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RESEARCH ARTICLE

USE OF POLYSTYRENE MATERIALS IN THE CONSTRUCTION OF BUILDINGS IN THE NORTH-CENTRAL REGION OF BURKINA FASO: ECONOMIC, SOCIAL AND ENVIRONMENTAL ISSUES

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Abstract

The acquisition of decent housing at lower costs is a major concern in Burkina Faso. Indeed, a largenumber of buildings are built in concrete and concrete blocks. This technique of building buildings with these materials is expensive and very energy-intensive, which poses an access problem for the majority of Burkinabe populations. In this research, we study the economic, social and environmental issues of building polystyrene buildings. Our study first focuses on the model of social housing adapted to the north-central region facing the housing problem caused by the displacement of populations fleeing areas with high security challenges. Then we carried out a dimensioning of the model of this building in polystyrene-based construction material. Finally, we carried out a comparative study between construction in polystyrene materials and construction in concrete materials.

Introduction:-

In this rapidly changing world, one of the major daily challenges for African populations, particularly Burkinabe, remains the acquisition of decent housing for a fulfilling living environment, guaranteeing everyone's privacy. In Burkina Faso, a large number of buildings are built of concrete and concrete blocks. In addition to being expensive to build, these construction techniques are very energy-intensive and not very relevant in equatorial climates, because they quickly transfer heat. It is with this in mind that our study focuses on the use of polystyrene material in the construction of buildings. Access to decent housing is a nagging question. The facts therefore indicate a fairly sensitive problem that questions us about the main reasons for the housing crisis in society. Faced with this situation, our research question is as follows: Would the use of polystyrene materials in the construction of buildings in Burkina Faso not be an economic and environmental solution? The answer to this question is the basis of our thinking throughout this study.

Our main objective in this study aims to build buildings in polystyrene materials in Burkina Faso in order to guarantee accessibility to modest housing for all and to reduce environmental pollution.

Method:-

Our study is interdisciplinary since it combines elements belonging to different disciplines. Given that we are interested in the construction of a building in polystyrene materials in the north-central region of Burkina Faso:

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economic, social and environmental issues, the disciplines concerned by our study are experimental sciences (in particular the design of 'a housing project), and applied sciences: the formulation of recommendations to the authorities who will make decisions to apply the results obtained to deal with housing problems in Burkina Faso.

Results and Discussions:-

Pre-sizing the Slab

$l_x = 3.92\ m$and$l_y = 4.15\ m$. The coefficient $\alpha = \frac{l_x}{l_y} = \frac{3.92}{4.15} = 0.94$. Since

0.40 ≤ α ≤ 1.00, we say that the slab carries in both directions. Then the average length L of the slab is: $L = \sqrt{l_x l_y} = \sqrt{3.92 * 4.15} = 4.03\ m$.Flexibility condition:

$h_0 \geq \frac{L}{30} = \frac{4.03}{30} = 0.134\ m$. So adopts h_0 = 20 cm. Compression slab = 4 cm. Polystyrenee honeycomb panel = 16 cm.

