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Structural performance of expanded polystyrene panels as an alternative building system

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ABSTRACT

Single lightweight panels of expanded polystyrene (EPS), known as sandwich EPS panels, or simply EPS panels, have emerged as a building system that complemented the conventional one. In this context, this study develops an architectural and structural design for a residence with sandwich EPS panels as a building system. To set the features of the project, we chose a plot in the city of Petrolina-PE and used the SAP2000 software for the structural modeling to establish the efforts to which the walls would be subjected. The structural elements were dimensioned based on the NBR6118:2014 and the crack opening was verified according to the NBR11173:1990. Due to the small overlapping of the walls in the architectural design, the building system needed to be integrated into EPS with beams and pillars of reinforced concrete. Most of the pillars presented minimum reinforcement, while the slabs showed a reinforced lattice beam pattern. In turn, the beams presented dimensions and robust reinforcements due to the higher values of the bending moments obtained. Despite the satisfactory results, further studies should investigate this building system, as well as the national standardization and implementation of specific modeling programs.

KEYWORDS: Expanded polystyrene panels. Structural performance. Dimensioning.

1 INTRODUCTION

Some types of building elements have emerged seeking a building system that complemented the conventional one (regionally constructed in structures of reinforced concrete and masonry fencing), including sandwich EPS panels (AZEVEDO, 2013). These walls are composed of an EPS core and two side plates from 3 to 4 cm in thickness formed by engineered mortar reinforced by electro-welded mesh, in addition to being stiffened with connectors between the plates, according to Siqueira (2017). The features that make this system attractive include its resistance, durability, thermal and acoustic isolation, impermeability, and ease of transportation and modeling.

Several studies and authors have focused on the structural analysis of sandwich EPS panels as a building system, among which it is worth highlighting Fernando, Jayasinghe, and Jayasinghe (2017); Chakraborty, Reddy, and Subramaniam (2021); Li and Fan (2021); Ahmad and Singh (2021); Garhwal, Sharma, and Danie Roy (2022). In the Brazilian context, research studies on single panels of expanded polystyrene have been delimited to the following aspects: the use of this system as a component of structural concrete and their practical procedure installation compared with the building system of structural masonry, both from the point of view of construction planning and environmental sustainability. However, for the structural aspect, there has been a timid introduction of the structural dimensioning and detailing of projects, being more common to find studies that perform comparative analyses and environmental impact assessments using EPS.

Therefore, considering that this building method is relatively recent in Brazil, whose methodology differs from the main systems traditionally used, some factors prevent it from being adopted on a large scale in the country. Thus, knowledge of this work methodology should be enlarged since, despite its advantages, it also implies some difficulties in implementation due to the lack of adequate expertise on the system by designers and builders (AZEVEDO, 2013).

Considering the importance of research studies on single panels of expanded polystyrene used as an alternative structural building system, our research introduces a real project scenario by developing an architectural and structural design for a residence, aiming to show the features of dimensioning and the elements that compose the analyzed building system. Therefore, this article contributes as a guideline to professionals who work with EPS panels considering the need for further content in the sector, in addition to contributing to the theme in the scientific scope given the current lack of national regulations on the structural project of these elements.

2 BUILDING SYSTEM WITH SINGLE EPS PANELS

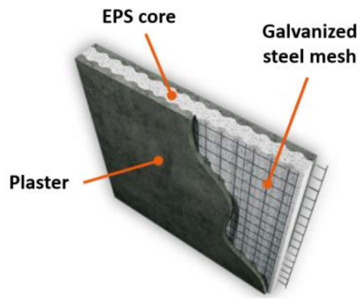
Civil construction now uses expanded polystyrene seeking more versatile, faster alternatives with better cost-benefit based on the following features: resistance and durability, thermal and acoustic isolation, impermeability, and ease of transportation and modeling.

The EPS panels system is formed by an EPS core (Styrofoam), a high-resistance mesh of galvanized steel, and engineered mortar coating (MONOLITE BRAZIL, 2021; Figure 1a). According to Chen and Hao (2014), the system is considered sustainable, economical, and light (facilitating handling and transportability), with thermo-acoustic insulation, being seismic-resistant, among other features. For its lightness, the filling with expanded polystyrene improves the quality of life of collaborators since the physical wear and tear generated by assembling the panels is lower than the efforts involved in services using the system conventional, thus resulting in a faster assembly of the panels (REIS, 2015).

Another element linked to handling is the ease of embedding electrical and plumbing fittings due to the expanded polystyrene core (Figure 1b). In addition, such a building system has a reduced load on the ground (LUEBLE, 2004), which often enables the construction of residences with sill plate foundation – a faster and simpler type of foundation –, in addition to being more economical depending on the case.

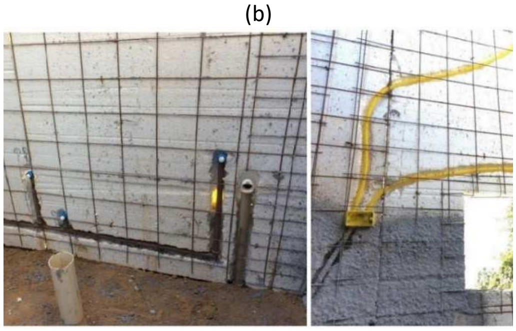
Figure 1 – Building system with single EPS panels

(a)



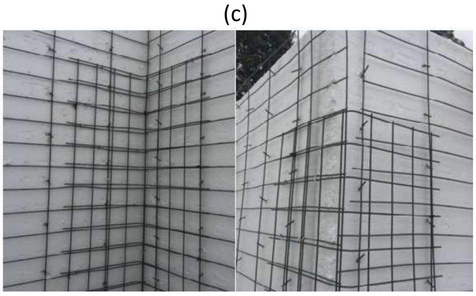
Source: Monolite Brasil, 2021.

