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Construction using EPS Technology

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Abstract: *With the increase in demand for construction material, man has improved a lot in construction techniques of structures. In earlier ages structures were constructed with heavy materials and methods which were time consuming, costly and maintenance would be more. But this modern era is following the latest techniques in construction which have lot of advantages so the use of lightweight materials and faster construction has been are started. Thus, one of latest techniques being adopted at present is use of expanded polystyrene (Thermocol) in construction of walls, slabs etc., i.e., used for non-structural elements which imparts light weight, economic, faster construction, acts have insulator and which results in a sustainable future as the resources can be saved to some extent. Expanded polystyrene (EPS) is a lightweight material that many people recognize as being used in packaging materials. EPS is an innovation building material that lends to design and structural integrity of many building projects. Nowadays, EPS became a powerful design element and an ideal choice for green building design, offering tangible environmental advantages that can maximize energy efficiency, provide improved indoor environmental quality and enhance durability.*

Keywords: EPS Technology

I. INTRODUCTION

1.1 General

An 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. 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:

1. The outer layer of shotcrete.
2. Welded reinforcing mesh of high wire.
3. The core of expanded polystyrene sheet.
4. Diagonal wire (stainless or galvanized wire).
5. 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. EPS panel is a versatile structural element designed for floors, walls, partitions, roof and stairs. shows the welded reinforcing mesh of the EPS panels at different cross-sections. 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. 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.

Expanded Polystyrene (EPS) is a lightweight cellular plastic material made up of small hollow spherical balls that can be used in a variety of applications. That EPS has such extraordinary properties is due to the fact that it is constructed entirely of closed cells. EPS is available in a broad range of densities, each of which has a unique set of physical features to offer. It is used as insulation in walls, roofs, and foundations. It is also used as a component of structural insulated panels (SIPs), insulated concrete forms (ICFs), and exterior insulation and finish systems (EIFS).

EPS products have been the subject of extensive research and evaluation over a 50-plus year lifespan. Encompassing a multitude of applications, the EPS industry stands behind its product with real-world test results. Research data from academia as well as third party testing laboratories such as Oak Ridge National Laboraties, National Research Council of Canada, Home Innovation Research Labs (formerly National Association of Homebuilders Research Center) and the International Safe Transit Association lends confidence to specifiers, architects and packaging engineers. EPS transport packaging meets five of the eight criteria of a sustainable packaging as defined by the Sustainable Packaging Coalition.

In 1992, the EPS industry established an internal recycling program that allows us to reintroduce post-consumer EPS into the manufacturing process to make new, recycled content packaging and durable goods such as plastics lumber, planters and picture frames. The 2019 U.S. EPS Recycling Report shows that over 136 million pounds of EPS were recycled in 2019, including 46.4 million pounds of post-consumer packaging and 90.4 million pounds of post-industrial packaging. The 2019 Canadian EPS Recycling Report shows 378 thousand kilograms (833 thousand pounds) post-consumer and 3.5 million kilograms (7.7 million pounds) post-industrial EPS was recycled. Approximately 50% of all EPS collected is used to manufacture new EPS transport packaging and loose fill packaging, which has reduced requirements for raw material resources and energy consumption. On average 5-15% recycled content is achieved using a regrind process to incorporate collected EPS into the manufacturing process. EPS is made of 98% air and is an inert material without harmful chemicals that off-gas or leach during its use of disposal. EPS represents less than 1% of the total municipal solid waste stream by weight and volume. Available in a variety of custom-moulded shapes, EPS containers are water resistant and hygienic with high thermal-insulating properties. Which is what makes it a common choice for shipping food throughout the world.

EPS is a lightweight plastic material that most people recognize as being used in packaging material. EPS is one of the most common lightweight building and construction materials used in many countries around the word, with this sector making up approximately 65% of all EPS use in Australia (Expanded Polystyrene Australia, EPSA, 2016). EPS offering excellent insulation and strength properties at a very light weight. When handled and installed correctly, it is safe, practical and cost effective, especially when taking into account its insulation properties over the life of a building. The end product of the EPS is typically around 98% air and 2% polymer, consisting of small spheres in a closed cellular construction which gives it valuable characteristics for the building and construction industry, including being: (1) exceptionally cost effective and light weight construction material, (2) 100% recyclable, (3) versatile and easy to cut and mold for different purposes, (4) easy to install and maintain, (5) water resistant, (6) an excellent thermal insulator, (7) shock absorbent, (8) a high load-bearing material at low weight, (9) saving energy, (10) providing improved indoor environmental quality and enhancing durability, and (9) a good vapor, air and dust barrier.

EPS is produced in a three-stage process: (1) Pre-expansion; steam causes the raw polystyrene beads to expand up to 50 times their original volume. (2) Conditioning; after expansion, the beads are then conditioned and undergo a maturing period in preparation for molding. (3) Molding; the beads are then placed within a mold and reheated with steam, expanding further to completely fill the mold and fuse together (Medne, 2010, Calbureanu et al, 2010 and Khole and Mohod, 2016)). As construction material, EPS becomes an innovative building material that lends to the design and structural integrity of many building projects. Raj et al (2014) show that the unit weight of EPS embedded structure is up to 35% less than the conventional concrete structure and the pre-assembled units reduces the overall cost of structure significantly. Ngugi et al, (2017) noticed that the EPS was initially mainly used for insulation foam for closed cavity walls, roofs and floor insulation. Following continued research and innovation, EPS usage has extended in the building and construction industry in road construction, bridges, floatation, railway lines, public buildings, drainage facilities and family residences. EPS is a thermoplastic material manufactured from styrene monomer, using a polymerization process which produces translucent spherical beads of polystyrene.

Nowadays, the EPS panels sandwiched between two mats of welded wire mesh. The mats of wire mesh are connected by thirty-three connectors per two meters realizing a 3D hyper static reinforcement steel. The panels are assembled at site then finished with concrete blasting or/and pouring on each side. Ede and Ogundira in 2014 carried out research illustrating the application of this material in building and construction projects. They illustrator that the EPS used for building construction are of various types and sizes with the most common ones being for wall panels and for slab that are erected with steel meshes. The steel wire mesh serves as reinforcement. The EPS 3D reinforced wall system usually transfers shear and compression forces along the wall plane. The wall system is completed by applying concrete layers of acceptable thickness on both sides to perform the dual functions of protecting the reinforcements against corrosion and for transference of compressive forces.

Typically, there are four types of EPS panels; single panel, double panel, high strength panel and roof panel. However, in case of installation, the system needs a linear foundation that could be made using a continuous concrete footing or any type of foundation in accordance with the geotechnical characteristics of the terrain. Trace the position of the interior and exterior walls using a measure or similar tool. The anchor bars are usually inserted before pouring the foundation. Alternatively, it is possible to drill holes in the existing slab and then anchor the bars with an approved system. Due to its lightweight, a single operator can easily lift and place panels where necessary. There is another factor that contributes to saving labors compared to traditional techniques. The false frames are mounted in the openings cut according to the requirements that join the anchor steel with the steel wire mesh of the panel. Immediately after the placement of the panels, the perfect linearity and verticality of the walls is checked and ensured. A hot air gun or torch is used to create channels in the polystyrene for the placement of switch boxes, electrical conduits, cables, pipes, etc. Once the floor panels are placed, supported by the walls and from below, additional steel reinforcement is installed, if necessary, then, the concrete is poured. The lattice girders are suitable for this application as reinforcement steel they will be incorporated in the intended locations on the floor panels. Both sides of the walls of single panel are sprayed with shotcrete and subsequently finished with plaster. Once the reinforcement steel is placed, proceed with the concrete is poured in the superior part. Finally, the finishing works are completed which include painting and other finishing touches.

II. IMPORTANCE

1. EPS panels, tailored for specific projects are used as wall panels, for portioning and floor slabs. This are normally finished on site by applying concrete/sand crate with pneumatic devices.
2. EPS in the building industry worldwide can be summed up as lifetime durability, moisture resistance, proven acoustic and excellent thermal insulaton, design versatility, cost effective, easy installation leading time consumption and structural stability.
3. Lower cost per thermal resistance value than many other insulation products.