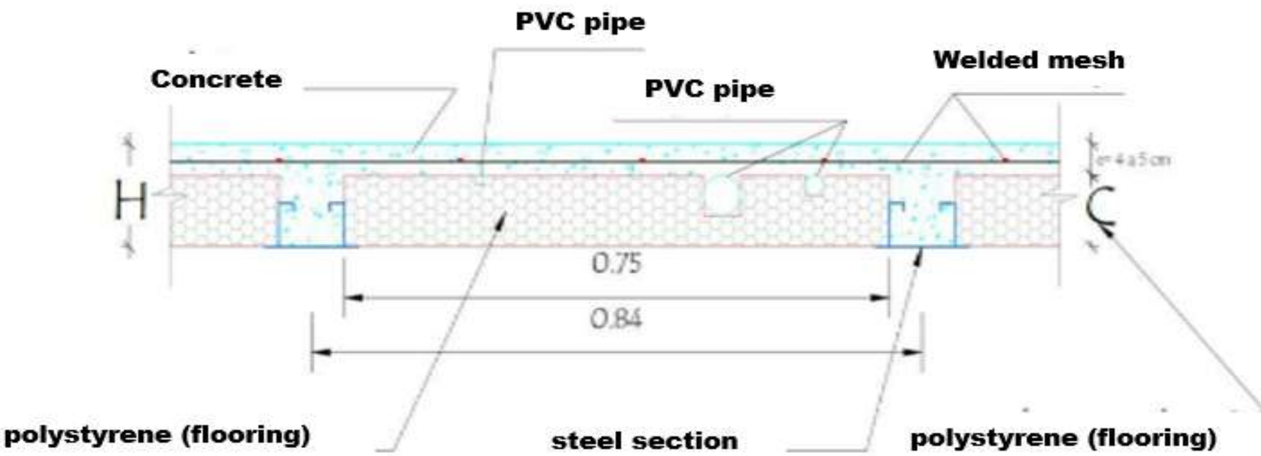

Figure 1:- Sectional view of a slab.

Joist pre-sizing

The span of the joist is:$l = 3.92\ m$. The height of the beams is generally determined by:

$\frac{l}{16} \leq h \leq \frac{l}{10}$. AN: $0.245 \leq h \leq 0.392$ .We will take h =25 cm.

The width is determined by: 0.3h ≤ b ≤ 0.6h results in 0.075 ≤ b ≤ 0.15

We take b = 0.15 cm. The section of the beams will be 15 cm*20 cm. Because the condition of non-flexibility of the slab gives us H_0 = 20 cm.

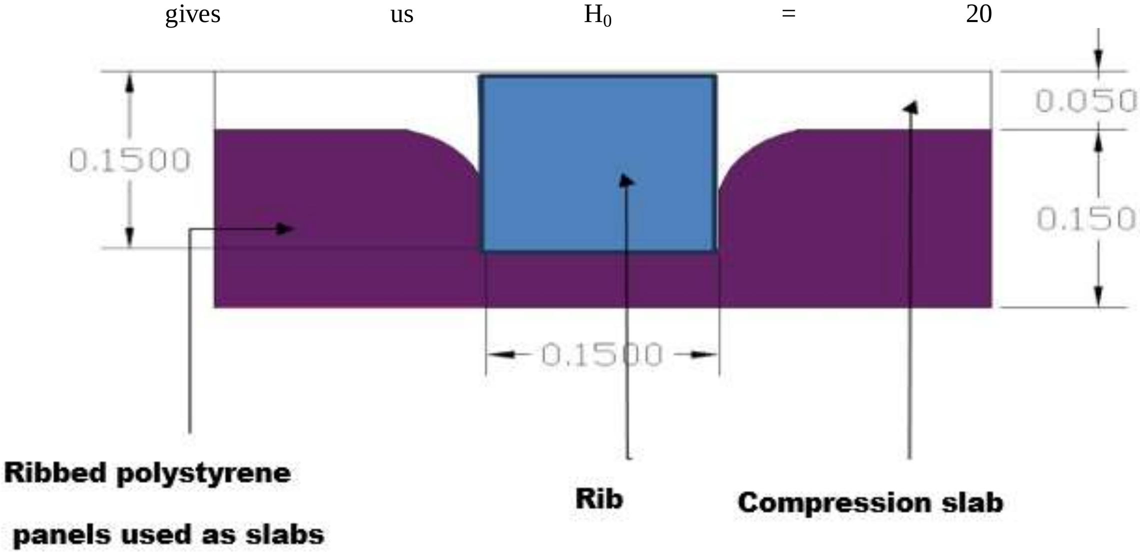

Figure 2:- Detail of the joist.