(b)



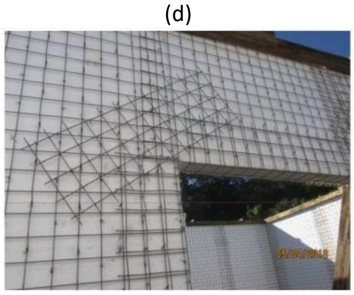
Source: Balbino, 2020.

(c)



Source: Silveira, 2018.

(d)



Source: Balbino, 2020.

Once the foundation bars were fixed, the walls started being assembled by the edges. The panels are attached to each other through an electro-welded mesh, which is I-shaped (width considerably larger than the width) if the next panel is on the same axis and requires reinforcement; or L-shaped if the next panel is perpendicular to the previous one (Figure 1c). The openings of spans for doors and windows, after being cut, have their edges reinforced by a

U-shaped electro-welded mesh (arranged “holding” the edges of the opening) and an I-shaped mesh (arranged at an inclination of 45° at the edges of the openings, Figure 1d). Expansive polyurethane foams are used to fix the frames.

The light composition of the panels enables architectural versatility (REIS, 2015) by allowing the execution of elements that are not possible or feasible in the conventional system. Furthermore, the use of a recyclable, sustainable structure that generates little waste (LUEBLE, 2004) can be seen as cleaner work, generating better use of the investment made, in addition to being environmentally friendly.

Finally, for being lightweight, these walls often do not require the use of beams and pillars, which implies a reduction of supplies linked to these structures. Thus, the benefits of using EPS panels are clear, both for the builder, since the work is faster, more productive, cleaner, and more economical, and for the customer, who will receive a cheaper, faster, more sustainable, and safer service, with good thermo-acoustic comfort and more architectural options than traditional building systems.

3 METHODOLOGY

3.1 Data survey

The project site presented herein is in Nova Petrolina, in the city of Petrolina, Pernambuco state. The plot has an area of 170.56 m², with dimensions of 8 m in width and 21.32 m in depth. According to the city master plan, the allotment is within Residential Area 4 (ZR4), whose urban indices are shown in Table 1.

Table 1 – Urbanistic parameters of ZR4

ZR4 AREA		
	Minimum	0.2
Utilization Coefficient (UC)	Basic	2.5
	Maximum	3
Maximum Occupancy Rate (OR)		70%
Minimum Rate of Natural Soil (RNS)		10%
Frontal Clearance (FC)		2.00 m
Side and Bottom Clearance (SBC)		1.50 m

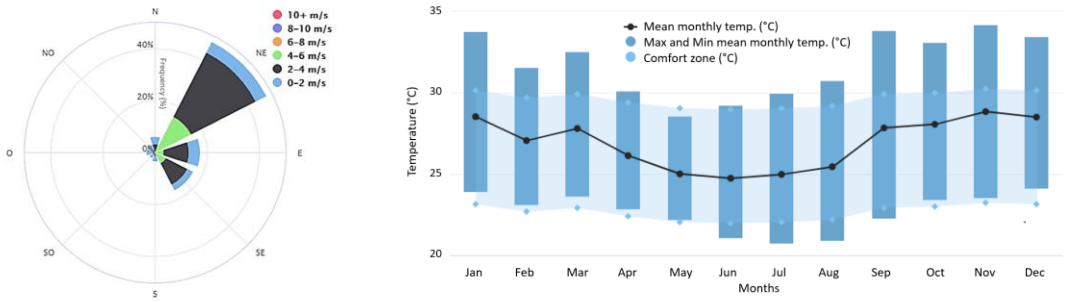
Source: Adapted from Diário Oficial de Petrolina, 2006.

To ensure that the building has an energy-efficient performance, it is important to have relevant data, such as the angle between the north of the project and the geographic north, which defines the solar behavior over the residence during the year, determining the location of the building and the arrangement of the rooms for better use of natural lighting and thermal comfort. In addition, wind data (direction, frequency, and speed) and monthly mean temperatures are also important for the study of ventilation and thermal comfort.

Important climate data for the project are obtained by government institutions and provided on various platforms. The main bodies involved in this work are the National Water Agency (ANA), the National Institute of Meteorology (INMET – abbreviation in Portuguese), and state agencies such as the Pernambuco Water and Climate Agency (APAC – abbreviation in Portuguese). To facilitate access to these data and assist in energy-efficient solutions, the Ministry of Environment (MMA) partnered with the Federal University of Santa Catarina (UFSC) in "Projeteee – Designing Energy Efficient Buildings" (abbreviation in Portuguese), becoming the first national platform to group data and solutions for efficient building design (Figure 2).