III. LITERATURE REVIEW

[1]. CSIR-CBRI Report No.: S.E(G)/ 0605: EPS core Panel system is a modern, efficient, safe and economic construction system for the construction of buildings. EPS core Panel system is a modern, efficient, safe and economic construction system for the construction of buildings. The design shall satisfy the standards of IS 456, IS 1905, IS 11447, IS 875 (Part1-5), 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 superstructure with the foundation spread over the entire wall length over the network of RC plinth beams.

[2]. UNIVERSITA' DEGLI STUDI DI NAPOLI FEDERICO II Schnell-home: The objective of the collaboration between the Department of Structures for Engineering and Architecture of the University of Naples "Federico II" (DIST – UniNa) and Schnell Home is the mechanical characterization, in a static or dynamic regime, of the sandwich panel made of reinforced concrete and polystyrene with features mentioned below. In particular, the experimental campaign was focused on the behavioral study of the single panels subjected to static actions and the dynamic response on vibrating table of a three-dimensional specimen made by assembling said panels. The reference seismic input has been scaled in intensity levels gradually increasing up to PGA values of about 14 m/sec2. For all tests performed, any sliding of the floor toward the vertical elements has been registered. There isn't any record of significant rotation of the top part of the structure since the maximum difference of the measured displacement is equal to about 2 mm.

[3]. Indian Institute of Technology Roorkee: An experimental study on mechanical behavior of EPS core-based RC sandwich panels is conducted. The strength estimated using these tests has been compared with that using the Indian and other codes for ordinary reinforced concrete panels. It is observed that in absence of more rigorous models for EPC-RC composite panels, the models available in codes can be used for estimating the strength with reasonable conservativeness. The small-scale shear and flexure tests have been simulated using Finite Element Analysis. Two models, first using layered shell elements in SAP 200 Nonlinear software and the other using solid (brick) elements for concrete and truss (bar) elements for the reinforcement in ABAQUS have been used. It is observed that the solid element model in ABAQUS yields reasonably accurate simulation of the experimentally obtained load-deflection curve in diagonal compression, but the layered shell element model over-estimates the capacity. In case of the out-of-plane flexure test, initial portion of the load-deflection curve obtained from finite element analysis in ABAQUS matches with the experimental curves, but the latter part of the curves does not match. The results of modelling using layered shell element in SAP 2000 show higher stiffness and strength in comparison to the experimental results. In addition to the simulation of tests on small scale specimens, detailed analysis of a proposed 4 storey (G+3) building has been performed to study its seismic capacity. Two types of analysis have been performed. First a simple 'pier analysis' is performed considering idealized modelling of piers as fixed end vertical frame elements and assuming the spandrels to be rigid. In the second case, a finite element model using layered shell element has been developed in SAP2000 Nonlinear software.

[4]. R. Shahrin & T.R. Hossain, "Seismic performance evaluation of residential buildings in Dhaka city by using pushover analysis." (2011): Bangladesh is situated in moderate earthquake prone region. Major metropolitan cities of our country are under serious threat because of faulty design and construction of structures. Weak buildings designed without seismic consideration could be vulnerable to damage even under low levels of ground shaking from distant earthquakes. So, the structural engineers now-a-days are more concerned about the different earthquake analysis procedures. According to BNBC (2006) the buildings are designed according to equivalent static force method, response spectrum method and time history analysis. But the actual performance of a structure can be hardly found by these methods. Nonlinear inelastic pushover analysis provides a better understanding about the actual behavior of the structures during earthquake. The pushover analysis which is not very familiar to many structural engineers has wide range of applications in the seismic evaluation and retrofit of structure. There are mainly two guidelines of this analysis-FEMA and ATC 40. The paper mainly follows the procedures of ATC 40 in evaluating the seismic performance of residential buildings in Dhaka. The present study investigates as well as compares the performances of bare, full in filed and soft ground storey buildings. For different loading conditions resem-bling the practical situations of Dhaka city, the performances of these structures are analyzed with the help of capacity curve, capacity spectrum, deflection, drift and seismic performance level. The performance of an in filled frame is found to be much better than a bare frame structure. It is seen that consideration of effect of the infill leads to significant change in the capacity. Investigation of buildings with soft storey shows that soft storey mechanism reduces the performance of the structure significantly and makes them most vulnerable type of construction in earthquake prone areas.

[5]. G. S. Saisaran, V. Yogendra Durga Prasad, T. Venkat Das, "Push Over Analysis for Concrete Structures at Sesimic Zone-3 using Etabs Software", (2016): In this paper we are going to discuss about the analysis on the RC building frame, i.e., PUSHOVER analysis is a static nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force displacement relationship or the capacity curve for a structure or structural element. The analysis involves applying of horizontal loads, in a prescribed pattern, to the structure incrementally, i.e., pushing the structure and plotting the total applied shear force and associated lateral loads at each increment until the structure or collapse condition. In technique a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniformly). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of the structure. The seismic response of RC building frame in terms of performance point and the effect of earthquake forces on multi story building frame with the help of pushover analysis is carried out in this paper. In the present study a building frame is designed as per Indian standard i.e., IS 456:2000 and IS 1893:2002. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis by software E-tabs at only zone-3 earthquake.

[6]. Vaseem Inamdar & Arun Kumar, "Pushover Analysis of Complex Steel Frame with Bracing Using Etabs", (2014).

Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In the present study, pushover analysis of complex steel frame building was investigated. These investigations were based on stiffness and ductility. This paper is intended to compare the performance of structure by using ISMB and ISNB (hollow pipes) steel sections as bracing element on 15-story complex steel frame. Displacement analyses were performed using the Extended 3D Analysis of Building Systems (ETABS) software for investigating stiffness of these system and pushover analysis were performed. The results of these outputs indicated that performance of structure greatly influenced by the way and sections adopted for bracing system.

[7]. S.C.Pednekar, H.S.Chore, S. B.Patil, "Pushover Analysis of Reinforced Concrete Structures",(2015)

The present study gives an effect of increase in number of storeys on seismic responses by performing pushover analysis. Reinforced concrete structures of G+4, G+5 and G+ 6 storey have been modelled and analysed using CSi ETABS 9.7.4 software. Comparison of seismic responses of the structure in terms of base shear, time period and displacement has been done by performing nonlinear static pushover analysis. From analysis results it has been observed that base shear and spectral acceleration is reduced, whereas displacement, time period, spectral displacement is increased as the number of storey increases. Analysis also shows location of plastic hinges at performance point of the structures with different number of storeys.

[8]. Govind M.Kiran K.Shetty K.Anil Hegde, "Nonlinear static pushover analysis of irregular space frame structure with and without t shaped columns", (2014).

The static pushover analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. The expectation is that the pushover analysis will provide adequate information on seismic demands imposed by the design ground motion on the structural system and its components. The recent advent of structural design for a particular level of earthquake performance, such as immediate post-earthquake occupancy, (termed as performance-based earthquake engineering), has resulted in guidelines such as ATC-40, FEMA-356 and standards such as ASCE-41. Among the different types of analysis, pushover analysis comes forward because of its optimal accuracy, efficiency and ease of use. In the present study, the behaviour of G+20 storied R.C frame buildings (H shape in plan, with and without T shaped column) subjected to earthquake, located in seismic zone III is discussed briefly using ETABS software. Gravity loads and laterals loads as per IS 1893-2002 are applied on the structure and it is designed using IS 456. Displacement control pushover analysis is carried out.

