947.96}{386.11+0.003\times199947.96}\times0.85\times120.65$$

$$a_b = 62.39mm$$

$$P_b = 0.85\times f_{ck}\times a_b\times b + A_s^{'} f_y - A_s f_s$$ [Eq. 5.7 Park, R., & Paulay, (1975)]

Because of equal steel area at each face, the steel forces cancel out, and the equation below is used for calculating axial load carrying capacity,

$$P_b = 0.85\times f_{ck}\times a_b\times b$$
$$P_b = 0.85\times17.23\times62.39\times304.80/1000$$
$$P_b = 278.50kN$$

According to IS 456:2000, section 39.3, the axial load carrying capacity of the section replaced by EPS,

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$
$$P_u = 0.4\times17.23\times63.50\times304.80/1000$$
$$P_u = 133.39kN$$

Partial Safety Factor, ϕ= 0.8

Residual Load carrying capacity, $P_u = \phi(P_b - P_u)$

$$P_u = 0.8\times(278.50-133.39)$$

P_u = 116.09kN

Since the reinforcement is symmetrical the plastic centroid, d" is at the center of the section.

$$P_u\times e = 0.85 f_c a_b b\left(d - d^{"} - 0.5a_b\right) + A_s f_y\left(d - d^{'} - d^{"}\right) + A_s f_s d^{"}$$

[Eq. 5.10 Park, R., & Paulay, T. (1975)]

$$P_u\times e = 116.09\times1000\times\left(120.65-50.8-\left(0.5\times62.39\right)\right)+42.39\times386.11\times\left(120.65-19.05-50.8\right)$$
$$+42.39\times386.11\times50.8$$

$$P_u\times e = 6150513.726N-mm = 6.15kN-m$$

$$c_b = \frac{a_b}{\beta_1}$$
$$c_b = \frac{62.39}{0.85}$$
$$c_b = 73.40$$

Checking the compression steel stress,

$$\frac{f_y}{E_s} = \frac{386.11}{199947.96}$$ [Eq 5.15 Park, R., & Paulay, T. (1975)]

$$\frac{f_y}{E_s} = 0.0019$$

$$\varepsilon_s^{'} = 0.003\frac{c_b - d^{'}}{c_b}$$

$$\varepsilon_s^{'} = 0.003 \times \left(\frac{73.40 - 20}{73.40}\right)$$

$$\varepsilon_s^{'} = 0.0022$$

$$\varepsilon_s^{'} - \frac{f_y}{E_s} = 0.0022 - 0.0019$$

$$\varepsilon_s^{'} - \frac{f_y}{E_s} = 0.0003$$

The above value is positive, therefore compression steel is yielding and the considered assumption is correct.

Therefore we get calculated values of P_u and $P_u \times e$ give the coordinates of point B in the interaction diagram i.e. (6.15, 116.09).

Pure Bending Condition

$$\phi P_n = 0$$

Strength Reduction Factor, $\phi = 0.85$

$$a = \frac{A_s f_y}{0.85 f_c b}$$

[EB – 212. Appendix-D]

$$a = \frac{42.39 \times 386.11}{0.85 \times 17.23 \times 304.80} = 3.66mm$$

$$\phi M_n = \phi A_s f_y \left(d - \frac{a}{2}\right)$$ [EB – 212. Appendix-D]

$$\phi M_n = 0.85 \times 42.39 \times 386.11 \times \left(120.65 - \frac{3.68}{2}\right) = 1652992.96 N - mm$$

$$\phi M_n = 1.65 kN - m$$

Therefore we get calculated values coordinates of point C in the interaction diagram i.e. (1.65,0).

C

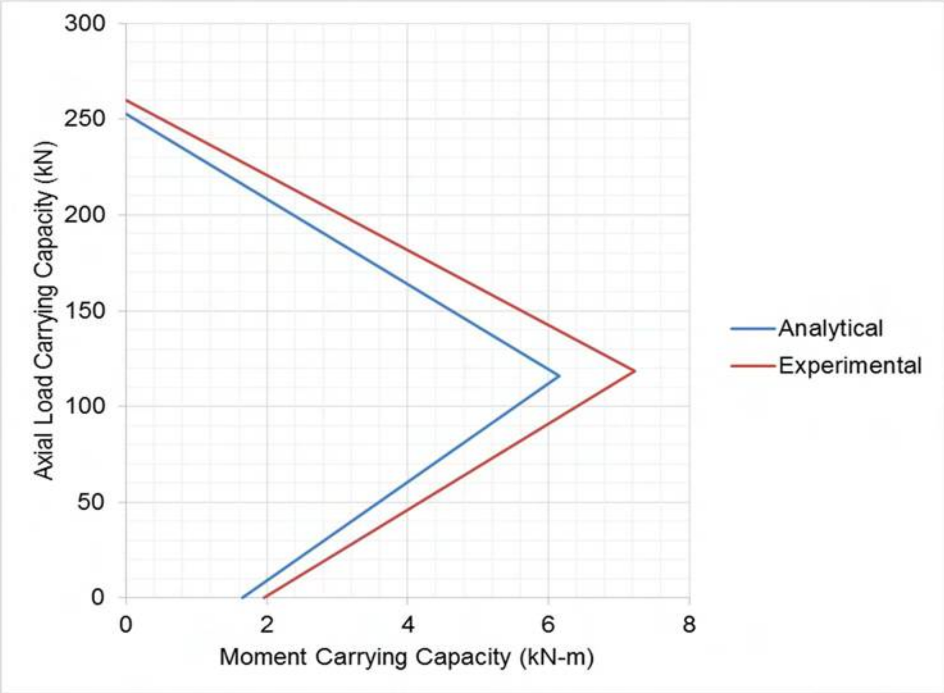


Fig. 2.4 – Interaction Diagram for EPS Walls

Table 2.5: Values of Axial Load & Moment Carrying Capacity for the analytical and experimental curve

	Analytical		**Experimental**	
	x(M_n)	**y(P_n)**	**x(M_n)**	**y(P_n)**
A	0	252.71	0	259.72
B	6.15	116.09	7.22667	118.33
C	1.65	0	1.958845	0

β	Factor 0.85 for f_c'≤4000 psi ACI 10.2.7.3	Dimensionless
ε_c	Strain in Concrete	Dimensionless
ε_y	Yield Strain in reinforcement	Dimensionless
Ø	Strength reduction factor 0.7 for combined axial load and flexure as per ACI 9.3.2	Dimensionless
a	Depth of the equivalent rectangular stress block as per ACI 9.3.2	mm
A_g	Gross area of concrete section	mm^2
A_s	Area of tensile reinforcement	mm^2
b	Width of compression face	mm
c	Distance from extreme compression fiber to neutral axis	mm
C_c	Compression force in concrete	N
C_s	Compression force in reinforcement	N
d	Distance from extreme compression fiber to centroid of tension reinforcement	mm
E_s	Modulus of elasticity of reinforcement 29,000,000 psi as per ACI 8.5.2	MPa
f_c	Specified compressive strength of concrete	MPa
f_y	Specified yield strength of reinforcement	MPa

*Residual Load carrying capacity has been calculated because of placing of EPS core in place of concrete.

*If the width increases, the amount of reinforcement will also be increased.

EPS panels of 6 m height, 1 m width and 150 mm thickness form the external walls of a building with steel rigid frames for a building situated in Roorkee. Calculate the loading on the panels and check for its safety under flexure.

2.5 Design Example of a EPS Non-load Bearing Wall System (As per ACI-318)

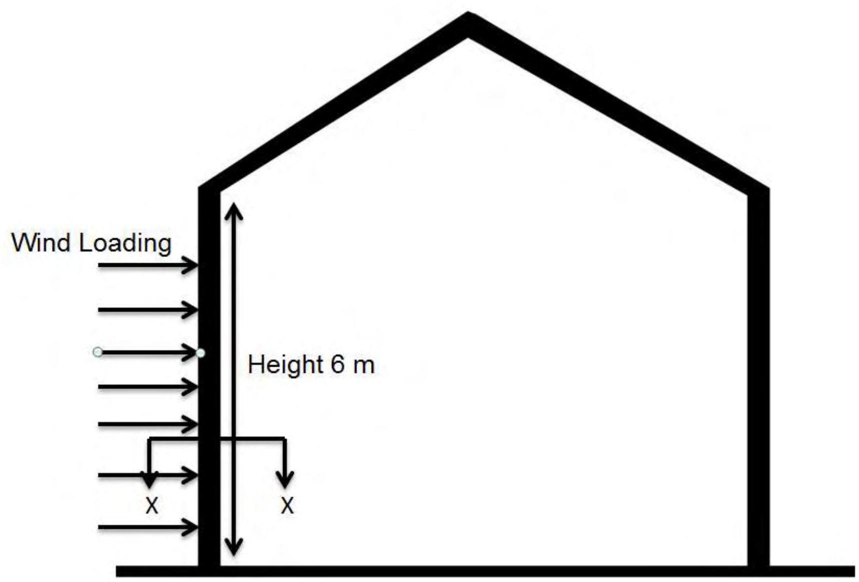


Fig 2.5: Steel frame structure of Non load bearing EPS Panel

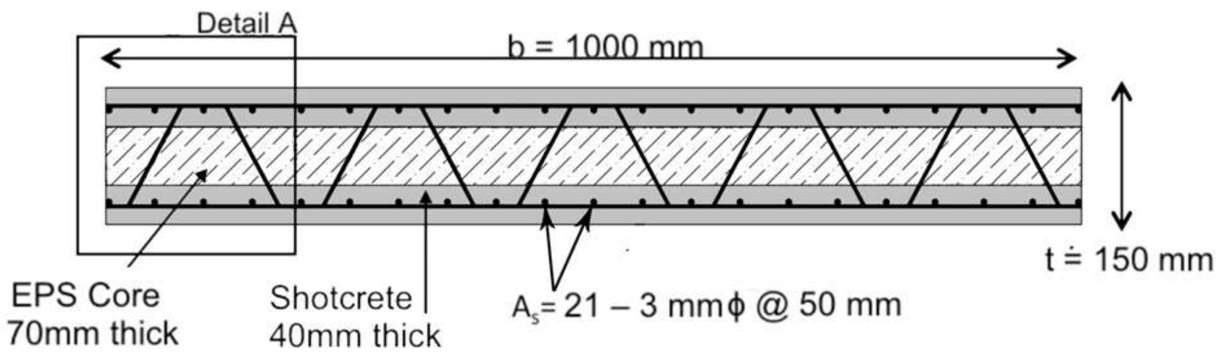


Fig 2.6: Cross Section of EPS Panel at X-X

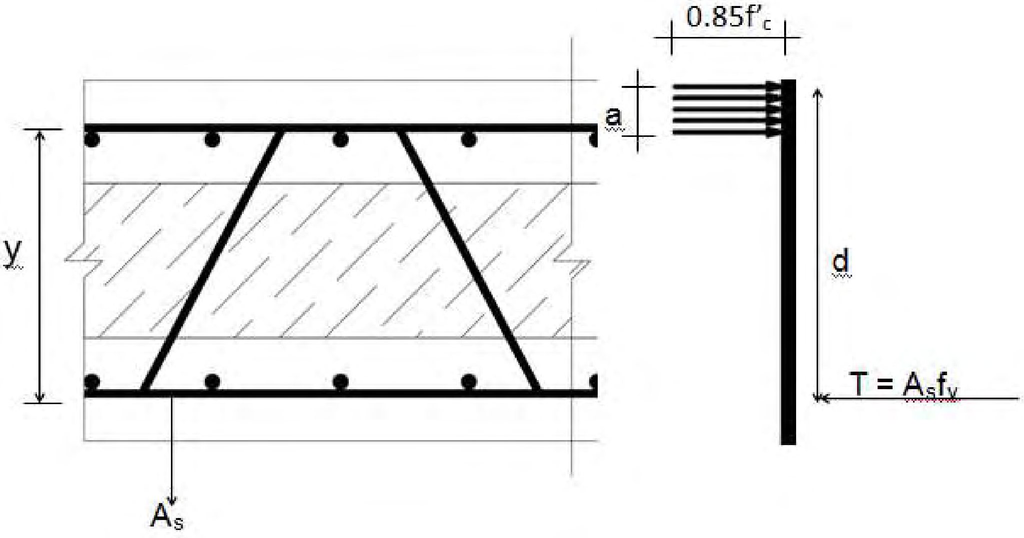


Fig 2.7: Detail A

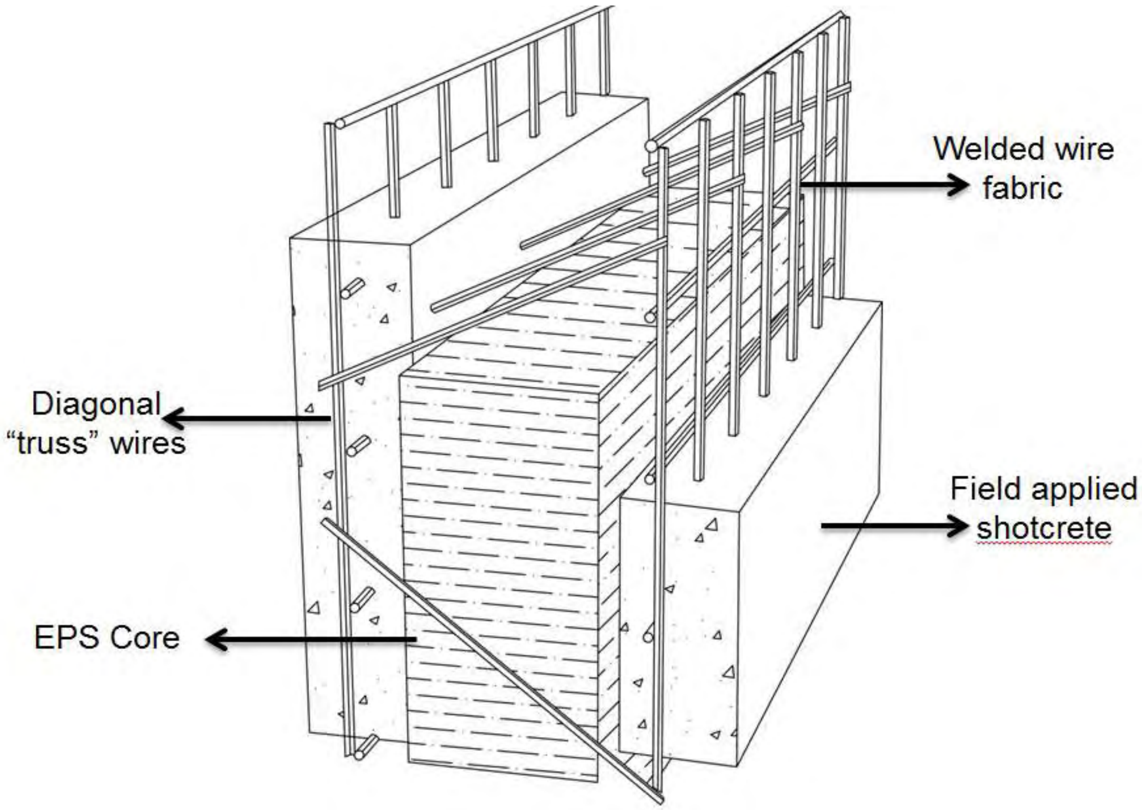


Fig 2.8: 3D Cross Section of EPS Panel

When a panel is used as a non-load bearing wall framed with other materials, they are usually designed to resist wind forces as flexural members.

Wind Load:

Basic Wind Speed, V_b= 39 m/s

Risk Factor, k_1= 1

Building height terrain factor (Class A, Category III), k_2= 0.91

Topographical Factor, k_3= 1

Design Wind Speed, V_z= V_bx k_1x k_2x k_3 = 39 x 1 x 0.91 x 1 = 35.49 m/s

Design wind pressure, P_z= 0.6 V_z^2 = 0.6 x $(35.49)^2$ /1000 = 0.76 kN/m^2

= 0.76 kN/m per unit width

Calculation of forces acting on the panel:

Applied Bending Moment, $M = \frac{wl^2}{8} = \frac{0.76(6)^2}{8} = 3.42 kN - m$

Applied Shear Force, $V = (0.76*6)/2 = 2.28 kN$

Load factor (ACI 318) =1.3

Factored Bending Moment, $M_f = 1.3 \times 3.42 = 4.45 kN - m$

Factored Shear Force, $V_f = 1.3 \times 2.28 = 2.97 kN$

Calculation of moment and shear capacity of the EPS Panel:

Assuming:

Grade of concrete (Shotcrete) M20 i.e f_{ck} = 20 Pa

Grade of galvanized steel wires Fe 415 i.e f_y = 415MPa

A_s (Area of Steel on the Tension face; 21–3 ϕ @ 50 mm) = 148.36 mm^2

Total panel thickness, t = 150 mm

Width of the panel, b = 1000 mm

Depth of Shotcrete = 40 mm

Thickness of EPS core (Density = 15kg/m^3) = 70 mm

Nominal Moment Capacity of the Panel, $M_n = \phi A_s f_y \left(d - \frac{a}{2} \right)$

Where, d is the effective depth, a is the depth of equivalent rectangular concrete stress block and ϕ is the strength reduction factor.

$$d = Total\ \ Panel\ Thickness - \frac{Depth\ \ of\ \ Shotcrete}{2} = 150 - 20 = 130mm$$

$$a = \frac{A_s f_y}{0.85 f_{ck} b} = \frac{148.36 \times 415}{0.85 \times 20 \times 1000} = 3.62mm$$

$$M_n = \phi A_s f_y \left(d - \frac{a}{2} \right) = 0.9 \times 148.36 \times 415 \times \left(130 - \frac{3.62}{2} \right) = 7.10kN - m > 4.45kN - m$$

Nominal Shear Strength, $V_n = \phi bd \left(0.5\sqrt{f_{ck}} \right)$

Where, b is the width of the panel, d is the effective depth, f_{ck} is the compressive strength of concrete and ϕ is the strength reduction factor.

Use Imperial unit system

1MPa = 145.038 psi

25.4mm = 1inch

1kN = 0.2248 kips

*f_{ck}= 20MPa= 20*145.038=2900.76psi*

b=1000mm=1000/25.4inch=39.37inch

d=130mm=130/25.4inch=5.12inch

$$V_n = \phi bd \left(0.5\sqrt{f_{ck}} \right) = \left(0.85 \times 39.37 \times 5.12 \times 0.5 \times \sqrt{2900.76} \right) / 1000 = 4.61kips$$

$$V_n = 20.50kN > 2.97kN$$

Since M_n> M_f and V_n>V_f, therefore the assumed panel is safe against flexure and shear. Cross-section of EPS Panel is shown in Fig. 2.8.

$$I_g = 1000 \times 40 \times 110^2 / (2 \times 1000^4) = 2.42 \times 10^{-4} m^4$$

$$I_e = I_g / 5 = 4.84 \times 10^{-5} m^4 = 116.28 in^4$$

$$w = 0.76 kN / m = 15.87 psf$$

$$l = 6m = 19.685 ft$$

$$E_c = 57000\sqrt{2900.76} = 3069946.13 psi$$

Deflection= $\dfrac{5wl^4}{384E_cI_e} = \dfrac{5 \times (15.87/12) \times (19.68 \times 12)^4}{384 \times \left(57000\sqrt{2900.76}\right) \times 116.28} = 0.15 in = l/1575 < l/240$

2.6 Design Example of a EPS Non-load Bearing Wall System (As per ACI 318, IS 456:2000 & IS 1893:2002)

This design example incorporates the use of ACI 318, IS 456:2000 & IS 1893:2002.

A G+3 storeyed building as shown in the Fig.2.9 (Plan of building) & Fig. 2.10 (Elevation of building) is situated at Roorkee. The building is to be constructed using EPS panels for exterior walls.

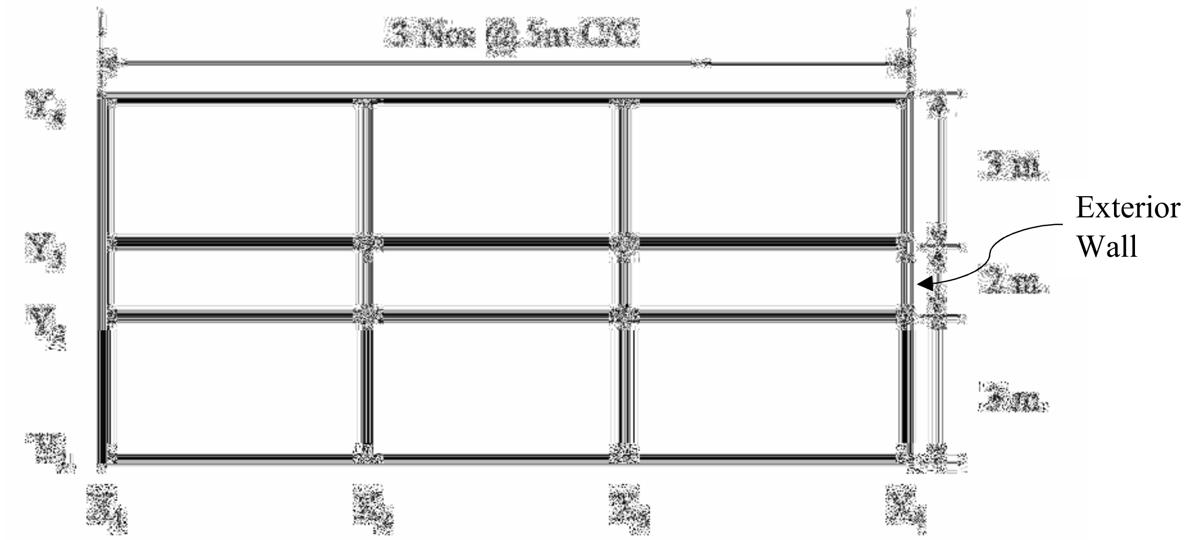


Fig.2.9 Plan of Building

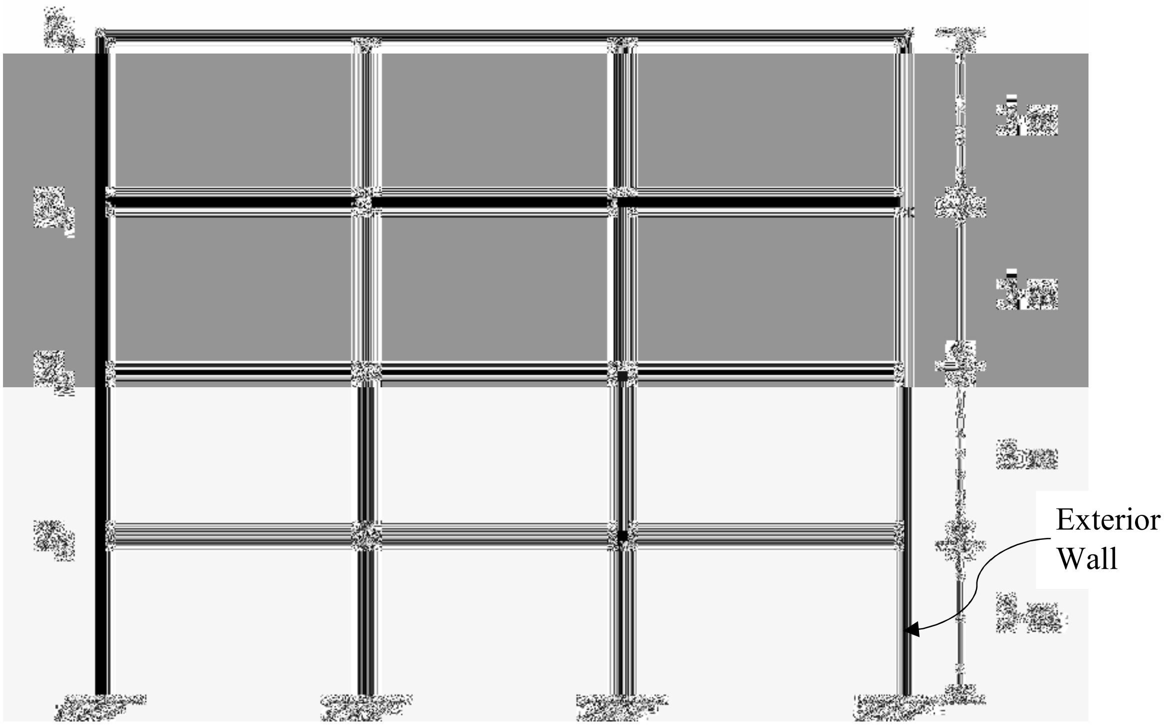


Fig. 2.10 Elevation of building

Design the EPS load bearing wall panel building for following -

Dead load = 2.01kN/m^2 (Calculation shown in later text)

Wall Load = 2.01kN/m^2 (Calculation shown in later text)

Live load = Typical - 2kN/m^2 (as per IS 875-2: 1987)

Corridor - 4kN/m^2 (as per IS 875-2: 1987)

Roof live load = 1.5kN/m^2 (as per IS 875-2: 1987)

Design the exterior wall panel and check for its safety for the above loading.

Assumption:

If the building is located in a seismically active region. The floor is assumed to act as a diaphragm, distributing the seismic forces to the load-bearing walls. Check the safety of the wall panels for in-plane shear forces.

EXTERIOR WALL

Consider a wall panel of following dimensions as shown in the Fig. 2.11 & Fig. 2.12. Fig. 2.13 shows the 3D view of the EPS wall panel.