Main beam
The span of the main beam is: l = 4.15 m. The height of the main beams is generally determined by: l/18 ≤ h ≤ l/14.
AN: 0.23 ≤ h ≤ 0.29 We take h = 0.3 m
The width is determined by: 0.3h ≤ b ≤ 0.6h. AN: 0.09 m ≤ b ≤ 0.18 m
We take b =15 cm and we obtain main beams with a section: 15 cm*30 cm.
We will take the section of 15x30 cm for all the beams in the structural calculation

Figure 3:- Beam on two supports with a section of 15 x 30 cm.

Pre-sizing of Posts and Footings
To determine the footings of our work, we used the CBS structural calculation software for the pre-sizing of the isolated footings taking into account the slab sections, posts and beams found above and subsequently we used the ROBOT software STRUCTURAL Analyzes for reinforcement calculation and structural analysis.

From the pre-sizing using the CBS software, we resulted in the foundations following the foundation plan below for a soil with an admissible stress = 1.5 bars.

Table 1:- Dimensions of soles.				**Table 2: -** Post dimensions.			
№	**DIMENSIONS**			**№**	**DIMENSIONS**		
	A(CM)	**B(CM)**	**A(CM)**		**A(CM)**	**B(CM)**	**HT(CM)**
A1	60	P1	20	P1	15	20	200
A2	60	P2	20	P2	15	20	200
A3	60	P3	20	P3	15	20	200
A4	60	P4	20	P4	15	20	200
A5	80	P5	20	P5	15	20	200
A6	60	P6	20	P6	15	20	200
A7	60	P7	20	P7	15	20	200
A8	80	P8	20	P8	15	20	200
A9	60	P9	20	P9	15	20	200
A10	80	P10	20	P10	15	20	200
A11	60	P11	20	P11	15	20	200
A12	60	P12	20	P12	15	20	200
A13	80	P13	20	P13	15	20	200
A14	60	P14	20	P14	15	20	200

Description of polystyrene materials
Hourdis
They will be made of expanded polystyrene (EPS) panel, of particular shape allowing the incorporation of the beams, enclosed between two plates of welded mesh connected together by steel connectors. These panels are used

for the construction of floors and roofs. Panel thickness and geometry can be modified depending on project scope and requirements.

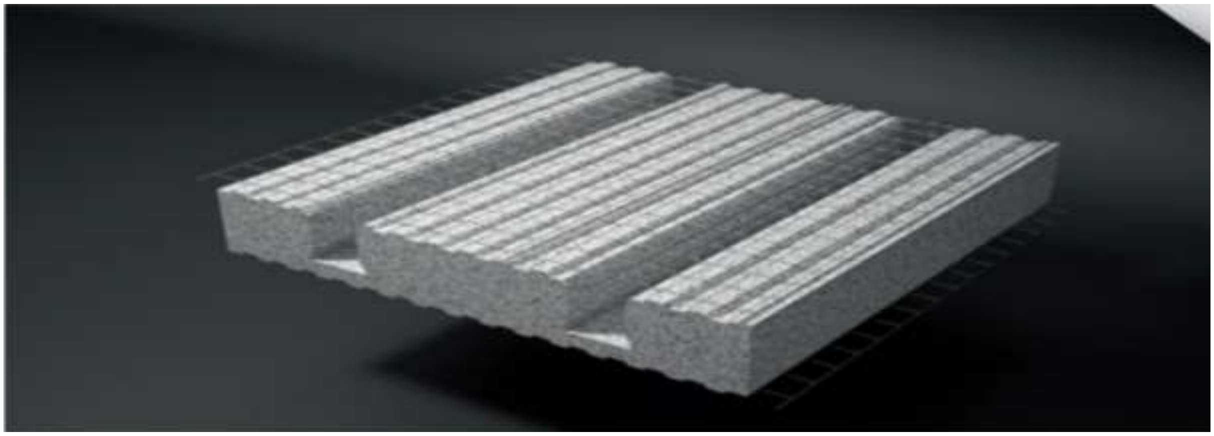

Figure 4:- Polystyrene slabs for slab.