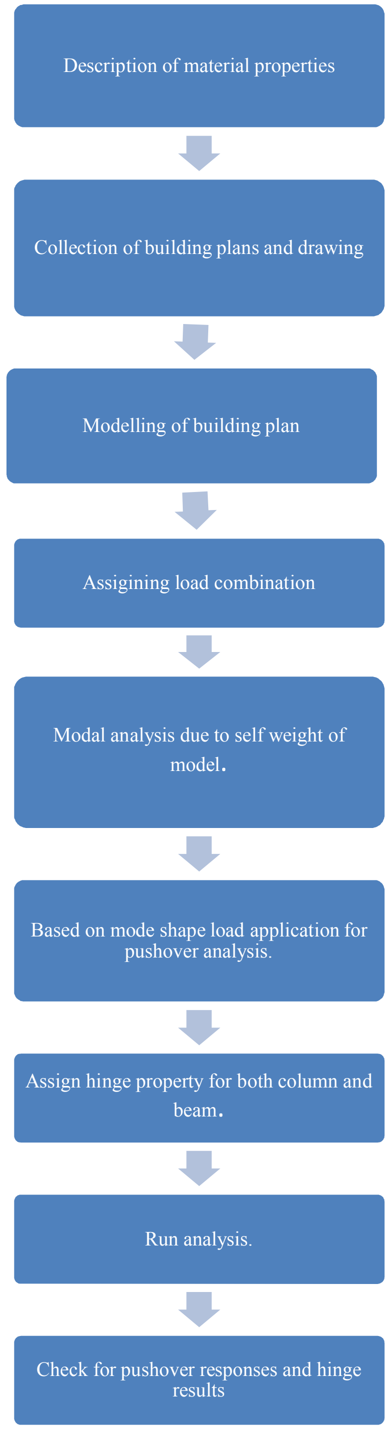
IV. OBJECTIVES

1. To analyse the structure in terms of story displacement, story drift by performing the Pushover analysis in E-Tabs.
2. To validate the responses of Pushover analysis in terms of pushover curve

V. METHODOLOGY

Expanded polystyrene is one of the biggest product polymers produced in the world. It is stiff foam with a unique combination of features such as its lightweight, good thermal insulation, strong absorption of shock, high compressive strength and good moisture resistance in building and construction industries EPS is been used on a very large scale to make insulation foam for walls, roofs and floor insulation EPS also has a great application.

Thousands of small units of styrene called monomers are link together to form a large molecule of polystyrene this process is called as polymerization. These processes take place in three stage area pre-expansion, intermediate maturing and final moulding. At initial stage raw materials called beads to swell up to 50 times of the original size once the desired volume is archived it is released in the bed dryer where it is kept to become dry. Once it's dried it is taken to second stage intermediate maturing stage were the cooled expanded beads which has form a vacuum in their interior must be equalized to atmospheric pressure to prevent collision or impulsion of the beads this process is called as aging process which also help to achieve a greater mechanical elasticity and improve expansion capacity of the beads. At the final stage of this pre-expander beads are transferred to a mould where they are compressed to form a block with the help of steam. This block is further cut into desired shape and thickness and with the help of reinforcement assembly machine a galvanised steel truss is been Installed at bottom face ofthe EPS panel. This panel are then used for wall, floor, staircase and roof. They also possess good load carrying capacity, earthquake resistance, moisture resistance.



VI. WORK CARRIED OUT

6.1 Single Block Plan

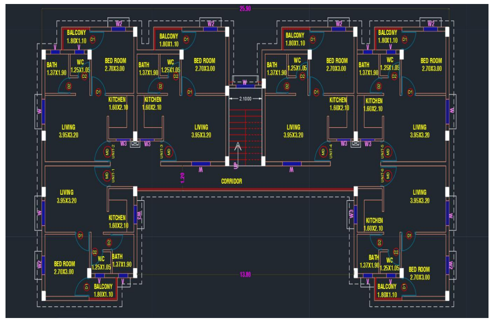


Fig 6.1- Building Block Plan

6.1.1 Carpet Area

Carpet area means an area that can be covered by carpet or net usable area is called carpet area. The carpet area is the distance between the inner walls. Common areas such as lift, lobby, etc. are not included under the carpet area.

1. HALL : 12.64sqm
2. BEDROOM :8.10sqm
3. KITCHEN :3.36sqm
4. BATH :2.85sqm
5. WC :1.31sqm
6. BALCONY :1.98sqm

6.1.2 Elevation

The successive story height of building plan is uniform throughout the height of building.

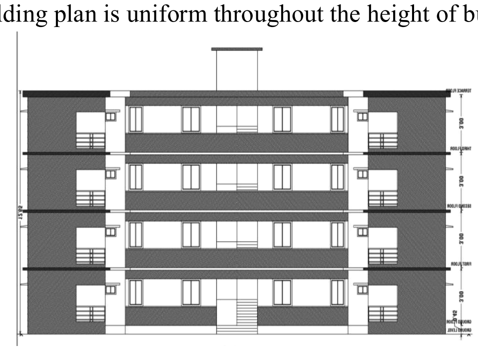


Fig 6.2- Building Block Elevation

6.1.3 Cluster Detail:

1. Ground floor :254.62sqm
2. First floor : 254.62sqm
3. Second floor : 254.62sqm
4. Third floor :254.62sqm

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6.1.4 Project Plan

The project building block plan is uniform to its cross-section with respect to story height of the building.

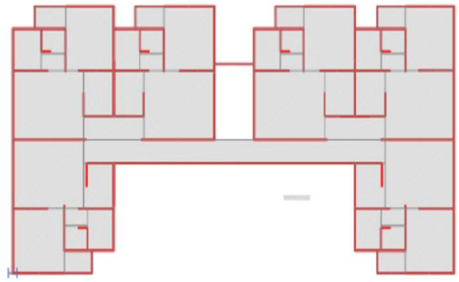

Fig 6.3- Building Block Plan Elevation

6.1.5 Plan Elevation

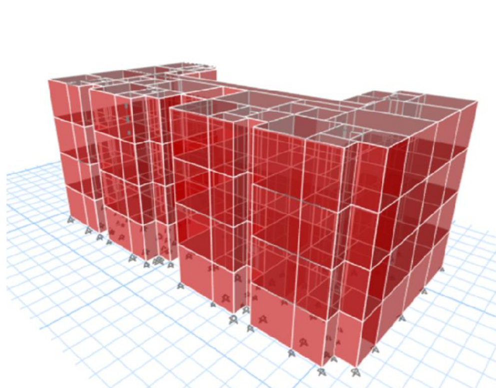

Fig 6.4- 3D View of Building Block Plan

6.1.6 Main Wall Detail

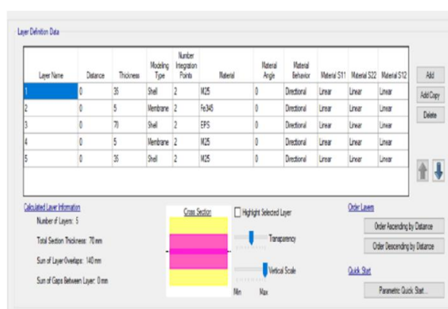

Fig 6.5- Main Wall Properties

6.1.7 Partition Wall

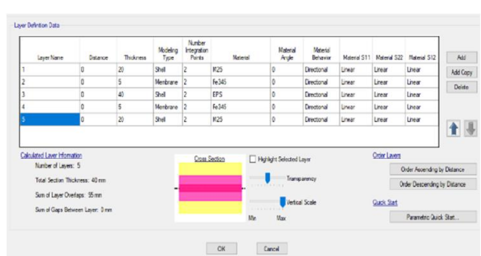

Fig 6.6- Partition Wall Properties

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6.1.8 Floor Slab Detail

The slab thickness of model varies with respect loading condition such as dead load, live load, floor loading conditions.

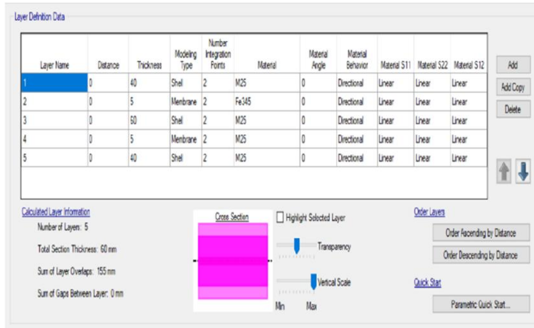

Fig 6.7 Floor Slab Properties

6.1.9 EPS Material Properties

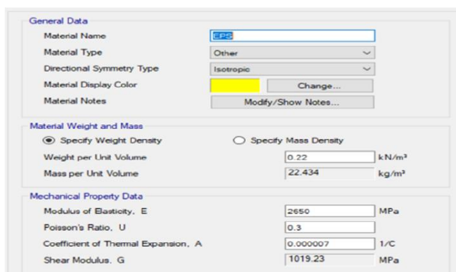

Fig 6.8- EPS material Properties

- Minimum density =15kg/m^3 (for minimum thickness of 60mm)
- Mesh diameter = 2.5-3.5mm (minimum yield stress of 600MPa)
- Compressive resistance =10-60psi
- Tensile strength =22-95psi

VII. G+4 BUILDING BLOCK

- Analysis done in Etabs with help of IS 456, IS 1893:2016(PART-1).
- Two more tall structures should be analyzed in Etabs.
- Pushover Analysis should be performed on a structure and it should be checked manually using code book.

