

## Semi-Permanent Schools with Reinforced Polystyrene as an Alternative for Communities Affected by Disaster or Crisis

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### Abstract:

Education was and still is one of the most important components of the progress of all nations, so international conventions affirmed the right to education for all children as one of their most important rights. However, disasters and crises have a significant negative impact on societies, especially children, and the extent to which appropriate educational services are provided to them. Therefore, strategies must focus on the need to ensure children's access to education, especially in areas affected by disasters and crises. The study presents the concept of semi-permanent buildings as a suitable tool to accelerate the construction of schools, which facilitates the process of rapid recovery from the effects of disasters and emergency crises, in addition to being economical, safe and easy to use. The study mentions the rapid construction methods for semi-permanent buildings, and in particular the method of construction with reinforced polystyrene panels as one of the modern construction methods, taking into account factors such as speed of construction, flexibility and sustainability. To demonstrate the capabilities of the proposed construction system, the research presents a comparison of this system with an existing model that was built in the traditional manner. By analyzing the results of the comparison, the study concluded that the advantages of using this system for semi-permanent buildings allow providing the appropriate educational environment in the fastest time and at an appropriate cost..

### Keywords:

Disasters, semi-permanent buildings, schools, rapid build systems, reinforced Polystyrene

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### 1. Introduction

In light of the continuous civilizational and technological development of man, his negative impact on the environment has increased, especially with his blatant interference in changing the natural environment and depleting its resources, in conjunction with the effects of natural disasters. Which worldwide caused a great deal of economic damage and death. According to the Food and Agriculture Organization. (FAO, 2015) , between 2003 and 2013 alone, disaster damage amounted to about \$1.5 trillion, with 1.15 million people killed and more than 2 billion affected. The studies also dealt specifically with the effects of disasters on partial and macro outcomes. Partial outcomes such as education. (Gitter, 2007) These factors have caused crises in providing adequate shelter for people and great difficulties in providing the appropriate level of services necessary for human life, such as health and educational facilities, and others.

While the education sector is not generally recognized as a priority in emergencies. No other sector consistently ranks as the least funded or has a lower share of funded humanitarian appeals. (Partnership, 2012). In addition, the international community spends only 1% of aid on disaster preparedness, even though it is an essential investment against the effects of natural hazards.

(UNDP, 2012)

This study examines the benefits and applications of semi-permanent buildings in supporting educational continuity for victims of disasters and crises. It is a versatile and effective solution. It also highlights the building system with reinforced Polystyrene panels, in the construction of educational buildings that combine speed of construction, durability and functional efficiency, which contributes to supporting educational continuity for children's.

The study is concerned with the Middle East region due to its desert and semi-desert nature, and its proximity to the nature of building materials and cultural concepts in general. The Kingdom of Saudi Arabia is currently witnessing a major urban development, which leads to the development and replacement of slums on a large scale, and thus the need to provide educational services to the residents of these areas, until the completion of these mega projects. This makes it a realistic model for dealing with emergency crises, and thus the study can provide an analytical comparison that combines the traditional construction method with reinforced Polystyrene panels as a fast and appropriate construction system. Especially since it has begun to establish itself as one of the alternative building systems for bricks and reinforced concrete, as it is closer to the characteristics and requirements of our

local desert environment. The study concluded by presenting the advantages of the new building system and clarifying recommendations to benefit from it.

### 1.1. Research Goal

The research aims to take advantage of modern construction techniques in providing distinguished educational buildings for those affected by disasters and crises. The focus is on a reinforced Polystyrene board system that achieves speed of implementation, reduces costs and is compatible with the local environment. As an alternative to traditional building systems with bricks and reinforced concrete, achieving rapid recovery for society from the negative effects of disasters and crises, and giving children their right to obtain a distinguished education.

### 1.2. Research Methodology

In this context, the right of children to recover quickly from the negative effects of disasters and crises and to receive a quality education in an appropriate environment must be taken into account as described in the text of the United Nations Educational, Scientific and Cultural Organization UNESCO on the right to education as follows: "We re-affirm the vision of the World Declaration on Education for All (UNESCO, World Declaration on Education for All and Framework for Action to Meet Basic Learning Needs, 1990), supported by the Universal Declaration of Human Rights and the Convention on the Rights of the Child, that all children, young people, and adults have the human right to benefit from an education, that will meet their basic learning needs in the best and fullest sense of the term, an education that includes learning to know, to do, to live together and to be. It is an education geared to tapping each individual's talents and potential, and developing learners' personalities so that they can improve their lives and transform their societies" (UNESCO, Dakar Framework for Action Education for All: Meeting Our Collective, 2000). The research approach is based on formulating a methodology through which the research objectives can be achieved on three levels:

First. Identify the negative effects of crises and disasters on educational buildings.