Figure 2 – (a) Wind data in Petrolina-PE; (b) Temperature data in Petrolina

(a) (b)



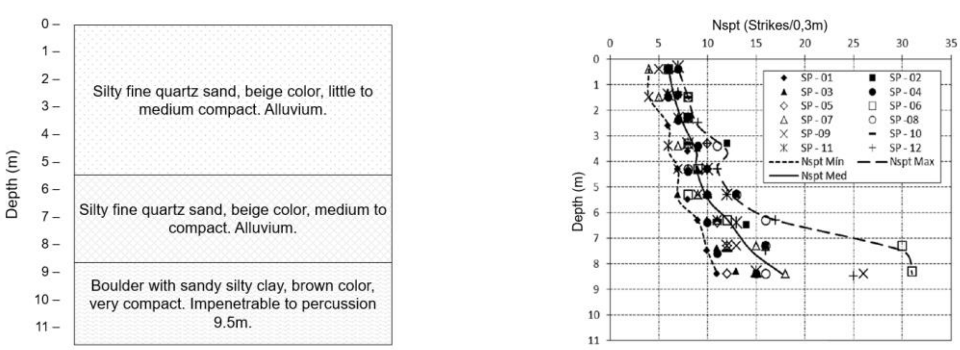
Source: Projeteee, 2021.

To understand the behavior of the soil at the site, a search was made for drilling studies in the city to provide a reference. Thus, a study on the soil of Petrolina (TORRES, 2014) was carried out using 12 percussion boreholes, reaching the impenetrable at a depth of 9.50 m (30 ft), composed of the three layers shown in Figure 3a. Figure 3b illustrates how the Soil Penetration Resistance Index (N_{spt}) in Petrolina grows with depth (Z in m), considering the mean values of N_{spt} (Equation 1):

$$N_{SPT} = 1.5\,Z + 3.6 \qquad (r^2 = 0.91) \qquad \text{Eq. 1}$$

Figure 3 – Data of percussion boring samplings in the soil of Petrolina: (a) Sampling profile; (b) N_{spt} of the soil

(a) (b)



Source: Torres, 2014.

3.2 Architectural project elaboration

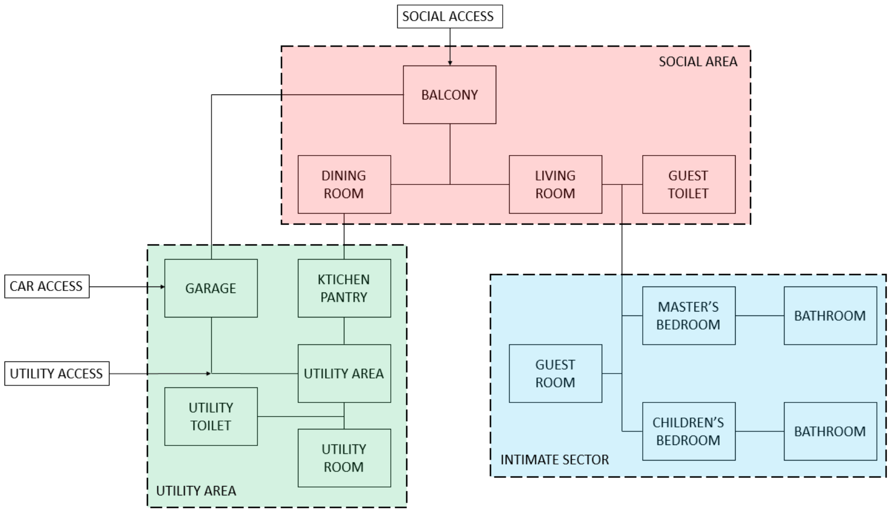
The project site is in the semi-arid region of Pernambuco state, characterized by a high index of insolation and high temperatures throughout the year (Figure 2b). In addition, the plot is in a little urbanized region and, according to the master plan of Petrolina-PE, large-scale buildings are not allowed, which favors ventilation.

Holanda (1976) describes a script for constructions in tropical climates aimed at the Northeast region, pointing out the following elements: use of high ceilings with openings that allow the passage of air; use of recessed walls to protect them from direct sunlight; hollow walls to filter light and allow air to pass through; protection from direct sunlight over windows; use of wide doors that can be left open, and hollow doors that can guarantee privacy without losing light and airflow.

Based on the urban parameters (Table 1), we determined a maximum area of ground occupation of 119 m², with up to 425 m² of constructed area. In addition, front, side, and back setbacks must be complied with. However, it is allowed to build on one of the boundaries, as long as it complies with the requirements of the master plan. This allows us to have information about the arrangement of the property in the plot, also paying attention to the collected climatic data (Figure 2) and the solar chart of the place since it enables the process of evaluating the possible environments and location within the building begins.

Architecture arranges environments through flowcharts based on a requirements program that defines the most adequate arrangement of environments. Flowcharts are schematic representations of the transit between the rooms in the building (BRAIDA; ALBERTO, 2011), which are divided into three areas: social, private, and utility (Figure 4).

Figure 4 – Example of the flowchart for the elaboration of the architectural design of a residence.



Source: Adapted from Gurgel, 2018.

3.3 Structural project elaboration

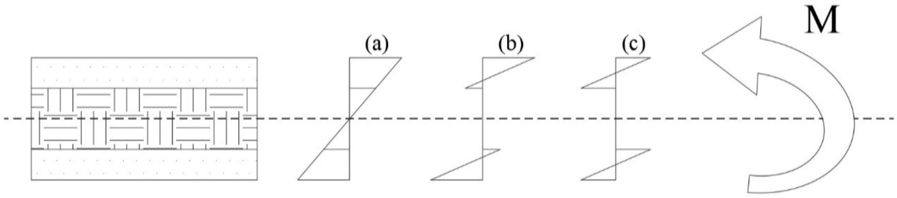
The elements made with reinforced concrete were dimensioned following the recommendations of NBR 6118 (ABNT, 2014), verifying the ultimate limit state (ULS) and service limit state (SLS). Finally, we designed the shape and frame plans.