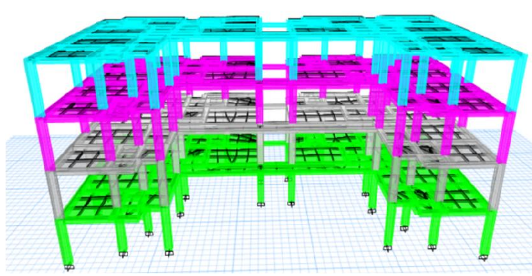

Fig 7.1- G+4 Building Plan

7.1 Description of Frame Structure

A G+7 storied building is analyzed by Pushover analysis and this structure is designed according to IS 1893:2016 and is located in Zone 3. The material properties are M30 grade concrete and Fe-415 steel.

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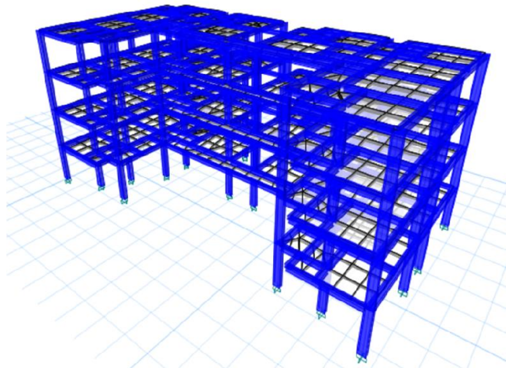

Fig 7.2- 3D View of G+4 Building

7.2 Specification of Structure

Type of structure	Multistorey RC frame
Floor to Floor height	3 m
Soil type	Type-II (Medium Soil)
Damping	5%
Support conditions	Fixed
Importance Factor, I	1
Response Reduction Factor	5

Slab Thickness 150mm
Live load $2KN/m^2$
Seismic zone factor 0.16
Soil type 2
Size of Beam (230*350)
Size of Column (230*450)
Dead load of Beam 1.93 KN/m
Dead load of Column 2.5 KN/m
Dead load of Slab $3.75KN/m^2$

7.3 Modeling Approach

The general finite element package ETABS has been used for analyses. A three-dimensional model of each structure has been created to undertake the non-linear analysis. The existing model and loading structure shown in figure. Beams and columns are modelled as non-linear frame elements with lumped plasticity at the start and the end each element. ETABS provides default hinge. Mass of the column is neglected and whole mass is lumped into slab portion.

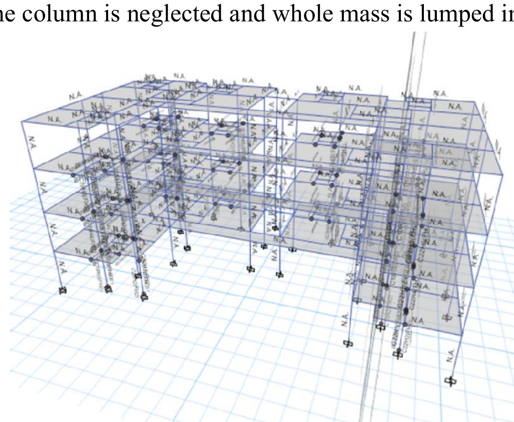

Fig 7.3- Frame Hinge Details

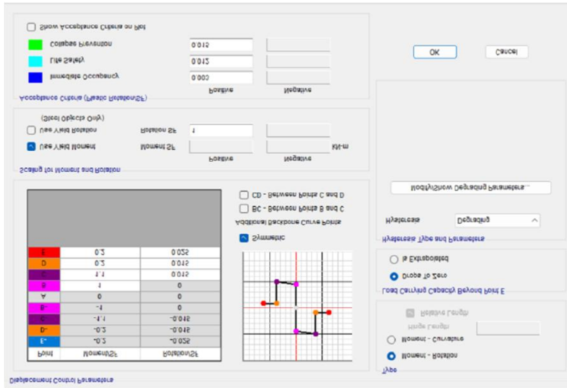

Fig 7.4 Beam Hinge Details

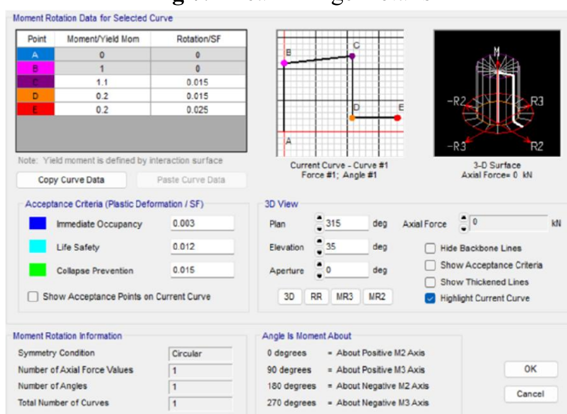

Fig 7.5 Column Hinge Details

7.4 Modal Analysis

Modal Pushover Analysis (MPA) considering the effect of higher modes on the structural performance. It is an improved pushover analysis by the combination of the responses of each mode with a constant lateral load pattern. The total response is determined from the response of each mode by a certain rule. Since the higher modes are taken into consideration, the modal pushover analysis has a superior accuracy and fits the actual solution better. The response spectrum analysis (RSA) is also introduced in this thesis which is shown to be equivalent to the modal pushover analysis for elastic systems. The advantage of modal pushover analysis lies in its accuracy and simplicity for nonlinear analysis. Nevertheless, the lateral load patterns for MPA are assumed to be constant after yielding, an approximation similar to the pushover analysis, which induces issues that must be solved in the future.

The evaluation is based on an assessment of important performance parameters, including floor displacements, inter-story drift ratios, column shears, inelastic element deformations between elements, and element and connection forces. The inelastic static pushover analysis is regarded as an effective method for predicting seismic forces and deformation demands, which approximately accounts for the redistribution of internal forces that occurs when the structure is subjected to inertia forces that can no longer be resisted within the elastic range of structural behavior

7.5 Structural Output

Table 7.1 - Story Definitions

Tower	Name	Height m	Master Story	Similar To
T1	Story4	3	No	None
T1	Story3	3	No	None
T1	Story2	3	No	None
T1	Story1	3	No	None

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Table 7.2 - Load Pattern Definitions

Name	Is Auto Load	Type	Self-Weight Multiplier	Auto Load
~LLRF	Yes	Other	0	
Dead	No	Dead	1	
EQX	No	Seismic	0	IS 1893:2016
EQY	No	Seismic	0	IS 1893:2016
Live	No	Live	0	

Table 7.3 - Load Case Definitions

Name	Type
Modal	Modal - Eigen
GRAVITY	Nonlinear Static
Live	Linear Static
EQX	Linear Static
EQY	Linear Static
PA-X	Nonlinear Static
PA-Y	Nonlinear Static
DEAD	Linear Static

7.6 IS 1893:2016 Seismic Load Calculation along X-Direction

This calculation presents the automatically generated lateral seismic loads for load pattern EQX according to IS 1893:2016, as calculated by ETABS.