- Reaction to fire: M1
- Type of materials: (F) self-extinguishing
- Sound transmission class: 45dB
- Thermal transmission coefficient K: 0.47 w/m²°c

Les Murs

The walls are made of expanded polystyrene (EPS) panels assembled with two welded mesh plates connected together by steel wires. The shape and thickness may vary depending on needs. These panels can be used as a supporting structure for buildings, exterior partitions and walls, fences and floors. These panels after assembly will be coated with a layer of 3 cm of mortar per side

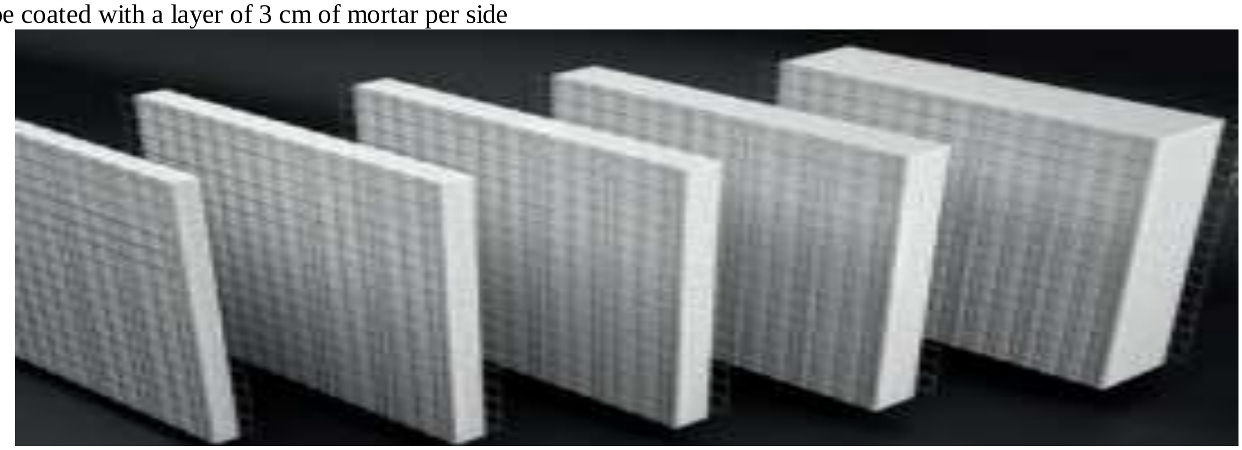

Figure 5:- Expanded polystyrene walls.

Features:

- Reaction to fire: M1
- Type of materials: (F) self-extinguishing
- Sound transmission class: 38 dB
- Thermal transmission coefficient: K. (see table below)

Panneau *Panel*	K(W/m²° C)
SAP 4	0,769
SAP 5	0,636
SAP 6	0,543
SAP 8	0,420
SAP 10	0,342
SAP 12	0,289
SAP 15	0,234
SAP 19	0,187

Table 6:- Classification of panels according to thermal coefficient and thickness.

For our construction, we will use SAP 15

Framing and roofing work

The roof was made of a traditional wooden frame and a polystyrene sandwich panel cover. The frame is made of a solid wood frame (generally oak, fir or pine). Made up of trusses, purlins and rafters, this type of framework can be chosen for attics that can be converted or not. The wood used will be of first choice. All parts will be treated after machining with approved fungicidal, insecticide and water-repellent products. The cover is made of sandwich polystyrene panels. A sandwich panel is a one-piece panel made up of three layers:

Two external layers serving as facing and protection. These are generally resistant materials such as galvanized steel, metal, wood, polyester, aluminum, marine plywood, fiber cement, etc.

A layer of insulating material (often expanded polystyrene or polyurethane. This layer of interior insulation is also called the core of the sandwich panel.