The dimensioning of single EPS panels requires first understanding their "sandwich" structure with layers of reinforced mortar. This structural element contains features that resemble different types of structures: structural masonry walls, reinforced concrete walls, and elements of reinforced mortar, in addition to pillars, wall pillars, and wall beams. Thereby, the following regulations were used to support the theoretical dimensioning of the walls:

- NBR 16055 (ABNT, 2012): cast-in-place concrete wall for the construction of buildings.
- NBR 16868 (ABNT, 2021): structural masonry walls.
- NBR 11173 (ABNT, 1990): execution and project of reinforced mortar.
- NBR 6118 (ABNT, 2014): reinforced concrete structures.

According to Bertini (2002), walls with a "sandwich" structure might present non-composite, partially composite, or fully composite behaviors (Figure 5), which represents different levels of interaction between the reinforced mortar layers, resulting in a change in the stiffness of the wall and its resistance to efforts, especially if subjected to bending.

Figure 5 – Section composition: (a) fully composite, (b) partially composite, and (c) not composed.



Source: Adapted from Bertini, 2002.

Calculating the wall is easier and more accurate if the behavior is fully composite. However, for being properly industrialized, with greater quality control and good results between theory and methodology, fully composite panels were not used in the analysis. It is worth highlighting that the knowledge of this type of behavior is already consolidated.

In contrast, the same is not true for non-composite panels. Thus, knowing about constructions made using this type of panel, we sought to use a calculation methodology to estimate its resistance. Generally, its building process is regarded as not having proper quality control, being likely to present low resistance and resulting in a potential financial risk, in addition to, more importantly, the risk to the lives involved due to the possibility of the collapse of the structure. In addition, panels that present a partially composite behavior tend to be more economical than fully composite panels since usually there is no need for a complete interaction to resist safely to the current efforts in building with the pattern analyzed herein.

The international standardization process for the dimensioning of single panels of expanded polystyrene requires rupture tests that normally use an interaction chart with vertical and horizontal coordinate axes as the regular effort and bending moment, respectively. Three points must be determined in this chart to define the conditions of efforts in which the panel can be used. These points are defined by the values of the tests of rupture by compression (centered normal), simple bending (only bending moment), and composite bending (normal with eccentricity). In addition, finite element analysis programs are used to determine the efforts to which the walls will be subjected, as they simulate the structural behavior of the walls with greater quality. Thus, we used the SAP2000 software to model the structure.

Due to the lack of experimental results, we determined the wall resistance through formulations of the bending-compression theory, according to Fusco (1981) and Araújo (2010), which uses an iterative process that determines the depth of the neutral line x, given a cross-section, at the interval [0,∞), hence the deformation range of the structural element to be dimensioned. For such a purpose, the values of the efforts and the geometry of the reinforced section must be known, according to the variables in Equation 2, which will have ξ (relationship between the position of the neutral line *x* and the height of the h section) as the only unknown in the equation:

$$f(\xi) = [\mu - 0.5\,\nu - r_c(\xi)\,\beta_c(\xi)] \sum_{i=1}^{n'} (n_i\,\sigma_{sdi}) + (\nu - r_c) \sum_{i=1}^{n'} (n_i\,\beta_i\,\sigma_{sdi}) = 0 \qquad \text{Eq. 2}$$

where: *i* is the steel layer; *n'* is the number of reinforcement layers; n_i is the number of *i* layer bars; *n* is the total number of bars in the cross-section; r_C and β_C are dimensionless terms as a function of ξ; ν is the reduced regular effort; μ is the reduced bending moment; σ_{sdi} is the steel tension on the *i* layer height of steel bars; β_i is the dimensionless time equal to the ratio between the *i* steel layer and the longer edge (d_i) by the height of the cross-section.

To apply the above equations, we need to determine the share of the efforts distributed to each layer of reinforced mortar. However, data and research studies on this topic are few and sometimes outdated. Nevertheless, the existing data indicate that the walls with non-composite behavior showed, in laboratory tests, moments of rupture and cracking that point out to some degree of shear transfer, as described by Bertini (2002) analyzing tests carried out by several researchers. Therefore, the resistant capacity of the walls could be increased with the shear stress between the layers and the EPS core of the walls, because even with a low adhesion resistance, the contact areas are high. Thus, this effect impacts the behavior of the wall, resulting in a higher stiffness, depending on the case, than initially predicted in the calculations.

Therefore, even though the panels are not composed, the connections arranged between the meshes ensure that, concerning the instability analysis (buckling), the reinforced mortar layers interact as a single layer, thus being considered a wall with greater equivalent thickness than merely the sum of the thickness values of the layers individually.

The share of each layer of the resistant wall will be established based on a consideration that seeks to represent the structural behavior of the wall in the function of the transmission of efforts (Equations 3). Thus, the efforts calculated for the structure (bending moment – M_d and regular effort– N_d) on the modeling program are used to verify the structural safety of the panels.

$$N_{d\,1.2} = \frac{N_d}{2} \mp \frac{M_d}{t + t_{EPS}} \qquad \text{Eq. 3}$$

where: t is the thickness of the reinforced mortar layer; t_{EPS} is the thickness of the EPS core; N_{d1} and N_{d2} are the efforts in the center of the reinforcements of each layer, more or less comprised, respectively.

The crack opening was checked according to NBR 11173 (ABNT, 1990), as it is more appropriate to the situation of the wall layer the NBR 6118 (ABNT, 2014). Excessive deformation was checked following the NBR 6118. Finally, shear was checked in case of horizontal efforts.