Direction and Eccentricity

Direction = X

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 3]

Z=0.16

R=5

I=1

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.2] $\frac{S_a}{g} = \frac{1.36}{T}$

$$\frac{S_a}{g} = 1.868764$$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2] $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

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Calculated Base Shear

Table 7.4 Time Period Along X-Direction

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	0.728	7055.47	210.95

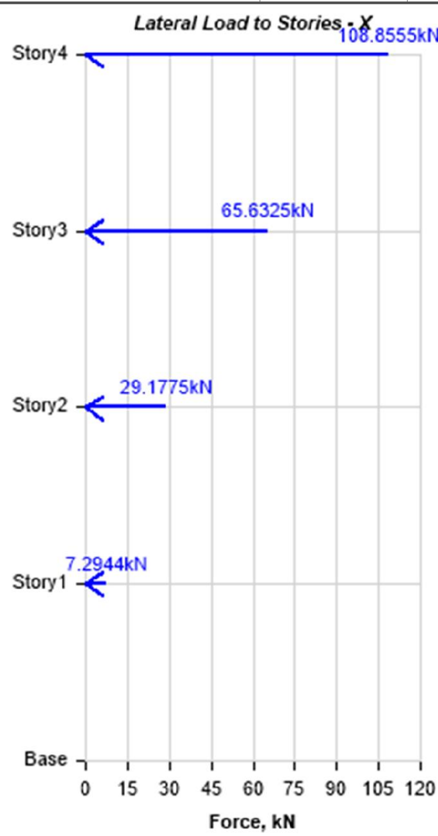

Fig 7.6: Applied Story Forces along X-Direction

Table 7.5: Base Shear along X-Direction

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story4	12	108.85	0
Story3	9	65.65	0
Story2	6	29.15	0
Story1	3	7.29	0
Base	0	0	0

7.7 IS 1893:2016 Seismic Load Calculation along Y-Direction

This calculation presents the automatically generated lateral seismic loads for load pattern EQY according to IS 1893:2016, as calculated by ETABS.

Direction and Eccentricity

Direction = Y

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 3]	$Z = 0.16$
	$R = 5$
	$I = 1$

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.2]	$\frac{S_a}{g} = \frac{1.36}{T}$	$\frac{S_a}{g} = 1.372438$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2]	$A_h = \frac{ZI\frac{S_a}{g}}{2R}$

Calculated Base Shear

Table 7.6: Time Period Along Y-Direction

Direction	Period Used (sec)	W (kN)	V_b (kN)
Y	0.991	7055.47	154.92

Fig 7.7- Applied Story Forces along Y-Direction

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story4	12	0	79.98
Story3	9	0	48.21
Story2	6	0	21.48
Story1	3	0	5.39
Base	0	0	0

Table 7.7 – Base Shear Along Y-Direction

Table 7.8 – Story Drift

Story	Output Case	Case Type	Direction	Drift
Story4	GRAVITY	NonStatic	X	0.0009
Story4	GRAVITY	NonStatic	Y	0.000117
Story4	GRAVITY	NonStatic	X	0.0002
Story4	GRAVITY	NonStatic	Y	0.000117
Story4	Live	LinStatic	X	0.0001
Story4	Live	LinStatic	Y	4.3E-05
Story4	PA-X	NonStatic	X	0.0007
Story4	PA-X	NonStatic	Y	0.000266
Story4	PA-X	NonStatic	X	0.00778
Story4	PA-Y	NonStatic	X	0.000638
Story4	PA-Y	NonStatic	Y	0.000117
Story4	PA-Y	NonStatic	Y	0.007392
Story4	DEAD	LinStatic	X	0.0005
Story4	DEAD	LinStatic	Y	0.000117
Story3	GRAVITY	NonStatic	X	0.0006
Story3	GRAVITY	NonStatic	Y	0.000112
Story3	GRAVITY	NonStatic	X	0.0007
Story3	GRAVITY	NonStatic	Y	0.000112
Story3	Live	LinStatic	X	0.00023
Story3	Live	LinStatic	Y	0.00042
Story3	PA-X	NonStatic	X	0.00035
Story3	PA-X	NonStatic	Y	0.000273
Story3	PA-X	NonStatic	X	0.012075
Story3	PA-Y	NonStatic	X	0.001147
Story3	PA-Y	NonStatic	Y	0.000112
Story3	PA-Y	NonStatic	Y	0.013583
Story3	DEAD	LinStatic	X	0.00091
Story3	DEAD	LinStatic	Y	0.000112
Story2	GRAVITY	NonStatic	X	0.0007
Story2	GRAVITY	NonStatic	Y	0.000101
Story2	GRAVITY	NonStatic	X	0.00075
Story2	GRAVITY	NonStatic	Y	0.000101
Story2	Live	LinStatic	X	0.00032
Story2	Live	LinStatic	Y	0.00056
Story2	PA-X	NonStatic	X	0.0005
Story2	PA-X	NonStatic	Y	0.000215
Story2	PA-X	NonStatic	X	0.014476

Story	Output Case	Case Type	Direction	Drift
Story2	PA-Y	NonStatic	X	0.001559
Story2	PA-Y	NonStatic	Y	0.000101
Story2	PA-Y	NonStatic	Y	0.018211
Story2	DEAD	LinStatic	X	0.00036
Story2	DEAD	LinStatic	Y	0.000101
Story1	GRAVITY	NonStatic	X	0.00086
Story1	GRAVITY	NonStatic	Y	0.00072
Story1	GRAVITY	NonStatic	X	0.0006
Story1	GRAVITY	NonStatic	Y	0.00045
Story1	Live	LinStatic	X	0.0004
Story1	Live	LinStatic	Y	0.00042
Story1	PA-X	NonStatic	X	0.00038
Story1	PA-X	NonStatic	Y	0.000171
Story1	PA-X	NonStatic	X	0.009455
Story1	PA-Y	NonStatic	X	0.00104
Story1	PA-Y	NonStatic	Y	0.014017
Story1	DEAD	LinStatic	X	0.0002
Story1	DEAD	LinStatic	Y	0.0001

Table 7.9- Modal Periods and Frequencies

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	0.991	1.009	6.3406	40.20
Modal	2	0.89	1.123	7.059	49.82
Modal	3	0.728	1.374	8.6337	74.54
Modal	4	0.32	3.127	19.6453	385.93
Modal	5	0.279	3.579	22.4857	505.60
Modal	6	0.216	4.625	29.0622	844.60
Modal	7	0.186	5.382	33.8174	1143.61
Modal	8	0.156	6.414	40.2983	1623.95
Modal	9	0.137	7.32	45.9905	2115.12
Modal	10	0.112	8.917	56.0265	3138.97
Modal	11	0.111	9.024	56.6965	3214.49
Modal	12	0.092	10.845	68.1439	4643.59

Table 7.10 - Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	SumUX	SumUY	RX	RY	RZ
Modal	1	0.991	0.0009	0.8448	0.0009	0.8448	0.1691	0.0002	0.0063
Modal	2	0.89	0.0007	0.0067	0.0016	0.8515	0.0012	0.0002	0.8291
Modal	3	0.728	0.8146	0.0008	0.8161	0.8523	0.0001	0.2102	0.0008
Modal	4	0.32	0.0001	0.1025	0.8162	0.9549	0.6962	0.0002	0.0004
Modal	5	0.279	0.0001	0.0003	0.8163	0.9552	0.0023	0.0005	0.1095
Modal	6	0.216	0.1198	0.0001	0.9361	0.9552	0.0004	0.6077	0.0001
Modal	7	0.186	0.0001	0.035	0.9361	0.9902	0.085	0.0002	0.0005
Modal	8	0.156	0.0002	0.0003	0.9361	0.9902	0.0001	0.0001	0.041
Modal	9	0.137	0	0.0097	0.9361	0.9999	0.0455	0.0006	0.0006
Modal	10	0.112	0.0004	0	0.9362	0.9999	0	0.0001	0.0121
Modal	11	0.111	0.0481	0	0.9843	0.9999	0	0.1208	0
Modal	12	0.092	0	0	0.9843	0.9999	0	0.0007	0

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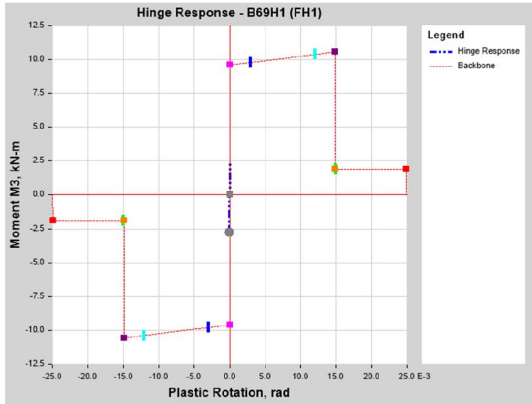