Second. Review of modern building systems for semi-permanent buildings as a tool for providing educational buildings quickly, efficiently and at an appropriate cost.

Third. Exploring the performance efficiency of the reinforced Polystyrene panel's construction system compared to the prevailing traditional building system.

## 2. An Overview of Disasters and

## Crises Effects

A disaster refers to a sudden and overwhelming event or series of events that cause severe damage, destruction, loss of life and property, displacement of populations, destruction of infrastructure, disruption of basic services such as water and electricity supplies, and in the long run. Social and economic influences. Disasters and Crises can be natural, or they can be man-made, and they can be identified in the following points:

### 2.1. Literature Review of the Concept of Disasters and Crises

#### 2.1.1. Disaster Definition

Many literatures define the concept of disasters, and it will suffice to include a simplified definition according to the United Nations International Strategy for Disaster Reduction, which states the following:

"A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its resources". It also illustrates that "Impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation." (UNISDR, 2009)

#### 2.1.2. Crisis Definition

Many literature define the concept of Crisis, it can be defined as "A situation faced by an individual, group or organization which they are unable to cope with by the use of normal routine procedures and in which stress is created by sudden change". (Booth, 1993) (Moe, 2006)

### 2.2. Types of Disasters and Crises and their Impact on Schools

Disasters and Crises, whether natural or man-made, have significant implications for educational infrastructure. Understanding the effects of various types of disasters and Crises on schools is essential for developing resilient school designs, disaster preparedness plans, and effective response strategies. This overview examines different disaster types and their specific impacts on educational infrastructure. (Setiadi, 2014) (FEMA, 2023)

- Earthquakes can cause severe damage to school buildings due to ground shaking, Buildings may collapse, or experience cracks in walls and ceilings, Utilities such as electricity, water, and sanitation systems may be compromised. Damaged structures may require closure or relocation, interrupting the

learning process.

- Floods can lead to extensive damage to school infrastructure, both within and outside the buildings. Water infiltration can weaken foundations, erode walls, and damage flooring, Electrical systems, plumbing, and water sources may be compromised
- Hurricanes and cyclones pose threats of strong winds, storm surges, and heavy rainfall. It can result in roof damage, shattered windows, and structural failure.
- Wildfires can impact schools in fire-prone regions. Flames can destroy buildings, infrastructure, and outdoor facilities, Air quality may be severely affected by Smoke and ash, requiring thorough cleaning and ventilation.
- Armed conflicts and wars lead to severe consequences for the educational infrastructure, including destruction and damage, and schools may be targeted, resulting in complete destruction or partial damage. As well as the displacement of students and teachers, as the conflict forces the migration of school residents and disrupts education. Schools may lose access to basic facilities, supplies and resources
- Pandemics, such as the COVID-19 outbreak, have profound impacts on the educational infrastructure, including widespread closures due to health concerns and the need for social distancing. Schools are also transitioning to online and distance learning methods. Students face challenges of isolation and anxiety.

This is in addition to a group of disasters that rarely occur and may not occur at all in the Middle East region, which are as follows: Avalanches, cold waves, hail, blizzards, tsunamis, volcanic activity, coastal flooding, and drought.

Some events have been classified as disasters, but they have a limited impact, and their repercussions are not included as an influencing factor in the study. They are as follows: Lightning, landslide, strong wind, winter weather and heat wave.

### **3. Overview of Fast Installation Semi Permanent Building Systems**

Rapid Building Systems play a crucial role in providing educational facilities to disaster victims. Especially the semi-permanent buildings, because they offer an effective solution for setting up schools. To ensure the continuity of education in post-disaster scenarios.

#### *3.1. Characteristics of Quick-Build School Designs for Disaster Victims.*

School Building Systems for Disaster Victims

are intended to provide temporary or semi-permanent educational facilities in the aftermath of a disaster. The most important features that must be distinguished to achieve this goal can be summarized in the following points: (Y, 2020)

- **Building Speed:** It prioritizes fast building and deployment. The designs typically use prefabricated components and modular construction techniques that allow for quick assembly and disassembly. By reducing construction time to a minimum.
- **Portability and Reusability:** Portability is a key feature of fast-build school designs. Mostly standard units are used. Transportability allows for the efficient relocation of schools as needed, whether to different locations within the same community or to new locations as recovery and reconstruction progress.
- **Uses lightweight yet sturdy materials** to ensure structural integrity while facilitating transportation and assembly. Materials such as steel, aluminium, fiberglass or reinforced Polystyrene are used due to their lightweight properties. These materials also provide resistance to environmental factors.
- **Modularity** is an essential feature of fast-build school designs, allowing for flexibility and adaptability to varying site conditions and educational needs. Modular components can be easily connected, stacked, or rearranged to create classrooms, administrative areas, libraries, or recreational spaces. The modular design also enables scalability, allowing the school's capacity to be expanded or reduced based on the changing needs of the affected population.
- **Safe and resilient**, where designs take into account the potential for future disasters, and implement resilience measures to mitigate risks and enhance the long-term sustainability of temporary schools.