Figure 7:- View of the roof.

Implementation of the work

Site installation

- **Fence:** The site is hermetically protected by a two-meter-high fence.
- **Supply of equipment for the site:** The equipment for implementation has been installed and stored on site. The storage areas for supplies being well defined and legible.
- **Barracks:** includes an office for site managers, for monitoring the execution and progress of the work and a room for the workers.

- **Construction site withdrawal:** At the end of the construction site the fence will be demolished, all equipment and unused materials will be removed from the construction site, so the place will be functional for its intended purpose.

Demolition work

This was carried out after cleaning, stripping the topsoil and filling in the necessary excavations. For the execution of the excavations, soles, stringers, as well as the pipes, the sinking dimensions were defined according to the dimensioning of the foundation accepted by the control authority and the various evacuation slopes. The embankments were made with land having received approval from the Control Authority.

Implementation of works and pickets

General staking consists of transferring onto the ground the position of the works defined by the general layout plan, by means of numbered stakes firmly fixed to the ground, the heads of which are connected in plan and in altitude to fixed benchmarks. The position of the stakes isnoted on a plan which can be the general plan for the installation of the works.

Execution of excavations and embankments

Excavations

The excavations are carried out in such a way as to ensure the safety of workers at all times; they are of the necessary dimensions to be able to encase all concrete or reinforced concrete pieces.

Embankments

The embankments are compacted in layers of 0.15 to 0.20m thickness wetted with the quantity of water which is determined and must be approved by the Control Authority. Backfilling along the foundation excavations must be carried out with the greatest care in order to avoid the penetration of water both into the foundation walls and under the footings.

Masonry or concrete work in elevation can only be undertaken after the backfilling of the excavations has been carefully carried out.

Execution of the foundation

This work was carried out according to the rules of the art while respecting the plans. For a good construction of this foundation, all the following steps were followed:

- Pouring of the BP after excavation of the excavations;
- Formwork and pouring of insulated footings;
- Formwork and casting of post starters;
- 15x15x40 cm chipboard filling of the exterior edges;
- Backfill + compaction using draining material;
- Hedgehog Ing; composed of all 0/40 compacted and adjusted to a thickness of 15 cm. The top is finished with smaller stones;
- Pouring of a 7 cm thick concrete slab;
- Using a ruler or template, we trace the walls and partitions (which reduces implementation time);
- Using a drill, we drill the holes for sealing the connecting reinforcements;
- These ø 8 iron reinforcements can be placed before pouring the screed.

It is good to know that for the construction of polystyrene homes, the system provides a linear foundation which can be made up of a continuous sole or any other type of foundation sized according to the geotechnical characteristics of the ground. The lightness of the product allows savings in the foundation.

Figure 8:- Paving on foundation.

Installation of panels
After raising the posts, we move on to installing the panels; it is an operation which consists of lifting and placing the panels. Thanks to their light weight, a single operator can easily lift and place the panels. This is a factor that contributes to savings in labor and time compared to traditional techniques. This operation takes place in the same way after the construction of the upper floor of the ground floor and consists, after tracing the walls, of:
- Transport and install the panels;
- Carry out bending and wedging;
- Create the openings;
- Install electrical pipes, drainage pipes and water supply pipes.
- Carry out the general check of linearity and verticality.

Figure 9:- Installation panels and rules.

Immediately after placing the panels, the linearity and verticality of the walls must be ensured and checked.

Creation of openings
This step consists of creating the openings to measure and according to the distribution plan on the panels. This involves cutting the panels where the openings have been planned using a grinding wheel and reinforcing the angles by fixing the pre-frames. This work will be done following the following steps:
- Identification and tracking of openings;
- Cutting using a grinding wheel;
- Fixing the pre-frames at the corners as reinforcement.

Figure 10:- 90X210 cm doors.

Figure 11:- Window model created.

Installation of electrical pipes, water drains and water supplies.