Fig 7.8- Beam Hinge Response Curve

Table 7.11 – Beam Hinge Response Values

Step	M3	R3	R3 Max	R3 Min	State	Status
	kN	rad	rad	rad		
0	-2.7614	-0.000034	0	-0.00003	A to <=B	A to <=IO
1	-1.5356	-0.000019	0	-0.00003	A to <=B	A to <=IO
2	2.362	0.000029	0.000029	-0.00003	A to <=B	A to <=IO
3	2.362	0.000029	0.000029	-0.00003	A to <=B	A to <=IO

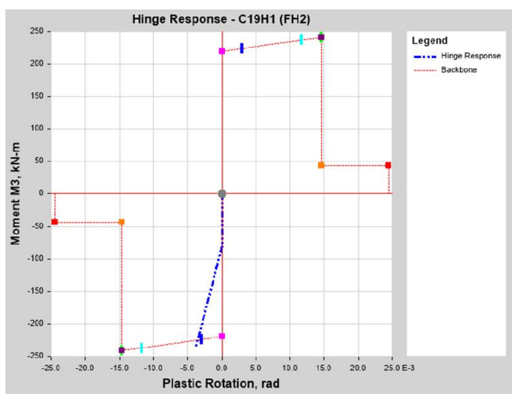

Fig 7.9- Column Hinge Response Curve

Table 7.12 – Column Hinge Response Values

Step	P	U1	M2	R2	M3	R3	State	Status
	kN	mm	kN	rad	kN	rad		
0	-300.603	0	-1.2192	0	0.64	0	A to <=B	A to <=IO
1	-351.3374	0	-3.235	0	-79.99	0	A to <=B	A to <=IO
2	-513.511	0.33	2.5667	-0.0010	-237.35	-0.0032	B to <=C	IO to <=LS
3	-513.511	0.33	2.5667	-0.0010	-237.35	-0.0032	B to <=C	IO to <=LS