#### *3.2. Overview of Types of quick-build schools construction systems*

Building systems for semi-permanent buildings are diverse and quick to implement. They strike a balance between speed and efficiency of construction, affordability and ease of deployment, while ensuring the safety and functionality of school structures. The following is an overview of the rapid build school building systems commonly used for disaster recovery.

##### *3.2.1. Container-based schools*

These structures offer a practical and efficient solution for providing temporary or semi-permanent classrooms in disaster-affected areas. Here are key features and considerations related:

(UNICEF, 2022)

- **Mobility and Flexibility:** Container-based schools are designed with mobility in mind, they can be relocated to different sites as needed, making them suitable for areas prone to recurring disasters or where land availability is limited. This flexibility ensures continued access to education for affected communities as shown in Fig. 1.
- **Modular and Expandable Design:** Containers offer a modular design, enabling easy expansion or reconfiguration as required. Additional containers can be added to accommodate more classrooms or other educational spaces, allowing for flexibility in adapting to changing needs as shown in Fig. 2.
- **Cost-Effective Solution:** The containers themselves are relatively affordable, and their reuse reduces construction and material costs compared to traditional building methods.



Fig. 1. Multi floors Container building (ABNewswire, 2020)



Fig. 2. Single floor Container building (Obinna, 2022)

### 3.2.2. Prefabricated school buildings

Prefabricated school buildings are structures that are manufactured off site in a factory and then transported to the desired location for assembly. It is an effective option as a quick fix that is highly resilient to the effects of disasters to create sustainable urban environments at a later date. Its characteristics can be viewed in the following points: (Ryan M. Colker, 2019)

- Prefabricated units are constructed in a controlled factory environment, allowing for precise quality control and efficient production processes. This method reduces construction time and ensures consistent quality standards.

Fig 3

- Prefabricated buildings can be customized to meet standard design requirements and functional needs. They offer flexibility in terms of floor plans, room configurations, and architectural styles, allowing for tailored solutions that align with the educational objectives
- Prefabricated school buildings are characterized by their rapid construction time. As the building components are manufactured in advance, the on-site assembly can be completed quickly, minimizing project timelines.
- Prefabricated buildings often offer cost savings compared to traditional construction methods. The streamlined manufacturing process, bulk purchasing of materials, and reduced labor costs contribute to overall affordability.
- Prefabricated school buildings can be designed to be easily dismantled, transported, and reassembled at a different location if needed. This feature is particularly advantageous for communities that may require temporary educational facilities due to changing demographics or disaster-related circumstances. Fig 4



Fig. 3. Prefabricated units (Rahman, 2020)



Fig. 4. Prefabricated linear walls (Mishra, 2020)

### 3.2.3. Modular and lightweight structures

Buildings with modular structures are lightweight. They allow for easy prefabrication and assembly on site. They can be manufactured off-site and transported to the disaster-affected area, reducing construction time and providing a faster response. Here are some types of lightweight structures: (Y, 2020)

- **Steel Frame Structure:** Use steel frames as a lightweight and strong structural system. As shown in Fig 5. Or the wooden frame as shown in Fig 6. It features easy assembly and quick disassembly. It is also resistant to earthquakes and strong winds.
- **Composite wall systems:** They are implemented from lightweight panels with insulating properties. These panels can be made of materials such as expanded Polystyrene , fiber cement, or lightweight concrete. They provide thermal insulation, fire resistance and fast construction.
- **Prefabricated insulated panels:** They are lightweight, thermally efficient and provide quick assembly. They can be made with insulating materials such as Polystyrene foam or mineral wool.
- **Truss systems:** steel or wood designed for the roof structure. Trusses provide stability, allow for longer spans, and reduce the overall weight of the roof.