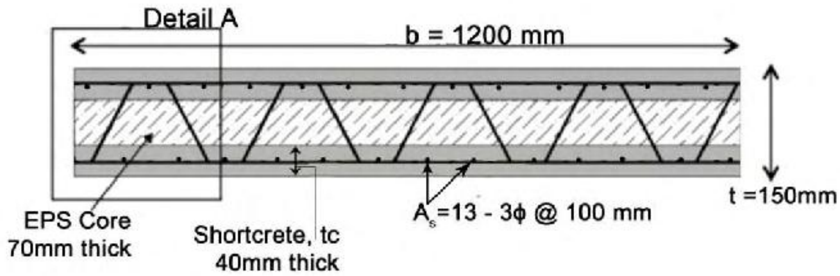


Fig. 2.11: Cross-section of the EPS wall Panel

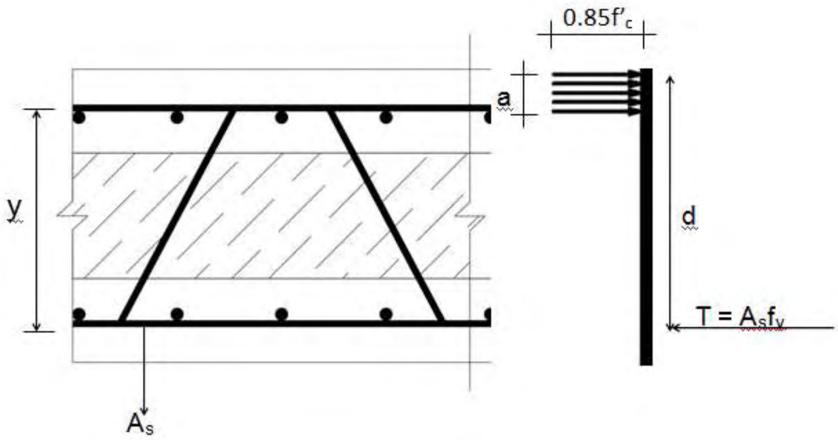


Fig. 2.12: Detail A

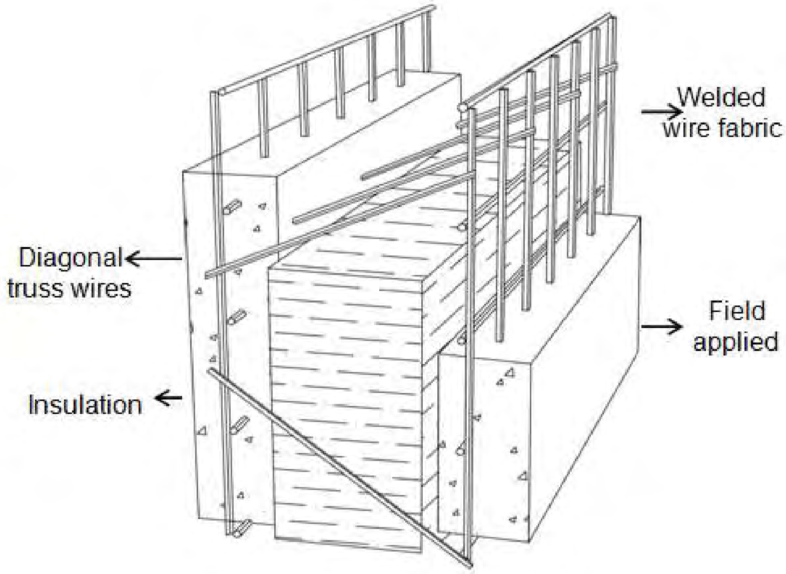


Fig. 2.13: The 3D view of the EPS Wall Panel

Details of the Assumed Wall Panel

b (Width of the Panel)	1200mm
T (Total Panel thickness)	150mm
T_c(Depth of the Shotcrete on one side)	40mm
y (Distance between Compression and Tension Reinforcement)	110mm
T (Thickness of EPS core)	70mm
f_y(Yield Strength of Steel Wires)	415MPa
E_s(Elastic Modulus of Steel)	200000 MPa
f_{ck}(Compressive Strength of Concrete)	20MPa
β_1 Factor for fc $\leq$ 30 MPa	0.85
d Distance from the extreme compression fiber to the centroid of tension reinforcement	130mm
d' Distance from the extreme compression fiber to the centroid of compression reinforcement	20mm
d" Distance from the plastic centroid to the centroid of the tension steel of the wall panel when eccentrically loaded.	55mm
a_b Depth of the equivalent rectangular concrete stress block	65.32mm
Density of Shotcrete	25kN/m^3
Density of EPS	0.15kN/m^3
Thickness of the Slab	150mm
Area of tension and compression Steel, As	91.85 mm^2 (13-3 ϕ@ 100mm)

Calculation of loads acting upon the exterior wall panel

Wind Load:

Basic Wind Speed at Roorkee, V_b= 39 m/s

Risk Factor, k_1 = 1

Building height terrain factor (Class A, Category III), k_2= 0.91

Topographical Factor, k_3 = 1

Design Wind Speed, $V_z = V_b \times k_1 \times k_2 \times k_3 = 39 \times 1 \times 0.91 \times 1 = 35.49 m/s$

Design wind pressure, $P_z = 0.6\ V_z^2 = 0.6 \times (35.49)^2 /1000 = 0.76\ kN/m^2$

<u>Calculation of Dead Load & Wall Load</u>

Dead Load per m^2 & Wall Load per m^2 = (*Density of Concrete × Thickness of concrete in the wall panel) + (Density of EPS × Thickness of EPS in the wall panel)*

= (25 × 0.08) + (0.15×0.07)

=2.01kN/m²

<u>Dead load per panel</u>

Floor & Roof Load = (*Dead Load per m²) × (Span of the slab/2) × (Number of storey's) × (Width of the panel)*

= 2.01× (5/2) × 4× 1.2= 24.12kN

Wall Load= (*Wall Load per m²) × (Height of the wall) ×(Number of storey's)× (Width of the panel)*

= 2.01 × 3× 4× 1.2= 28.94kN

Total Dead Load= *(24.12+28.94) kN/m=53.06kN*

<u>Live load per panel</u>

Consider the wall at corridor,

Floor Load at Corridor= (*Corridor Live Load per m²) × (Span of the slab/2) × (Number of storey's - 1)× (Width of the panel)*

= 4× (5/2) × 3× 1.2= 36kN

Roof Load= (*Roof Live Load per m²) × (Span of the slab/2) × (Width of the panel)*

= 1.5 × 2.5×1.2= 4.5kN

Total Live Load= 36+4.5= 40.50kN

Axial Force due to Total Dead and total Live Load,

$$P_u = 1.4(Total\ Dead\ load) + 1.7(Total\ Live\ Load)$$

$$P_u = 1.4(53.06) + 1.7(40.50) = 143.13kN$$

If the eccentricity of 25mm is assumed.
Eccentric Moment due to *Pu,* $M_u = P_u \times 0.025$

$$M_u = 143.13 \times 0.025 = 3.58kN - m$$

Moment due to wind, $M_w = \frac{0.76 \times 3^2}{8} = 0.85kN - m$

Axial Force for combined D+L+W

$$P_f = 0.75[1.4D + 1.7L + 1.7W]$$

$$P_f = 0.75 \times 143.13$$

$$P_f = 107.35kN$$

Moment for eccentric axial load and wind load,

$$M_f = 0.75[M_u + 1.7M_w]$$

$$M_f = 0.75[3.58 + 1.7(0.85)]kN$$

$$M_f = 3.77kN - m$$

Slenderness:

$$\beta_d = \frac{Factored\ Dead\ Load}{Factored\ Total\ Load} = \frac{1.4 \times 53.06}{143.13} = 0.52$$

(Note: β_d does not apply to wind load moments)

Gross Moment of Inertia, I_g= (Width of the panel × Thickness of the shotcrete at one side × (Distance between Compression and Tension Reinforcement)^2)/2

Gross Moment of Inertia, $I_g = \frac{1200 \times 40 \times 110^2}{2 \times 1000^4} = 2.90 \times 10^{-4} m^4$

$$E_c = 5000\sqrt{f_{ck}} \times 10^3\ kN/m^2$$

$$E_c = 5000\sqrt{20} \times 10^3\ kN/m^2$$

$$E_c = 22360.68 \times 10^3\ kN/m^2$$

$$EI = \frac{E_c I_g/5}{1+\beta_d} = \frac{22360.68 \times 10^3 \times 2.90 \times 10^{-4}/5}{1+0.52} = 853.24$$

$$P_c = \frac{\pi^2 EI}{l_u^2} = \frac{\pi^2 \times 853.24}{3^2} = 934.73kN$$

$$\delta = \frac{1}{1 - \frac{P_f}{\phi P_c}} = \frac{1}{1 - \frac{143.13}{0.85 \times 934.73}} = 1.22$$

Modified Moments due to slenderness,

D+L, $M_f = 3.58 \times 1.22 = 4.36 kN - m$

D+L+W, $M_f = 3.77 \times 1.22 = 4.59 kN - m$

In-Plane Shear

Calculation of Seismic Weight

$W_{DeadLoad}$ = (Thickness of Shotcrete at both sides × ((Breadth of the building × Height of the wall × Number of storey's) + (Length of the building × Height of the wall × Number of storey's)) × ((Number of storeys-1) + 0.5) × Density of Concrete) + (Thickness of EPS × ((Breadth of the building × Height of the wall × Number of storey's) + (Length of the building × Height of the wall × Number of storey's)) × ((Number of storeys-1) + 0.5) × Density of EPS)+(Density of Concrete × Length of the building ×Breadth of the building ×Thickness of Shotcrete at both sides× Number of storey's)+ (Density of EPS × Length of the building ×Breadth of the building ×Thickness of EPS× Number of storey's)

$$W_{DeadLoad} = \underbrace{(0.08 \times ((8 \times 3 \times 4) + (15 \times 3 \times 4)) \times 3.5 \times 25)}_{\text{Dead Load of the Concrete in Walls}} +$$

$$\underbrace{(0.07 \times ((8 \times 3 \times 4) + (15 \times 3 \times 4)) \times 3.5 \times 0.15)}_{\text{Dead Load of the EPS in Walls}} +$$

$$\underbrace{((25 \times 15 \times 8 \times 0.08 \times 4) + (0.15 \times 15 \times 8 \times 0.07 \times 4)}_{\text{Dead Load of the slab}}$$

$= 0.08 \times (96 + 180) \times 87.5 + 0.07 \times (96 + 180) \times 52.5 + 960 + 504$

$= 0.08 \times 276 \times 87.5 + 0.07 \times 276 \times 52.5 + 960 + 504$

$= 1932 + 10.14 + 960 + 5.04$

$W_{DeadLoad}$= 2907.18kN

$W_{LiveLoad}$ = ((Area of the Floors × (Number of storeys-1)) × Live Load on the floor per m^2) + ((Area of the corridor × (Number of storeys-1)) × Live Load on the corridor per m^2) + (Area of the roof × Live Load on the roof per m^2)

$$W_{LiveLoad} = \underbrace{(3 \times 5 \times 6 \times 3 \times 2)}_{\text{Live on the floors up to 3 storey's}} + \underbrace{(2 \times 5 \times 3 \times 3 \times 4)}_{\text{Live on the corridors up to 3 storey's}} + \underbrace{(15 \times 8 \times 1.5)}_{\text{Live Load on the roof}}$$

$= 540 + 360 + 180$

$W_{LiveLoad} = 1080kN$

$W = W_{DeadLoad} + (0.25 \times W_{LiveLoad})$

$= 2907.18 + (0.25 \times 1080)$

$= 3177.18kN$

Calculation of Design Seismic Base Shear According to IS 1893:2002B

$V_b = A_h \times W$

Where, V_b is the total design lateral force or design seismic base shear.

A_h is the Design horizontal acceleration spectrum value as per 6.4.2 IS 1893

W = Seismic weight of the building as per 7.4.2

$$A_h = \frac{ZIS_a}{2Rg}$$

Where,

Z = Zone factor given in Table 2.2, IS 1893 is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 is the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I= Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake, functional needs, historical value, or economic importance (Table 2.6, IS 1893).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0 (Table 2.7, IS 1893). The values of R for buildings are given in Table 2.7, IS 1893.

S_a/g = Spectral Acceleration

$V_b = 2.5 \times (1/3) \times (0.24/2) \times 3177.18$

$V_b = 317.71kN$

Shear Strength of the Assumed EPS Panel:

According to ACI 11.1 318R-08 design of cross sections subject to shear are based on:

$\phi V_n \geq V_u$

Where, V_u is the factored force at the section considered and V_n is the nominal shear strength computed by:

$V_n = V_c + V_s$ [ACI 11.1.1 318R-08]

V_c is the nominal shear strength provided by concrete and V_s is the nominal shear strength provided by shear reinforcement.

$V_c = 2\sqrt{f_c^{'}}hd$ [ACI 11.2.1 318R-08]

h = 2 × (40) = 80mm

d = 0.8 × l_w *= 0.8 × 5 = 4m = 4000mm*

Use Imperial unit system

1MPa = 145.038 psi

1inch = 25.4mm

1kN = 0.2248 kips

h = 80mm = 3.15inch

d = 4000mm = 157.48inch

f_{ck}*= 20MPa = 2900.75psi*

$$V_c = \frac{2 \times \sqrt{2900.75} \times 3.15 \times 157.48}{1000} = 53.43kips$$

$$V_c = 237.67kN$$

Area of wire = *77.715mm*^{2}in a *1000mm* width of a panel,

A_v *= 2× (77.715) = 155.43mm*^{2}*, s = 1000mm*

$$V_s = \frac{A_v f_y d}{s} = \frac{155.43 \times 415 \times 4000}{1000 \times 1000} = 258.01kN$$ [ACI 11.9.9.1 318R-08]

$$\phi V_n = \phi\left(V_c + V_s\right) = 0.85\left(237.67 + 258.015\right) = 421.33kN > 317.71kN$$

Interaction Diagram

Interaction diagram represent the relationship for combination of axial load and bending moment on EPS walls and are used as a design aids to assist the designer with the selection of the various parameters such as reinforcement, thickness, width etc. Point located with the interaction curve and the reference axis represent the combination of axial load and bending moment that the wall can support.

For EPS walls, interaction diagram can be approximately constructed by connecting three basic points with straight line as shown in Figure.

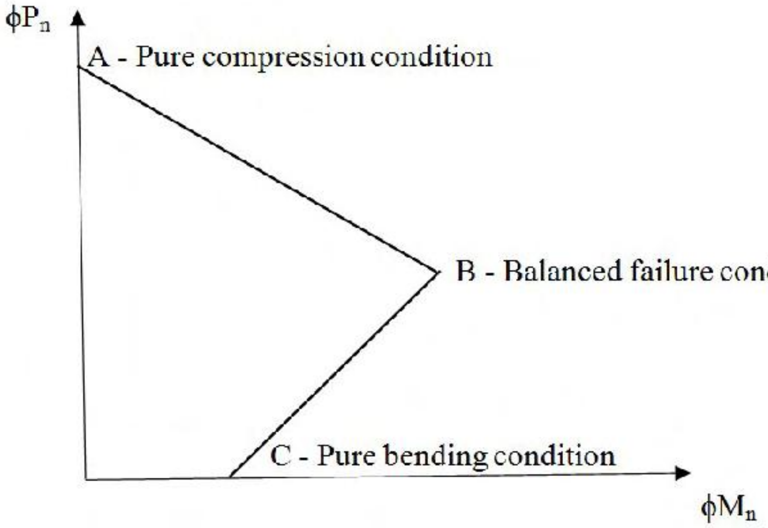


Fig. 2.14 – Interaction Diagram for EPS Walls

1. Pure compression with zero bending moment (concrete compression failure).
2. Tension steel is yielding; the compression steel is also yielding (balanced failure).
3. Pure bending with zero axial loads (under reinforced with the ductile reinforcement tensile failure).

<u>Capacity of the EPS wall panel</u>

1. Pure compression with zero bending moment (concrete compression failure)

Compression in Concrete, $C_c = 0.85 f_{ck}\left(\left(\left(T - T_{EPScore}\right)\times b\right)-\left(2\times A_s\right)\right)$

[EB – 212. Appendix-D]

$C_c = 0.85\times 20\left(\left(\left(150-70\right)\times 1200\right)-\left(2\times 91.85\right)\right)$

$C_c = 1628877.10kN$

Compression in Reinforcement, $C_s = 2\times A_s \times f_y$ [EB – 212. Appendix-D]

$C_s = 2\times 91.85\times 415$

$C_s = 76235.50kN$

Strength of Reduction Factor, $\phi = 0.85$

Axial Load carrying capacity, $\phi P_n = \phi(C_c + C_s)$

$\phi P_n = 0.85\times(1628877.10 + 76235.50)$

$\phi P_n = 1449345.71N$

$\phi P_n = 1449.34kN$

$\phi M_n = 0$

Maximum Axial Load carrying capacity,

$\phi P_{n,\max} = 0.8P_n$

$\phi P_{n,\max} = 0.8 \times 1449.34$

$\phi P_{n,\max} = 1159.47kN$

Coordinates of point A in the interaction diagram is (0, 1159.47)

<u>Balanced Failure</u>

The tension steel is yielding $f_c = f_y$. Assume that the compression steel is also yielding from we have,

Depth of the equivalent rectangular concrete stress block, $a_b = \frac{0.003E_s}{f_y + 0.003E_s}\beta_1 d$

[Eq 5.13 Park, R., & Paulay, T. (1975)]

$$a_b = \frac{0.003 \times 200000}{415 + 0.003 \times 200000} \times 0.85 \times 130$$

$a_b = 65.32mm$

$P_b = 0.85 \times f_{ck} \times a_b \times b + A_s^{'} f_y - A_s f_s$ [Eq 5.7 Park, R., & Paulay, T. (1975)]

Because of equal steel area at each face, the steel forces cancel out, and the equation below is used for calculating axial load carrying capacity,

$P_b = 0.85 \times f_{ck} \times a_b \times b$

$P_b = 0.85 \times 20 \times 65.32 \times 1200 / 1000$

$P_b = 1332.53kN$

According to IS 456:2000, section 39.3, the axial load carrying capacity of the section replaced by EPS,

$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$P_u = 0.4 \times 20 \times 70 \times 1200 / 1000$

$P_u = 672kN$

Partial Safety Factor, ϕ= 0.8

Residual Load carrying capacity, $P_u = \phi\left(P_b - P_u\right)$

$P_u = 0.8 \times \left(1332.53 - 672\right)$

P_u = 528.42kN

Since, the reinforcement is symmetrical the plastic centroid, d” is at the center of the section.

$$P_u \times e = 0.85 f_c a_b b\left(d - d^{"} - 0.5a_b\right) + A_s f_y\left(d - d^{'} - d^{"}\right) + A_s f_s d^{"}$$

[Eq 5.10 Park, R., & Paulay, T. (1975)]

$$P_u \times e = 528.42 \times 1000 \times \left(130 - 55 - \left(0.5 \times 65.32\right)\right) + 91.85 \times 415 \times$$
$$\left(130 - 20 - 55\right) + 91.85 \times 415 \times 55$$
$$P_u \times e = 24308592.01N - mm = 24.31kN - m$$
$$c_b = \frac{a_b}{\beta_1}$$
$$c_b = \frac{65.32}{0.85}$$
$$c_b = 76.84$$

Checking the compression steel stress,

$$\frac{f_y}{E_s} = \frac{415}{200000}$$

[Eq 5.15 Park, R., & Paulay, T. (1975)]

$$\frac{f_y}{E_s} = 0.002075$$
$$\varepsilon_s^{'} = 0.003\frac{c_b - d^{'}}{c_b}$$
$$\varepsilon_s^{'} = 0.003 \times \left(\frac{76.84 - 20}{76.84}\right)$$
$$\varepsilon_s^{'} = 0.00221$$
$$\varepsilon_s^{'} - \frac{f_y}{E_s} = 0.00221 - 0.002075$$
$$\varepsilon_s^{'} - \frac{f_y}{E_s} = 0.00014$$

The above value is positive, therefore compression steel is yielding and the considered assumption is correct.

Therefore, we get calculated values of P_u and $P_u \times e$ give the coordinates of point B in the interaction diagram i.e. (24.31, 528.42)

Pure Bending Condition

$$\phi P_n = 0$$

Strength Reduction Factor, $\phi = 0.85$

$$a = \frac{A_s f_y}{0.85 f_c b}$$ [EB – 212. Appendix-D]

$$a = \frac{91.85 \times 415}{0.85 \times 20 \times 1200} = 1.86mm$$

$$\phi M_n = \phi A_s f_y \left(d - \frac{a}{2} \right)$$ [EB – 212. Appendix-D]

$$\phi M_n = 0.85 \times 91.85 \times 415 \times \left(130 - \frac{1.86}{2} \right) = 4181741.315 N - mm$$

$$\phi M_n = 4.18 kN - m$$

Therefore, we get calculated values coordinates of point C in the interaction diagram i.e. (4.18, 0).

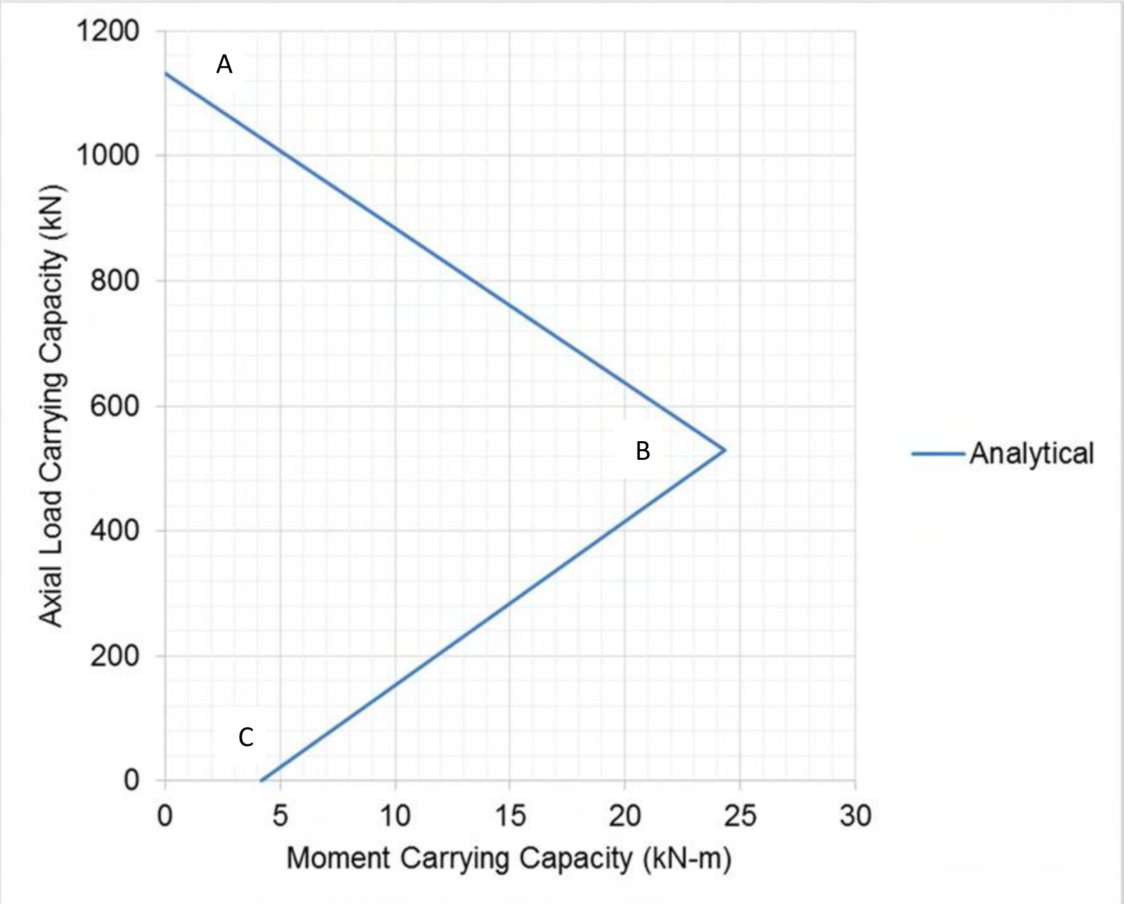


Fig. 2.15 : Interaction Diagram

From the above Interaction curve, it can be verified that the coordinates (4.59, 143.13) lie inside it, hence it can be deduced that the panel is safe for the above loading conditions.

Design Example of EPS Floor Panel System

Design an EPS floor panel for a room measuring *3m x 5m* size. The floor panel is to be designed as an interior panel according to IS 456:2000. The loading on the panel is as mentioned below:

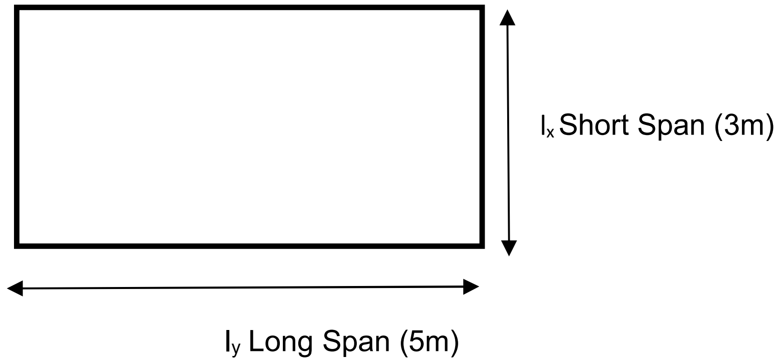
Dead load: 2.01kN/m^2

Live load: Typical - 3kN/m^2

Floor finis: 1.5kN/m^2

Design the floor panel and check for its safety for the above loading.

Solution for Design of Floors/Roofs Panels



l_y= 5000 mm
l_x= 3000 mm

l_y/l_x= 5000/3000 = 1.67

Floor Panel

Consider a floor panel of following dimensions as shown in the Fig. 2.16. Fig. 2.17 Shows the 3D view of the EPS floor panel.

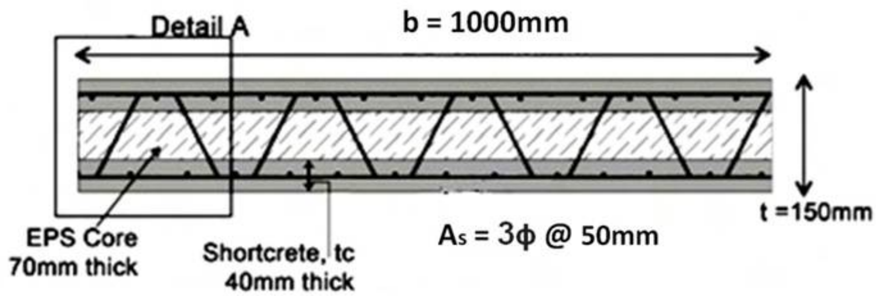


Fig. 2.16: Cross-section of the EPS Floor Panel

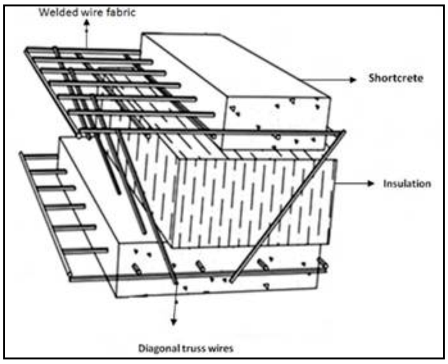


Fig. 2.17: The 3D view of the EPS Floor Panel

<u>Details of the Assumed Wall Panel</u>

b (Width of the Panel)	1000mm
T (Total Panel thickness)	150mm
T_c(Depth of the Shotcrete on one side)	40mm
y (Distance between Compression and Tension Reinforcement)	110mm
T (Thickness of EPS core)	70mm
f_y(Yield Strength of Steel Wires)	415MPa
E_s(Elastic Modulus of Steel)	200000 MPa
f_{ck}(Compressive Strength of Concrete)	20MPa
Density of Shotcrete	25kN/m^3
Density of EPS	0.15kN/m^3
Tension and compression Steel	3 ϕ@ 50mm

Loading on slab:

<u>Calculation of Dead Load</u>

Dead Load of Floor Panel per m^2 = (*Density of Concrete × Thickness of concrete in the wall panel) + (Density of EPS × Thickness of EPS in the wall panel)*

= (25 × 0.08) + (0.15×0.07)

=2.01kN/m²

Live Load = 3kN/m^2

Floor Finish = 1.5kN/m^2

Total Load = 6.51 kN/m^2

Factored Load $= 1.5 \times 6.51 = 9.77 kN/m^2$
= 11.33kN/m per unit width

According to IS 456:2000 Table 26 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners.

Bending Moment Coefficients,

$\alpha_x^+ = 0.044$

$\alpha_x^- = 0.058$

$\alpha_y^+ = 0.032$

$\alpha_y^- = 0.024$

$$M_{ux}^+ = \alpha_x^+ W_u l_x^2 = 0.044 \times 9.77 \times 3 \times 3 = 3.87 kN-m$$
$$M_{ux}^- = \alpha_x^- W_u l_x^2 = 0.058 \times 9.77 \times 3 \times 3 = 5.09 kN-m$$
$$M_{uy}^+ = \alpha_y^+ W_u l_x^2 = 0.032 \times 9.77 \times 3 \times 3 = 2.81 kN-m$$
$$M_{uy}^- = \alpha_y^- W_u l_x^2 = 0.024 \times 9.77 \times 3 \times 3 = 2.11 kN-m$$

Minimum Area of Steel Wire Mesh is 3ϕ-50mm c/c

Area of Steel = $= \dfrac{1000 \times Area\ of\ steel\ wire \times 2}{Spacing\ between\ steel\ wires} = \dfrac{1000 \times 7.1 \times 2}{50} = 284\, mm^2/m$

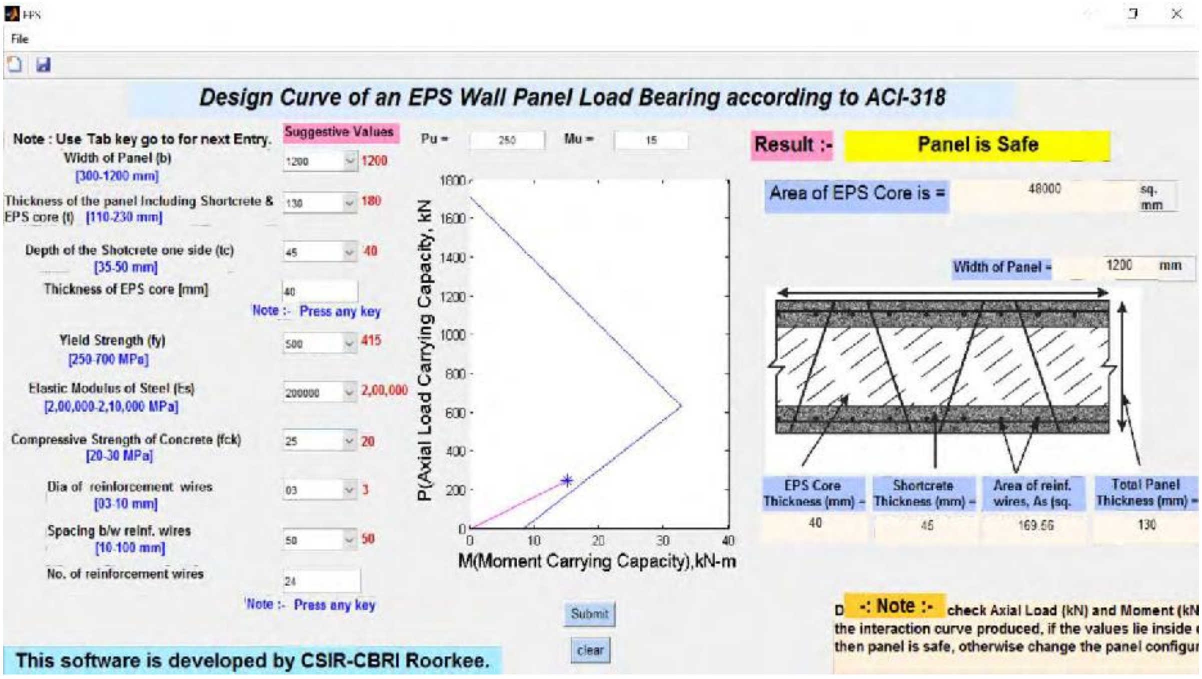
Moment of Resistance, $M_{RES} = 0.87 \times f_y \times A_{st} \times Lever\ Arm$

$$Lever\ Arm = d - \frac{0.5d}{2}$$
$$M_{RES} = 0.87 \times 415 \times 284 \times \left(130 - \frac{0.5 \times 130}{2}\right)$$
$$M_{RES} = 0.87 \times 415 \times 284 \times 97.5$$
$$M_{RES} = 9997474.50 N-mm/m$$
$$M_{RES} = 9.99 kN-m/m$$

Since, factored moment demand is less than moment of resistance, floor panel is safe.