3.3.3 Sill plate

The sill plate foundation was chosen for being more economical, easier, and faster to execute, which is allowed by its lighter structure resulting from the building method used, in addition to performing well with low resistance for distributing the efforts in larger areas. It is complex to dimension sill plates without using an analysis program of finite elements since the plate efforts always depend on the arrangement of the structures that overlap the foundation. In addition, these programs are generally supported by the grid theory, which replaces the sill plate with a mesh system with springs at the nodes (DÓRIA, 2007). In this sense, the procedure used to determine the coefficient of the springs that represent the resistance of the soil was performed according to Silva (2021). Thereby, we also used the SAP2000 program for the sill plate dimensioning since it allows modeling the superstructure and infrastructure in an integrated manner, providing quality and interaction in the results achieved.

The processing of the model in SAP2000 required data on the sill plate and the soil. However, the soil features (soil type, Nspt, modulus of elasticity, Poisson's ratio, soil layer, etc.) interfere the most in the analysis of the efforts on the sill plate since by determining how the soil reacts to the stress loads; hence the need for Equation 1 and the borehole profiles of Figure 3. Based on the efforts generated in the software, we used the procedure for calculating massive slabs, according to NBR 6118 (ABNT, 2014).

4 RESULTS AND DISCUSSIONS

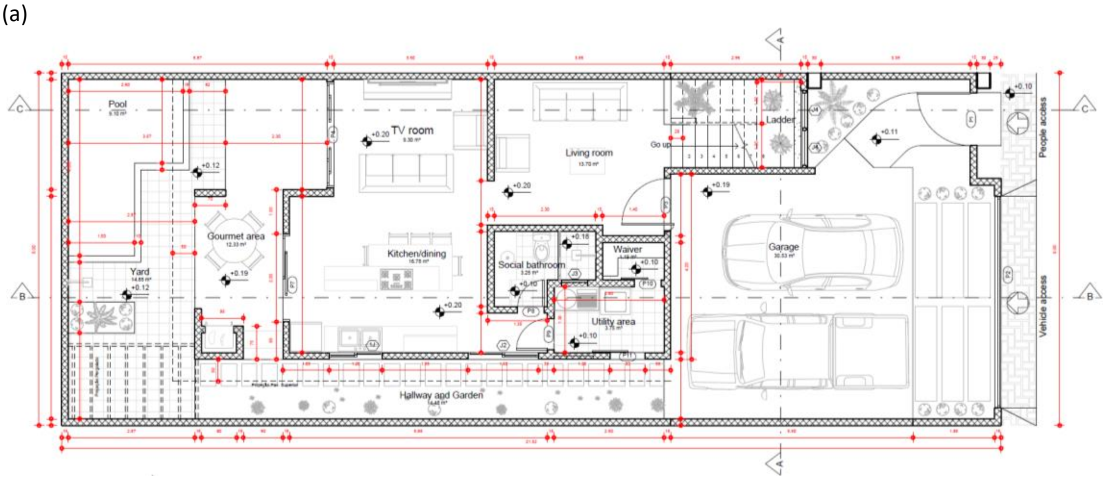
4.1 Architectural project

The architectural design (Figure 6) focused on the use of environments with higher ceilings. Nonetheless, the height limit imposed by the master plan for buildings in Residential Area 4 (ZR4), in addition to the dimensions of the beams, prevented the use of ceilings taller than 2.70 m. Another recommendation followed was the use of recessed walls and eaves that help in shading the windows. The recommendations of using wide doors, walls with hollowed-out elements, wet areas in the direction of the rising sun, and doors with ventilation openings were also considered.

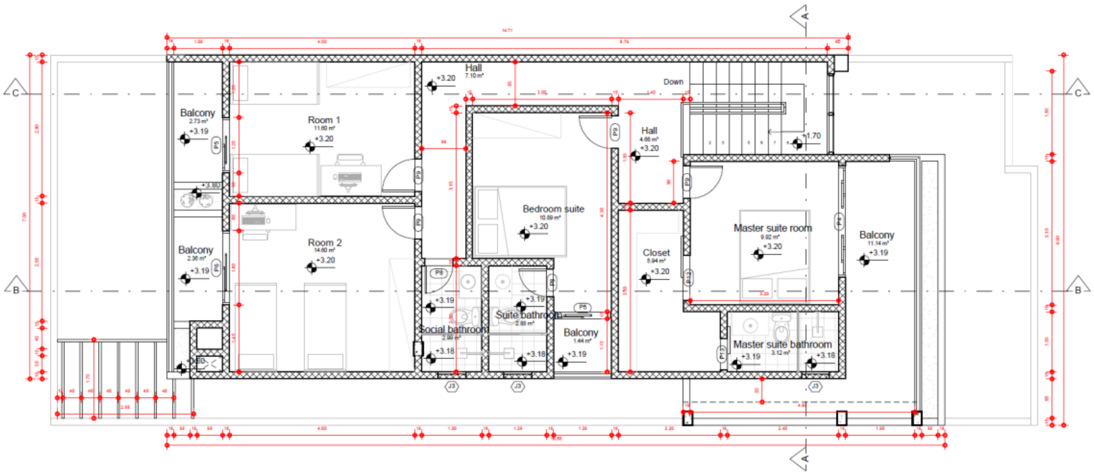
The main problem associated with the architectural project was the difficulty of structural design due to the reduced number of overlapping walls since the building method using EPS panels, like the structural masonry and concrete walls, requires that the structural walls between the floors are overlapped to ensure safety and ease of dimensioning of the structural project. Thereby, our project demanded an integration of the building system of single EPS panels with beams and pillars of reinforced concrete since the irregular distribution of the walls between the floors did not allow their partial use as structural elements, thus limiting the exclusive use of walls as structural elements of the superstructure of the analyzed building.