Fig. 5. Lightweight metal structures. (Obinna, 2022)



Fig. 6. Lightweight wood structures (Welch, 2022)

#### 3.2.4. Insulated Concrete Formwork (ICF), and Expanded Polystyrene System (EPS)

Insulated Concrete Formwork (ICF) is a construction technique that involves using interlocking foam panels or blocks as formwork for pouring concrete walls. The foam acts as both insulation and temporary formwork, providing a quick and efficient method for constructing solid, reinforced concrete walls as shown in Fig. 7. (W. Maref, 2012)

Expanded Polystyrene (EPS) core reinforced Panel system is a modern, efficient, safe and economical construction system for the construction of buildings. These panels can be used both as load-bearing as well as non-load-bearing elements as shown in Fig. 8. The EPS core panel is a 3D panel consisting of a 3-dimensional welded wire space frame provided with the Polystyrene

insulation core. The panel is placed in position and shotcrete is on both sides. The EPS panels utilize the truss concept for stress transfer and stiffness, including welded reinforcing meshes of high-strength wire, and diagonal wire, then shotcrete is applied to the panel assembled at the construction site. (CBRI, 2017). Here are some of the key features and benefits of reinforced Polystyrene panels:

- The combination of concrete and foam insulation in the building provides excellent thermal and acoustic insulation capabilities. This is particularly useful for educational facilities where a conducive learning environment is critical.
- As the concrete is poured it cures and hardens, creating a solid and durable wall structure. The walls provide high strength and durability and are resistant to impact, fire and extreme weather conditions.
- Interlocking foam panels or blocks are easily assembled on site, to form the desired wall shape. The foam acts as a guide for setting the concrete, eliminating the need for traditional formwork.
- Provides flexibility in design, allowing for different architectural styles and wall configurations. Foam panels or blocks can be easily cut or shaped to create custom openings, curves or architectural features.
- Buildings with these systems promote sustainability by reducing energy consumption, minimizing construction waste and using recyclable materials. Foam insulation is often made from recycled materials, and the concrete used can include supplemental cementitious materials to reduce carbon emissions



Fig. 7. EPS core panel detail (CBRI, 2017)



Fig. 8. Insulated Concrete Formwork (ICF) (W. Maref, 2012)

### 4. Choosing the Scope of the Study and Documenting Comparison Models

#### 4.1. Define and Choose the Scope of Comparison Models

The use of semi-permanent buildings is not limited to areas of harmful disasters and crises, it can also be an effective means of providing temporary educational services in cases of huge projects to replace slums or unplanned areas or to provide educational services in remote areas until they are developed. Therefore, the comparison model was chosen from the Middle East region, specifically the Kingdom of Saudi Arabia, due to the Kingdom's ambitious development plan to replace unplanned areas with others based on the latest building systems and distinguished architectural planning. The Kingdom's large area, which includes many sparsely populated areas remote from cities represents a suitable environment for applying the concept of semi-permanent buildings.

The vision of 2030 aims to provide high-quality education at all levels, from primary education to higher education. The plan focuses on expanding and modernizing the educational infrastructure, including schools, universities, and research centers. This includes the construction of new educational facilities and the renovation of existing facilities to create an enabling learning environment. (CEDA, 2016)

#### 4.2. Documentation of the Study Sample Models.

To clarify the possibilities of building with the reinforced Polystyrene board system, an actual model that had been constructed before was selected, documented and then analyzed for all its components, which is a model for example for a secondary school with a capacity of 18 classrooms. To achieve a balanced comparison, a proposed design model was made to clarify the capabilities of the proposed building system. In achieving the functional goals of the school, according to standards, while achieving speed of implementation, and reducing the total cost of the facility compared to the traditional model. Where the buildings with prefabricated units of reinforced Polystyrene and covered with a layer of whiteness to be suitable for weather conditions in the desert environment, are compatible with the building pattern in the usual urban environment, and do not require the availability of heavy equipment, because they can be dealt with by regular labor without the need for skilled and specialized labor. The following is the documentation for comparison models:

First. The author developed a model that simulates the same area spaces for the study elements according to installing recommendations for the EPS core panel, the model has a height of two floors with a capacity of 18 classrooms, and all spaces meet the requirements of the Engineering Standards Guide for Educational Buildings in the Kingdom of Saudi Arabia, which is shown (Table No. 1).