2.7 **User friendly interactive software**

A User friendly interactive software, for the design of EPS load bearing wall panels has been be prepared. A snapshot of the Graphic User Interface (GUI) interactive software for the design of EPS load bearing wall panels is shown as below.


Design Curve of an EPS Wall Panel Load Bearing according to ACI-318
Note : Use Tab key go to for next Entry.
Suggestive Values
Width of Panel (b) [300-1200 mm]
Thickness of the panel Including Shortcrete & EPS core (t) [110-230 mm]
Depth of the Shotcrete one side (tc) [35-50 mm]
Thickness of EPS core [mm]
Note :- Press any key
Yield Strength (fy) [250-700 MPa]
Elastic Modulus of Steel (Es) [2,00,000-2,10,000 MPa]
Compressive Strength of Concrete (fck) [20-30 MPa]
Dia of reinforcement wires [03-10 mm]
Spacing b/w reinf. wires [10-100 mm]
No. of reinforcement wires
Note :- Press any key
Pu =
Mu =
P(Axial Load Carrying Capacity, kN
M(Moment Carrying Capacity),kN-m
Submit
clear
Result :-
Panel is Safe
Area of EPS Core is =
Width of Panel =
EPS Core Thickness (mm) =
Shortcrete Thickness (mm) =
Area of reinf. wires, As (sq.
Total Panel Thickness (mm) =
-: Note :-
This software is developed by CSIR-CBRI Roorkee.

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30. IS: 875-1987 (part-3) for Wind Loads, code of practice of Design loads (other than earthquake) for buildings and structures.

CHAPTER – 3

FABRICATION, CONSTRUCTION SEQUENCE, TRAINING MODULE AND MANPOWER REQUIREMENT

This chapter discusses about the Construction details of EPS Core Panel Systems, and Training Modules for Professionals & Artisans and Manpower Requirement.

3.1 Typical Construction Sequence of EPS Core Panel Systems

Foundations

Foundations for the EPS Core Panel system whether strip or raft is conventional. If strip foundations are used, they should be level and stepped as this makes panel positioning easier. For EPS Core panels, parallel sided timber or metal template of the width of panel shall be required to mark the position of the wall panels on the foundation and the spacing of the starter bar holes.

Wall start up

I. Line wall positions shall be marked and profiled.
II. A timber or metal template of the exact width of panel (from wire to wire) shall be used to mark the position of the panels with chalk or pencil lines.(Fig.3.1)
III. On the panel lines, positions shall be marked to drill the starter bar holes. These should be in a zig-zag pattern at 600mm centres on each side of the panels. Starter bars should be at all panel joints and on the opposite side in mid panel plus at all wall corners and joints. (Fig.3.2)
IV. Starter bars should be either 6mm or 8mm dia. 500mm long with 100mm drilled into the foundations and 400mm above.
V. Drill bits shall be used to give a tight fit with the starter bars.
VI. Once starter bars are in position, place the EPS Core panels between the starter bars starting from a corner. Starter bars shall be wire-tied to the panel mesh and the panels to each other on the overlapping mesh. (Fig.3.3 & 3.4)

Wall construction

I. All corners and wall joints shall be reinforced with right angled wire mesh to the full height of the walls. (Fig.3.5 & Fig.3.6)
II. To cut panels to fit for door & window openings, wire should be cut with a wire cutter or angle grinder. Measure and mark the cut lines before starting to cut. (Fig.3.7 & Fig.3.8)
III. After the wire mesh has been cut, EPS shall be cut with a hacksaw blade or stiff blade hand saw. (Fig.3.9)
IV. Added steel mesh reinforcement (U type meshes) shall be required around door and window openings to ensure that no plaster cracks form in these areas. Mesh reinforcement strips shall be tied diagonally with wire around openings before plastering. (Fig.3.10)
V. Once wall panels are in place and tied together, bracing shall be required to hold them vertical before plastering. This shall be done only on one side of the panels. (Fig.3.11& Fig.3.12)

VI. Once the panels are plastered on one side, the wall bracing shall be removed after 24 hours. Plastering on other side can be done without bracing.

Door and Window fittings

First method

I. Fix a metal angle iron or hollow tube sub frame into the openings before plastering. Fix and plaster these in place and then secure the frames to the sub frame.
II. In order to secure heavy door/window frames, it is advisable to burn or cut away the EPS where the fixing bolts are to be secured to the wall and to fill this space with mortar or concrete to hold the bolts. (Fig.3.13 & Fig.3.14)

Second method

I. Before plastering metal 'cliscoe' type window and door frames (which should be sized to the width of the panels) may be fitted into the pre-cut panels.
II. Metal lugs from the back of metal frames shall be wire tied to the panel mesh to keep the frames in position. (Fig.3.15)

Roof/floor panel

I. After the vertical panels are assembled, verticality of the walls shall be checked and the bending meshes positioned on all the corners. Thereafter, horizontal bending meshes shall be placed to connect the floor/roof to the vertical panels. The bending meshes shall be fixed throughout the perimeter of the floor/roof, at the level of intrados.
II. When the horizontal bending meshes are fixed and checked, floor/roof panel shall be placed on these. The lower mesh of the panel shall be fixed by steel wire to the bending meshes.
III. Between the edges of floor/roof panel and vertical panel, gap of 35 mm should be left to ensure structural continuity. The plaster applied on the walls shall be continued from one level to another level.
IV. Placing of the EPS Core Panel elements for the floor and/or roof should be done before the application of the external layer of plaster on the walls. Casting of concrete on the floor/roof panels (after placing the additional reinforcing bars, if required) should be done after the walls are plastered and a number of props shall be put to limit the deformation of the panel.

Plastering

I. Plastering shall be done by machine or hand. The indicative quantity of each material per cum. should conform to relevant Indian Standards and shall be:
(i) Cement: 350kg
(ii) Sand with mixed granulometry: 1600kg. Sand should be without clay or any organic substance and totally washed.
(iii) Water – 160litres. The quantity of water may be different according to the natural sand humidity. The parameters that should be constant are: W/C = 0.52 and I/C = 4.50.
II. Any problem of workability should be solved without adding water. The retraction cracks formation may be avoided by adding polypropylene fibres in the mix (1kg/m^3).

III. In order to control the final plaster thickness, some guides should be used. These shall be removed as soon as the plaster 'sets up' and the spaces are filled and are smoother before the plaster gets dry.
IV. Spray application should be done in two steps with a first layer covering the mesh applied on both the sides of the wall and the finishing layer as soon as the first layer gets dry.

Plumbing and electrical fittings (Fig. 3.16 & 3.17)

I. Plumbing and electrical conduits shall be behind the panel wire mesh before plastering.
II. The space behind the wire mesh shall be opened up by using a blow torch to partially melt the EPS along the lines of the conduits.
III. As the EPS used in the panels is fire retardant, it will melt under the flame but not burn.
IV. The wire mesh shall be cut with wire clippers to make space for DB boards, switches and plug boxes.
V. For the installation of HVAC suitable strengthening measures (in form of mess size and no.) should be provided as and when required.
VI. At the time of installation of HVAC suitable additional reinforcement mess should be provided to take care of HVAC unit as per the strength requirement. of the panel.

Tools required

I. Parallel side timber or metal template to mark portion of the wall panel on the foundation.
II. Electric drill and extension cord with connect drill bits (6 or 8m) for drilling holes for the starter bar.
III. Tape to measure, dimension.
IV. Pliers for wire tying
V. Level and or plumb lines to ensure panels are plumb and straight.
VI. Heavy duty wire cutters.
VII. Hand hold blow torch.
VIII. Normal plaster tools.


Fig. 3.1


Fig. 3.2

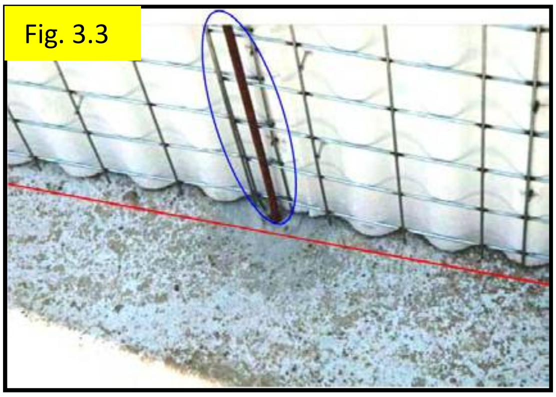


Fig. 3.3

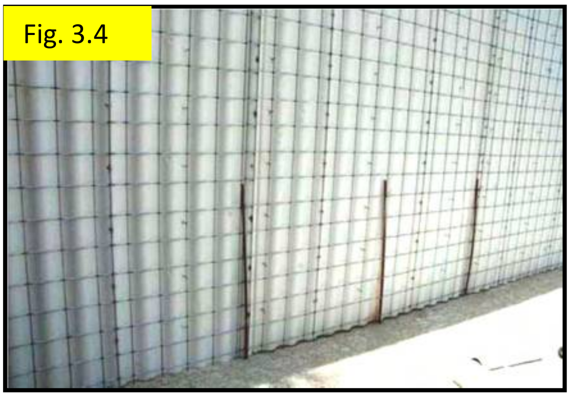


Fig. 3.4


Fig. 3.5


Fig. 3.6


Fig. 3.7


Fig. 3.8


Fig. 3.9


Fig. 3.10


Fig. 3.11


Fig. 3.12


Fig. 3.13

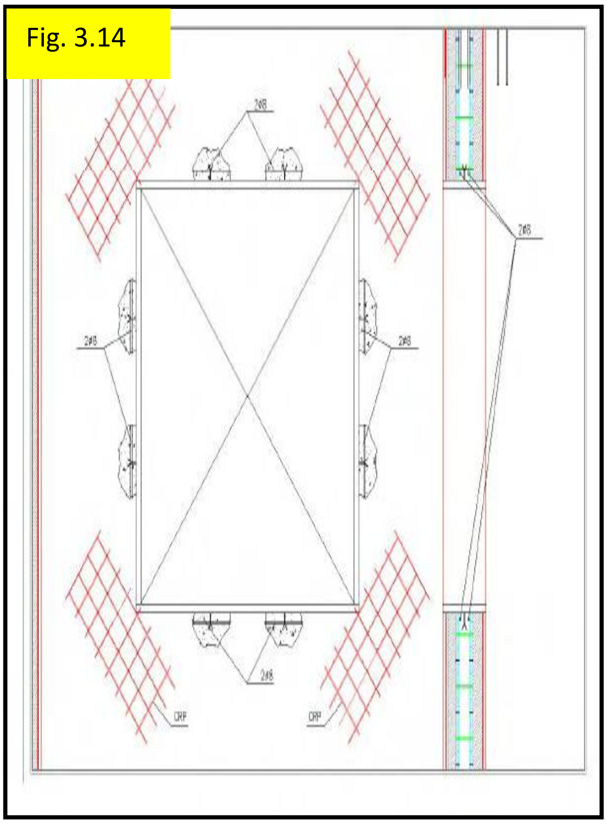


Fig. 3.14

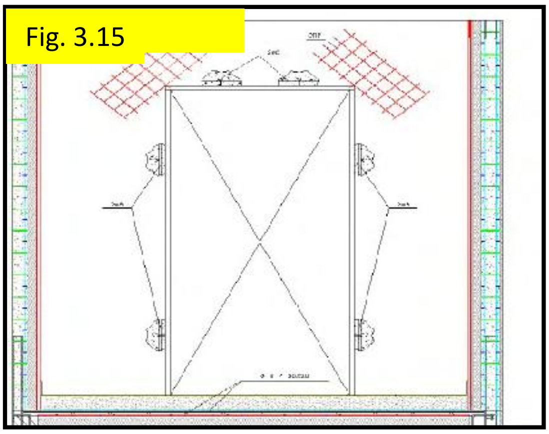


Fig. 3.15


Fig. 3.16


Fig. 3.17

3.2 Training Modules for Professionals & Artisans.

Training Modules

Separate training module has been designed for professional and artisans, as started below

For Professionals

Modules	Topics	Hours	
		Theory	Lab
Module – 1	Fundamentals of EPS core panel system and its application in housing sector.	3	2
Module – 2	Basic design methodology for EPS panel system for load & non – load bearing systems.	5	2
Module – 3	Construction techniques and procedures for EPS core panel systems.	3	2
Module – 4	Safety & management issues, Dos & Don'ts related to EPS panel system of construction.	3	2

For Artisans

Modules	Topics	Hours	
		Theory	Lab
Module – 1	Basics of EPS – Handling procedure, Dos & Don'ts	5	10
Module – 2	Training and hands on practice with special type of tools and machineries. Training on filling of Performa and checklists.	5	10
Module – 3	Training on detailed Construction sequence - Installation details of internal services, i.e., plumbing, sanitary, electrical, waterproofing, HVAC etc	5	10
Module – 4	Safety practices – Safety drills etc.	5	10

3.3 Manpower Requirement

Sl.No.	Work	Man Power Requirement (As per Field Experience)
1.	Installation of starter bars	20 bars (6mm dia) of size 600mm may be executed in 01 man days.
2.	Erection of wall panels	8-10 panels of size 3m x 1.2m may be executed 01 man days in normal local conditions.
3.	Placing of roof panels	32-35 sqm area may be covered using EPS panel of size 3x 1.2m in one man days in normal local conditions.
4.	Installation of electrical fittings and plumbing work	Regular electrification and plumbing work to be done in pre constructional stage (before shotcreting).
5.	Shotcreting	
	Wall Panels	14-16 sqm may be covered per man days.
	Top of Roof Panel	14-16 sqm may be covered per man days.
	Bottom of Roof Panel	10-12 sqm may be covered per man days.

CHAPTER – 4

PLANT AND MACHINERY REQUIREMENT

This chapter discusses about the Infrastructure Requirement for EPS Core Panel System.

4.1 Introduction

For successful adoption of EPS Core Panel Systems in the building industries, apart from conventional equipments, it is strongly recommended to have some special equipment. This chapter highlights the list of equipments and the process that are required for achieving speedy and quality construction with economy of scale.

4.2 List of Equipments

4.2.1 Equipment for Preparation of EPS Blocks required for panel making.

4.2.1.1 Batch pre-expander

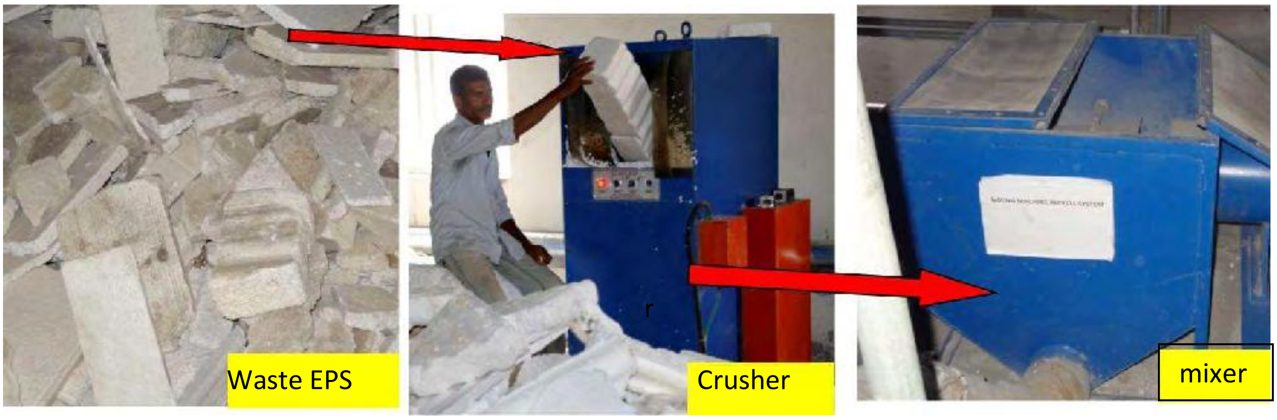
EPS granules are fed into batch pre-expander which expands the granules into beads of 0.93-1.05 mm.

4.2.1.2 Silos for Storage of EPS

EPS beads are then fed into storage silos from the batch expander to cool down and allow collection of adequate amount of EPS required for block making.

4.2.1.3 Crusher for Utilization of waste EPS

Waste EPS sheets are recycled by crushing them back into EPS beads in a crusher and remixing it with fresh EPS stored in silos (up to 15% Mixing).



4.2.1.4 EPS Block Making Machine

The mixture of fresh and recycled EPS from the storage silos are fed to block moulding machine (Make: China-Shanghai Zhongji Machinery Manufacturing Co. Ltd.) to produce blocks of size 4080 mm x 1230 mm x1050 mm. (Density ≈ 15 kg/m^3). The machine fuses the expanded granules into blocks by the heat supplied from steam.

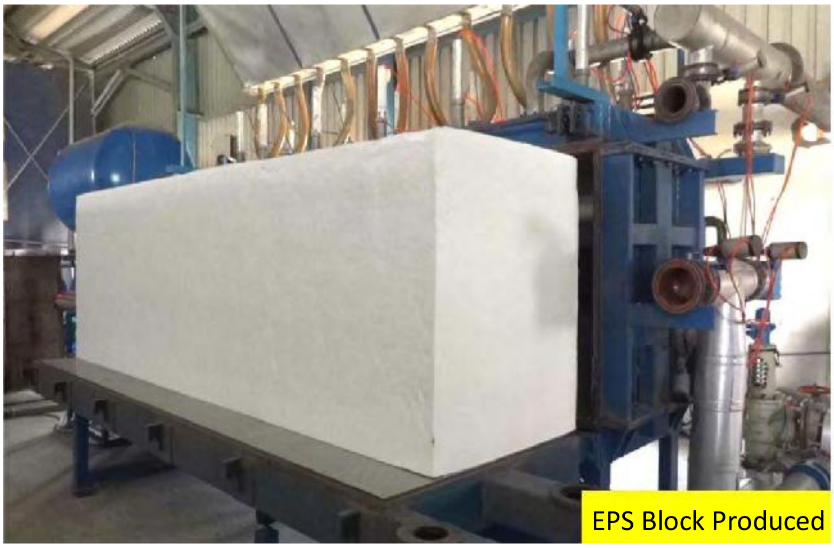
Consumption of air = $0.5m^3$/block

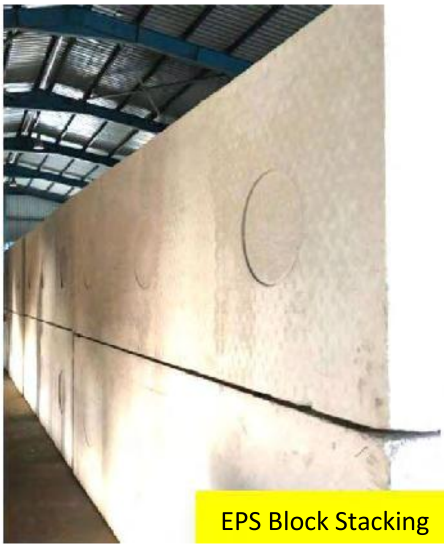
Steam = 10-15 kg/m^3

Cooling water = 0.6 m^3/cycle.

After EPS blocks are manufactured they are stacked to get rid of excess moisture before it proceeds towards panel cutting process.

EPS Block Making Machine

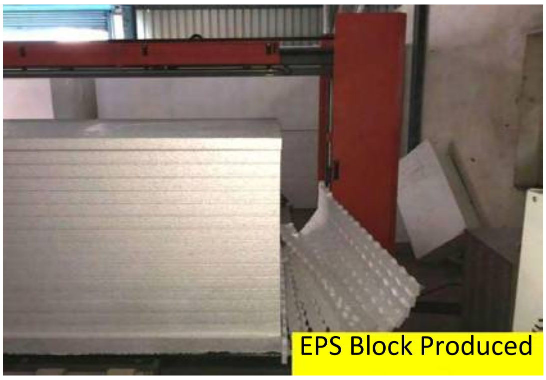




4.2.2 Equipment for Preparation of EPS Wall Panels

4.2.2.1 Block cutting machine

EPS block of size 4080 x 1230 x 1240mm can be cut into panels by passing them through the hot wires of a computerized block cutting machine. (Make: Schnell Wire System, Italy). The machine can be programmed to cut any custom drawn profile. The minimum cutting thickness of the machine is 10mm. Wall panels varying from 60 – 100 mm thickness are manufactured for EPS technology houses.


EPS Block Produced


Cut EPS Panels

4.2.3.1 Wire Straightening Machine

Wire (steel 3 mm GI fencing wire) received from vendor is generally in the form of coil, which needs to be straightened. This can be done efficiently by wire straightening machine (Schnell). Maximum length of the straight wire that can be obtained is 6 m, and minimum length is 1m.

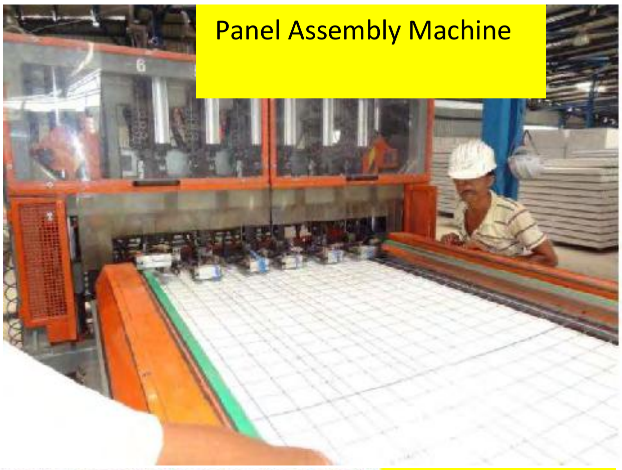

GI Wire Coils
Straightening machine
Straight Cut GI Wires

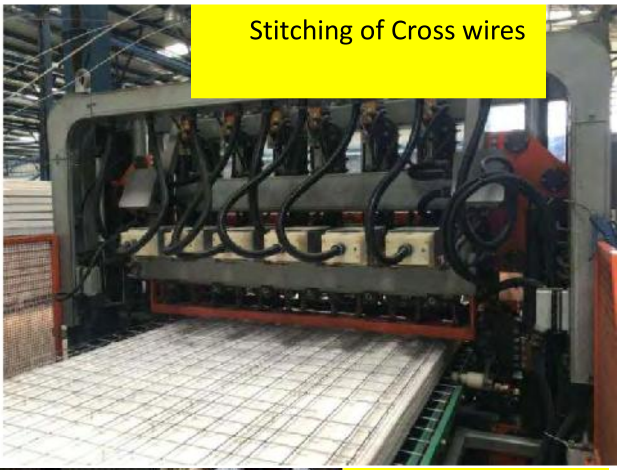
4.2.3.2 Wire Mesh Welding Machine

The straight cut GI wire obtained from wire straightening machine can be fed in this machine. The machine electro-welds the vertically falling straight wires from the top onto the horizontal drawn wires at the bottom to produce the wire mesh. Maximum length of the mesh is 6 mtr and width is constant i.e 1.24 m.

4.2.4 EPS Panel assembly machine

One EPS sheet can be sandwiched between two GI wire meshes and is then fed into this machine to produce a finished EPS wall panel. Maximum length of the panel is 6 m and constant width of 1.24 m. The panels are stacked and are now ready to be sent to the construction site.





4.2.5 Mesh Cutting Machine

Mesh cutting machine is used to cut meshes of desired size. These cut meshes are required to tie two wall panels vertically with overlaps. Maximum length of the mesh that can be cut is 4 m.

4.2.6 Mesh Bending Machine

Single bend (L Shape) and double bend (U Shape) wire meshes are required at the wall-roof junctions for tying up separate EPS panels. These are also required along the lining of door and window openings. This mesh bending machine bends the flat mesh into L and U shape with maximum length up to 4 m.

4.2.7 Shotcreting Equipment

In EPS panel construction, Shotcreting plays a major role in ensuring the structures are durable and are able to perform satisfactorily in its desired life time.

For this reason it is highly recommended that the executing agencies ensure that a proper efficient shotcreting machines are employed at the site.

Shotcreting machine manufactured by Kappa Building Machines Pvt Ltd. can be used successfully in housing project (up to G+12). It is piston based machine which pumps (2 bar) the concrete and then sprays it on the EPS panel surface using compressed air pressure (6-8 bars). The raw materials include the granulated fine aggregate (< 5 mm), cement, water and admixtures. The admixture used is supplied by the same company which ensures proper workability and spread ability, water reduction and minimized segregation. The machine has a pumping capacity of upto 40 m height and the rebound loss is negligible.

CHAPTER – 5

QUALITY CONTROL, RELEVANT TESTS AND GENERAL MAINTENANCE

This chapter discusses about the Quality control and General Maintenance for EPS Core Panel System along with relevant tests that are required to insure quality of construction in EPS Core panel system.

5.1 Introduction

The properties of the completed structure shall be consistent with the requirements and the assumptions made during the planning and the design, The construction should result in satisfactory strength, serviceability and long term durability so as to lower the overall life-cycle cost. Quality assurance in construction activity relates to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care during the use of structure including timely maintenance and repair by the owner.

The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete and shotcreting, workmanship in all stages of batching, mixing, transportation; placing, compaction and curing; and the related plant, machinery and equipments; resulting in the output in the form of concrete and shotcreting in place. To ensure proper performance, it is necessary that each step in concreting/ shotcreting which will be covered by the next step is inspected as the work proceeds.

A quality assurance plan shall define the tasks and responsibilities of all the people involved, including adequate control and checking procedures, and the organization maintaining adequate documentation of building process and its results. Such documentation should generally include:

a) Test reports and manufacturers certificate for materials, concrete mix design details etc.
b) Pour cards for site organization and clearance for concrete placement.

c) Record of site inspection of workmanship, field tests, non-conformance reports, change orders, quality control charts, statistical analysis.

5.2 Performance Measures and Functional Integration

The following parameters should be considered to measure the performance of EPS panels, based on the physical characteristics:

1. Safety - Shear, axial, bending, tension, point loads, surface loads, impact loads, lifting & transportation loads etc.
2. Dimensions - Shape, size, thickness & tolerance
3. Durability - Surface material, degradation, moisture penetration & corrosion
4. Energy - Thermal conductivity (performance)
5. Fire - Smoke, fuel, flame spread etc.
6. Functions - Visual assess, acoustic, pipes, conduits, fixtures,
7. Aesthetics - Surface material, colour, texture etc.
8. Connectivity - With other walls, floors, roofs, openings etc.
9. Handling - Transportation, lifting, settling etc.

To meet out the above requirements, various codes and manuals are available, as per the requirement, the relevant code may be referred. However, some standard tests should be done for the basic materials i.e. cement, sand, stone aggregate, water, reinforced cement concrete (RCC), steel bars, welding work, EPS, shotcrete etc., either in field or in laboratory as per requirement.