Figure 6 – Floor plan of the architectural project: (a) first floor and (b) upper floor.

(a)



(b)



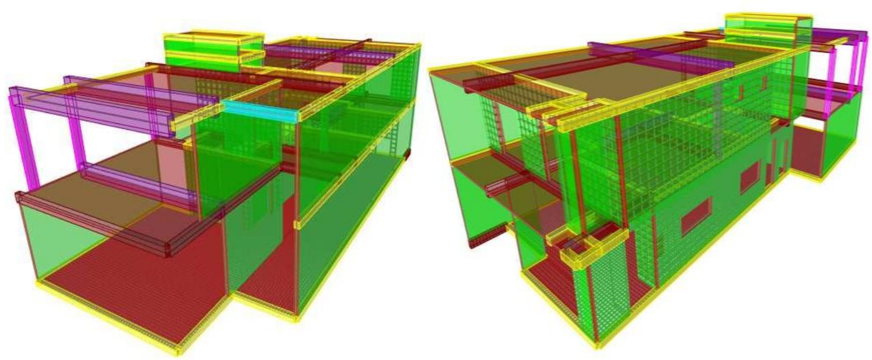
4.2 Structural project

As mentioned in the previous section, before designing the structure, we expected that all walls could be used as a structure for a better distribution of loads. However, such an idea was disregarded upon observing that it would imply a misunderstanding in the distribution of efforts for the structure modeling. Thereby, the structure was remodeled according to the scheme in Figure 7.

Based on the modeling analysis, walls perpendicular to the beams of unidirectional slabs and distant from the edges parallel to the beams can be used as structural walls and regarded as concentrated loads on the slab profile. However, such a possibility should be avoided or disregarded if there is no detailed study.

Figure 7 – Isometric perspective of the structure modeling: (a) front and (b) back

(a) (b)



Constructions built in this system do not require using panels for all walls, allowing the use of less resistant panels for non-structural walls, which will result in greater savings due to the likely price difference. The use of pillars and beams can be omitted when using composed panels with resistance defined by tests, or if the building has a simple structural arrangement.

The dimensioning of the EPS panels was performed to generate the values of resistance of non-composite panels. Thus, the analysis resulting from the modeling in the

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SAP2000 allowed defining the set of critical efforts (bending moment and effort normal). Table 2 shows the parameters that represent the wall used in the project, which are detailed in Figure 8.

Table 2 – Parameters of single EPS panels

Description	Value
Structural wall thickness	14 cm
Panel width in the analysis	100 cm
Wall height in the analysis	300 cm
Mean thickness of the EPS panel	8 cm
Thickness of the reinforced mortar layer	3 cm
Characteristic mortar resistance	35 MPa
Φ mesh	3.4 mm
Characteristic steel resistance	600 MPa
Mesh arrangement	10 cm x 10 cm
EPS core	Classification F

Figure 8 – Illustration of EPS panels

(a) 3D view of the wall (b) wall cross-section

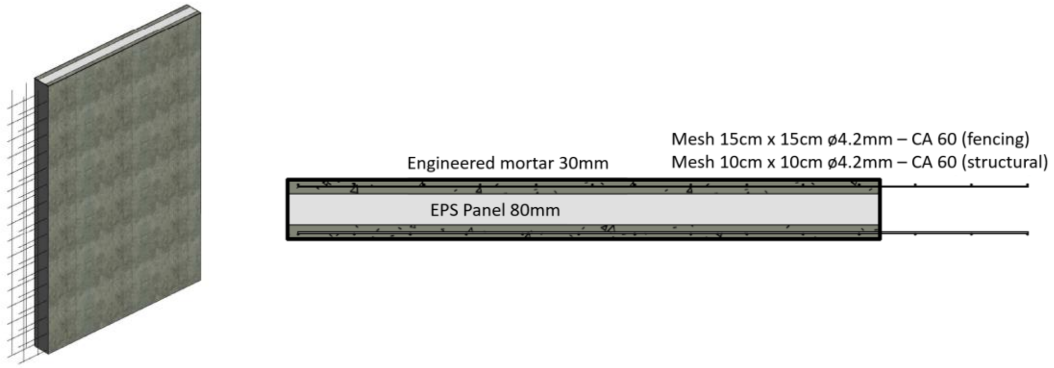


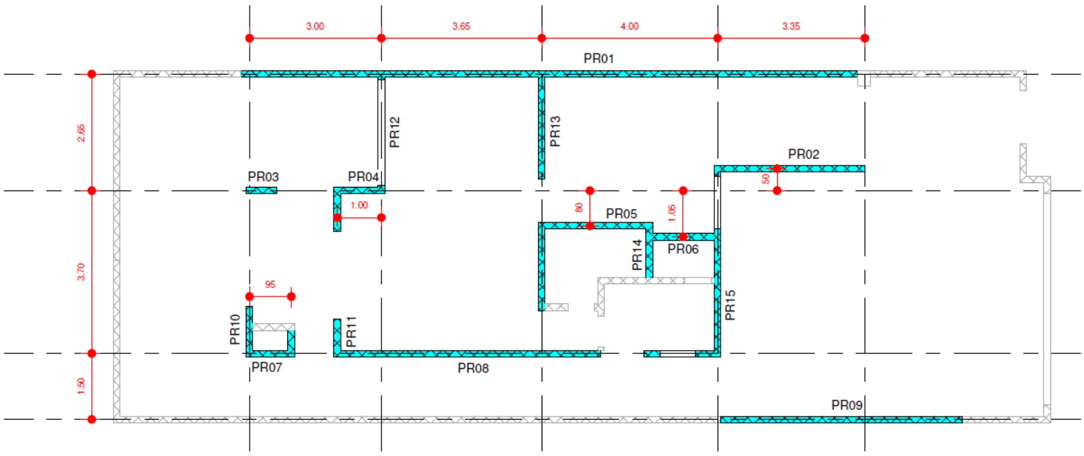
Figure 9 illustrates the arrangement designed for the walls and pillars.