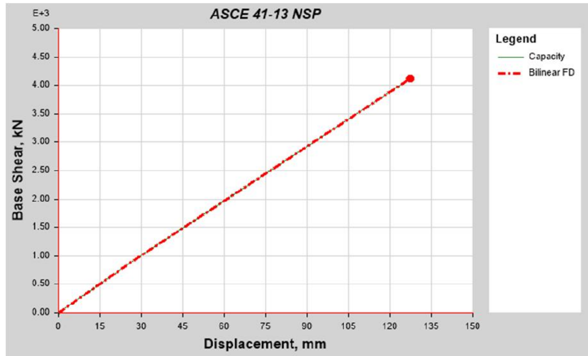

Fig 7.10- Pushover Response Curve along X-Direction

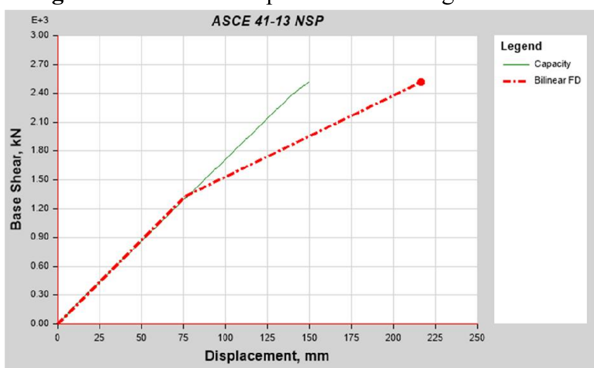

Fig 7.11- Pushover Response Curve along Y-Direction

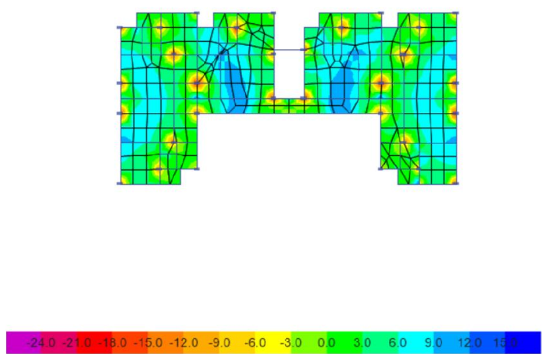

Fig 7.12- 1st Floor Shell Moment Diagram

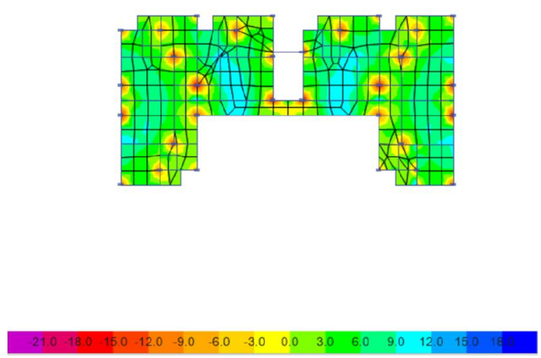

Fig 7.13- Top Floor Shell Moment Diagram

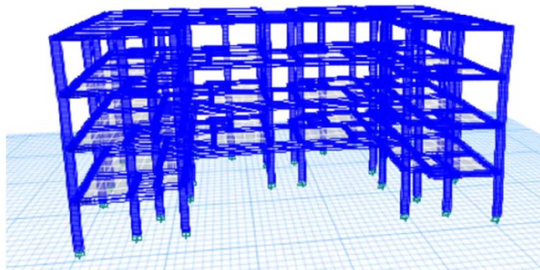

Fig 7.14- 1st Floor Mode Shape Diagram

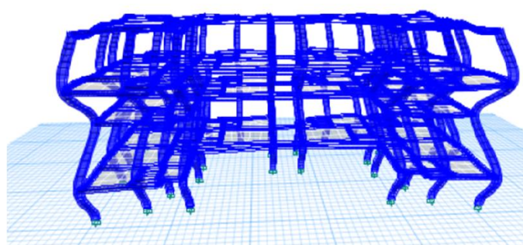

Fig 7.15- Top Floor Mode Shape Diagram

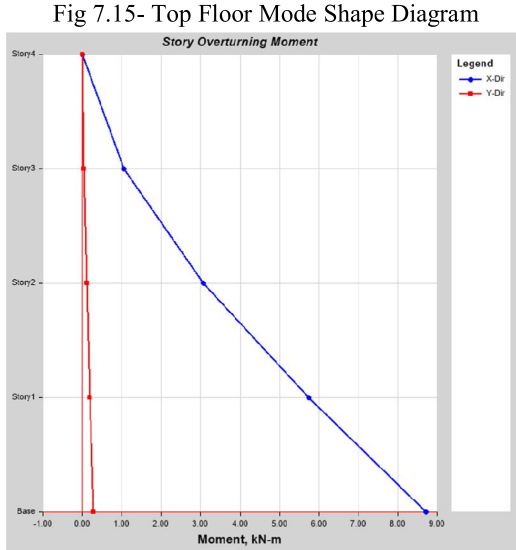

Fig 7.16 - Overturning Moment Diagram

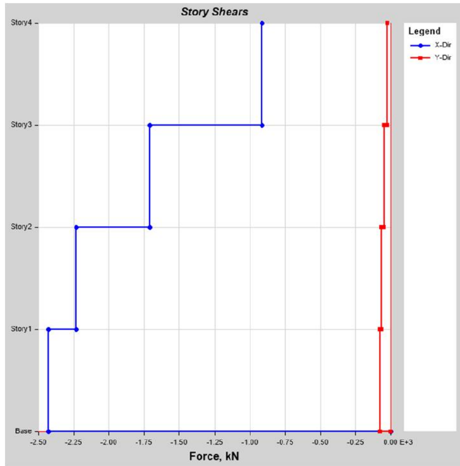

Fig 7.17 – Shear Force Diagram

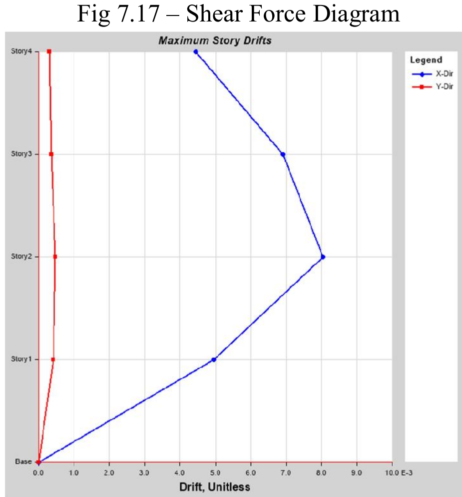

Fig 7.18 – Shear Drift Diagram

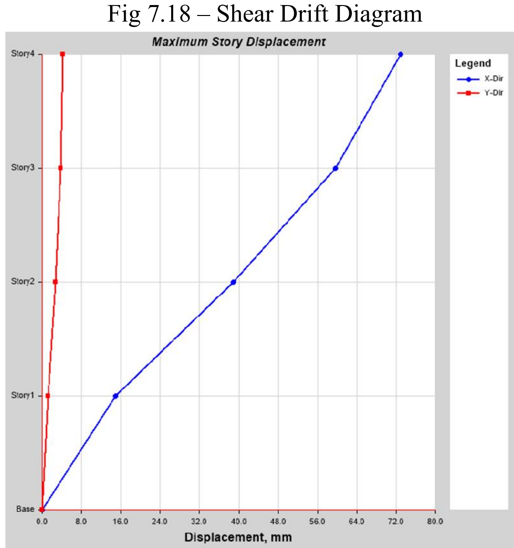

Fig 7.19- Story Displacement Diagram

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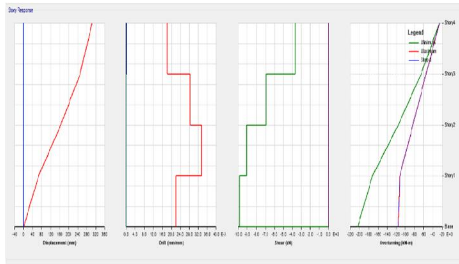

Fig 7.20- Combined Story Responses

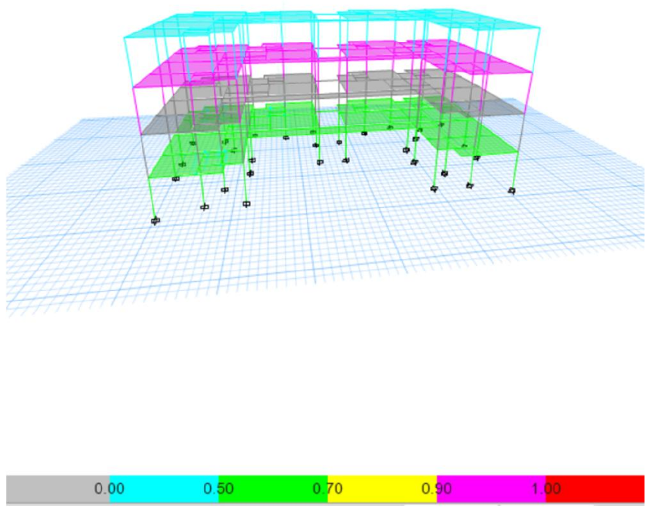

Fig 7.21- Performance Point Level

VIII. WALL FRAME STRUCTURE

Expanded Polystyrene (EPS) wall Panel system is a modern, efficient, safe and economic construction system for the construction of buildings. These wall 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. EPS panel after shotcrete has the following five components they are:

- The outer layer of shotcrete.
- Welded reinforcing mesh of high wire.
- The core of expanded polystyrene sheet.
- Diagonal wire (stainless or galvanized wire).
- The inner layer of shotcrete.

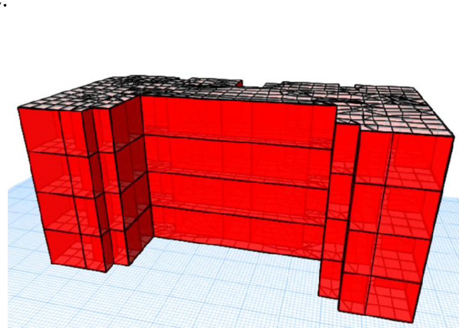

Fig 8.1- Wall Frame structure

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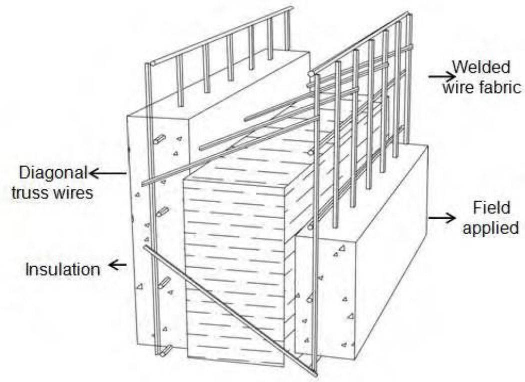
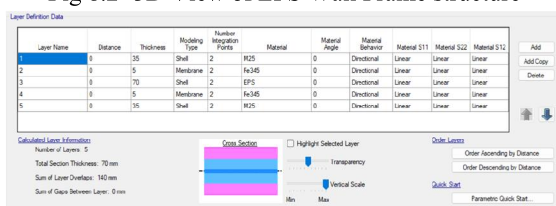


Fig 8.2- 3D View of EPS Wall Frame structure

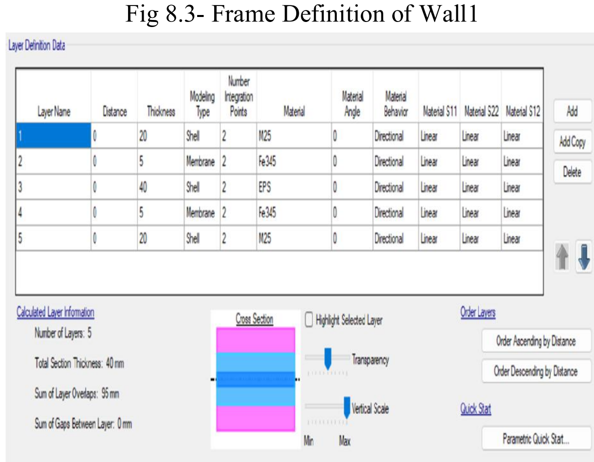


Layer Definition Data

Layer Name	Distance	Thickness	Modeling Type	Number Integration Points	Material	Material Angle	Material Behavior	Material S11	Material S22	Material S12
1	0	35	Shell	2	M25	0	Directional	Linear	Linear	Linear
2	0	5	Membrane	2	Fe345	0	Directional	Linear	Linear	Linear
3	0	70	Shell	2	EPS	0	Directional	Linear	Linear	Linear
4	0	5	Membrane	2	Fe345	0	Directional	Linear	Linear	Linear
5	0	35	Shell	2	M25	0	Directional	Linear	Linear	Linear

Calculated Layer Information
Number of Layers: 5
Total Section Thickness: 70 mm
Sum of Layer Overlaps: 140 mm
Sum of Gaps Between Layer: 0 mm

Fig 8.3- Frame Definition of Wall1



Layer Definition Data

Layer Name	Distance	Thickness	Modeling Type	Number Integration Points	Material	Material Angle	Material Behavior	Material S11	Material S22	Material S12
1	0	20	Shell	2	M25	0	Directional	Linear	Linear	Linear
2	0	5	Membrane	2	Fe345	0	Directional	Linear	Linear	Linear
3	0	40	Shell	2	EPS	0	Directional	Linear	Linear	Linear
4	0	5	Membrane	2	Fe345	0	Directional	Linear	Linear	Linear
5	0	20	Shell	2	M25	0	Directional	Linear	Linear	Linear

Calculated Layer Information
Number of Layers: 5
Total Section Thickness: 40 mm
Sum of Layer Overlaps: 95 mm
Sum of Gaps Between Layer: 0 mm

Fig 8.4- Frame Definition of Wall2

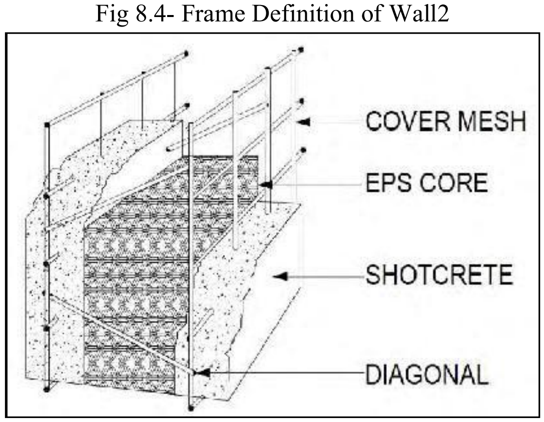


Fig 8.5- Cross Section of Wall Frame

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Fig 8.6- Reinforcing mesh expanded polystyrene core anddiagonal wire.