A blowtorch is used to create the passage in the polystyrene for the installation of electrical conduits, water evacuation pipes, water supply pipes, switch boxes and junction boxes. It's about:

- identifying and tracing the areas to be heated using a marker;
- cutting out the identified areas;
- the installation and bending on the panel of the element.
-

Figure 12:- Installation of electrical conduits.

Formwork And Concreting of Beams

A beam is the supporting element transmitting the loads to the posts and is rectangular in shape with a section of 15 x 30 cm. After installation of the panels, the reinforcements of the reinforced beams will be placed on the panels then formed and concreted following the implementation process below:

- Tracing for checking levels (leveling of posts);
- Formwork;
- Installation of reinforcements and concrete blocks;
- Concreting and vibration;
- Stripping of formwork.

Figure 13:- Post + beam + panels assembly.

It is important to specify that beams are only necessary for thin panels such as 10 cm, 12 cm and 15 cm thick panels. The 20cm panels which have good compressive strength are used as load-bearing walls.

Creating The Floors

The floor is a horizontal construction element separating two successive floors, constituting the framework of the building and playing a bracing role. The floor is made up of compression slabs and "T" shaped beams and is cast on site. The slabs are replaced here by special shaped panels. These expanded polystyrene (EPS) panels are particular shapes because they allow the incorporation of beams, enclosed between two welded mesh plates connected together by steel connectors.

The installation of these panels requires a formwork plan to finally rationalize the use of the panels and coffers in an optimal manner. The reinforcements for the beams are made and placed in the spaces provided. Those of the compression slab are assembled on site on the panels using concrete wedges.

The concreting is carried out while maintaining the same level with simple tools such as the "level rule", and respecting all standards and precautions. The main constructive requirements in the construction of floors is optimal shoring which will allow good horizontality and flatness of the slab after pouring.

Figure 14:- Floors awaiting concreting.

Stairs Work

Stairs provide access between two successive levels. The implementation steps are as follows:

- Implementation and tracing;
- Shoring;
- Formwork for the bottom of the bench;
- Installation of steels and wedging,
- Formwork for edges and risers;
- Sinking and vibration.

Carrying out each step requires specialized and competent workers.

Construction of the roof

After raising the floor, we immediately move on to the assembly of the wooden frame which will be followed by the installation of the sandwich panel cover.

The work on the frame is done in 5 stages:

- Calculation of the positions and composition of the frame which consists of calculating the material that will be used (boards, rafters, slats) and the slope of the roof depending on the coverage;
- Preparation of the outline of the framework which consists of drawing the farm to a real size;
- Assembling the different wooden elements of the farm consists of manufacturing the trusses;
- Setting up the trusses by positioning them on the top chaining of the floor;
- Assembly of the frame on the house by connecting them through the purlins and attaching it to the posts so that it is stable and solid.

As for the polystyrene sandwich panel covers, they are fixed to the purlins of the frame using screws. To ensure a good seal at the fixing point, each fixing screw has an aluminum washer and two bitumen felt washers.

Wall coating

The coating of the walls consists of applying either with sprayed concrete or with a trowel, a tightly mixed mortar, pushed back with a trowel and spread regularly in three layers. Before the first layer is completely dry, it is covered by the next, the last layer is troweled with a tight mortar. When the mortar has released its water and taken on a certain consistency, the smoothing is repeated several times, without wetting the surface. After completion, the coating must be homogeneous and regular in appearance without cracks or blisters.

This work is done over the entire building and provides an elegant appearance to the walls through their flatness and uniformity.

Subsequently, the work which will follow, namely the supply and installation of openings, plumbing and sanitary facilities, electricity, painting, roads and various networks will be carried out as described in the paragraph describing the materials and will allow us to have a beautiful and solid building as illustrated in the figure below.

Figure 15:- Vues externes du batiment fini.