We observed that the walls that are on slabs and parallel to their beams present stress peaks at the lower edges due to the slab displacement (Figure 10a), which makes the contact between the wall and the slab non-existent, i.e., lack of support for the compressed diagonals formed in the walls. Therefore, we recommend not to use structural walls in this condition, or, if they are supported around the slabs, they should be considered beam walls, as is the case for reinforced concrete walls in item 17.1 of NBR 16055. (ABNT, 2012).

Continuous structural walls (present in more than one slab), which are over the spans of the slabs, might cause the suspension of the contact point (the wall works as an inverted beam) because of casting, which may not be predicted, thus generating an unsafe structural behavior, as well as being constructively unfeasible (Figure 10b). If a structural wall must be considered in the above-mentioned scenario, it is recommended to avoid the opening of spaces close to the edges of the wall since, due to the compressed diagonal direction, such an opening would prevent the distribution of compression tensions, which is potentially dangerous. In addition, if an accurate analysis of load distribution is not established, it is recommended to consider that the wall has half of the predicted resistance since it might have a distribution to only one of the edges, instead of both.

Figure 9 – Location plan of single EPS panels: (a) first floor and (b) upper floor

(a)



(b)

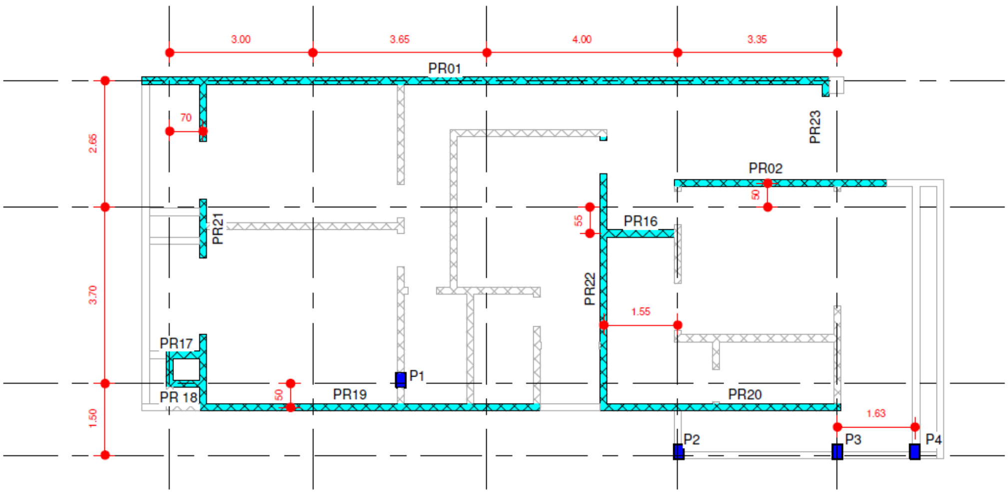
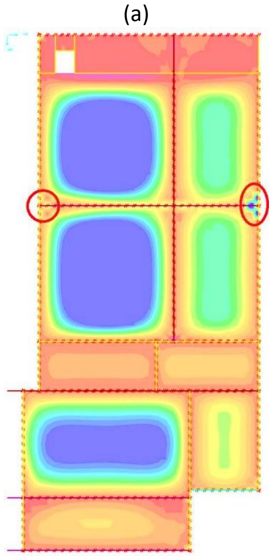
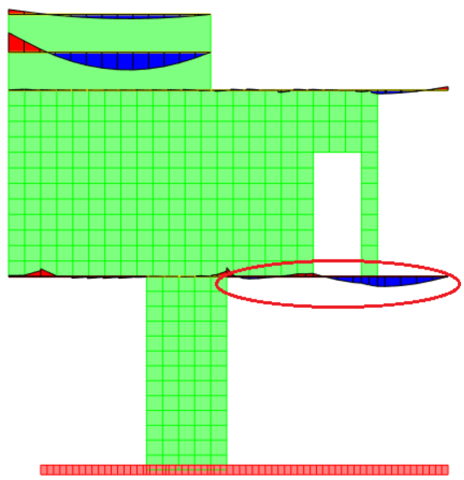


Figure 10 – (a) Illustration of the tension peaks on the lower edges of walls supported on the slab and (b) Diagram of the unforeseen bending moment

(a)



(b)



In addition, the beams VC02, VC03, VC06, and VC07 of the upper floor need to be inverted due to the ceiling height and the height limit of the building. Therefore, we found that the architectural design of buildings should pay attention to the overlapping of walls between floors and simplification of the structure so that the structural design is more optimized, simpler, and hence more economical.

Tables 3, 4, 5, and 6 show the results of the dimensioning of conventional elements of reinforced concrete, such as slabs, beams, pillars, and sill plates. These elements were dimensioned through an electronic spreadsheet, according to NBR 6118 (ABNT, 2014).