5.3 Relevant Tests

The following tests are mandatory for Expanded Polystyrene (EPS) Core Panel system:

THE MANDATORY TESTS SHALL BE AS FOLLOWS

Material	Test	Field / laboratory test	Test procedure	Minimum quantity of material / Work for carrying out the test	Frequency of testing
1.	2.	3.	4.	5.	6.
Cement	Test requirement	Fineness (m²/kg)	IS 4031 (Part-II)	Each fresh lot	Every 50 MT or part There of
		Normal consistency	IS 4031 (Part IV)		
		Setting time (minutes) a) Initial b) Final	IS 4031 (Part-V)		
		Soundness a)Le-Chat expansion (mm) b) Autoclave (%)	IS 4031 (Part III)		
		Compressive Strength (Mpa) a) 72+/-1 hr b) 168+/-2hr	IS 4031 (Part-VI)		
Stone Aggregate	a) Percentage of soft or deleterious materials	General visual / Lab test where required by the Engr-in Charge	IS 2386 Part II	One test for each source	One test for each source
	Particle size distribution	Field / Lab	-	10 cum	Every 40 cum. Or part thereof and

	Estimation of Organic impurities	Field / Lab	IS 2386 Part II	10 Cum	-do-
	b) Specific Gravity	Field / Lab	IS 2386	10 Cum	-do-
	Bulk Density				
	b)Aggregate crushing strength				
	c)Aggregate impact value				
1.	**2.**	**3.**	**4.**	**5.**	**6.**
Sand	Bulking of Sand	Field	-	20 CU.M.	Every 20 cu.m or part thereof or more frequently as decided by Engineer-In-Charge
	Silt content	Field	IS 383	20 CU.M.	-do-
	Particle size and distribution	Field/ Laboratory decided by Engineer -in-Charge	IS:383	40 CU.M.	Every 40 cum. of fine aggregate / sand required in RCC work only.
	Organic Impurities	Field	IS 383	20 CU.M.	Every 20 cu.m or part thereof or more frequently as decided by Engineer-In-Charge.
Water for Construction purpose	Ph value Limits of Acidity Limits of	Lab	IS 3025	Water from each source	Before commencement of work & thereafter:

	Alkali Percentag e of solids Chlorides Suspende d matter Sulphates Inorganic solids Organic solids				Mandatory – Once in one year from each source; Optional: once in 3 months from each source; Municipal supply - optional.
Reinforced Cement Concrete	b) slump test	Field	IS: 1199	a) 20 cu.m. for slabs, beams and connected columns . b) 5 Cu.m in case of columns	a) 20 cu.m. Part there of or more frequently as require by the Engr.-in-Charge. b) Every 5 Cu.m.
	c) cube test	Lab	IS : 516	a) 20 cu.m. In slab, beams, & connected columns. b) 5 cum in case of columns	a) Every 20 cum of a day's concreting (Ref. as per frequency of sampling). b) Every 5 cum.
1.	**2.**	**3.**	**4.**	**5.**	**6.**
Welding Work	Weld Dimension s, Strength and Slug	Lab/ Site	IS:822-1970		The completed weld should be examined visually, preferably with the assistance of a magnifying lens.

Steel bars	Physical tests: a) Tensile strength b) Retest c) Re-bound test d) Nominal mass e) Bend test f) Elongation test g) Proof stress Chemical Tests: 1 .Carbon Constituent 2.Sulphur 3.Phosphorus 4.Phosphorus & Sulphur	Lab / field	IS 1608 IS 1786 IS 1786 IS 1786 IS 1599 IS 1786 IS 1786	Each lot from each source from each diameter of bar	Below 100 Tonnes Dia < 10 mm one sample for each 25 tonnes or part thereof If dia is >10 mm but less than 16 mm: One sample each 35 tonnes or part thereof. If dia >16 mm one sample for each 45 tonnes Above 100 Tonnes Dia < 10 mm one sample for each 40 tonnes or part thereof If dia is >10 mm but less than 16 mm One sample for each 45 tonnes or part thereof. If dia >16 mm one sample for each 50 tonnes.
EPS	Compressive Strength at	Lab	IS : 4671 -	Carry out the determinatio	

	10% Deformation, Cross-Breaking Strength, Water Vapour Permeance, Thermal Stability, Water Absorption and Flammability.		1984	n on five test specimens cut at random from different portions of the test sample.	
1.	**2.**	**3.**	**4.**	**5.**	**6.**
Shotcrete	Small un-reinforced test panels, at least 30 cm^2 and 75 mm thick, shall be gunned and cores or cubes extracted for compression tests & visual examination	Lab	IS 9012: 1978		Structural Plaster (1:4) used with minimum grade of M-25 for an average thickness of 35 mm on both sides.
Expanded Polystyrene (EPS) Core Panel	Visual Inspection,	Site			Panels shall be truly rectangular in shape with straight & square edges and true surfaces.

	Rebound hammer test (for surface hardness),	Site	IS:13311 -1992		Relative Compressive Strength shall be not less than 25 N/mm^2.
	Evaluation of joints & system (Load Test, Axial Compression Test, Shearing Tests on Walls)	Site/ Lab	IS:456 - 2000		

SPECIFICATION FOR EXPANDED POLYSTYRENE (EPS)

Bulk Density of Expanded Polystyrene (EPS)

The bulk density of the material, calculated at nominal thickness, excluding facing, shall be 15, 20, 25, 30 or 35 kg/m^2, when tested in accordance with the method prescribed in IS : 5688- 1982. A tolerance of ± 5% percent shall be allowed on bulk density.

Dimensions

Size - In the case of finished boards, the size shall be 3.0 x 0.6 m or as agreed to between the purchaser and the supplier.

Thickness - The material shall be supplied in thicknesses of 15, 20, 25, 40, 50, 60, 75 and 100 mm unless otherwise agreed to between the purchaser and the supplier.

Tolerance - The tolerance on the dimensions of the finished boards shall be as given below. A tolerance of finished boards (± 2 mm) shall be allowed on length, width and thickness.

Thermal Conductivity - The thermal conductivity at 0 and 10°C, respectively of the material shall not exceed the values given below when determined in accordance with the method prescribed in IS: 3346-1980.

Bulk Density (Kg/m³)	Thermal Conductivity (mW/cm°C)	
	0°	10°
15.0	0.34	0.37
20.0	0.32	0.35
25-0	0.30	0.33
30-0	0.29	0.32
35.0	0.28	0.31

The material shall also comply with the requirements given in Table 5.1.

TABLE 5.1

Item No.	Characteristic	Requirement of Apparent Densities, Kg/m³				
		15	20	25	30	35
I	Compressive strength at 10% deformation, in kg/cm², Min.	0.7	0.9	1.1	1.4	1.7
ii	Cross breaking strength, in kg/cm², Min.	11.4	1.6	1.8	2.2	2.6
iii	Water vapour Permeance, in g/m2, 24 h, Max.	50	40	30	20	15
iv	Thermal stability, percent, Max	1	1	1	1	1
v	Moisture absorption, percent	2	1	1	1	1
vi	Flammability	The material shall be of self-extinguishing type				

DETERMINATION OF COMPRESSIVE STRENGTH AT TEN PERCENT DEFORMATION [Table 5.1, Item (i)]

TEST SPECIMEN

The test specimen shall be 200 x 200 mm and 50 ± 1 mm thick. The specimen may be prepared by plying up boards of not less than 15 mm of thickness.

NUMBER OF TEST SPECIMENS

Carry out the determination on five test specimens cut at random from different portions of the test sample.

CONDITIONING

Condition the test specimens at a temperature of 27 ± 2°C for at least 24 hours before testing.

APPARATUS

Any suitable compression testing machine, capable of operating at a constant rate of motion of the movable head, may be used. It is recommended that one platen may be self-aligning and the dimensions of both platens may be larger than the test specimens so as to give an overlap.

A load indicating mechanism, which will permit measurement of load to an accuracy of ± 2 percent. A deformation indicating mechanism, which will permit measurement to an accuracy of ± 5 percent of the measured deformation. A micrometer dial gauge, calipers or rule suitable for measuring the test specimen to an accuracy of ± 0.5 percent.

PROCEDURE

Place the test specimen centrally between two parallel plates of the compression testing machine and compress it at a rate of 5.0 ± 0.5 mm per minute until the test specimen is reduced to 90 percent of its original thickness. Note the maximum load reached during the reduction in thickness.

CALCULATION

The compressive strength at 10 percent deformation shall be calculated by dividing the load by the original cross-sectional area of the test specimen.

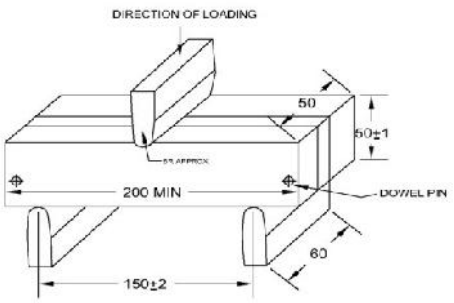
REPORT

The mean of the five determinations shall be reported as the compressive strength at 10 percent deformation.

DETERMINATION OF CROSS-BREAKING STRENGTH [Table 5.1, Item (ii)]

TEST SPECIMEN

The test specimen shall be a rectangular bar not less than 200 mm long. The width and thickness of the test specimen shall be 50 ±1 mm. The specimen may be prepared by plying up boards not less than 15 mm thick. The load shall be applied, parallel to the plies. The plies may be held together by tape, dowel pins or similar means applied outside the test area, but no adhesive shall be applied to the faces of the plies (see Fig. 1).



All dimension in millimetres

FIG.1 ARRANGEMENT OF TEST SPECIMEN AND LOADING FOR CROSS-BREAKING STRENGTH

NUMBER OF TEST SPECIMENS

Carry out the determination on five test specimens cut at random, from different portions of the test sample.

CONDITIONING

Condition the test specimens at a temperature of 27 ± 2°C for at least 24 hours before testing.

PROCEDURE

Determine the mean width and mean thickness of each specimen by taking the mean of three measurements evenly spaced along the length. If the width or thickness of any specimen varies by more than 1.0 mm along the length, the specimen shall be rejected. Place the specimen symmetrically across two parallel supporting blocks. The contact edges of the supporting blocks shall have a radius of approximately 6 mm and shall not be less than 50 mm long. The distance between the lines of contact of the supports with the specimen shall be 150 ± 2 mm. Apply a load uniformly across the width of the specimen blocks by means of a third block parallel to and midway between the supporting blocks. This is effected by the use of any suitable compression testing machine. The loading block shall act upon the bar at a substantially constant speed of 25 mm per minute. Increase the load steadily so that the specimen fractures and note the load in kilograms at fracture to an accuracy of ± 2 percent.

CALCULATION

Cross-breaking strength, in $kg/cm^2 = 1.5\ WL/\ BD^2$

Where,

W = load in kg at fracture,

L = distance in cm between supports,

B = mean width in cm of specimen, and

D = mean thickness in cm of specimen.

REPORT

The mean of the five determinations shall be reported as the cross breaking strength of the test sample material.

DETERMINATION OF WATER VAPOUR PERMEANCE [Table 5.1, Item (iii)]

GENERAL

Water Vapour Permeance of the material is determined for a specimen 50 mm thick. The test shall be carried out at a temperature of 38.0 ± 0.5% with relative humidity of 90 ± 2 % on one side of the specimen and < 2 % on the other side.

TEST SPECIMEN

The test specimen shall be a cylinder of 50 ± 1 mm in height. The diameter shall be such that the specimen can be pushed into the beaker used for test without undue compression on the sides of the specimen. For test specimen less than 50 mm thick, plying up without the use of adhesive, is permissible. It is cut from the board by a sharp-edged, thin hollow cylindrical steel cutter. The flat faces shall be lightly sanded unless they have been freshly cut by means other than a hot wire.

NUMBER OF TEST SPECIMENS

Carry out the determination on five test specimens cut at random from different portions of the sample.

APPARATUS

250 ml Glass Beaker - of approximately 65 mm internal diameter.
Humidity Cabinet - maintained at 38 ± 0.5% and 90 ± 2 percent relative humidity.

REAGENTS

Sealing Wax - The wax compound used for sealing shall be stable and non-absorbent to water vapour and shall not be brittle at room temperature. It shall strongly adhere to the beaker and the specimen. A suitable composition is a mixture of 90 parts of microcrystalline wax, such as paraffin wax, and 10 parts of suitable non-reactant plasticizer, for example, polyethylene film scrap, shredding, etc. The melting point of the sealing wax shall be below 75°C.

PROCEDURE

Fill the beaker with anhydrous calcium chloride to about 6 mm below the expected position of the underside of the specimen. The weight of the desiccant shall be at least ten times the total expected take up of water during the test. Insert the specimen in the beaker so that the flat surface of the test specimen remaining exposed to the atmosphere is in level with the tip of the beaker rim. Seal the test specimen in position by running the melted sealing wax around the inner rim of the beaker (see Fig. 2), care being taken not to contaminate the exposed flat surface of the specimen. The temperature of the wax shall not be high enough to soften the specimen. Weight accurately each assembly to OS001 g and place it in the humidity cabinet. Weigh successively at intervals of 24 hours and plot cumulative weight increase against time until at least three points (excluding the point of origin) lie on a straight line.

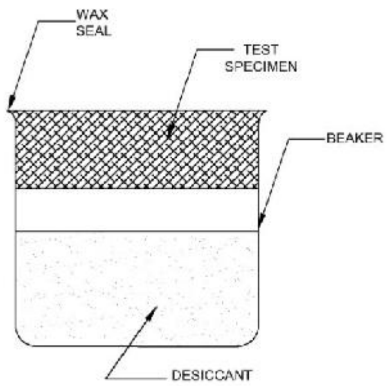


FIG.2 ARRANGEMENT OF SPECIMEN FOR WATER VAPOUR PERMEANCE TEST

CALCULATION

Water Vapour Permeance (WVP) shall be calculated from the slope of the straight line drawn as nearly as possible through those points on the graph which represents a substantially constant rate of gain.

Water vapour permeance, in g/m^2 in 2 hours = 240W/ AT

Where, W = weight increase in milligrams,

A = area of the test specimen in cm^2, and

T = time for weight increase in hours.

REPORT

The mean of five determinations shall be reported as the water vapour permeance of the test sample material.

DETERMINATION OF THERMAL STABILITY [Table 5.1, Item (iv)]

TEST SPECIMEN

The test specimen shall be a rectangular bar of 300x75x25 mm and shall be prepared by a fine saw or sharp knife.

NUMBER OF TEST SPECIMENS

Carry out the determination on five test specimens cut at random from different portions of the test sample.

CONDITIONING

Condition the test specimens at a temperature of 27 ± 2°C for at least 24 hours before testing.

PROCEDURE

Mark the test specimen at approximately 250 mm apart, on the, central line of the specimen. Place the test specimen flat on an expanded metal shelf in air-circulating oven, maintained at 80 ± 1°C. Keep the test specimen for seven days. Remove the test specimen after this period from the oven and condition at 27 ± 2°C for at least 2 hours. Measure the distance between the gauge marks.

CALCULATION

$$\text{Thermal stability, percent} = 100\ l / L$$

Where, l = change in length of the specimen in millimeters, and

L = original length of the specimen in millimeters.

REPORT

The mean of five determinations shall be reported as the thermal stability of the test sample material.

DETERMINATION OF WATER ABSORPTION [Table 5.1, item (v)]

GENERAL

This method covers the determination of water absorption of rigid cellular plastics by measuring the change in the buoyant force resulting from immersion of a specimen under a 50 mm head of distilled water for 7 days. Corrections are specified to take into account any change in volume of the specimen and also to correct for the volume of water in the cut surface cells of the specimen. Water absorption is expressed as percentage by volume, as it is of significance in use of cellular plastics.

TEST SPECIMEN

Dimensions - The test specimens for cellular plastics shall be cubes with edges of 50 mm. The distance between two faces shall not vary more than 1 percent (tolerance for parallelism).

PREPARATION AND CONDITIONS

Free the specimens from any moulding skin. Cut their faces with a mechanical saw. Machine them, if necessary, without modifying the original structure of the product and remove any dust.

Dry the specimens at room temperature until the results of two successive weighing at intervals of at least 12 hr, do not vary more than 1 percent of their mean.

Number of Specimen - At least three specimens should be tested.

APPARATUS

Balance – with minimum resolution of 0.01 g.

Mesh Cage - made of a stainless material not attacked by distilled water and large enough to contain the specimens. A sinker of approximately 125 grams in mass (to compensate for the up-thrust of the test specimens) shall be attached to the base of the cage. The cage shall be fitted with a means of suspending it from the balance (see Fig. 3).

Cylindrical vessel, approximately 3 Litres in volume, 120 mm in diameter and 240 mm in height.

Distilled Water - de-aerated.

Low-permeability plastic film, for example, polyethylene.

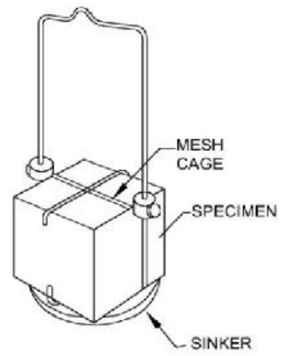


FIG.3 SPECIMEN PLACED IN THE MESH CAGE

PROCEDURE

Fill the cylindrical vessel with de-aerated distilled water at room temperature. Weigh the specimen to the nearest 0.01 gram (mass ml). Immerse the assembled cage, remove any bubbles, attach it to the balance and determine the apparent mass (m^3) to the nearest 0.01 gram.

Place the specimen in the cage, re-immerse the cage so that the distance between the surface of water and the base of the specimen is approximately 100 mm. Remove obvious air bubbles from the specimen with a brush or by agitation.

After 7 days or other agreed immersion period, determine the mass (m^3) to the nearest 0.01gram of the submerged cage containing the specimen. Between weighing, cover the cylindrical vessel with a low permeability plastic film.

After the immersion period, if the specimen shows no evidence of non-uniform deformation, proceed as follows:

Remove the specimen from water and re-measure its dimensions. The correction for uniform swelling of the specimen S_o is:

$$S_o = (V_1 - V_o)/ V_o$$

Where V_0 = the original volume of the specimen

$V_1 = d_1.l_1.b_1/ 1000$

d_1 = being the specimen thickness in millimeters after immersion,

l_1 = being the specimen length in millimeters after immersion, and

b_1= being the specimen width in millimeters after immersion.

Determine the percentage of open cell as a function of the ratio of surface to volume of the specimen for at least three specimens obtained from the same original sample of material as the water absorption specimens (see Fig. 4).

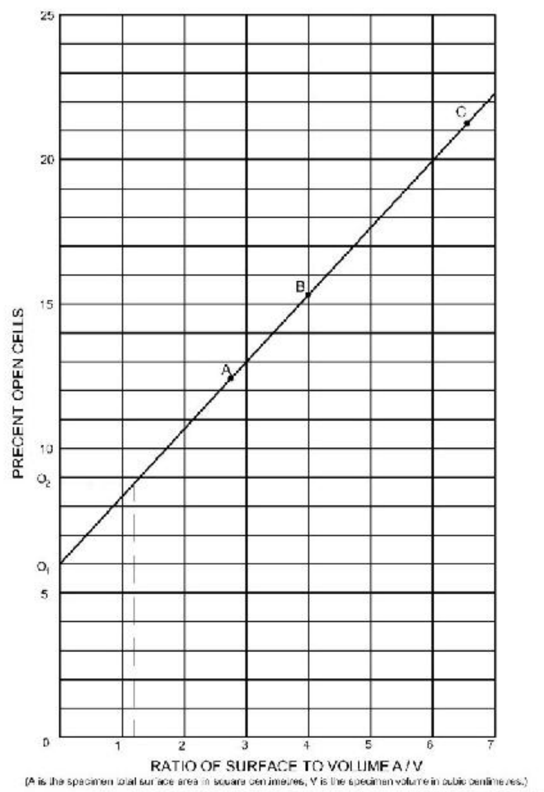


FIG. 4 PERCENTAGE OF OPEN CELLS AS A FUNCTION OF THE SURFACE TO VOLUME RATIO OF THE SPECIMEN

From this graph, determine the correction factor C for cut surface cells as follows:

Read of O_1= percentage open cells for ratio of surface to volume.

Read of O_2= percentage open cells for ratio of surface to volume of water absorption specimen A/V_0.

$C = O_2 - O_1/100$

If the specimens show any evidence of non-uniform deformation, proceed as follows:

Obtain a cylindrical vessel and fill this vessel with water until it runs from the overflow. When the water level has stabilized, place a graduated receptacle of at least 150 ml capacity under the overflow. This receptacle must be capable of allowing the volume of water deposited in it to be measured to ± 0.5 ml.

Remove the specimen and cage from the original vessel. Allow to drain for approximately 2 minutes (until the surface water has drained). Carefully immerse the specimen and cage in the filled vessel and determine the volume of water displaced (V_2), Repeat this procedure with the empty cage to determine its volume (V_3). The combined swelling and surface correction factor is:

$$S_1 = V_2 - V_3 - V_0/ V_0$$

Where,

V_0 = is the original volume of the specimen

CALCULATION

Calculate the original volume of the specimen.

$$V_0 = d.l.b/ 1000$$

Where, V_0 = the original specimen volume in cubic centimeters;

d = the original specimen thickness, in millimeters;

l = the original specimen length, in millimeters; and

b = the original specimen width, in millimeters.

Calculate the surface area of the specimen.

$$A = (l.b + l.d + b.d)/ 50$$

Where, A = the original surface area in square centimeters.

Calculate the water absorption, expressed as a percentage by volume (WA_V).

If the specimen has not deformed non-uniformly

$$WA_V = [m_3 + (1 + S_0 - C)V_0 - (m_1 + m_2)]/V_0 \times 100$$

If the specimen has deformed

$$WA_V = [m_3 + (1 + S_1)V_0 - (m_1 + m_2)]/V_0 \times 100$$

TEST FOR FLAMMABILITY [Table 5.1, Item (VI)]

TEST SPECIMEN

The test specimen shall be 200 x 25 x 10 mm. It may be prepared by means of a fine toothed saw or by hot wire, and shall be marked with lines at 50 and 75 mm from one end.

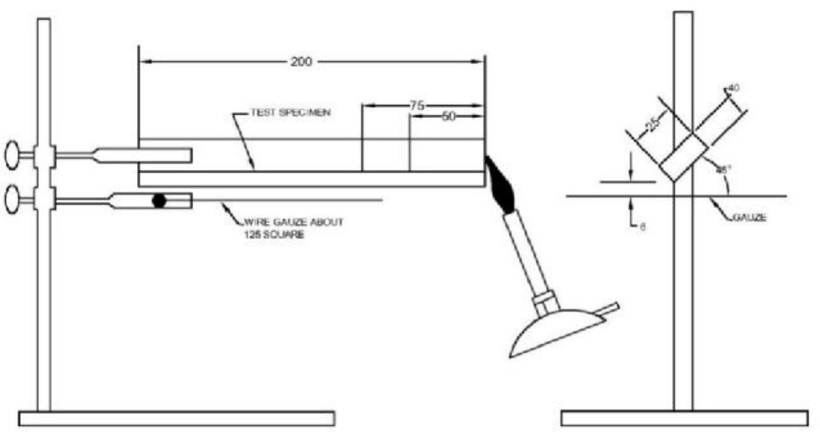
NUMBER OF TEST SPECIMENS

Carry out the test on five test specimens cut at random from different portions of the test sample.

CONDITIONING

Condition the test specimens at a temperature of 27 ± 2°C and 65 ± 5 percent relative humidity for at least 48 hours before testing.

PROCEDURE



ALL DIMENSIONS IN MILLIMETRES.

FIG. 5 SPECIMEN UNDER FLAMMABILITY TEST.

The specimen shall be tested in a draught-free atmosphere. Clamp the specimen in a rigid support (see Fig. 5), at the end farthest from the 60-mm mark, with its longitudinal axis horizontal and traverse axis inclined at 45^0 to the horizontal. Clamp 10 mm aperture wire gauze, 125 mm square 6 mm below the edge of the specimen. Place a 10 mm barrel Bunsen burner fitted with 50 mm nominal width batts wing top and gas supply. The non-luminous flame without central core shall be about 2 cm long. The Bunsen burner shall be held in such a way that its level shall be below the plane of the wire gauze. The Bunsen burner shall be held at an angle (approximately 45^0) and parallel to the slope of the specimen to prevent the material dripping into the tube. Maintain the flame in contact with the specimen until the specimen burns or melts away to the 50-mm mark. Then remove the flame immediately. If the specimen does not burn beyond the second mark, it shall be classed as self-extinguishing.

NOTES:

- The mandatory tests shall be carried out when the quantity of materials incorporated in the work exceeds the minimum quantity specified.
- Optional tests specified, or any other tests, shall be carried out in case of specialized works or important structures as per direction of the Engineer-in-Charge.
- Testing charges, including incidental charges and cost of sample for testing shall be borne by the contractor for all mandatory tests.
- In case of non-IS materials, it shall be the responsibility of the contractor to establish the conformity of material with relevant IS specification by carrying out necessary tests.

5.4 General Maintenance requirement

EPS wall panels require very little maintenance over the life span of the structure. Standard maintenance on this type of construction includes only occasional cleaning as aesthetically desired, and maintenance of the caulking and waterproofing systems. Panels only require re-caulking every 15 to 20 years to maintain their reliability. The insulated concrete wall panel system will deliver a service life of more than 75 years.

CHAPTER - 6

COST ANALYSIS AND DETAILED ESTIMATE FOR A TYPICAL BUILDING OF G+ 3 STOREYS

This chapter discusses the following things

i. Architectural drawing, structural design including estimate(Bill of quantity) a typical G+3 storeyed building having 4 DUs on floor with minimum carpet area of 30m^2, situated at Roorkee to be constructed using EPS core panel technology for a typical building of G+3 storey's.

ii. Cost analysis and Schedule of Rates for EPS core panel technology

iii. Cost Comparison of EPS Core panel construction vs. RCC Construction.

6.1 Architectural drawing, structural design including estimate(Bill of quantity) a typical G+3 storeyed building having 4 DUs on floor with minimum carpet area of 30m2, situated at Roorkee to be constructed using EPS core panel technology for a typical building of G+3 storey's.

A G+3 storeyed building as shown in the Fig. 6.1 (Plan and section of building) & Fig. 6.2 (Elevation of building) is situated at Roorkee. The building is to be constructed using EPS core panel's technology.

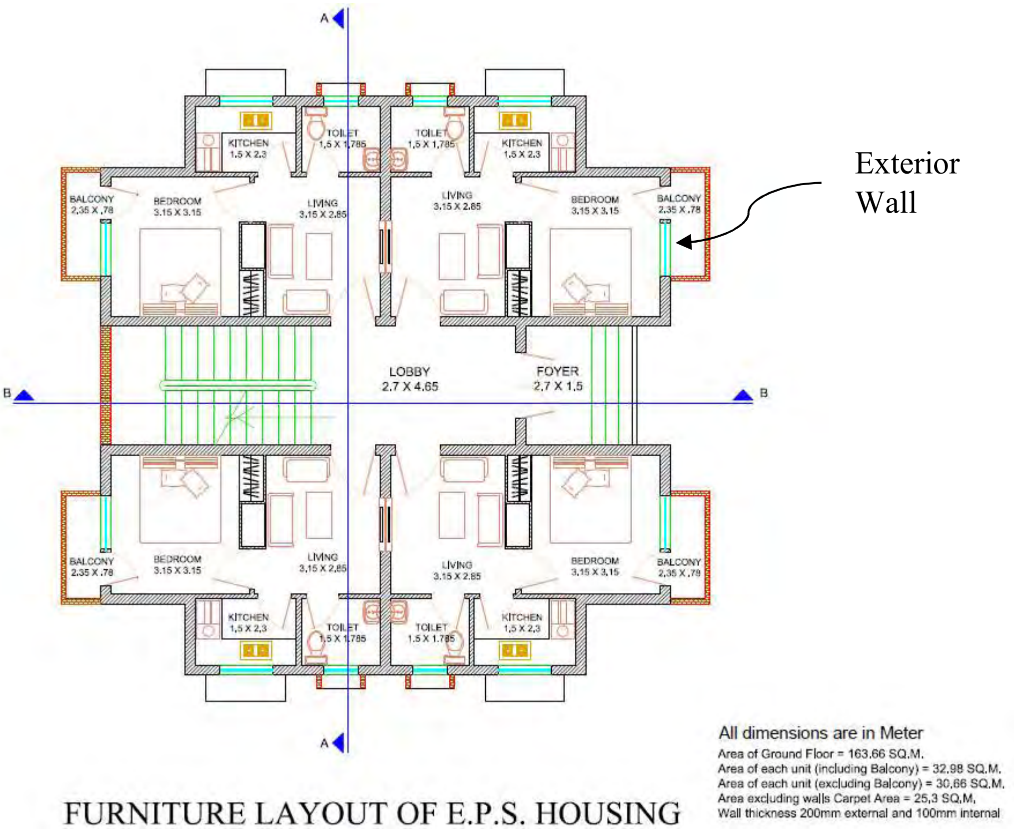


Fig. 6.1 Typical G+3 building having 4 DUs on each floor with minimum carpet area of 30 m^2

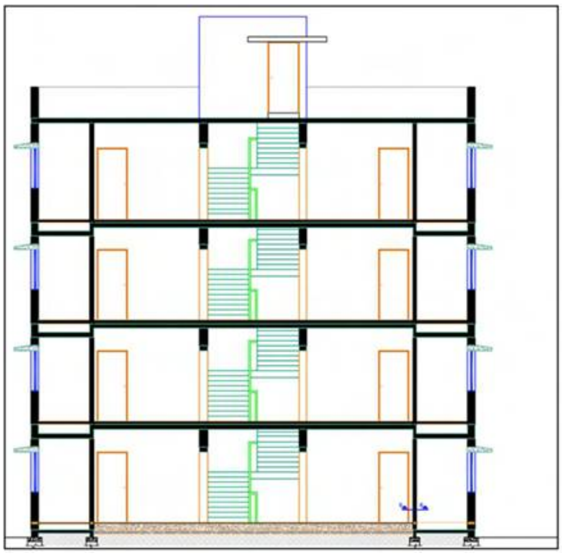


Fig. 6.1a Section A-A of the building

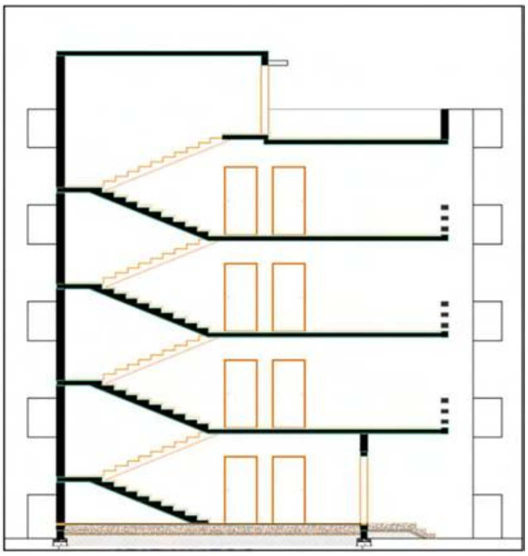


Fig. 6.1b Section B-B of the building

Fig. 6.2a Front elevation building

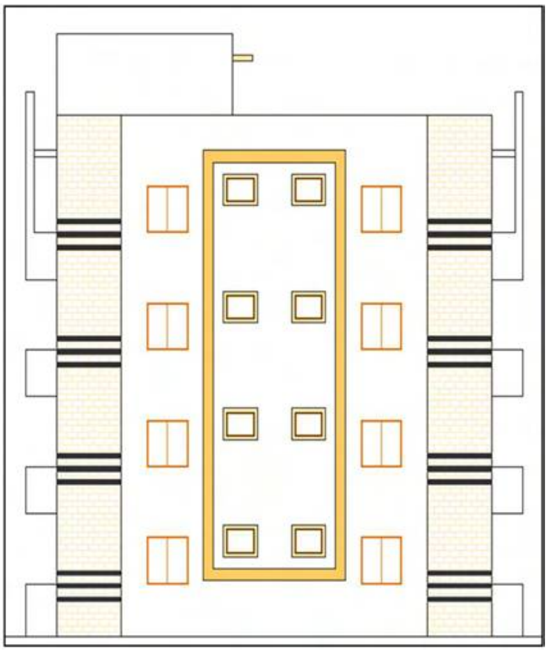


Fig. 6.2b Front elevation building

Structural Design

Design the EPS load bearing wall panel building for following -

Dead load - 2.015kN/m^2 (Calculation shown in later text)

Wall Load - 2.015kN/m^2 (Calculation shown in later text)

Live load - 2kN/m^2 (as per IS 875-2: 1987)

Roof live load - 1.5kN/m^2 (as per IS 875-2: 1987)

Design the exterior wall panel and check for its safety for the above loading.