EPS core panel ensure high levels of thermal insulation, sound insulation, as well as sanitaryand fire safety. EPS 3-D panels allow no additional cost to erect buildings in areas with moving soil, especially heaving, subsidence, frozen ground, and remote areas. Strength and durability - used extruded polystyrene virtually inert and does not absorb moisture, is durable and resistant to decay.

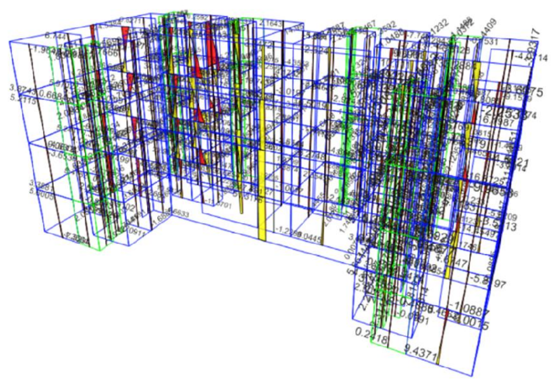

Fig 8.7- Bending Moment of Wall Frame

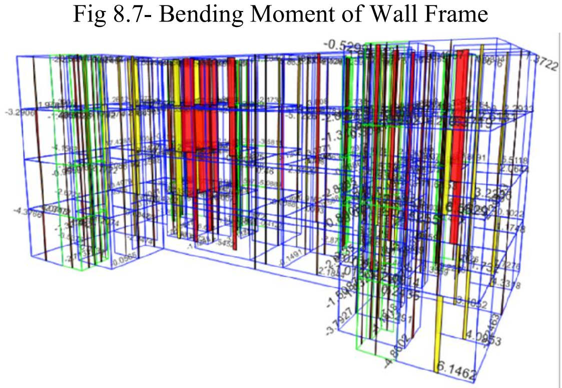

Fig 8.7- Shear Force Diagram of Wall Frame

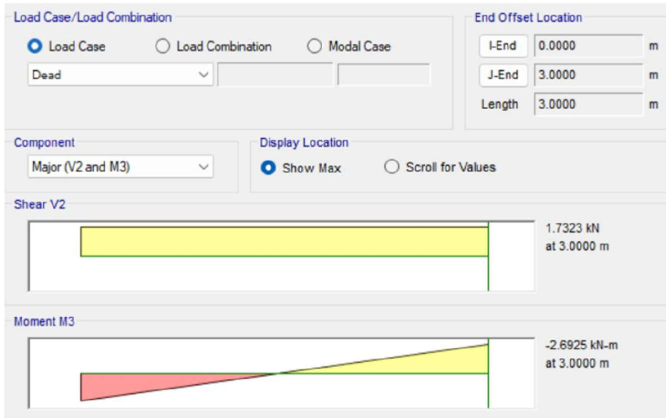

Fig 8.8- Shear Force and Bending Moment Diagram of Single Frame

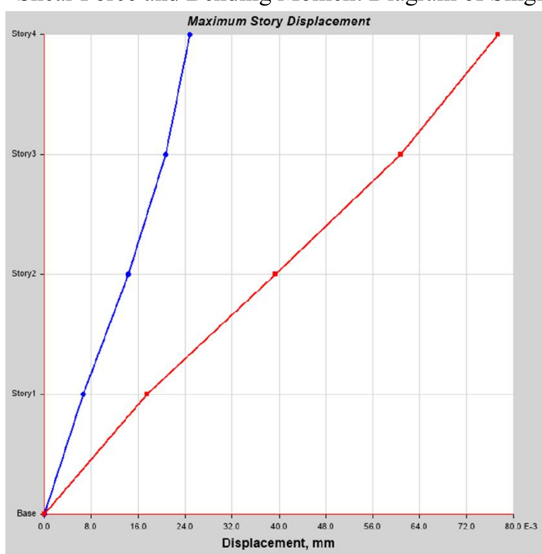

Fig 8.9- Wall Displacement Graph

Table 8.1- Story Displacement Values

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story4	12	Top	0.025	0.077
Story3	9	Top	0.021	0.061
Story2	6	Top	0.014	0.039
Story1	3	Top	0.007	0.017
Base	0	Top	0	0

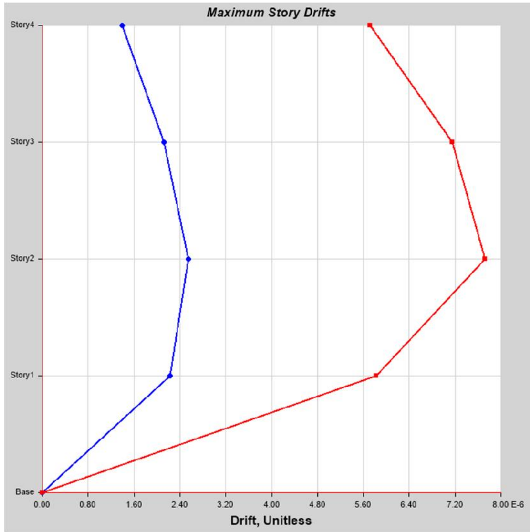

Fig 8.10- Wall Drift Graph

Table 8.2- Story Displacement Values

Story	Elevation	Location	X-Dir	Y-Dir
	m			
Story4	12	Top	0.000001	0.000006
Story3	9	Top	0.000002	0.000007
Story2	6	Top	0.000003	0.000008
Story1	3	Top	0.000002	0.000006
Base	0	Top	0	0

Table 8.3 - Modal Periods and Frequencies

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	0.042	23.79	149.49	22348.79
Modal	2	0.032	31.58	198.48	39395.36
Modal	3	0.031	32.61	204.90	41986.19
Modal	4	0.028	36.15	227.16	51605.85

Table 8.4 - Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	Sum UX	Sum UY	RX	RY	RZ	SumRX
Modal	1	0.042	0.001	0.41	0.001	0.418	0.2459	0	0.33	0.24
Modal	2	0.032	0.3115	0.009	0.312	0.419	0.0017	0.16	0.02	0.24
Modal	3	0.031	0.2804	0.06	0.592	0.479	0.0358	0.15	0.02	0.28
Modal	4	0.028	0.1032	0.15	0.696	0.633	0.1152	0.053	0.35	0.35

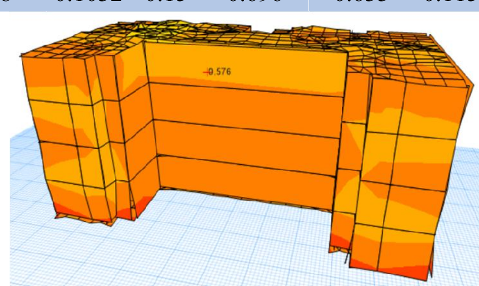

Fig 8.11- Maximum Shell Stress Forces

IX. CONCLUSION

- The EPS technology is found to be economical in terms of material and time requirement is less compared to conventional system of construction.
- Expanded polystyrene can be one of the alternative materials used in achieving the affordability and sustainability in the construction sector. And proper use of this technology in construction project will lead to achieve long run of life of building and can be used as green building structure.
- Pushover analysis has been the preferred method for seismic performance due to its simplicity and has been viewed as an attractive alternative to the nonlinear time history analysis
- Pushover analysis was carried out separately in the X and Y directions. The resulting pushover curves in terms of Base shear – Displacement given for both X and Y direction separately. The slope of the pushover curve is gradually changed with increase in the lateral displacement of the building. This is due to the progressive formation of plastic hinges in beam and column throughout the structure.
- From the results obtained in Y-direction exceeding the limit level between life safety (LS) and collapse prevention (CP), This means that the building requires retrofitting at extreme failure.
- The thickness of the concrete provided for the wall frame structure i.e., 70mm and 40mm and steel wire wire mesh is adequate enough to safely withstand the design forces.

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