Comparative Study

Cost of building the building

For the study of the construction cost we limit ourselves to the structural work part because the finishing part is not influenced by the construction material, it depends more on the desired level of comfort. The structural work part designates all the elements which constitute the solidity and stability of the building and those which are inseparable from it. We find there the foundation, the masonry in elevation, the frame and the roof.

Based on the prices applied by the urban community of Douala, we deduce that the price per m^2 per level of a permanent construction is 150,000 Francs. This price includes the cost of the structural work and the finishing touches. The structural part represents 50% of the total cost, or $75000 Frs/m^2$//level. As for a polystyrene construction, the cost of the structural work is $68500 Frs/m^2$/level. In the case of the construction of a single storey building, this cost will be further reduced to $38000 Frs/m^2$.

Building Properties

Concerning the properties of the building we retain 7 criteria, namely: mechanical resistance, waterproofing, thermal resistance, acoustic resistance, fire resistance, manageability and ecological status.

Mechanical resistance

Mechanical resistance is the property possessed by a material to resist rupture or deformation under the action of physical forces or phenomena (pressure, temperature, traction, bending, etc.), chemical (corrosion, etc.). Hard walls have very good mechanical resistance to compression, rated at 4MPa for 15*20*40 concrete blocks. Polystyrene walls have a mechanical resistance of 60kPa. Note that this value is raised when welded mesh is incorporated into the polystyrene panel. In addition to being less resistant, polystyrene has low resistance to rodents compared to concrete.

Waterproofing

In construction, waterproofing is for a wall, the constructive principle which prevents the passage of water in all its states. The water permeability of concrete block walls is high because concrete block is a porous material. This is the main cause of rising capillaries and the development of mold on walls with harmful consequences on health. Polystyrene walls, on the other hand, have practically zero water permeability: They are waterproof. This quality is important in an equatorial environment characterized by high humidity.

Thermal resistance

The conditions for efficient insulation are to use insulators which offer the highest thermal resistance. The higher the thermal resistance of the wall, the less energy will be needed. Hollow concrete blocks have negligible thermal resistance (0.23 m². K/W for a 20 cm thick concrete block). Therefore, additional insulation is essential. As for polystyrene panels, they have very good thermal resistance: 6.25 m². K/W for a 20cm thick panel. This value is greater than the 4m2.K/W recommended for the facade walls of a construction meeting low-consumption building requirements.

Acoustic resistance

Noise is one of the main sources of nuisance for residential residents. Sound insulation of the building walls helps limit them. Polystyrene walls and concrete block walls have moderate acoustic resistance, but not always sufficient.

Fire resistance

Fire resistance corresponds to the time during which construction elements maintain their functionality despite the action of fire. The reaction to fire is the behavior of a material which, under specific test conditions, fuels a fire to which it is exposed through its own disintegration. As a synthetic insulation, polystyrene is flammable. It is classified E in the European fire reaction classification (Euro class). This therefore means that it is a very combustible product. Concrete is classified A: it is non-combustible and therefore has better fire resistance than polystyrene.

Maneuverability and ecological status

Polystyrene is light and therefore easier to handle than concrete blocks. As a result, labor costs during the construction of a polystyrene building are lower than those of a concrete block building. However, polystyrene is a petroleum derivative, it is very toxic in the event of fire and is non-biodegradable: it is not ecological. Even if it is not combustible, concrete block also has a poor ecological record because its production process is responsible for significant CO2 emissions and therefore greenhouse gases.

KIVIAT Diagram (Radar Chart)

Based on the comparative study carried out above, we bring out the table below.

Table 12:- Rating of construction solutions based on criteria.