Assumption

If the building is located in a seismically active region. The floor is assumed to act as a diaphragm, distributing the seismic forces to the load-bearing walls. Check the safety of the wall panels for in-plane shear forces.

Exterior Wall

Consider a wall panel of following dimensions as shown in the Fig. 6.3 & Fig. 6.4. Fig. 6.5 shows the 3D view of the EPS wall panel.

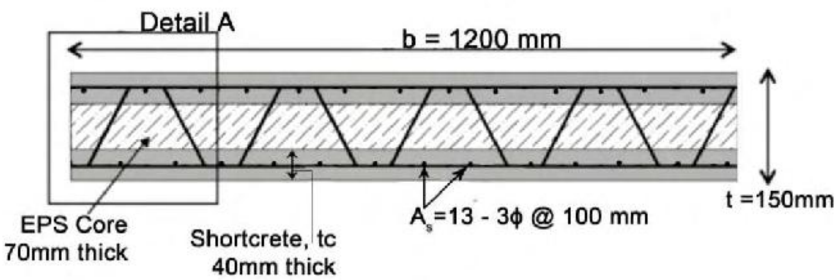


Fig. 6.3: Cross-section of the EPS wall Panel

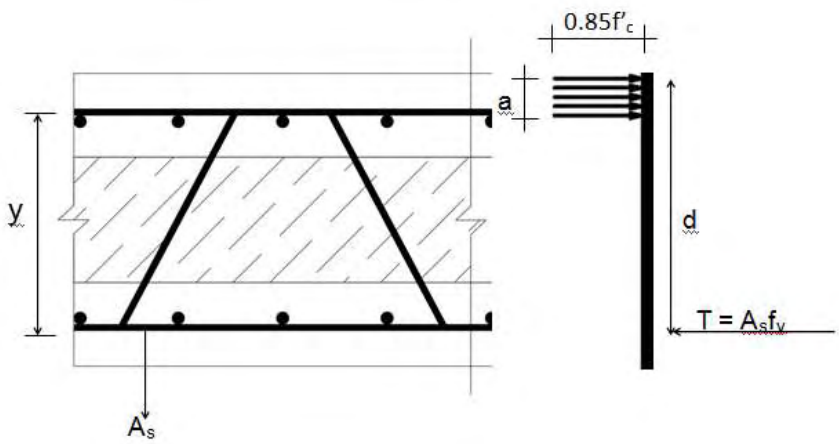


Fig. 6.4: Detail A

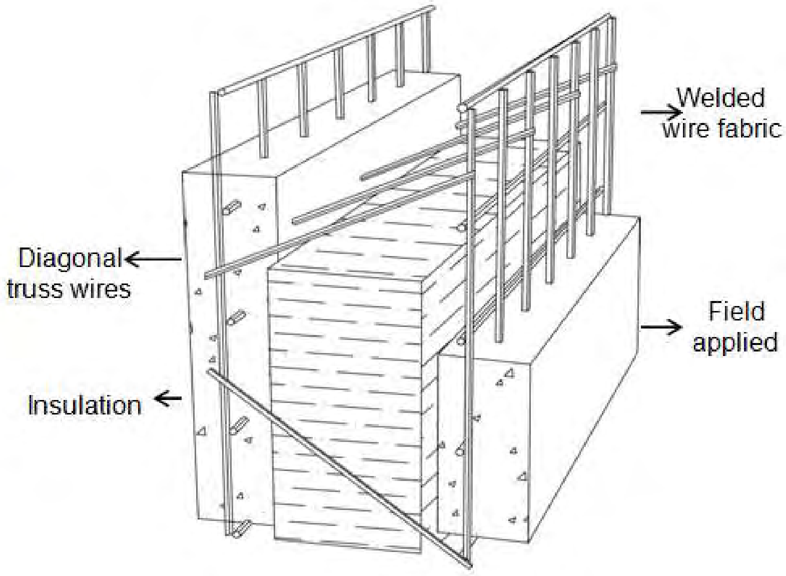


Fig. 6.5: The 3D view of the EPS Wall Panel

Details of the Assumed Wall Panel

b (Width of the Panel)	1200mm
T (Total Panel thickness)	180mm
T_c(Depth of the Shotcrete on one side)	40mm
y (Distance between Compression and Tension Reinforcement)	140mm
t (Thickness of EPS core)	100mm
f_y(Yield Strength of Steel Wires)	415MPa
E_s(Elastic Modulus of Steel)	200000 MPa
f_{ck}(Compressive Strength of Concrete)	20MPa
$\beta_1 \text{Factor for fc} \leq 30\text{ MPa}$	0.85
d Distance from the extreme compression fiber to the centroid of tension reinforcement [T-(T_c/2)]	160mm
d' Distance from the extreme compression fiber to the centroid of compression reinforcement [T_c/2]	20mm
d" Distance from the plastic centroid to the centroid of the tension steel of the wall panel when eccentrically loaded.[(T-T_c)/2]	70mm
a_b Depth of the equivalent rectangular concrete stress block	80.39mm
Density of Shotcrete	25kN/m^3
Density of EPS	0.15kN/m^3
Thickness of the Slab	180mm
Area of tension and compression Steel	13-3 ϕ@ 100mm

Calculation of loads acting upon the exterior wall panel

Wind Load:

Basic Wind Speed at Roorkee, V_b= 39 m/s

Risk Factor, k_1 = 1

Building height terrain factor (Class A, Category III), k_2= 0.91

Topographical Factor, k_3 = 1

Design Wind Speed, $V_z = V_b \times k_1 \times k_2 \times k_3 = 39 \times 1 \times 0.91 \times 1 = 35.49 m/s$

Design wind pressure, P_z = 0.6 V_z^2 = 0.6 x $(35.49)^2$ /1000= 0.76 kN/m^2

Calculation of Dead Load & Wall Load

Dead Load per m^2 & Wall Load per m^2 = (*Density of Concrete × Thickness of concrete in the wall panel) + (Density of EPS × Thickness of EPS in the wall panel)*

= (25 × 0.08) + (0.15×0.1)

=2.015kN/m^2

Dead load per panel

Floor & Roof Load = (*Dead Load per m^2) × (Span of the slab/2) × (Number of storey's) ×(Width of the panel)*

= 2.015× (6/2) × 4× 1.2= 29.02kN

Wall Load= (*Wall Load per m^2) × (Height of the wall) × (Number of storey's)×(Width of the panel)*

= 2.015 × 3× 4× 1.2= 29.02kN

Total Dead Load= *(29.02+29.02) kN/m=58.04kN*

Live load per panel

Consider the wall at corridor,

Floor Live Load = (*Live Load per m^2) × (Span of the slab/2) ×*

(Number of storey's - 1)× (Width of the panel)

= 2× (6/2) × 3 × 1.2= 21.60kN

Roof Load= (*Roof Live Load per m^2) × (Span of the slab/2) × (Width of the panel)*

= 1.5×(6/2)×1.2= 5.40kN

Total Live Load= 21.60+5.40= 27kN

Axial Force due to Total Dead and Total Live Load,

$$P_u = 1.4(Total\ Dead\ load) + 1.7(Total\ Live\ Load)$$

$$P_u = 1.4(58.04) + 1.7(27) = 127.16kN$$

If the eccentricity of 25.4 mm is assumed.
Eccentric Moment due to *P_u*, $M_u = P_u \times 0.0254$

$$M_u = 127.16 \times 0.0254 = 3.22kN - m$$

Moment due to wind, $M_w = \dfrac{0.76 \times 3^2}{8} = 0.85kN - m$

Axial Force for combined D+L+W

$$P_f = 0.75[1.4D + 1.7L + 1.7W]$$

$$P_f = 0.75 \times 127.16$$

$$P_f = 95.37kN$$

Moment for eccentric axial load and wind load,

$$M_f = 0.75[M_u + 1.7M_w]$$

$$M_f = 0.75[3.22 + 1.7(0.85)]kN$$

$$M_f = 3.49kN - m$$

Slenderness:

$$\beta_d = \frac{Factored\ Dead\ Load}{Factored\ Total\ Load} = \frac{1.4 \times 58.04}{127.16} = 0.64$$

(Note: β_d does not apply to wind load moments)

Gross Moment of Inertia,I_g= (Width of the panel × Thickness of the shotcrete at one side × (Distance between Compression and Tension Reinforcement)^2)/2

Gross Moment of Inertia, $I_g = \dfrac{1200 \times 40 \times 140^2}{2 \times 1000^4} = 4.70 \times 10^{-4} m^4$

$$E_c = 5000\sqrt{f_{ck}} \times 10^3\ kN/m^2$$

$$E_c = 5000\sqrt{20} \times 10^3\ kN/m^2$$

$$E_c = 22360.68 \times 10^3\ kN/m^2$$

$$EI = \frac{E_c I_g/5}{1+\beta_d} = \frac{22360.68 \times 10^3 \times 4.70 \times 10^{-4}/5}{1+0.64} = 1281.65$$

$$P_c = \frac{\pi^2 EI}{l_u^2} = \frac{\pi^2 \times 1281.65}{3^2} = 1404.06kN$$

$$\delta = \frac{1}{1 - \dfrac{P_f}{\phi P_c}} = \frac{1}{1 - \dfrac{127.16}{0.85 \times 1404.06}} = 1.12$$

Modified Moments due to slenderness,

D+L, $M_f = 3.22 \times 1.12 = 3.61 kN - m$

D+L+W, $M_f = 3.49 \times 1.12 = 3.91 kN - m$

In-Plane Shear

Calculation of Seismic Weight

Calculation of Dead Load & Wall Load

Dead Load per m^2& Wall Load per m^2 (For 180mm Exterior Wall) = (*Density of Concrete × Thickness of concrete in the wall panel) + (Density of EPS × Thickness of EPS in the wall panel)*

= (25 × 0.08) + (0.15×0.1)

=2.015kN/m^2

Dead Load per m^2& Wall Load per m^2 (For 120mm thick Interior Wall) = (*Density of Concrete × Thickness of concrete in the wall panel) + (Density of EPS × Thickness of EPS in the wall panel)*

= (25 × 0.07) + (0.15×0.05)

=1.757kN/m^2

Dead load

Floor Load = (*Dead Load per m^2) × (Area of Slab) × (Number of storey)*

= 2.015× (12.96 × 12.96) × 4 = 1353.7kN

Exterior Wall Load= (*Wall Load per m^2) × (Height of the wall) × (Total Length of the exterior wall per storey) × (Number of storey)*

= 2.015 × 3× 80.42 × 3.5 = 1701.50kN

Interior Wall Load= (*Wall Load per m^2) × (Height of the wall) × (Total Length of the exterior wall per storey) × (Number of storey)*

= 1.757 × 3× 24.14 × 3.5= 445.34kN

Total Dead Load= *(1353.7+1701.50+445.34) kN=3500.54kN*

Live load

Consider the wall at corridor,

Floor Load at Corridor= (*Live Load per m^2) × (Area of Slab) ×*

(Number of storey's - 1)

= 2× (12.96×12.96) × 3= 1007.76kN

Roof Load= (*Roof Live Load per m^2) × (Area of the slab)*

= 1.5 × (12.96×12.96) = 251.94kN

Total Live Load= 1007.76+251.94= 1259.7kN

Seismic Weight = DL+0.25LL = 3500.54+ (0.25 × 1259.70)

= 3815.46kN

Calculation of design seismic base shear according to IS 1893:2002

$V_b = A_h \times W$

Where, $V_b$is the the total design lateral force or design seismic base shear.

A_h is the, Design horizontal acceleration spectrum value as per 6.4.2 IS 1893

W = Seismic weight of the building as per 7.4.2

$$A_h = \frac{ZIS_a}{2Rg}$$

Where,

Z = Zone factor given in Table 2, IS 1893 is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I= Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance (Table 6, IS 1893).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0 (Table 7, IS 1893). The values of R for buildings are given in Table 7, IS 1893.

S_a/g = Spectral Acceleration

V_b = *2.5 × (1/3) × (0.24/2) ×3815.46*

V_b = *381.55kN*

Shear Strength of the Assumed EPS Panel:

According to ACI 11.1 318R-08 design of cross sections subject to shear are based on

$$\phi V_n \geq V_u$$

Where V_u is the factored force at the section considered and V_n is the nominal shear strength computed by

$$V_n = V_c + V_s \qquad \text{[ACI 11.1.1 318R-08]}$$

V_c is nominal shear strength provided by concrete and V_s is nominal shear strength provided by shear reinforcement

$V_c = 2\sqrt{f_c^{'}}hd$ [ACI 11.2.1 318R-08]

h = 2 × (40) = 80mm (h is the thickness of shotcrete used in the wall)

d = 0.8 × l_w *= 0.8 × 6.3 = 5.04m = 5040mm*

Use Imperial unit system

1MPa = 145.038 psi

1inch = 25.4mm

1kN = 0.2248 kips

h = 80mm = 3.15inch

d = 4000mm = 198.42inch

f_{ck}*= 20MPa = 2900.75psi*

$$V_c = \frac{2 \times \sqrt{2900.75} \times 3.15 \times 198.42}{1000} = 67.32kips$$

$$V_c = 299.49kN$$

Area of wire = *77.715mm*^{2}in a *1000mm* width of a panel,

A_v *= 2×(77.715) = 155.43mm*^{2}*, s = 1000mm*

$$V_s = \frac{A_v f_y d}{s} = \frac{155.43 \times 415 \times 5040}{1000 \times 1000} = 325.09kN$$ [ACI 11.9.9.1 318R-08]

$$\phi V_n = \phi\left(V_c + V_s\right) = 0.85\left(325.09 + 299.49\right) = 530.89kN > 381.55kN$$

Interaction Diagram

Interaction diagram represent the relationship for combination of axial load and bending moment on EPS walls and are used as a design aids to assist the designer with the selection of the various parameters such as reinforcement, thickness, width etc. Point located with the interaction curve and the reference axes represent the combination of axial load and bending moment that the wall can support.

For EPS walls, interaction diagram can be approximately constructed by connecting three basic points with straight line as shown in Fig.6.6

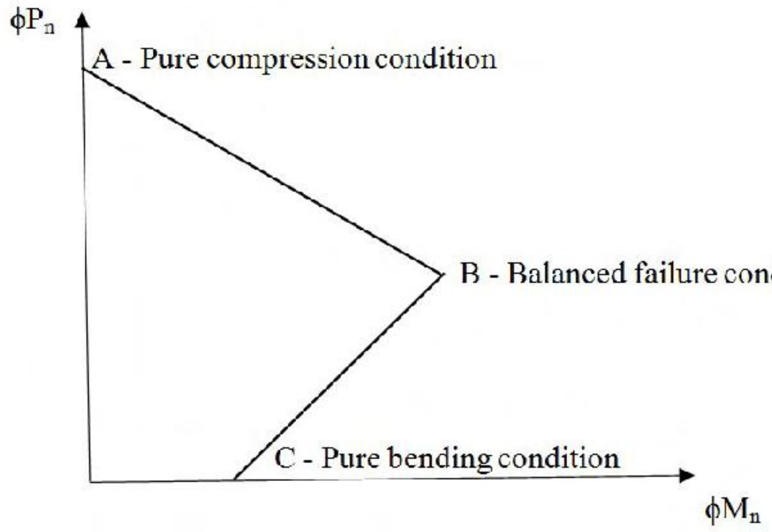


Fig. 6.6 – Interaction Diagram for EPS Walls

4. Pure compression with zero bending moment (concrete compression failure).
5. Tension steel is yielding; the compression steel is also yielding (balanced failure).
6. Pure bending with zero axial loads (under reinforced with the ductile reinforcement tensile failure).

<u>**Capacity of the EPS wall panel**</u>

2. Pure compression with zero bending moment (concrete compression failure)

Compression in Concrete, $C_c = 0.85 f_{ck}\left(\left(\left(T - T_{EPScore}\right)\times b\right)-\left(2\times A_s\right)\right)$

[EB – 212. Appendix-D]

$C_c = 0.85\times 20\left(\left(\left(180-100\right)\times 1200\right)-\left(2\times 91.85\right)\right)$

$C_c = 1628877.10N$

Compression in Reinforcement, $C_s = 2\times A_s \times f_y$ [EB – 212. Appendix-D]

$C_s = 2\times 91.85\times 415$

$C_s = 76235.50N$

Strength of Reduction Factor, $\phi = 0.85$

Axial Load carrying capacity, $\phi P_n = \phi(C_c + C_s)$

$\phi P_n = 0.85\times(1628877.10 + 76235.50)$

$\phi P_n = 1449345.71N$

$\phi P_n = 1449.34kN$

$\phi M_n = 0$

Maximum Axial Load carrying capacity,

$\phi P_{n,\max} = 0.8P_n$

$\phi P_{n,\max} = 0.8\times 1449.34$

$\phi P_{n,max} = 1159.47kN$

Coordinates of point A in the interaction diagram is (0, 1159.47)

Balanced Failure

The tension steel is yielding f_c = f_y. Assume that the compression steel is also yielding from we have,

Depth of the equivalent rectangular concrete stress block, $a_b = \frac{0.003E_s}{f_y + 0.003E_s}\beta_1 d$

[Eq 5.13 Park, R., &Paulay, T. (1975)]

$$a_b = \frac{0.003 \times 200000}{415 + 0.003 \times 200000} \times 0.85 \times 160$$

$$a_b = 80.39mm$$

$P_b = 0.85 \times f_{ck} \times a_b \times b + A_s' f_y - A_s f_s$ [Eq 5.7 Park, R., &Paulay, T. (1975)]

Because of equal steel area at each face, the steel forces cancel out, and the equation below is used for calculating axial load carrying capacity,

$$P_b = 0.85 \times f_{ck} \times a_b \times b$$

$$P_b = 0.85 \times 20 \times 80.39 \times 1200 / 1000$$

$$P_b = 1639.96kN$$

According to IS 456:2000, section 39.3, the axial load carrying capacity of the section replaced by EPS,

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

$$P_u = 0.4 \times 20 \times 100 \times 1200 / 1000$$

$$P_u = 960kN$$

Partial Safety Factor, ϕ= 0.8

Residual Load carrying capacity, $P_u = \phi(P_b - P_u)$

$$P_u = 0.8 \times (1639.97 - 960)$$

P_u = 543.96kN

Since the reinforcement is symmetrical the plastic centroid, d" is at the center of the section.

$$P_u \times e = 0.85 f_c a_b b\left(d - d'' - 0.5a_b\right) + A_s f_y \left(d - d' - d''\right) + A_s f_s d''$$

[Eq 5.10 Park, R., &Paulay, T. (1975)]

$$P_u \times e = 543.96 \times 1000 \times (160 - 70 - (0.5 \times 80.39)) + 91.85 \times 415 \times (160 - 20 - 70) + 91.85 \times 415 \times 70$$

$$P_u \times e = 32.42 kN - m$$

$$c_b = \frac{a_b}{\beta_1}$$

$$c_b = \frac{80.39}{0.85}$$

$$c_b = 94.58$$

Checking the compression steel stress,

$$\frac{f_y}{E_s} = \frac{415}{200000}$$ [Eq 5.15 Park, R., &Paulay, T. (1975)]

$$\frac{f_y}{E_s} = 0.002075$$

$$\varepsilon_s^{'} = 0.003 \frac{c_b - d^{'}}{c_b}$$

$$\varepsilon_s^{'} = 0.003 \times \left(\frac{94.58 - 20}{94.58} \right)$$

$$\varepsilon_s^{'} = 0.00237$$

$$\varepsilon_s^{'} - \frac{f_y}{E_s} = 0.00237 - 0.002075$$

$$\varepsilon_s^{'} - \frac{f_y}{E_s} = 0.000295$$

The above value is positive, therefore compression steel is yielding and the considered assumption is correct.

Therefore we get calculated values of P_u and $P_u \times e$ give the coordinates of point B in the interaction diagram i.e. (32.42, 543.96)

Pure Bending Condition

$$\phi P_n = 0$$

Strength Reduction Factor, $\phi = 0.85$

$$a = \frac{A_s f_y}{0.85 f_c b}$$ [EB – 212. Appendix-D]

$$a = \frac{91.85 \times 415}{0.85 \times 20 \times 1200} = 1.86 mm$$

$$\phi M_n = \phi A_s f_y \left(d - \frac{a}{2} \right)$$ [EB – 212. Appendix-D]

$$\phi M_n = 0.85 \times 91.85 \times 415 \times \left(160 - \frac{1.86}{2} \right) = 5153743.94 N - mm$$

$\phi M_n = 5.15 kN - m$

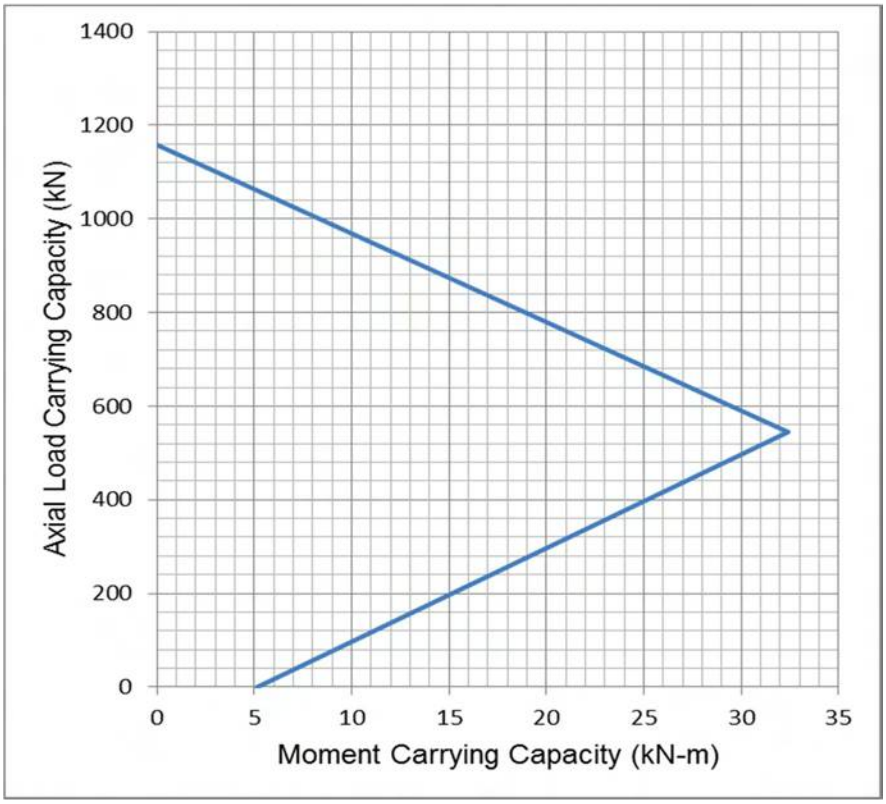


Fig. 6.7

From the above Interaction curve, it can be verified that the coordinates (3.91, 127.16) lie inside it, hence it can be deduced that the panel is safe for the above loading conditions.

Design Example of a Floor Panel Design

Design an EPS floor panel for a room measuring *3m x 5m*size. The floor panel is to be designed as an interior panel according to IS 456:2000. The loading on the panel is as mentioned below:

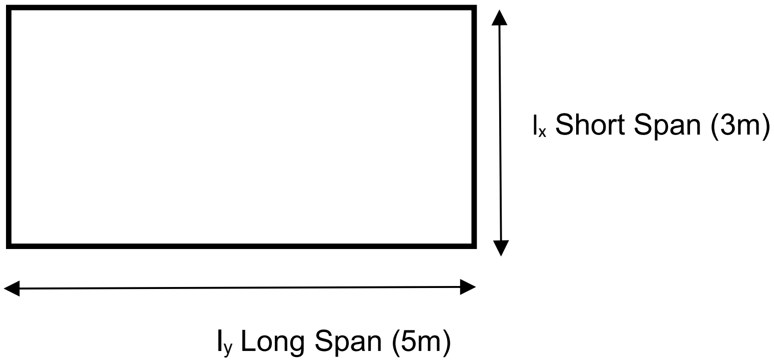
Dead load: 2.015 kN/m^2

Live load: Typical - 3kN/m^2

Floor finis: 1.5kN/m^2

Design the floor panel and check for its safety for the above loading.

Solution for Design of Floors/Roofs Panels



l_y= 6000 mm
l_x= 3150 mm
l_y/l_x= 6000/3150 = 1.90

Floor Panel

Consider a floor panel of following dimensions as shown in the Fig. 6.8 and Fig. 6.9.shows the 3D view of the EPS floor panel.

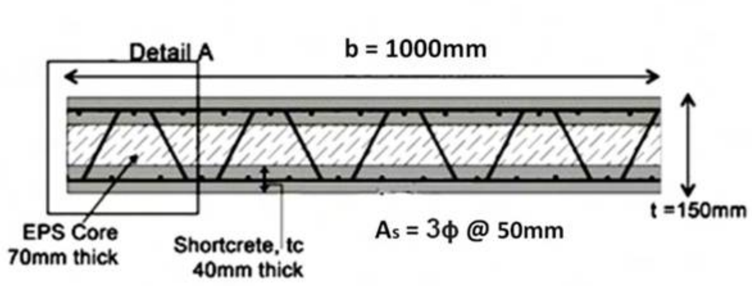


Fig. 6.8: Cross-section of the EPS Floor Panel

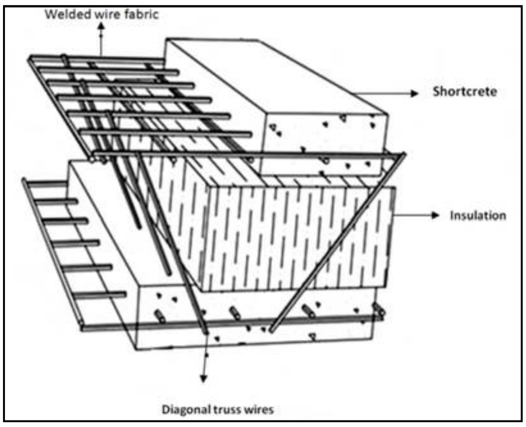


Fig. 6.9: The 3D view of the EPS Floor Panel

Details of the Assumed Wall Panel

b (Width of the Panel)	1000mm
T (Total Panel thickness)	180mm
T_c(Depth of the Shotcrete on one side)	40mm
y (Distance between Compression and Tension Reinforcement)	140mm
T (Thickness of EPS core)	100mm
f_y(Yield Strength of Steel Wires)	415MPa
E_s(Elastic Modulus of Steel)	200000 MPa
f_{ck}(Compressive Strength of Concrete)	20MPa
Density of Shotcrete	25kN/m^3
Density of EPS	0.15kN/m^3
Tension and compression Steel	3 ϕ@ 50mm

Loading on slab:

Calculation of Dead Load

Dead Load of Floor Panel per m^2 = (*Density of Concrete* × *Thickness of concrete in the wall panel) + (Density of EPS × Thickness of EPS in the wall panel)*

= (25 × 0.08) + (0.15×0.1)

=2.015kN/m^2

Live Load = 2 kN/m^2
Floor Finish = 1.5 kN/m^2

Total Load = 5.51 kN/m^2

Factored Load $= 1.5 \times 5.51 = 8.265 kN / m^2$

According to IS 456:2000 Table 26 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners.