Three out of four pillars in the project had minimum reinforcements, while part of the beams had robust dimensions and reinforcements due to higher bending moments. Most slabs presented only the reinforced lattice beam pattern as positive reinforcement, except as indicated in Table 5.

For the sill plate, as the efforts are well distributed due to the arrangement of the structural walls, only a simple arrangement was necessary (Table 6), requiring reinforcements in some areas of greater loading.

As a standardization criterion, meshes of 15 cm x 15 cm with bars of 4.2 mm in diameter were used in the following scenarios: distribution reinforcement, negative reinforcement (complemented, if necessary, with bars of 5.0 mm in diameter) in the slabs, as well as the main reinforcement, distribution reinforcement, and negative reinforcement (if necessary) in the sill plate.

Table 3 – Detail design of the pillars

Code	**Cross-section**		**Longitudinal reinforcement**		**Stirrups**	
	h (cm)	**b (cm)**	**Φ (mm)**	**Amount**	**S (cm)**	**Φ (mm)**
P1	30	20	10.0	6	12	5.0
P2 = P3 = P4	30	20	10.0	4	12	5.0

Table 4 – Detail design of the beams

Code	Cross Section		Positive reinforcement		Negative reinforcement		Stirrups	
	h (cm)	b (cm)	Φ (mm)	Qtd.	Φ (mm)	Qtd.	S (cm)	Φ (mm)
VS01	40	20	8,0	2	10.0	8	7	8.0
VS02; VC02; VC07	40	20	10.0	6; 4; 4	10.0	6; 3; 2	20	6.3
VS03	30	15	10.0	2	8.0	2	15	5.0
VS04; VC01	30	15	8.0	2	6.3; 8.0	2; 4	15	5.0
VS05	30	15	10.0	2	10.0	2	15	6.3
VS06; VC05	30	15	10.0	3; 2	6.3	2	15	5.0
VS07; VS08; VC04	30	15	10.0	2	10.0	2	15	5.0
VS09	50	20	10.0	7	6.3	2	14	5.0
VS10; VC06	40	20	10.0	4; 6	6.3	2	20	6.3
VC03	50	20	12.5	5	10.0	4	14	5.0

Table 5 – Detail design of the slabs

Code	**L_x (cm)**	**L_y (cm)**	**h (cm)**	**Complementary reinforcement/beam**
LS01; LS02; LS04; LS05; LS07; LS08; LS09; LS11; LS12; LS15; LS16; LS17; LS18; LC01; LC04; LC05;	1.28; 2.30; 2.45; 1.55; 2.15; 1.28; 1.30; 1.80; 2.45; 0.58; 0.58; 0.58; 0.58; 1.28; 1.55; 2.15;	2.65; 2.65; 3.45; 3.70; 5.68; 3.10; 3.70; 3.70; 2.90; 0.58; 0.70; 8.40; 1.55; 2.65; 3.70; 3.11;	12	No addition

LC06; LC09; LC11; LC12; LS03; LS13; LS14; LC02	1.28; 1.55; 1.53; 0.58; 2.65; 1.55; 0.58; 2.65	3.10; 3.15; 5.63; 1.10; 3.65; 2.65; 0.60; 4.15		
LC03	2.65	4.25	12	1x Φ5.0 mm
LS06; LS10	3.35; 2.85	5.68; 3.70	12	1x Φ6.3 mm
LC07; LC08	4.15; 4.15	4.20; 4.25	16	1x Φ8.0 mm
LC10	3.35	5.63	12	1x Φ8.0 mm

Table 6 – Information on the sill plate project

Description	Value
Sill plate height	15 cm
Ballast height	5 cm
Characteristic resistance (f_{ck})	25 MPa
Upper mesh used	15 cm x 15 cm Φ4.2 mm
Lower mesh used	15 cm x 15 cm Φ4.2 mm
Reinforcement in requested areas	Mesh 15 cm x 15 cm Φ4.2 mm
Characteristic steel resistance (f_{yk})	600 MPa

5 CONCLUSIONS

The analyses performed herein allow us to conclude that the architecture of a building must be adequate to its local climate to ensure the comfort and well-being of users. It is also worth highlighting the need for a good structural design for the building system of EPS wall panels.

Further research is needed on non-composite panels, as previous studies have found them to be considerably resistant, exhibiting partially composite behavior. However, there is no standard methodology for determining the degree of interaction between the layers and the EPS core.

Simplification for system dimensioning is possible and feasible, but there must be a standardization of the calculations and specific considerations. For example, parameters can be defined by a function of the connectors and their spacings since these are the main differentiators among commercialized panels. Based on previous studies, the connectors determine the composed, partially composite, or non-composite behaviors of the wall and its stiffness.

Much information that enables standardization can be extracted from existing regulations, such as the regulations for cast-in-place reinforced concrete walls, NBR 16055 (ABNT, 2012), masonry structural walls, NBR 16868 (ABNT, 2021), execution and project of reinforced mortar, NBR 11173 (ABNT, 1990), and reinforced concrete structures, NBR 6118 (ABNT, 2014), in addition to some studies on the subject.

To facilitate the large-scale use of EPS wall panels, it is interesting to have programs adapted to their dimensioning since the currently available way to do so is rather slow, complex, and labor-intensive than the usual dimensioning of reinforced concrete structures. Thus, the lack of a specific regulation also affects the development of commercial programs as it hinders the creation of adequate dimensioning scripts.

Our findings allow us to conclude that future studies could include rupture tests to better understand the single panels of expanded polystyrene. It would be important, for example, to develop a more accurate theoretical formulation of the distribution of the work efforts and dimensioning of the panels.

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