	CONCRETE	POLYSTYRENE
Cost	3	4
Mechanical resistance	4	3
Waterproofing	2	5
Thermal resistance	2	5
Acoustic resistance	3	3
Resistance au feu	4	2

L’exploitation de ces résultats nous permet d’obtenir le diagramme de Kiviat présentée ci-dessous :

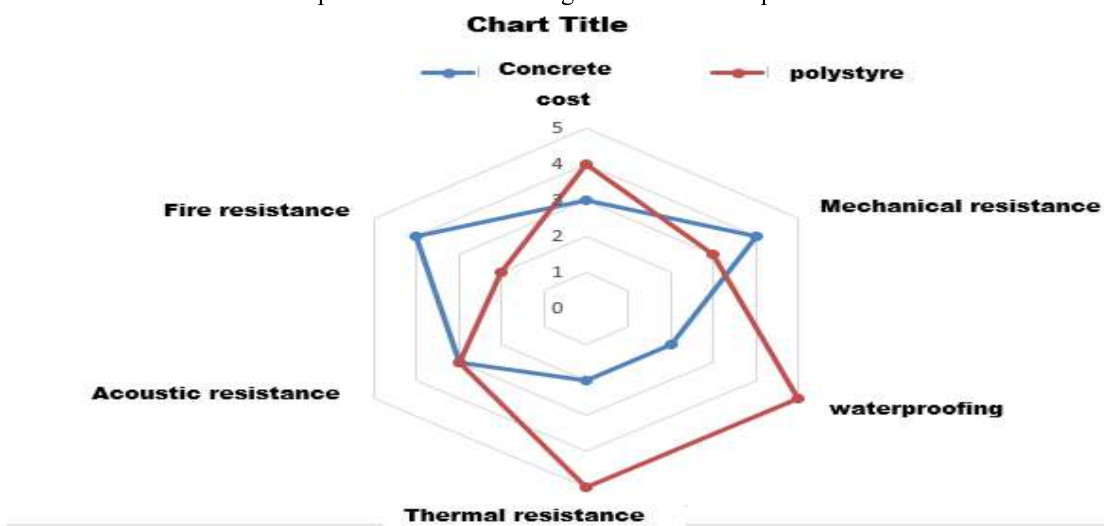

Figure 31: - Diagramme radar.

We observe that the surface area associated with polystyrene is greater than that associated with concrete. This result stipulates that polystyrene constructions are generally better than those made of concrete blocks. In particular, the advantageous prices and the thermal comfort they provide give them a significant advantage over concrete block constructions. It is therefore possible to considerably reduce the cost price of a house, and thus offer everyone safe and comfortable housing. In addition, the low weight of polystyrene panels makes them suitable for constructions on low-bearing soils such as that of the Littoral region in Cameroon. The risk of ground subsidence and therefore collapse would be reduced.

However, these materials have low mechanical resistance compared to concrete and are particularly vulnerable to fires. In addition, when building with polystyrene panels, polystyrene waste is released into the environment. Without recycling actions, they will pollute the environment for nearly 1000 years. All these specifications should be taken into account when choosing the construction material.

Having reached the end of our comparison study, several observations emerge between the construction of a polystyrene construction and solid construction. As an interest for polystyrene construction, we first note a gain of $6\ 500 \mathrm{Frs/m^2}$/level on the price of construction of the structural work for R+1 buildings and that of 37,000 Frs/m² for single-storey buildings. Then, polystyrene offers better sealing and very good thermal resistance, i.e., 6.25 m² K/W for a 20 cm thick panel, a value much higher than that recommended. Good handling is also to be credited to the use of this material.

Conclusion:-

At the end of our study, it appears that polystyrene constructions have a clear advantage over concrete constructions from an economic and social point of view because they are less expensive for the same level of comfort offered. This is more beneficial for African populations whose economic situation is difficult; even more so for populations living in equatorial zones, where diseases linked to high humidity are rife. However, the use of a combustible and non-biodegradable material is particularly harmful to the environment if no measures are taken to ensure recycling. The adoption of polystyrene as a replacement for traditional construction materials would require better education of populations on the use of this material which seems to be a solution to the challenges facing Africa in terms of construction. Thus, we hope that our study can contribute to improving construction projects.

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