Bending Moment Coefficients,

$\alpha_x^+ = 0.0474$

$\alpha_x^- = 0.063$

$\alpha_y^+ = 0.032$

$\alpha_y^- = 0.024$

$$M_{ux}^{+} = \alpha_x^{+} W_u l_x^2 = 0.0474 \times 8.265 \times 3.15 \times 3.15 = 3.88 kN - m$$
$$M_{ux}^{-} = \alpha_x^{-} W_u l_x^2 = 0.063 \times 8.265 \times 3.15 \times 3.15 = 5.17 kN - m$$
$$M_{uy}^{+} = \alpha_y^{+} W_u l_x^2 = 0.032 \times 8.265 \times 3.15 \times 3.15 = 2.62 kN - m$$
$$M_{uy}^{-} = \alpha_y^{-} W_u l_x^2 = 0.024 \times 8.265 \times 3.15 \times 3.15 = 1.97 kN - m$$

Minimum Area of Steel Wire Mesh is 3ϕ-50mm c/c

Area of Steel $= \dfrac{1000 \times Area\ of\ steel\ wire \times 2}{Spacing\ between\ steel\ wires} = \dfrac{1000 \times 7.1 \times 2}{100} = 142\, mm^2/m$

Moment of Resistance, $M_{RES} = 0.87 \times f_y \times A_{st} \times Lever\ Arm$

$$Lever\ Arm = d - \frac{0.5d}{2}$$
$$M_{RES} = 0.87 \times 415 \times 142 \times \left(160 - \frac{0.5 \times 160}{2}\right)$$
$$M_{RES} = 0.87 \times 415 \times 284 \times 120$$
$$M_{RES} = 6152292 N - mm/m$$
$$M_{RES} = 6.15 kN - m/m$$

Since factored moment demand is less than moment of resistance, floor panel is safe.

6.2 Cost analysis and Schedule of Rates for EPS core panel technology

- The basic materials incorporated in this SoR are considered to be conforming to BIS Standards / CPWD Specifications / Materials of good quality generally available in the market. Based on Delhi Schedule of Rates (DSR) – 2014.

- SoR is based on the prevailing market rates of materials in Delhi as on 01.04.2014. The labour rates adopted are as per minimum wages rates issued by Govt. of Delhi w.e.f. 1/4/2014.

Sl. No.	Description	Unit	Rate (in Rs.)
1.	2.	3.	4.
Item of Work (1)	Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for external walls using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3 mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement: 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. 6 mm diameter steel (vertical) bars to be fixed in a zig-zag pattern at a distance of 600 mm c/c on each side of the panel (140 mm apart). The dowel bars should be fixed 600 mm above plinth/roof and 300 mm below plinth/roof. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).	Sq.m	1350.00
Item of Work (2)	Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for external walls using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement: 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).	Sq.m	1332.00
Item of Work (3)	Providing and laying 130 mm thick Expanded Polystyrene (EPS) Core Panel for partition walls using 50 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement: 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. 6 mm diameter steel (vertical) bars to be fixed in a zig-zag pattern at a distance of 600 mm c/c on each side of the panel (90 mm apart). The dowel bars should be fixed 600 mm above plinth/roof and 300 mm below	Sq.m	1124.00

	plinth/roof. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).		
1.	2.	3.	4.
Item of Work (4)	Providing and laying 130 mm thick Expanded Polystyrene (EPS) Core Panel for partition walls using 50 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement: 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).	Sq.m	1106.00
Item of Work (5)	Extra for joining two sheets/ corners strengthening on both sides using 3mm Hard Drawn Steel Wire mesh 600 mm wide, including straightening, cutting, bending, placing in position and binding all complete as per direction of the Engineer-in-Charge (The measurement is to be done in running metres).	Metre	283.00
Item of Work (6)	Extra for strengthening around wall openings on both sides, using 3mm Hard Drawn Steel Wire mesh of size 600 mm x 300 mm diagonally (45^0) at each corner, including straightening, cutting, bending, placing in position and binding all complete as per direction of the Engineer-in-Charge (The measurement is to be done in number of corners).	Each Corner	120.00

TAKE-OFF SHEET

Name of work: Proposed G+3 Building using Expanded Polystyrene Core Panel System (EPS)

S. N o.	Description	No.	Unit	L	B	H	Content	Tot. Qty.
1	**Surface Dressing**	1	100	15	15		2.25	
			sq.m				**Total**	2.250
2	**Plinth Area**							
	GF each unit							
		1	sq.m	6.4	3.51		22.464	
	Additional	1	sq.m	4.485	1.68		7.535	
	Balcony	0	sq.m	0.91	2.61		0	
							Total	29.999
	FF, SF & TF each unit							
		1	sq.m	6.4	3.51		22.464	
	Additional	1	sq.m	4.485	1.68		7.535	
	Balcony	1	sq.m	0.91	2.61		2.375	
							Total	32.374
3	**Anti-termite Treatment**							
	@ the rate of 1 liter/ 20 sq.m of area	4	liter	29.999	20		1.500	
							Total	1.500
4	**Centre Line length (s)**							
	<u>GF/FF/SF/TF/180</u>		mtrs.		2	0.09	0.18	
			mtrs.		2	3.15	6.3	
			mtrs.		2	0.18	0.36	
			mtrs.		2	2.85	5.7	
			mtrs.		1	3.15	3.15	
			mtrs.		1	0.13	0.13	
			mtrs.		1	1.5	1.5	
			mtrs.		1	0.18	0.18	
			mtrs.		0.5	0.18	0.09	
			mtrs.		0.5	1.5	0.75	
			mtrs.		0.5	0.13	0.065	
			mtrs.		0.5	3.15	1.575	
			mtrs.		0.5	2.7	1.35	
	C/L length: 180 = 21.33 m each unit						**Total**	*21.330*
	L-Junctions = 2 Nos.							
	<u>GF/FF/SF/TF/ 130</u>							
			mtrs.		1	0.09	0.09	
			mtrs.		1	1.5	1.5	
			mtrs.		1	0.13	0.13	
			mtrs.		1	3.15	3.15	
			mtrs.		1	0.18	0.18	
			mtrs.		1	2.3	2.3	

			mtrs.		1	0.13	0.13	
S. No.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
			mtrs.		1	1.785	1.785	
			mtrs.		1	0.09	0.09	
	C/L length: 130 = 9.355 m each unit						**Total**	*9.355*
	L-Junctions = 5 Nos.							
5	**Earthwork in Excavation:**							
	C/L length: 180 = 21.33 m each unit	4	cum	21.33	1.20	1.20	122.861	
	L-Junctions = 2 Nos.	-8	cum	0.60	1.20	1.20	-6.912	
	C/L length: 130 = 9.355 m each unit	4	cum	9.36	1.20	1.20	53.885	
	L-Junctions = 5 Nos.	-20	cum	0.60	1.20	1.20	-17.280	
							Total	152.6
	<u>Back Filling of excavated earth in Tranches:</u>		cum				152.6	
	(-) Lean Concrete (1:4:8) in Footing		cum				-12.7	
	(-) Concrete in Plinth Beams up to Plinth		cum				-3.0	
	(-) 9" Brick Work in Foundation & Plinth		cum				-61.0	
							Total	75.8
6	**Sand Filling under Floors**							
	Plinth Area GL each unit = 29.99 sq.m							
	Plinth Area GL4 units + Lobby/ Foyer =							
	= 4x29.99 + 2.7x13.0 = 155.0 sq.m	1	cum	155.00		0.15	23.25	
	Deduction for Wall length							
	C/L length: 180 = 21.33 m each unit	-4	cum	21.33	0.18	0.15	-2.30364	
	L-Junctions = 2 Nos.	8	cum	0.18	0.09	0.15	0.01944	
	C/L length: 130 = 9.355 m each unit	-4	cum	9.36	0.13	0.15	-0.72969	
	L-Junctions = 5 Nos.	20	cum	0.13	0.07	0.15	0.02535	
							Total	20.3
7	**Earth Filling under Floors**							
	Plinth Area GL each unit = 29.99 sq.m							
	Plinth Area GL4 units + Lobby/ Foyer =							
	= 4x29.99 + 2.7x13.0 = 155.0 sq.m	1	cum	155.00		0.11	17.05	
	Deduction for Wall length							
	C/L length: 180 = 21.33 m each unit	-4	cum	21.33	0.18	0.11	-1.689336	
	L-Junctions = 2 Nos.	8	cum	0.18	0.09	0.11	0.014256	
	C/L length: 130 = 9.355 m each unit	-4	cum	9.36	0.13	0.11	-0.535106	
	L-Junctions = 5 Nos.	20	cum	0.13	0.07	0.11	0.01859	
							Total	14.9
8	**PCC under Floors**							
	Plinth Area GL each unit = 29.99 sq.m							
	Plinth Area GL4 units + Lobby/ Foyer =							
	= 4x29.99 + 2.7x13.0 = 155.0 sq.m	1	cum	155.00		0.10	15.5	
	Deduction for Wall length							
	C/L length: 180 = 21.33 m each unit	-4	cum	21.33	0.18	0.10	-1.53576	
	L-Junctions = 2 Nos.	8	cum	0.18	0.09	0.10	0.01296	
	C/L length: 130 = 9.355 m each unit	-4	cum	9.36	0.13	0.10	-0.48646	
	L-Junctions = 5 Nos.	20	cum	0.13	0.07	0.10	0.0169	

							Total	13.5
S. No.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
9	**Lean Concrete (1:4:8)**							
	C/L length: 180 = 21.33 m each unit	4	cum	21.33	1.20	0.10	10.238	
	L-Junctions = 2 Nos.	-8	cum	0.60	1.20	0.10	-0.576	
	C/L length: 130 = 9.355 m each unit	4	cum	9.36	1.20	0.10	4.490	
	L-Junctions = 5 Nos.	-20	cum	0.60	1.20	0.10	-1.440	
							Total	12.7
10	**Concrete in Plinth Beams upto Plinth**							
	Plinth Beams							
	C/L length: 180 = 21.33 m each unit	4	cum	21.33	0.18	0.15	2.304	
	L-Junctions = 2 Nos.	-8	cum	0.09	0.18	0.15	-0.019	
	C/L length: 130 = 9.355 m each unit	4	cum	9.36	0.13	0.15	0.730	
	L-Junctions = 5 Nos.	-20	cum	0.07	0.13	0.15	-0.025	
							Total	3.0
11	**Brick Work in foundation upto plinth**							
	C/L length: 180 = 21.33 m each unit							
	L-Junctions = 2 Nos.							
	Ist Footing	4	cum	21.330	0.92	0.15	11.774	
		-8	cum	0.46	0.92	0.15	-0.508	
	2nd Footing	4	cum	21.330	0.69	0.15	8.831	
		-8	cum	0.35	0.69	0.15	-0.286	
	3rd Footing	4	cum	21.330	0.46	0.15	5.887	
		-8	cum	0.23	0.46	0.15	-0.127	
	Last Footing	4	cum	21.330	0.23	0.95	18.642	
		-8	cum	0.12	0.23	0.95	-0.201	
	C/L length: 130 = 9.355 m each unit							
	L-Junctions = 5 Nos.							
	Ist Footing	4	cum	9.355	0.92	0.15	5.164	
		-20	cum	0.46	0.92	0.15	-1.270	
	2nd Footing	4	cum	9.355	0.69	0.15	3.873	
		-20	cum	0.35	0.69	0.15	-0.714	
	3rd Footing	4	cum	9.355	0.46	0.15	2.582	
		-20	cum	0.23	0.46	0.15	-0.317	
	Last Footing	4	cum	9.355	0.23	0.95	8.176	
		-20	cum	0.12	0.23	0.95	-0.503	
							Total	61.0
12	**180 mm thick EPS Walls in Super Structure**							
	C/L length: 180 = 21.33 m each unit							
	L-Junctions = 2 Nos.							
		4	sqm	21.330	0.18	12	1023.840	
		-8	sqm	0.09	0.18	12	-8.640	
	Mumty	1	sqm	18.740	0.18	2.7	50.598	
	SRSS Window	-3	sqm	1.800	1.35		-7.290	
	Deductions							
	D	-8	sqm	1	2.1		-16.800	

	D1	-4	sqm	0.9	2.1		-7.560	
	W	-4	sqm	1.2	1.35		-6.480	
	W2	-4	sqm	0.9	1.2		-4.320	
S. No.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
	V	-4	sqm	0.75	0.45		-1.350	
							Total	1021.998
13	**130 mm thick EPS Walls in Super Structure**							
	C/L length: 130 = 9.355 m each unit							
	L-Junctions = 5 Nos.							
		4	sqm	9.355	0.13	12	449.040	
		-20	sqm	0.07	0.13	12	-15.600	
	Balcony	12	sqm	3.910	0.13	0.9	42.228	
	Parapet	1	sqm	52.120	0.13	0.9	46.908	
	Deductions							
	D1	-4	sqm	0.9	2.1		-7.560	
	D2	-4	sqm	0.75	2.1		-6.300	
							Total	508.716
14	**EPS Suspended Floors, Slabs, Roof, Landing etc.**							
	GF all four units							
		4	sq.m	29.999			119.996	
	FF, SF, TF all four units							
		12	sq.m	32.374			388.488	
	Lobby	4	sq.m	4.65	2.7		50.22	
	Foyer	1	sq.m	1.5	2.7		4.05	
	Mumty	1	sq.m	4	2.7		10.8	
							Total	573.554
15	**Concrete in Beams**							
	Balcony	4	cum	4.27	0.18	0.15	0.461	
	Stair-case	8	cum	3.06	0.18	0.30	1.322	
							Total	1.783
16	**RCC in Stair-Cases**							
	Staps (1x1/2 x 10 x 1.38 x 0.30 x 0.1625)	4	cu.m	10	1.38	0.3	0.1625	2.691
	landing (3.06 x 1.56 x 0.125)	8	cu.m	3.06	1.56		0.125	4.7736
	waist slab	8	cu.m	4.27	1.38		0.125	5.8926
							Total	13.357
17	**RCC in Chajja, Fins, Fascia etc.**							
	Front/ Rear Side	16	cu.m	1.2	0.78	0.075	1.123	
	V	16	cu.m	1.05	0.78	0.075	0.983	
							Total	2.106

18	**Floor Finish (Flooring Areas)**							
a)	Flooring for Toilets & Kitchens							
	Kitchens	16	sq.m	2.30	1.50		55.200	
	Toilets	16	sq.m	1.79	1.50		42.840	
S. No.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
	D1	16	sq.m	0.90	0.13		1.872	
	D2	16	sq.m	0.75	0.13		1.560	
							Total	101.472
b)	Flooring for Bed/ Living Rooms							
	Bed Rooms	16	sq.m	3.15	3.15		158.76	
	D	16	sq.m	1	0.13		2.08	
	D1	16	sq.m	0.9	0.18		2.592	
	Living Room	16	sq.m	2.85	3.15		143.64	
	D	16	sq.m	1	0.18		2.88	
							Total	309.952
c)	Flooring for Lobby/Stair-case/Foyer							
	Foyer	1	sq.m	2.4	2.7		6.48	
	Lobby	4	sq.m	4.65	2.7		50.22	
	Stair-Case Steps	80	sq.m	1.2	0.3		28.8	
	Landing	8	sq.m	2.7	1.2		25.92	
							Total	111.420
19	**Skirting & Dedo**							
a)	Dado for Toilets & Kitchens							
	Kitchens	16	sq.m	2.30	1.50	0.90	109.440	
	Toilets	16	sq.m	1.79	1.50	0.90	94.608	
	D1	-16	sq.m	0.90	0.13	0.90	-12.960	
	D2	-16	sq.m	0.75	0.13	0.90	-10.800	
							Total	180.288
b)	Skirting for Bed/ Living Room							
	Bed Rooms	16	sq.m	3.15	3.15	0.15	30.240	
	D	-16	sq.m	1	0.13	0.15	-2.400	
	D1	-16	sq.m	0.9	0.18	0.15	-2.160	
	Living Room	16	sq.m	2.85	3.15	0.15	6.84	
	D	-16	sq.m	1	0.18	0.15	-2.400	
							Total	30.120
c)	Skirting for Lobby/Stair-case/Foyer							
	Foyer	1	sq.m	2.4	2.7	0.15	1.530	
	Lobby	4	sq.m	4.65	2.7	0.15	2.790	
	Stair-Case Steps	80	sq.m	1.2	0.3	0.1625	15.600	
	Landing	8	sq.m	2.7	1.2	0.15	3.24	
							Total	23.160

20	**Roof Treatment (Bitumen Painting/ Mud Phuska/ Water Proofing Treatment)**							
	All four units	4	sq.m	30			120	
	Lobby	1	sq.m	4.65	2.7		12.555	
							Total	132.555
S. N o.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
21	**6 mm Cement Plaster on Ceiling**							
	All units	4	sq.m	132.555			530.22	
							Total	530.220
22	**Internal Finishing**							
	Bed Rooms	16	sq.m	3.15	3.15	2.85	574.560	
	Living Rooms	16	sq.m	2.85	3.15	2.85	547.200	
	Kitchens	16	sq.m	2.30	1.50	2.10	255.360	
	Toilets	16	sq.m	1.79	1.50	2.10	220.752	
	Lobby	4	sq.m	4.65	2.70	2.85	167.580	
	Mumty	4	sq.m	4.00	2.70	2.85	152.760	
	D	-32	sq.m	1.00		2.10	-67.200	
	D1	-32	sq.m	0.90		2.10	-60.480	
	D2	-16	sq.m	0.75		2.10	-25.200	
							Total	1765.332
23	**External Finishing**							
	Front/ Rear	2	sq.m	13.08		13.35	349.236	
	LHS/RHS	2	sq.m	12.98		13.35	346.566	
	Mumty	1	sq.m	13.4		2.70	36.180	
	W1	-16	sq.m	1.20		1.35	-25.920	
	W2	-16	sq.m	0.90		1.20	-17.280	
	V	-16	sq.m	0.75		0.45	-5.400	
							Total	683.382
24	**Reinforcement**							
	Concrete in Plinth Beams		kg	2.99	2.5%		586.501	
	Concrete in Beams		kg	1.78	2%		279.944	
	RCC in Stair-case		kg	13.36	1.5%		1572.810	
	RCC in Chajja, Fins & Fascia etc.		kg	2.11	1%		165.321	
							Total	2604.576
25	**Door Frames (Pressed Steel)**							
	D	32	mtrs.	1	2.1		198.400	
	D1	32	mtrs.	0.9	2.1		163.200	
	D2	16	mtrs.	0.75	2.1		79.200	
							Total	440.800
26	**Flush Shutters for Doors**							
	D	32	sq.m	1	2.55		81.600	
	D1	32	sq.m	0.9	2.1		60.480	
	D2	16	sq.m	0.75	2.1		25.200	

							Total	167.280
27	**Fixtures (Tower Bolts)**							
	Big size							
	D	32	each	1			32	
	D1	32	each	1			32	
	D2	16	each	1			16	
S. N o.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
							Total	80
	Small Size							
	D	32	each	1			32	
	D1	32	each	1			32	
	D2	16	each	1			16	
							Total	80
28	**Door Fixtures (Sliding Bolt) + Handles**							
	D	32	each	1			32	
	D1	32	each	1			32	
	D2	16	each	1			16	
							Total	80
29	**Standard Rolled Steel Section for windows & ventilators**							
	W1	16	sq.m	1.2	1.35		25.920	
	W2	16	sq.m	0.9	1.2		17.280	
							Total	43.20
	by weight @ 2.3 kg/m length							
	W1	16	kg	1.2	1.35	@ 2.3	425.040	
	W2	16	kg	0.9	1.2	@ 2.3	353.280	
							Total	778.32
30	**Window & Ventilator Fixtures**							
	Window Fasteners							
	W1 & W2	32	each	4			128	
							Total	128
	Window Peg Stays							
	W1 & W2	32	each	4			128	
							Total	128
31	**Painting/ Priming on Doors (Wood Work)**							
	D	32	sq.m	1	2.55		81.600	
	D1	32	sq.m	0.9	2.1		60.480	
	D2	16	sq.m	0.75	2.1		25.200	
	Factor		2					
							Total	334.560
32	**Priming/ Painting for SRSS (Steel Work)**							
	W1	16	sq.m	1.2	1.35		25.920	
	W2	16	sq.m	0.9	1.2		17.280	
	Factor		1.2					
							Total	51.840

33	**Hand Rail with Baluster for Stair-Cases**							
	waist slab	8	sqm	4.5		0.6	21.60	
							21.600	
	Weight LS @ 20kg/sq.m of Railing	1	kg	21.6	20		**Total**	432.0
	Length of Railing in RM	1	metres				**Total**	36.000
S. N o.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
34	**Plinth Protection**							
	Front/ Rear	2	sq.m	13.08		0.90	23.544	
	LHS/RHS	2	sq.m	12.98		0.90	23.364	
							Total	46.908
35	**Rain Water Pipes**							
	Appoximate Area = 150 sq.m							
	two r.w.p. is required for 150 sq.m of area	2	each	150	150		2	
	length	2	mtrs.	12.45			24.9	
							Total	24.90
36	**RWP Accessories**							
	a) Coupler	2	each	4			8	8
	b) Shoes	2	each	2			4	4
	c) Single tee without door	2	each	2			4	4
37	**Khurras**							
		2	each	1			2	2
38	**Gola**							
	Front/ Rear	2	mtrs.	13.08			26.160	
	LHS/RHS	2	mtrs.	12.98			25.960	
							Total	52.120
39	**Centering/ Shuttering Areas**							
a)	<u>Plinth Beams</u>							
	C/L length: 180 = 21.33 m each unit	4	sqm	21.33	0.18	0.15	25.596	
	L-Junctions = 2 Nos.	-8	sqm	0.09	0.18	0.15	-0.216	
	C/L length: 130 = 9.355 m each unit	4	sqm	9.36	0.13	0.15	11.226	
	L-Junctions = 5 Nos.	-20	sqm	0.07	0.13	0.15	-0.390	
							Total	36.216
b)	<u>Beams</u>							
	Balcony	4	sqm	4.27	0.18	0.15	8.198	
	Stair-case	8	sqm	3.06	0.18	0.30	19.094	
							Total	27.293
c)	<u>Stair-Cases</u>							
	Staps (1x1/2 x 10 x 1.38 x 0.30 x 0.1625)	4	sqm	10	1.38	0.3	0.1625	8.97
	landing (3.06 x 1.56 x 0.125)	8	sqm	3.06	1.56		0.125	38.1888

	waist slab	8	sqm	4.27	1.38		0.125	47.1408
							Total	94.300
d)	Chajja, Fins & Fascia etc.							
	Front/ Rear Side	16	sq.m	1.2	0.78	0.075	17.856	
	V	16	sq.m	1.05	0.78	0.075	15.624	
							Total	33.480
S. No.	**Description**	**No.**	**Unit**	**L**	**B**	**H**	**Content**	**Tot. Qty.**
40	**Pre-cast RCC in Shelves**							
	Living Room	64	cu.m	1	0.83	0.075	3.984	
	Bed Room	64	cu.m	1	0.83	0.075	3.984	
							Total	7.968
41	**MS Fan Clamps**							
	Bed Room	16	each	1			16	
	Living Room	16	each	1			16	
							Total	32

BILL OF QUANTITY						
Name of work: Proposed G+3 Building using Expanded Polystyrene Core Panel System (EPS)						
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**
1	Surface Dressing of the ground including removing vegetation and in-equalities not exceeding 15 cm deep and disposal of rubbish, lead up to 50 m and lift up to 1.5 m in all kind of soil.					
		Per 100 sqm	2.3			
2	Earth work in excavation by mechanical means (Hydraulic excavator)/manual means over areas (exceeding 30 cm in depth, 1.5 m in width as well as 10 sqm on plan) including getting out and disposal of excavated earth lead upto 50 m and lift upto 1.5 m, as directed by Engineer-in-charge. All kind of soil.					
		cum	152.6			
3	Filling available excavated earth (excluding rock) in trenches, plinth, sides of foundations etc. in layers not exceeding 20cm in depth, consolidating each deposited layer by ramming and watering, lead up to 50 m and lift upto 1.5 m.					
		cum	90.7			
4	Supplying and filling in plinth with sand under floors, including watering, ramming, consolidating and dressing complete.					
		cum	20.3			
5	Providing and laying in position cement concrete of specified grade excluding the cost of centering and shuttering – All work up to plinth level : 1:4:8 (1 cement : 4 coarse sand : 8 graded stone aggregate 40 mm nominal size).					
		cum	26.2			
6	Providing and laying in position cement concrete of specified grade excluding the cost of centering and shuttering – All work up to plinth level : 1:4:8 (1 cement : 4 coarse sand : 8 graded stone aggregate 40 mm nominal size).					
		cum	0.0			
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**

7	Providing and laying in position machine batched, machine mixed and machine vibrated design mix cement concrete of specified grade for reinforced cement concrete work including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. M-20 grade reinforced cement concrete. All work up to **Plinth, Plinth Beam, Sub-structure** etc.					
		cum	3.0			
8	Providing and laying in position machine batched, machine mixed and machine vibrated design mix cement concrete of specified grade for reinforced cement concrete work including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. M-20 grade reinforced cement concrete. In **Beam, Bands** etc. in super structure upto floor level V.					
		cum	1.8			
9	Providing and laying in position machine batched, machine mixed and machine vibrated design mix cement concrete of specified grade for reinforced cement concrete work including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. M-20 grade reinforced cement concrete. In **Stair-cases** etc. in super structure upto floor level V.					
		cum	13.4			
10	Providing and laying in position machine batched, machine mixed and machine vibrated design mix cement concrete of specified grade for reinforced cement concrete work including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. M-20 grade reinforced cement concrete. In **Chajjas, Fins, Fascias** etc. in super structure upto floor level V.					
		cum	2.1			

S.No.	Description	Unit	Tot. Qty.	Rate (in Rs.)	Amount (in Rs.)	Remarks
11	Providing & Fixing HS having fy= 415 N/mm^2 cold twisted bars/ TMT reinforcement in all reinforced concrete work including straightening cutting, bending, and placing in position to the shape and profile required at all levels and/or as directed, binding with 18 gauge annealed steel wire (including cost of binding wire).					
		kg	2604.6			
12	Providing & fixing approved wrought iron /fabrication sheet steel/plywood shuttering and centering for unexposed concrete work (plain and reinforced) in locations called for including strutting, propping, bracing, bolting wedging, casing, striking, removal etc. complete. Allow for forming grooves, drips throats, chamfers, cut-outs, openings etc. where called for and for dressing with approved shuttering oil to prevent adhesion. 'Unexposed' concrete surfaces subsequently lift untreated (in the condition obtained on removal of form work) shall not constitute exposed concrete work and include vibrating (mechanically), curing, making shear keys and provisions of construction joint as per design etc.					
a)	Lintels, beams, plinth beams, girders, bressumers and cantilevers	sqm	63.5			
b)	Stairs, (excluding landings) except spiral-staircases	sqm	94.3			
c)	Weather shade, Chajjas, corbels etc., including edges	sqm	33.5			
13	Providing, hoisting and fixing above plinth level up to floor five level precast reinforced cement concrete in shelves, including setting in cement mortar 1:3 (1cement: 3 coarse sand), cost of required centering, shuttering and finishing with neat cement punning on exposed surfaces but, excluding the cost of reinforcement, with 1:1.5:3 (1 cement: 1.5 coarse sand (zone-III): 3 graded stone aggregate 20 mm nominal size).					
		sqm	8.0			
14	First Class Brick Work in CM 1:6 (1 cement: 6 coarse sand) up to plinth.					
		cum	61.0			

S.No.	Description	Unit	Tot. Qty.	Rate (in Rs.)	Amount (in Rs.)	Remarks
15	Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for external walls using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3 mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement: 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. 6 mm dia steel (vertical) bars to be fixed in a zig-zag pattern at a distance of 600 mm c/c on each side of the panel (140 mm apart). The dowel bars should be fixed 600 mm above plinth/roof and 300 mm below plinth/roof. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).					
		sqm	1022.0			
16	Providing and laying 130 mm thick Expanded Polystyrene (EPS) Core Panel for partition walls using 50 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement: 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. 6 mm dia steel (vertical) bars to be fixed in a zig-zag pattern at a distance of 600 mm c/c on each side of the panel (90 mm apart). The dowel bars should be fixed 600 mm above plinth/roof and 300 mm below plinth/roof. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).					
		sqm	508.7			

17	Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for suspended floors, roofs having slope up to 15°, landings, balconies etc. using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).					
		sqm	573.6			
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**
18	Providing and fixing ISI marked flush door shutters conforming to IS: 2202 (Part I) non-decorative type, core of block board construction with frame of 1st class hard wood and well matched commercial 3 ply veneering with vertical grains or cross bands and face veneers on both faces of shutters: 30 mm thick including ISI marked Stainless Steel butt hinges with necessary screws.					
		sqm	167.3			
19	Providing and fixing ISI marked oxidized M.S. sliding door bolts with nuts and screws etc. complete, 300 x 16 mm.					
		each	80.0			
20	Providing and fixing ISI marked oxidized M.S. tower bolt black finish, (Barrel type) with necessary screws etc. complete : 250 x 10 mm					
		each	80.0			
21	Providing and fixing ISI marked oxidized M.S. tower bolt black finish, (Barrel type) with necessary screws etc. complete : 150 x 10 mm					
		each	80.0			
22	Providing and fixing ISI marked oxidized M.S. handles conforming to IS:4992 with necessary screws etc. complete : 125 mm					
		each	80.0			
23	Providing and fixing oxidized M.S. casement stays (straight peg type) with necessary screws etc. complete. 300 mm weighing not less than 200 gms.					
		each	128.0			

S.No.	Description	Unit	Tot. Qty.	Rate (in Rs.)	Amount (in Rs.)	Remarks
24	Providing and fixing factory made ISI marked steel glazed doors, windows and ventilators, side /top /center hung, with beading and all members such as F7D, F4B, K11 B and K12 B etc. complete of standard rolled steel sections, joints mitred and flash butt welded and sash bars tenoned and riveted, including providing and fixing of hinges, pivots, including priming coat of approved steel primer, but excluding the cost of other fittings, complete all as per approved design, (sectional weight of only steel members shall be measured for payment). Fixing with 15x3 mm lugs 10 cm long embedded in cement concrete block 15x10x10 cm of C.C. 1:3:6 (1 Cement : 3 coarse sand : 6 graded stone aggregate 20 mm nominal size).					
		Kg	778.3			
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**
25	Providing and fixing pressed steel door frames conforming to IS: 4351, manufactured from commercial mild steel sheet of 1.60 mm thickness, including hinges, jamb, lock jamb, bead and if required angle threshold of mild steel angle of section 50x25 mm, or base ties of 1.60 mm, pressed mild steel welded or rigidly fixed together by mechanical means, including M.S. pressed butt hinges 2.5 mm thick with mortar guards, lock strike-plate and shock absorbers as specified and applying a coat of approved steel primer after pre-treatment of the surface as directed by Engineer-in-charge: Profile B; Fixing with adjustable lugs with split end tail to each jamb.					
		Meters	440.8			
26	Providing and fixing M.S. fan clamp type I or II of 16 mm dia M.S. bar, bent to shape with hooked ends in R.C.C. slabs or beams during laying, including painting the exposed portion of loop, all as per standard design complete.					
		Each	32.0			
27	Providing and fixing hand rail of approved size by welding etc. to steel ladder railing, balcony railing, staircase railing and similar works, including applying priming coat of approved steel primer. M.S. Tube.					
		Kg	432.0			
28	Cement concrete flooring 1:2:4 (1 cement: 2 coarse sand : 4 graded stone aggregate) finished with a floating coat of neat cement, including cement slurry, but excluding the cost of nosing of steps etc. complete. 40 mm thick with 20 mm nominal size stone aggregate.					

		Sqm	421.4			
29	40 mm thick marble chips flooring rubbed and polished to granolithic finish, under layer 34 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 12.5 mm nominal size) and top layer 6mm thick with white, black, chocolate, grey, yellow or green marble chips of sizes from 1 mm to 4 mm nominal size, laid in cement marble powder mix 3:1 (3 cement : 1 marble powder) by weight in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume, including cement slurry etc. complete : Dark shade pigment with ordinary cement.					
		Sqm	101.5			
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**
30	Cement plaster skirting up to 30 cm height, with cement mortar 1:3 (1 cement: 3 coarse sand), finished with a floating coat of neat cement. 18 mm thick.					
		Sqm	53.3			
31	Marble chips skirting up to 30 cm height, rubbed and polished to granolithic finish, top layer 6 mm thick with white, black, chocolate, grey, yellow or green marble chips of sizes from smallest to 4 mm nominal size, laid in cement marble powder mix 3:1 (3 cement : 1 marble powder) by weight in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume : 18 mm thick with under layer 12 mm thick in cement plaster 1:3 (1 cement : 3 coarse sand); Dark shade pigment with ordinary cement .					
		Sqm	180.3			
32	10cm thick (average) mud phaska of damped brick earth on roofs laid to slope consolidated and plastered with 25 mm thick mud mortar with bhusha @ 35 kg per cum of earth and gobri leaping with mix 1:1 (1 clay: 1 cow-dung) and covered with machine moulded tile bricks, grouted with cement mortar 1:3 (1 cement: 3 fine sand) mixed with 2% of integral water proofing compound by weight of cement and finished neat. With common burnt clay F.P.S.(non modular) brick tile of class designation 10.					
		Sqm	132.6			

33	Providing gola 75x75 mm in cement concrete 1:2:4 (1 cement: 2 coarse sand : 4 stone aggregate 10 mm and down gauge), including finishing with cement mortar 1:3 (1 cement : 3 fine sand) as per standard design : In 75x75 mm deep chase.					
		Metres	52.1			
34	Making khurras 45x45 cm with average minimum thickness of 5 cm cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate of 20 mm nominal size) over P.V.C. sheet 1 m x1 m x 400 micron, finished with 12 mm cement plaster 1:3 (1 cement: 3 coarse sand) and a coat of neat cement, rounding the edges and making and finishing the outlet complete.					
		Each	2.0			
35	Providing and fixing on wall face unplasticised Rigid PVC rain water pipes conforming to IS : 13592 Type A, including jointing with seal ring conforming to IS : 5382, leaving 10 mm gap for thermal expansion, (i) Single socketed pipes. 75 mm dia.					
		Metres	24.9			
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**
36	Providing and fixing on wall face unplasticised - PVC moulded fittings/ accessories for unplasticised Rigid PVC rain water pipes conforming to IS : 13592 Type A, including jointing with seal ring conforming to IS : 5382, leaving 10 mm gap for thermal expansion.					
	75 mm Couplers	Each	8.0			
	75 x 75 x 75 Tee	Each	4.0			
	75 mm Shoes	Each	4.0			
37	12 mm cement plaster of mix: 1:6 (1 cement: 6 fine sand).					
		sqm	1765.3			
38	15 mm cement plaster on the rough side of single or half brick wall of mix: 1:6 (1 cement: 6 fine sand).					
		sqm	683.4			
39	6 mm cement plaster of mix: 1:3 (1 cement: 3 fine sand).					
		sqm	530.2			
40	Colour washing such as green, blue or buff to give an even shade: New work (two or more coats) with a base coat of white washing with lime.					

		sqm	2295.6			
41	Finishing walls with water proofing cement paint of required shade: New work (Two or more coats applied @ 3.84 kg/10 sqm).					
		sqm	683.4			
42	Applying priming coat:					
a)	With ready mixed pink or Grey primer of approved brand and manufacture on wood work (hard and soft wood.	sqm	334.6			
b)	With ready mixed red oxide zinc chromate primer of approved brand and manufacture on steel galvanized iron/ steel works.	sqm	51.8			
43	Painting with synthetic enamel paint of approved brand and manufacture to give an even shade: Two or more coats on new work.					
		sqm	386.4			
S.No.	**Description**	**Unit**	**Tot. Qty.**	**Rate (in Rs.)**	**Amount (in Rs.)**	**Remarks**
44	Making plinth protection 50mm thick of cement concrete 1:3:6 (1 cement : 3 coarse sand : 6 graded stone aggregate 20 mm nominal size) over 75mm thick bed of dry brick ballast 40 mm nominal size, well rammed and consolidated and grouted with fine sand, including necessary excavation, levelling & dressing & finishing the top smooth.					
		sqm	46.9			
				Total		

ANALYSIS OF RATE

Item of Work (1) : Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for external walls using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3 mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. 6 mm dia steel (vertical) bars to be fixed in a zig-zag pattern at a distance of 600 mm c/c on each side of the panel (140 mm apart). The dowel bars should be fixed 600 mm above plinth/roof and 300 mm below plinth/roof. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	2.	3.	4.	5.	6.	7.

Details of cost for 3.6 sqm (i.e. 3.0 m x 1.2 m size)

MATERIAL:

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	Two Panels of 50 mm thick Expanded Polystyrene (EPS) - type SE Core Panel (Size 2x3.0x1.2=7.2 sq.m+10% wastage i.e. 7.92 sq.m)	sqm	7.92	170.00	1346.40	No. 7091
	Carriage of EPS Core Panel (Rs. 5.00/ 3.0 mx1.2 m sheet by manual/ mechanical Transport including loading, unloading and stacking)			L.S.	10.00	-

2. 3 mm dia Hard Drawn Steel Wire @ 100 mm c/c

(Length:	2x1.2x31	= 74.40 m
	2x3x13	= 78.00 m
Cross bars	1x0.15x17x7	= 17.85 m
	Total	= 170.25 m
	Wastage @ 5 %	= 8.51 m
	Total	= 178.76 m

1.	2.	3.	4.	5.	6.	7.
	Weight: 178.76.0 @ 0.06 kg/m = 10.7 Kg	Kg	10.7	76.60	819.62	No. 5.22A.2
3.	6 mm dia Steel (vertical) Bars (Weight: 5x0.9x0.22 = 0.99 kg	Kg	0.99	64.95	64.30	No. 5.22A.1
4.	Welding by electric plant including transportation of Plant at site etc. complete. (Length: 2x17x7x0.2 cm = 47.6 cm	cm	47.6	2.85	135.66	No. 10.22
5.	Cast-in-situ Cement Concrete of 1:1.5:3 (1 cement: 1.5 course Sand: 3 graded stone aggregate 6 mm nominal size) (Quantity: Cement Concrete 2x1.2x3.0x0.04 = 0.288 cum)					
	Portland cement (0.288 x 0.400 = 0.1152 tonne)	tonne	0.1152	6300.00	725.76	No. 0367
	Carriage of Cement	tonne	0.1152	94.65	10.90	No. 2209
	Coarse Sand (Zone III) (0.288 x 0.425 = 0.1224 cum)	cum	0.1224	1200.00	146.88	No. 0982
	Carriage of Coarse Sand	cum	0.1224	106.49	13.03	No. 2203
	Stone Aggregate 06 mm nominal size (0.288 x 0.85 = 0.2448 cum)	cum	0.2448	1140.00	279.07	No. 0298
	Carriage of Stone Aggregate	cum	0.2448	106.49	26.07	No. 2202
	Super Plasticizer, confirming to IS 9130:1999 (0.288 x 1.2 = 0.3456 kg)	kg	0.3456	38.00	13.13	No. 7318
LABOUR:						
	Mason (1st Class)	day	0.0173	435.00	7.53	No. 0123
	Mason (2nd Class)	day	0.0173	399.00	6.90	No. 0124
	Beldar	day	0.4592	329.00	151.08	No. 0114

1.	2.	3.	4.	5.	6.	7.
	Coolie	day	0.9646	329.00	317.35	No. 0115
	Bhisti	day	0.2016	363.00	73.18	No. 0101
T & P:						
	Hire charges of Concrete Mixer 0.25 to 0.40 cum With Hopper	day	0.0202	800.00	16.16	No. 0002
	Pumping charges of concrete including Hire charges Of pump, piping work & accessories etc.	Cum	0.288	150.00	43.20	No. 0009
	Double Scaffolding	L.S.	65.9	1.78	117.30	No. 9999
	Sundries	L.S.	4.12	1.78	7.33	No. 9999
				TOTAL	4330.66	
	Add Water Charges @ 1%, except on Item Nos. 2, 3 & 4				33.11	
				TOTAL	4363.77	
	Add Contractor's Profit & Overheads@ 15%, except on Item Nos. 2, 3 & 4				496.66	
			Cost of 3.6 sqm		4860.4	
			Cost of 1 sqm		1350.12	
				Say	1350/- per sq.m	

Item of Work (2) : Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for external walls using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	2.	3.	4.	5.	6.	7.
	Details of cost for 3.6 sqm (i.e. 3.0 m x 1.2 m size)					
	MATERIAL:					
1.	Two Panels of 50 mm thick Expanded Polystyrene (EPS) - type SE Core Panel (Size 2x3.0x1.2=7.2 sq.m+10% wastage i.e. 7.92 sq.m)	sqm	7.92	170.00	1346.40	No. 7091
	Carriage of EPS Core Panel (Rs. 5.00/ 3.0 mx1.2 m sheet by manual/ mechanical Transport including loading, unloading and stacking)			L.S.	10.00	-
2.	3 mm dia Hard Drawn Steel Wire @ 100 mm c/c (Length: 2x1.2x31 = 74.40 m 2x3x13 = 78.00 m Cross bars 1x0.15x17x7 = 17.85 m Total = 170.25 m Wastage @ 5 % = 8.51 m Total = 178.76 m					
	Weight: 178.76.0 @ 0.06 kg/m = 10.7 Kg	Kg	10.7	76.60	819.62	No. 5.22A.2

1.	2.	3.	4.	5.	6.	7.
3.	Welding by electric plant including transportation of Plant at site etc. complete. (Length: 2x17x7x0.2 cm = 47.6 cm	cm	47.6	2.85	135.66	No. 10.22
4.	Cast-in-situ Cement Concrete of 1:1.5:3 (1 cement: 1.5 course Sand: 3 graded stone aggregate 6 mm nominal size) (Quantity: Cement Concrete 2x1.2x3.0x0.04 = 0.288 cum)					
	Portland cement (0.288 x 0.400 = 0.1152 tonne)	tonne	0.1152	6300.00	725.76	No. 0367
	Carriage of Cement	tonne	0.1152	94.65	10.90	No. 2209
	Coarse Sand (Zone III) (0.288 x 0.425 = 0.1224 cum)	cum	0.1224	1200.00	146.88	No. 0982
	Carriage of Coarse Sand	cum	0.1224	106.49	13.03	No. 2203
	Stone Aggregate 06 mm nominal size (0.288 x 0.85 = 0.2448 cum)	cum	0.2448	1140.00	279.07	No. 0298
	Carriage of Stone Aggregate	cum	0.2448	106.49	26.07	No. 2202
	Super Plasticizer, confirming to IS 9130:1999 (0.288 x 1.2 = 0.3456 kg)	kg	0.3456	38.00	13.13	No. 7318
LABOUR:						
	Mason (1st Class)	day	0.0173	435.00	7.53	No. 0123
	Mason (2nd Class)	day	0.0173	399.00	6.90	No. 0124
	Beldar	day	0.4592	329.00	151.08	No. 0114
	Coolie	day	0.9646	329.00	317.35	No. 0115
	Bhisti	day	0.2016	363.00	73.18	No. 0101

1.	2.	3.	4.	5.	6.	7.
T & P:						
	Hire charges of Concrete Mixer 0.25 to 0.40 cum With Hopper	day	0.0202	800.00	16.16	No. 0002
	Pumping charges of concrete including Hire charges Of pump, piping work & accessories etc.	Cum	0.288	150.00	43.20	No. 0009
	Double Scaffolding	L.S.	65.9	1.78	117.30	No. 9999
	Sundries	L.S.	4.12	1.78	7.33	No. 9999
				TOTAL	4266.36	
	Add Water Charges @ 1%, except on Item Nos. 2 & 3				33.11	
				TOTAL	4299.47	
	Add Contractor's Profit & Overheads@ 15%, except on Item Nos. 2 & 3				496.66	
				Cost of 3.6 sqm	4796.13	
				Cost of 1 sqm	1332.26	
				Say	1332/- per sq.m	

Item of Work (3) : Providing and laying 180 mm thick Expanded Polystyrene (EPS) Core Panel for suspended floors, roofs having slope up to 15°, landings, balconies etc. using 100 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	2.	3.	4.	5.	6.	7.

Details of cost for 3.6 sqm (i.e. 3.0 m x 1.2 m size)

MATERIAL:

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	Two Panels of 50 mm thick Expanded Polystyrene (EPS) - type SE Core Panel (Size 2x3.0x1.2=7.2 sq.m+10% wastage i.e. 7.92 sq.m)	sqm	7.92	170.00	1346.40	No. 7091
	Carriage of EPS Core Panel (Rs. 5.00/ 3.0 mx1.2 m sheet by manual/ mechanical Transport including loading, unloading and stacking)			L.S.	10.00	-
2.	3 mm dia Hard Drawn Steel Wire @ 100 mm c/c					

(Length:	2x1.2x31	= 74.40 m
	2x3x13	= 78.00 m
Cross bars	1x0.15x17x7	= 17.85 m
	Total	= 170.25 m
	Wastage @ 5 %	= 8.51 m
	Total	= 178.76 m

	Weight: 178.76.0 @ 0.06 kg/m = 10.7 Kg	Kg	10.7	76.60	819.62	No. 5.22A.2

1.	2.	3.	4.	5.	6.	7.
3.	Welding by electric plant including transportation of Plant at site etc. complete. (Length: 2x17x7x0.2 cm = 47.6 cm	cm	47.6	2.85	135.66	No. 10.22
4.	Cast-in-situ Cement Concrete of 1:1.5:3 (1 cement: 1.5 course Sand: 3 graded stone aggregate 6 mm nominal size) (Quantity: Cement Concrete 2x1.2x3.0x0.04 = 0.288 cum)					
	Portland cement (0.288 x 0.400 = 0.1152 tonne)	tonne	0.1152	6300.00	725.76	No. 0367
	Carriage of Cement	tonne	0.1152	94.65	10.90	No. 2209
	Coarse Sand (Zone III) (0.288 x 0.425 = 0.1224 cum)	cum	0.1224	1200.00	146.88	No. 0982
	Carriage of Coarse Sand	cum	0.1224	106.49	13.03	No. 2203
	Stone Aggregate 06 mm nominal size (0.288 x 0.85 = 0.2448 cum)	cum	0.2448	1140.00	279.07	No. 0298
	Carriage of Stone Aggregate	cum	0.2448	106.49	26.07	No. 2202
	Super Plasticizer, confirming to IS 9130:1999 (0.288 x 1.2 = 0.3456 kg)	kg	0.3456	38.00	13.13	No. 7318
LABOUR:						
	Mason (1st Class)	day	0.0173	435.00	7.53	No. 0123
	Mason (2nd Class)	day	0.0173	399.00	6.90	No. 0124
	Beldar	day	0.4592	329.00	151.08	No. 0114
	Coolie	day	0.9646	329.00	317.35	No. 0115

	Bhisti	day	0.2016	363.00	73.18	No. 0101
	Extra labour for lifting material upto floor V level:					
	Coolie (2.5x0.75)	day	1.875	329.00	616.88	No. 0115

1.	2.	3.	4.	5.	6.	7.
T & P:						
	Hire charges of Concrete Mixer 0.25 to 0.40 cum With Hopper	day	0.0202	800.00	16.16	No. 0002
	Pumping charges of concrete including Hire charges Of pump, piping work & accessories etc.	Cum	0.288	150.00	43.20	No. 0009
	Double Scaffolding	L.S.	65.9	1.78	117.30	No. 9999
	Sundries	L.S.	4.12	1.78	7.33	No. 9999
				TOTAL	4883.24	
	Add Water Charges @ 1%, except on Item Nos. 2 & 3				39.28	
				TOTAL	4922.52	
	Add Contractor's Profit & Overheads@ 15%, except on Item Nos. 2 & 3				595.09	
			Cost of 3.6 sqm		5517.61	
			Cost of 1 sqm		1532.67	
				Say	1533/- per sq.m	

Item of Work (4) : Providing and laying 130 mm thick Expanded Polystyrene (EPS) Core Panel for partition walls using 50 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. 6 mm dia steel (vertical) bars to be fixed in a zig-zag pattern at a distance of 600 mm c/c on each side of the panel (90 mm apart). The dowel bars should be fixed 600 mm above plinth/roof and 300 mm below plinth/roof. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	2.	3.	4.	5.	6.	7.
	Details of cost for 3.6 sqm (i.e. 3.0 m x 1.2 m size)					
	MATERIAL:					
1.	Single Panels of 50 mm thick Expanded Polystyrene (EPS) - type SE Core Panel (Size 1x3.0x1.2=3.6 sq.m+10% wastage i.e. 3.96 sq.m)	sqm	3.96	170.00	673.20	No. 7091
	Carriage of EPS Core Panel (Rs. 5.00/ 3.0 mx1.2 m sheet by manual/ mechanical Transport including loading, unloading and stacking)			L.S.	5.00	-
2.	3 mm dia Hard Drawn Steel Wire @ 100 mm c/c					
	(Length: 2x1.2x31 = 74.40 m					
	2x3x13 = 78.00 m					
	Cross bars 1x0.10x17x7 = 11.9 m					
	Total = 164.30 m					
	Wastage @ 5 % = 8.22 m					

	Total = 172.52 m					
	Weight: 172.5 @ 0.06 kg/m = 10.35 Kg	Kg	10.35	76.60	792.81	No. 5.22A.2

1.	2.	3.	4.	5.	6.	7.
3.	6 mm dia Dowel (Mild Steel) Bars (Weight: 5x0.9x0.22 = 0.99 kg	Kg	0.99	64.95	64.30	No. 5.22A.1
4.	Welding by electric plant including transportation of plant at site etc. complete. (Length: 2x17x7x0.2 cm = 47.6 cm	cm	47.6	2.85	135.66	No. 10.22
5.	Cast-in-situ Cement Concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) (Quantity: Cement Concrete 2x1.2x3.0x0.04 = 0.288 cum)					
	Portland Cement (0.288 x 0.400 = 0.1152 tonne)	tonne	0.1152	6300.00	725.76	No. 0367
	Carriage of Cement	tonne	0.1152	94.65	10.90	No. 2209
	Coarse Sand (Zone III) (0.288 x 0.425 = 0.1224 cum)	cum	0.1224	1200.00	146.88	No. 0982
	Carriage of Coarse Sand	cum	0.1224	106.49	13.03	No. 2203
	Stone Aggregate 06 mm nominal size (0.288 x 0.85 = 0.2448 cum)	cum	0.2448	1140.00	279.07	No. 0298
	Carriage of Stone Aggregate	cum	0.2448	106.49	26.07	No. 2202
	Super Plasticizer, confirming to IS 9130:1999 (0.288 x 1.2 = 0.3456 kg)	kg	0.3456	38.00	13.13	No. 7318
LABOUR:						
	Mason (1st Class)	day	0.0173	435.00	7.53	No. 0123

	Mason (2nd Class)	day	0.0173	399.00	6.90	No. 0124
	Beldar	day	0.4592	329.00	151.08	No. 0114
	Coolie	day	0.9646	329.00	317.35	No. 0115
	Bhisti	day	0.2016	363.00	73.18	No. 0101

1.	2.	3.	4.	5.	6.	7.
T & P:						
	Hire charges of Concrete Mixer 0.25 to 0.40 cum with Hopper	day	0.0202	800.00	16.16	No. 0002
	Pumping charges of concrete including Hire charges of pump, piping work & accessories etc.	cum	0.288	150.00	43.20	No. 0009
	Double Scaffolding	L.S.	65.9	1.78	117.30	No. 9999
	Sundries	L.S.	4.12	1.78	7.33	No. 9999
				TOTAL	3625.66	
	Add Water Charges @ 1%, except on Item Nos. 2,3 & 4				26.33	
				TOTAL	3651.99	
	Add Contractor's Profit & Overheads@ 15%, except on Item Nos. 2,3 & 4				394.93	
				Cost of 3.6 sqm	4046.92	
				Cost of 1 sqm	1124.15	
				Say	1124/- per sq.m	

Item of Work (5) : Providing and laying 130 mm thick Expanded Polystyrene (EPS) Core Panel for partition walls using 50 mm thick Expanded Polystyrene (EPS) Core reinforced on both sides using welded mesh made of 3mm Hard Drawn Steel Wire and covered on both sides with 40 mm thick cast-in-situ cement concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) and finished neat in superstructure above plinth level up to floor five level. The expanded polystyrene (EPS) - type SE cores having a minimum density of 15 kg/m^3. Complete in all respect as per direction of the Engineer-in-Charge. (The rate is inclusive of all materials, labours, T&P & scaffolding involved).

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
1.	2.	3.	4.	5.	6.	7.
	Details of cost for 3.6 sqm (i.e. 3.0 m x 1.2 m size)					
	MATERIAL:					
1.	Single Panels of 50 mm thick Expanded Polystyrene (EPS) - type SE Core Panel (size 1x3.0x1.2=3.6 sq.m+10% wastage i.e. 3.96 sq.m)	sqm	3.96	170.00	673.20	No. 7091
	Carriage of EPS Core Panel (Rs. 5.00/ 3.0 mx1.2 m sheet by manual/ mechanical transport including loading, unloading and stacking)			L.S.	5.00	-
2.	3 mm dia Hard Drawn Steel Wire @ 100 mm c/c					

(Length:	2x1.2x31	= 74.40 m
	2x3x13	= 78.00 m
Cross bars	1x0.10x17x7	= 11.9 m
	Total	= 164.30 m

	wastage @ 5 % = 8.22 m					
	Total = 172.52 m					
	Weight: 172.5 @ 0.06 kg/m = 10.35 Kg	Kg	10.35	76.60	792.81	No. 5.22A.2

1.	2.	3.	4.	5.	6.	7.
3.	Welding by electric plant including transportation of plant at site etc. complete. (Length: 2x17x7x0.2 cm = 47.6 cm	cm	47.6	2.85	135.66	No. 10.22
4.	Cast-in-situ Cement Concrete of 1:1.5:3 (1 cement : 1.5 course sand: 3 graded stone aggregate 6 mm nominal size) (Quantity: Cement Concrete 2x1.2x3.0x0.04 = 0.288 cum)					
	Portland Cement (0.288 x 0.400 = 0.1152 tonne)	tonne	0.1152	6300.00	725.76	No. 0367
	Carriage of Cement	tonne	0.1152	94.65	10.90	No. 2209
	Coarse Sand (Zone III) (0.288 x 0.425 = 0.1224 cum)	cum	0.1224	1200.00	146.88	No. 0982
	Carriage of Coarse Sand	cum	0.1224	106.49	13.03	No. 2203
	Stone Aggregate 06 mm nominal size (0.288 x 0.85 = 0.2448 cum)	cum	0.2448	1140.00	279.07	No. 0298
	Carriage of Stone Aggregate	cum	0.2448	106.49	26.07	No. 2202
	Super Plasticizer, confirming to IS 9130:1999 (0.288 x 1.2 = 0.3456 kg)	kg	0.3456	38.00	13.13	No. 7318
LABOUR:						
	Mason (1st Class)	day	0.0173	435.00	7.53	No. 0123

	Mason (2nd Class)	day	0.0173	399.00	6.90	No. 0124
	Beldar	day	0.4592	329.00	151.08	No. 0114
	Coolie	day	0.9646	329.00	317.35	No. 0115
	Bhisti	day	0.2016	363.00	73.18	No. 0101

1.	2.	3.	4.	5.	6.	7.
T & P:						
	Hire charges of Concrete Mixer 0.25 to 0.40 cum with Hopper	day	0.0202	800.00	16.16	No. 0002
	Pumping charges of concrete including Hire charges of pump, piping work & accessories etc.	cum	0.288	150.00	43.20	No. 0009
	Double Scaffolding	L.S.	65.9	1.78	117.30	No. 9999
	Sundries	L.S.	4.12	1.78	7.33	No. 9999
				TOTAL	3561.36	
	Add Water Charges @ 1%, except on Item Nos. 2 & 3				26.33	
				TOTAL	3587.69	
	Add Contractor's Profit & Overheads@ 15%, except on Item Nos. 2 & 3				394.93	
				Cost of 3.6 sqm	3982.62	
				Cost of 1 sqm	1106.28	
				Say	1106/- per sq.m	

Item of Work (6) : Extra for jointing two sheets/ corners strengthening on both sides using 3mm Hard Drawn Steel Wire mesh 600 mm wide, including straightening, cutting, bending, placing in position and binding all complete as per direction of the Engineer-in-Charge (The measurement is to be done in running metres).

Sl. No.	Description			Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
	Details of cost for 3.0 metres length (i.e. 3.0 m x 0.6 m size)							
MATERIAL:								
1.	3 mm dia Hard Drawn Steel Wire @ 100 mm c/c							
	(Length:	2x0.6x31	= 37.20 m					
		2x3x7	= 42.00 m					
		Total	= 144.00 m					
		wastage @ 5 %	= 7.2 m					
		Total	= 151.2 m					
	Weight: 151.2 @ 0.06 kg/m		= 9.08 Kg	Kg	9.08	76.60	695.53	No. 5.22A.2
LABOUR:								
	Beldar			day	0.2	329.00	65.80	No. 0114
	Scaffolding			L.S.	32.95	1.78	58.65	No. 9999
	Sundries			L.S.	4.12	1.78	7.33	No. 9999
						TOTAL	827.31	
	Add Water Charges @ 1%, except on Item No. 1						1.32	

				TOTAL	828.63	
	Add Contractor's Profit & Overheads@ 15%, except on Item No. 1				19.77	
				Cost of 3.0 metre	848.40	
				Cost of 1.0 metre	282.80	
				Say	283/- per metre	

Item of Work (7) : Extra for strengthening around wall openings on both sides, using 3mm Hard Drawn Steel Wire mesh of size 600 mm x 300 mm diagonally (45^0) at each corner, including straightening, cutting, bending, placing in position and binding all complete as per direction of the Engineer-in-Charge (The measurement is to be done in number of corners).

Sl. No.	Description	Unit	Quantity	Rate (in Rs.)	Amount (in Rs.)	DSR (2014)/ Remarks
	Details of cost for each corner (i.e. 600 mm x 300 mm size)					
MATERIAL:						
1.	3 mm dia Hard Drawn Steel Wire @ 100 mm c/c					
	(Length: 2x0.6x4 = 4.80 m					
	2x0.3x7 = 4.20 m					
	Total = 9.00 m					
	wastage @ 5 % = 0.45 m					
	Total = 9.45 m					
	Weight: 9.45 @ 0.06 kg/m = 0.57 Kg	Kg	0.57	76.60	43.66	No. 5.22A.2
LABOUR:						
	Beldar	day	0.1	329.00	32.90	No. 0114
	Scaffolding	L.S.	16.48	1.78	29.33	No. 9999
	Sundries	L.S.	2.06	1.78	3.67	No. 9999
				TOTAL	109.56	
	Add Water Charges @ 1%, except on Item No. 1				0.66	

	TOTAL	110.22
Add Contractor's Profit & Overheads@ 15%, except on Item No. 1		9.89
	Cost of each corner	120.11
	Say	120/- per corner

6.3 Cost Comparison of EPS Core panel construction vs. RCC Construction.

Item of Work: Cost comparison of enclosed plan, four storeyed building having four dwelling units on each floor (Covered Area ≈ 30.0 sq.m of each unit) with conventional type brick masonry RCC framed structure vs EPS panel walling and roofing system.

Sl. No.	Item of Work	Conventional Type			EPS Panels Type		
		Quantity	Rate as per DSR 2014	Amount (in Rs.)	Quantity	Rate as per SoR	Amount (in Rs.)
	Walling Material						
1.	230 mm thick Brick Masonry in Super Str.: [(4x76.56x0.23x2.7) - (4x31.92x0.23)] = 160.81 cu.m 180 mm thick EPS Panels: [(4x84.64x3.0) - (4x31.92)] = 888.0 sq.m	160.81 cu.m	5483.55 as per 6.3.1	**881809.70**	888.0 sq.m	1350.00 as per Item No. 1 SoR	**1198800.00**
	115 mm thick Brick Masonry in Super Str.: [(4x40.08x2.7) - (4x25.2)] = 332.06 sq.m 130 mm thick EPS Panels: [(4x39.96x3.0) - (4x25.2)] = 378.7 sq.m	332.06 sq.m	665.80 as per 6.13.2	**221085.50**	378.7 sq.m	1124.00 as per Item No. 3 SoR	**425658.80**
2.	Extra for joining two sheets/ corners strengthening on both sides EPS Panels: Length = (888.0+378.7)x4.2/3.6= 1477.8 m	-	-	-	1477.8 m	283.00 as per Item No. 5 SoR	**418217.40**
3.	Extra for strengthening around wall openings on both sides EPS Panels: Length = 4x4x38.9 = 622.4 m	-	-	-	622.4 m	120.00 as per Item No. 6 SoR	**74688.00**
	RCC Columns (300 mmx300 mm)						
4.	Quantity of Concrete in s/str.: 4x26x0.3x0.3x3.0 = 28.08 cu.m	28.08 cu.m	7014.55 as per 5.33.2	**196968.56**	-	-	-
5.	Centring & Shuttering of Columns in s/str.: 4x26x2x(0.3+0.3)x3.0 = 374.4 sq.m	374.4 sq.m	453.35 as per 5.9.6	**169734.24**	-	-	-
6.	Reinforcement in Columns in s/str.:	4408.6 kg	68.10 as per 5.22A.6	**300222.94**	-	-	-

Sl. No.	Item of Work	Conventional Type	EPS Panels Type				
	L.S. 2% of quantity of conc. i.e. 2x28.08x78.5 = 4408.6 kg						
Sl. No.	Item of Work	Conventional Type	EPS Panels Type				
		Quantity	Rate as per DSR 2014	Amount (in Rs.)	Quantity	Rate as per SoR	Amount (in Rs.)
	RCC Beams						
7.	Quantity of Concrete in s/str.: 4x4x32x0.23x0.3 = 35.33 cu.m	35.33 cu.m	7014.55 as per 5.33.2	**247824.05**	-	-	-
8.	Centring & Shuttering of Beams in s/str.: 4x4x32x(0.23+0.3+0.23) = 389.1 sq.m	389.1 sq.m	332.15 as per 5.9.5	**129239.57**	-	-	-
9.	Reinforcement in Beams in s/str.: L.S. 1.5% of quantity of conc. i.e. 1.5x35.33x78.5 = 4160.0 kg	4160.0 kg	68.10 as per 5.22A.6	**283296.00**	-	-	-
	Roof Slab						
7.	Quantity of Concrete in s/str.: 4x4x32.98x0.11 = 58.04 cu.m EPS Panel Roof: 4x4x32.98 = 527.68 sq.m	58.04 cu.m	7014.55 as per 5.33.2	**407158.15**	527.68	1332.00 as per Item No. 2 SoR	**702869.76**
8.	Centring & Shuttering of Slabs in s/str.: 4x4x32.98 = 527.68 sq.m EPS Panel Roof * : 4x4x32.98 = 527.68 sq.m * Since only centring is required for EPS, hence 50% cost of item No. 5.9.3 is being considered.	527.68 sq.m	401.65 as per 5.9.3	**211942.67**	527.68 sq.m	200.83 as per 50% of 5.9.3	**105973.97**
9.	Reinforcement in Slabs in s/str.: L.S. 1% of quantity of conc. i.e. 1.0x58.04x78.5 = 4556.1 kg	4556.1 kg	68.10 as per 5.22A.6	**310270.41**	-	-	-
	Total Cost of 527.68 sq.m Covered Area			**3359551.79**			**2926207.93**
	EPS Panel Type Structures are 12.9 % Cheaper than Conventional Type Structures(Fig.6.10)						

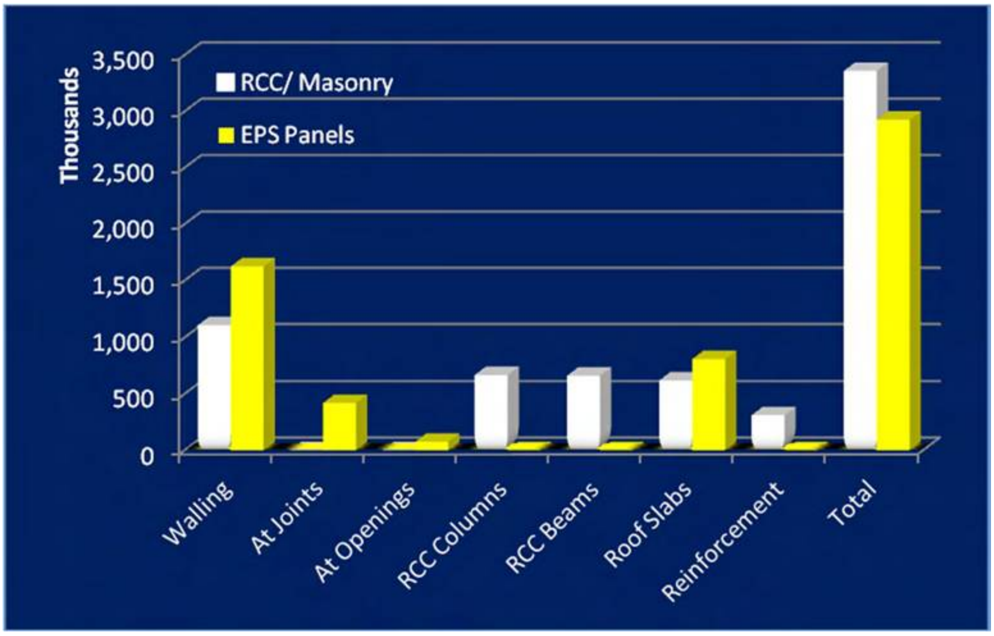


Fig. 6.10 Cost comparison of Conventional type brick masonry & RCC framed structure Vs EPS Core Panel System

CHAPTER – 7

LIST OF ARCHITECTS, DESIGNERS, STRUCTURAL ENGINEERS AND EXECUTING AGENCIES

This chapter discusses the list of Architects, Designers, Structural Engineers and Executing Agencies in the field of construction of EPS Core panel system.

7.1 Introduction

To know the industry sentiments on EPS Core panel housing technology, CBRI organized brain storming sessions, round table meetings (fig-7.1), expressed Expression of Interest (EOI) (fig-7.2) in leading English and Hindi newspaper etc. Based on the response received following list of Architects, Designers, Structural Engineers and Executing Agencies in the field of construction of EPS Core panel system has been prepared

Fig. 7.1. Brain storming sessions, round table meetings at CSIR-CBRI Roorkee.

सी. एस. आई. आर. - केन्द्रीय भवन अनुसंधान संस्थान, रुड़की - भारत
CSIR - Central Building Research Institute, Roorkee - INDIA

Advt. No.: CBRI/SEG/AKM/HFA-01/2017 06.02.2017

EXPRESSION OF INTEREST(EOI)

Expanded Polystyrene (EPS) Core Panel System is one of the technology adopted by Government of India under the mission Housing for All by 2022. CSIR - CBRI invites EOI from professionals/organizations/contractors interested in designing/adopting/ executing EPS construction technology for housing projects. EPS panels, consists of self extinguishing sintered expanded polystyrene sheet, sandwiched between two welded wire fabric mesh and with external shotcreting.

Details of EOI, submission requirements and templates are available at www.cbri.res.in.

All submissions should be sent by e-mail/post as per following details:

Dr. A K Mittal, Group Leader, Structural Engineering,
CSIR -CBRI, Roorkee- 247667. Email akmittal@cbri.res.in
Closing date 28th Feb 2017.

CSIR - CBRI reserves the right to reject any or all the EOI, without assigning any reasons thereof.

GL. Structural Engineering

Fig : 7.2(a) Hindustan Times Jalandhar Edition Dated 10th Feb 2017

सी. एस. आई. आर. - केन्द्रीय भवन अनुसंधान संस्थान, रुड़की - भारत
CSIR - Central Building Research Institute, Roorkee - INDIA

No.: CBRI/SEG/AKM/HFI - 01/2017 दिनांक : 08.02.2017

एक्सप्रेशन ऑफ़ इंटरेस्ट (EOI)

मिशन ''2022 तक सभी के लिए आवास'' के अंतर्गत Expanded Polystyrene (EPS) कोर पैनल सिस्टम भारत सरकार द्वारा अपनाई गई एक पद्धति है। आवास परियोजनाओं के लिए EPS निर्माण प्रौद्योगिकी के क्रियान्वियन के लिए CSIR - CBRI पेशेवरों/संगठनों/ठेकेदारों से जो कि डिजाइनिंग/इक्सिक्यूशॉन में रूचि रखते हैं, EOI आमंत्रित करता है।

EPS पैनल स्वयं शमन धातुमल Polystyrene शीट, दोनों तरफ से वेल्ड किया हुआ तारों का जाल और बाहरी शाटक्रीटिंग से बना हुआ होता है।

EOI का विवरण, प्रस्तुत आवश्यकता और टेम्पलेट्स www.cbri.res.in. पर उपलब्ध है। सभी प्रस्तुतियाँ ई-मेल/डाक द्वारा निम्नलिखित पते पर भेजने का कष्ट करें :

डॉ० ए० के० मित्तल, समूह प्रमुख,
संरचना अभियांत्रिकी, CSIR - CBRI रूड़की - 247667
ई-मेल : akmittal@cbri.res.in
अंतिम तिथि 28th Feb 2017.

सीएसआईआर - सीबीआरआई बिना कोई कारण बताए किसी एक या सभी EOI अस्वीकार करने का अधिकार सुरक्षित रखता है।

ग्रुप लीडर, एस.ई. विभाग

Fig : 7.2(b) Hindustan, Kanpur Edition Dated 10th Feb 2017

सी. एस. आई. आर. – केन्द्रीय भवन अनुसंधान संस्थान,
रूड़की – भारत
CSIR – Central Building Research Institute,
Roorkee - INDIA

No. CBRI/SEG/AKM/HFI-01/2017 **दिनांक:** 08/02/2017

एक्सप्रेशन ऑफ़ इंटरेस्ट (EOI)

मिशन "**2022 तक सभी के लिए आवास**" के अंतर्गत् Expanded Polystyrene (EPS) कोर पैनल सिस्टम भारत सरकार द्वारा अपनाई गई एक पद्धति है। आवास परियोजनाओं के लिए EPS निर्माण प्रौद्योगिकी के क्रियान्वियन के लिए CSIR – CBRI, पेशेवरों/ संगठनों /ठेकेदारों से जोकि डिजाइनिंग/ इक्सिकूशॉन में रुचि रखते हैं, EOI आमंत्रित करता है।

EPS पैनल स्वयं शमन धातुमल Polystyrene शीट, दोनों तरफ से वेल्ड किया हुआ तारो का जाल और बाहरी शॉटक्रीटींग से बना हुआ होता है।

EOI का विवरण, प्रस्तुत आवश्यकता और टेम्पलेट्स www.cbri.res.in पर उपलब्ध हैं। सभी प्रस्तुतियाँ ई-मेल / डाक द्वारा निम्नलिखित पते पर भेजने का कष्ट करें :

डॉ० ए० के० मित्तल, समूह प्रमुख,
संरचना अभियांत्रिकी, CSIR – CBRI, रूड़की – 247667
ईमेल: akmittal@cbri.res.in

अंतिम तिथि 28th Feb 2017.

सीएसआईआर – सीबीआरआई बिना कोई कारण बताए किसी एक या सभी EOI, अस्वीकार करने का अधिकार सुरक्षित रखता है।

सी. एस. आई. आर. – केन्द्रीय भवन अनुसंधान संस्थान,
रूड़की – भारत
CSIR – Central Building Research Institute,
Roorkee - INDIA

No. CBRI/SEG/AKM/HFI-01/2017 **Dated:** 08/02/2017

EXPRESSION OF INTEREST(EOI)

Expanded Polystyrene (EPS) Core Panel System is one of the technology adopted by Government of India under the mission **Housing for All by 2022**. CSIR – CBRI invites EOI from professionals/organizations/contractors interested in designing/adopting/ executing EPS construction technology for housing projects. EPS panels, consists of self extinguishing sintered expanded polystyrene sheet, sandwiched between two welded wire fabric mesh and with external shotcreting.

Details of EOI, submission requirements and templates are available at www.cbri.res.in.
All submissions should be sent by e-mail/post as per following details:

Dr. A K Mittal, Group Leader,
Structural Engineering, CSIR – CBRI, Roorkee- 247667.
Email **akmittal@cbri.res.in**

Closing date 28th Feb 2017.

CSIR – CBRI reserves the right to reject any or all the EOI, without assigning any reasons thereof.

Fig. 7.3. Expression of Interest published in newspaper by CBRI, Roorkee.

7.2 List of Architects, Designers, Structural Engineers

Sl. No	Name	Address & Contact Details
1.	NIRMAN Consultant Pvt. Ltd	Sh. Mansoor Ahmed E-135 Okhla Industrial Estate, Phase III New Delhi – 110020 URL – http://www.nirman.com/
2.	BEARDSELL Limited	Sh. Mukesh Kejriwal 114, Jyoti Shikhar Building Janakpuri New Delhi - 110058
3.	Braj Green Product Pvt. Ltd	Devashis Kishore Director Braj Green Product Pvt. Ltd URL – http://www.brajgreen.com
4	CSIR-Central Building Research Institute, Roorkee	Director CSIR – Central Building Research Institute Roorkee, Uttarakhand – 247667 Phone - +91 – 01332 272272 Email : director@cbri.res.in

5.	Mooreliving India Building Solutions LLP	4th Floor, Aastha Commercial Complex, A-4, Sarvodaya Enclave, Sri Aurobindo Marg , New Delhi - 110017, India Phone: +91 (11) 4155 1573 E-Mail : info@moorelivingindia.com
6.	M/s Architect Yetinder Mathur	U-21, Green Park Extn. New Delhi – 110016, India Phone No.: (011) 26198337, 26194313 E-mail : raghav@aymindia.com
7.	L & T Limited Construction	EDRC – Chennai, Mount Poonamallee Road, Manapakkam, P.B.No.979, Chennai – 600 089. Phone : 91 4422526000, Fax:+91-44-2249 3317 E-mail : info@lntecc.com
8.	Omaxe Celebration Mall	Shop No. 19 B, First Floor, Omaxe Celebration Mail, Sohna Road, Gurgaon, Haryana – 122001 Mob. : 9711800116 E- mail : arunkaggarwal@omaxe.com
9.	Chordia Techno Consultants	I-1738, Chittranjan Park Lower Ground Floor, New Delhi, India, 110019 Phone: +91 11 41603914/15/16, E- mail: chordiatech@gmail.com
10.	Intercontinental Consultants & Technocrats Pvt. Ltd.	A-8 & A-9, Green Park Main, New Delhi - 110 016, INDIA Tel : +91-11-40863000, 26569418 Fax : +91-11-26855252 E-mail : marut.gupta@ict.co.in
11	Supertech Limited	B 28-29, Sector 58 Noida Uttar Pradesh - 201307 Contact No : 0120 - 4572600 E-mail Id : sales@supercast.in
12	Amrapali Group	Amrapali Corporate Tower C - 56 / 40, Sector - 62 Noida - 201307 Phone : + 911204055555 Fax : 91120 4233556 E-mail : mkt@amrapali.in
13.	E-construct Design & Build Pvt. Ltd.	#42A, 1st Floor, Above post office inside BDA Complex, HSR Layout, Sector 06, Bangalore 560 102. Phone - 080-25720559 E-mail : Shraddha@e-construct.in
14.	Consulting Engineers Association of India	CEAI Centre, OCF Plot No 2, Pocket 9, Sector B, Vasant Kunj, New Delhi 110070. Tel: +91-11-26134644 Telefax: 26139658 Email: info@ceai.org.in, ceai.ceai@gmail.com
15.	Tata Consulting Engineers Ltd.	247 Park Tower 'A', 4th Floor LBS Marg Vikhroli (West) Mumbai - 400 083

		Tel: + 91 22 6114 8181 Email: mail@tce.co.in

7.3 List of Executing Agencies

Sl.No	Name	Address & Contact Details
1.	H*i*ndustan Prefab Ltd.	HPL (A Govt. of India Enterprise) Jangpura, New Delhi – 110014, India Website: http://www.hindprefab.org/
2.	National Buildings Construction Corporation Ltd.	NBCC Limited NBCC Bhawan, Lodhi Road New Delhi - 110 003, India Telephone No : 011 - 24367314 - 17, 24367573 Fax : 011 - 24366995 E-Mail : bd.nbcc@nic.in Website: http://www.nbccindia.com/nbccindia/index.jsp
3.	Tata Steel Ltd.	6th Floor, Gummidelli Towers, 1-10-39 to 40, Begumpet, Airport Road, Hyderabad-500 003. India
4.	Jindal Steel & Power Ltd.	Jindal Centre 12, Bhikaiji Cama Place, New Delhi - 110 066, INDIA. Tel: +91 11 26188340-50, 4146000 Fax: +91 11 26161271 Email Id : info@jindalsteel.com
5.	Schnell India Machinery Pvt. Ltd.	No-14/15/16, B-Wing, Sai Mansarovar C.H.S. Ltd. Satya Nagar, Borivali West, Mumbai - 400092, Maharashtra, India
6.	Synergy Thrislington	CORPORATE OFFICE: A1, Phase -1, Industrial Area Mohali, Chandigarh - 160055 Tele:+91- 172 2270461 Fax:+91- 172 2264319 Website: http://synergythrislington.com/
7.	Consortium techno solutions Pvt Ltd.	1-8-64/A, 2nd Floor, SS Heights, North Kamala Nagar ECIL Post, Kapra, Hyderabad – 500062 Tele/Fax: 040-27154166 Email: info@ctsplgroup.com Website: http://www.ctsplgroup.com/

CHAPTER – 8

CASE STUDIES

This chapter discusses about the observations during the site visit.

8.1 Introduction

Following two sites were visited to report the practical issues of EPS Core panel system

i. Residential Township at Angul Odisha by JSPL. Ltd
ii. Technology Park at Hindustan Prefab Limited (HPL), New Delhi.

- The biggest township in India using EPS Core Panel System is being constructed by Jindal Steel and Power Limited (JSPL) at Angul Odisha.
- A technology park showcasing the various prefab housing technologies for public awareness is being built by Hindustan Prefab Limited (HPL), New Delhi.

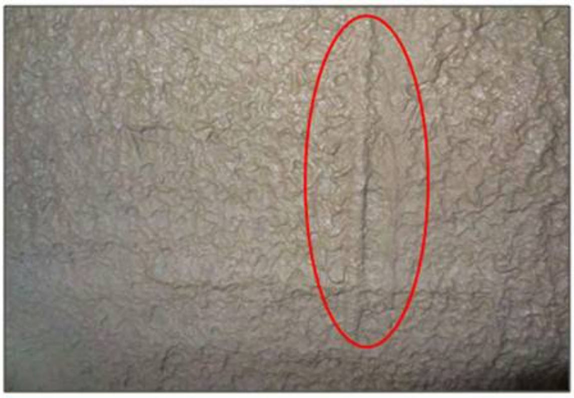
Some of the observations that were observed after visiting the above sites are as stated below:

Formation of Shrinkage cracks in the wall

Wide Visible Shrinkage cracks in the wall

Observation	Reason
▪ Crack formation in the walls of EPS Non Load Bearing (EPS-NLB) panels.	▪ Improper Shotcreting ▪ Lack of curing

Observation	Reason
▪ Deterioration of EPS panels prolonged exposure to Sun.	▪ Improper construction practices.



Observation	Reason
▪Improper Shotcreting in the wall	▪ Improper Shotcreting ▪ Lack of proper scaffolding for facilitating workers for carrying out Shotcreting

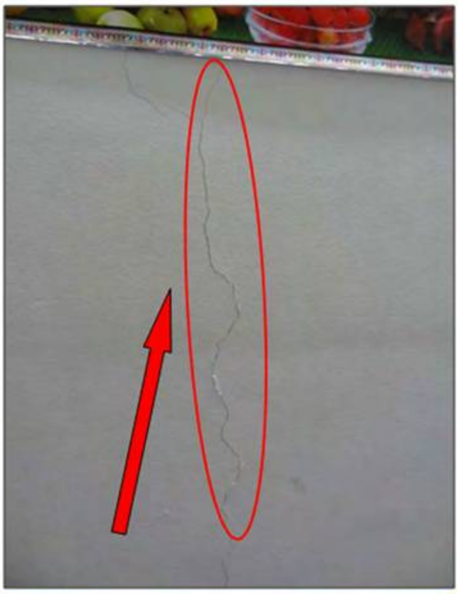
Observation	Reason
▪ Improper Shotcreting of load bearing members	▪ Improper Shotcreting technique

Observation	Reason
▪ Breakage of sunshade/ chajja	▪ Due to falling of debris ▪ Improper Construction practice

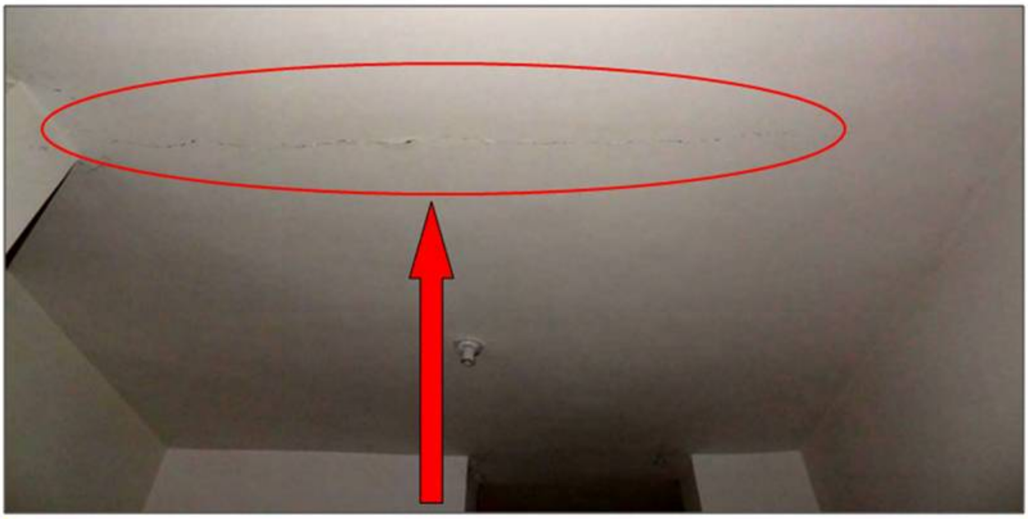
Observation	Reason
▪ Poor management of constructional wastes & Environmental hazard	▪ Lack of awareness

Cracks visible at the jointing of the panel in the exterior surface.

Formations of Cracks along the Joints in the roofing panel



Formations of Cracks along the Joints in the wall panel



Formations of Cracks along the Joints in the roofing panel

8.2 Limitation of the Technology

Following are some of the limitations of the EPS Core panel technology

i. Considerable amount of site work is involved in this type of construction which sometimes may lead to quality control issues.

ii. Improper construction schedule may lead to deterioration of EPS panels (yellowing of panels) which may lead to degradation of insulation property of EPS.

iii. There can be movement of moisture in EPS Core panel due to improper shotcreting, presence of gap in between the panels which may give rise to serious maintenance issues after the construction.

iv. The current practice of Shotcreting the EPS-LB/NLB panels do not ensure even thickness and depth of concrete in the panel.

v. Initial cost of investment in setting up of factories for production of EPS panels is high.

CHAPTER – 9

CONCLUSIONS & RECOMMENDATIONS

- EPS core Panel system is a modern, efficient, safe and economic construction system for the construction of buildings. It has got the potential in achieving the Government of India's ambitious project "Housing for all by 2022".

- After carrying out extensive research, industry interaction meetings, feedback received, EPS Core panel system is

  i. 3 times faster than conventional RCC construction
  ii. 12 – 14 % cheaper than conventional RCC construction
  iii. Low carbon footprint, as the material used in the construction is sustainable in nature.

- The Interactive User friendly Software developed by CBRI will help engineers, designers etc. in designing safe efficient Load bearing and non load bearing EPS core panels.

- Proper construction schedule should be followed for ensuring the time between erections to shotcreting is completed within 48 hours. This will avoid deterioration of EPS panels, which leads to reduced insulation properties.

- A specially designed cost effective light weight machine should be developed for shotcreting the EPS-LB/NLB panels.

- Proper waste disposal system should be in place, ensuring minimum wastage and spillage of concrete in the surrounding areas.

- A self-supporting scaffolding system need to be designed for EPS panel construction.

- In the current practice there is cracking at the joints of EPS –LB/NLB panel. The crack can be avoided by providing chicken mesh as per the structural requirement.

- Durability study, life cycle analysis study etc. should be carried out on EPS Core panel system for a better understanding and acceptability of the technology in the construction sector.
- EPS Core panel system should be adopted for construction only with the full list of equipments and machineries.

- Though EPS Core panel system has some practical issues, the same can be solved by suitable technological interventions.

- Certified training programme should be conducted for artisans and professionals.

- Government should take active initiatives to make public aware of EPS Core panel housing technology by organizing seminars, training programmes, Construction of Demo units in deferent parts of the country.