**Table 1:** Documentation of a developed model using EPS core panel. (Author, A design model developed with one of the companies that produce foam insulation panels reinforced with reinforcing wires, 2023)

Floor	No	Space Name	Floor Plan Drawings
Ground Floor Plan	01	Classroom	
	02	Main Entry	
	03	Chemistry. lab	
	04	Preparatory	
	05	Physics lab	
	06	Biology lab	
	07	Multipurpose Hall	
	08	M. Teacher. Toilets	
	09	Students Toilets	
	10	Staff Entry	
	11	Admin	
	12	Asst. Supervisor	
	13	Teachers Room	
	14	Shaded area	



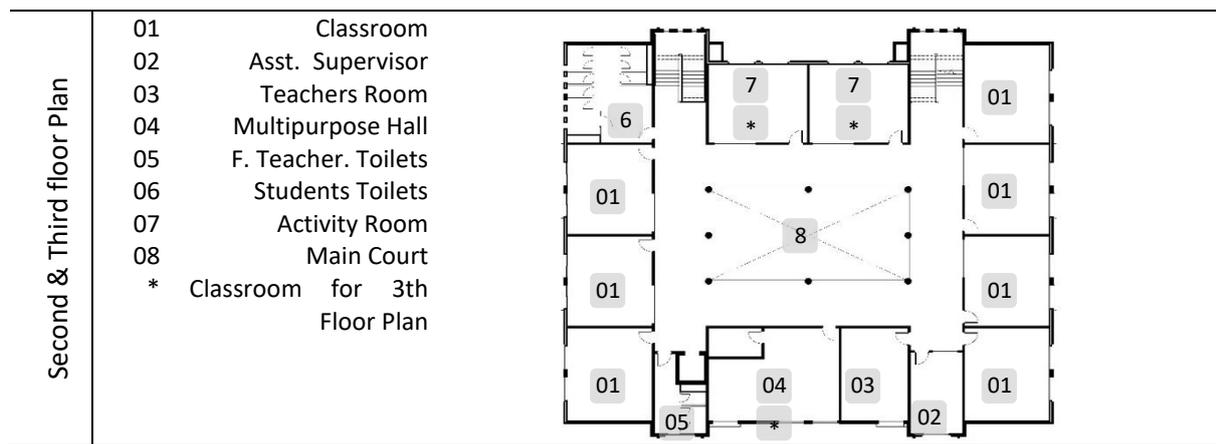
First Floor Plan	01	Classroom	
	02	Com. & Language Lab	
	03	Pantry	
	04	Learning Res. Center	
	05	Activity Room	
	06	F. Teacher. Toilets	
	07	Students Toilets	
	08	Store	
	09	Asst. Supervisor	
	10	Teachers Room	

Second. A traditional model was chosen, which is Al-Azizia School, the model has a height of four floors with the same capacity of 18 classrooms, All spaces meet the requirements of the

Engineering Standards Guide for Educational Buildings in the Kingdom of Saudi Arabia, which is shown (Table No. 2).

**TABLE 2:** Documentation of Al-Azizia Secondary School. (Author, Field documentation of the study area, 2022)

Floor	No	Space name	Floor Plan Drawings
Ground Floor Plan	01	Main Entry	
	02	Classroom	
	03	Admin	
	04	Staff Entry	
	05	Learning Res. Center	
	06	M. Teacher. Toilets	
	07	Chemistry. lab	
	08	Preparatory	
	09	Students Toilets	
	10	Main Court	
First Floor Plan	01	Classroom	
	02	Asst. Supervisor	
	03	Teachers Room	
	04	Multipurpose Hall	
	05	F. Teacher. Toilets	
	06	Students Toilets	
	07	Physics lab	
	08	Biology lab	
	09	Main Court	



4.3. Documentation of the Study Sample Models.

Through the comparison model between traditional design and building with reinforced Polystyrene panels, the following is clear: Fig. 9

- The total area of the walls in the semi-permanent model is less than the traditional system as a result of the reduced thickness of the walls from 35 cm with insulation for the external walls and 20 cm for the internal walls to 16 cm for internal walls.
- The area of the corridors decreases as a result of loading the rooms with corridors in two directions with the corridors of the proposed model instead of individual loading with the corridors in the traditional model.
- Reducing the total volume of air through the inner atrium space, as it is not present in the proposed model, greatly reduces air conditioning loads.
- The height of the building in the proposed model is two floors, and in the traditional model four floors, although the area occupied

on all floors is close, this is a result of the presence of a middle courtyard in the traditional model, which increases the cost of construction in general and the cost of foundations in particular.

- The staircase area increased slightly in the proposed model as a result of the L-shaped design, so that there are three staircases instead of two in the traditional model, the multiplicity of staircases allows greater flexibility in movement.
- Through the comparison model, it is clear that the percentage of savings in the total areas of the building at the level of all floors reached about 23.0%, which reduces the cost in general for the structure and leads to reducing the cost of energy consumption in general also reducing the building’s structural loads, which is reflected in a large saving in the elements of The construction of the building, especially the foundations.

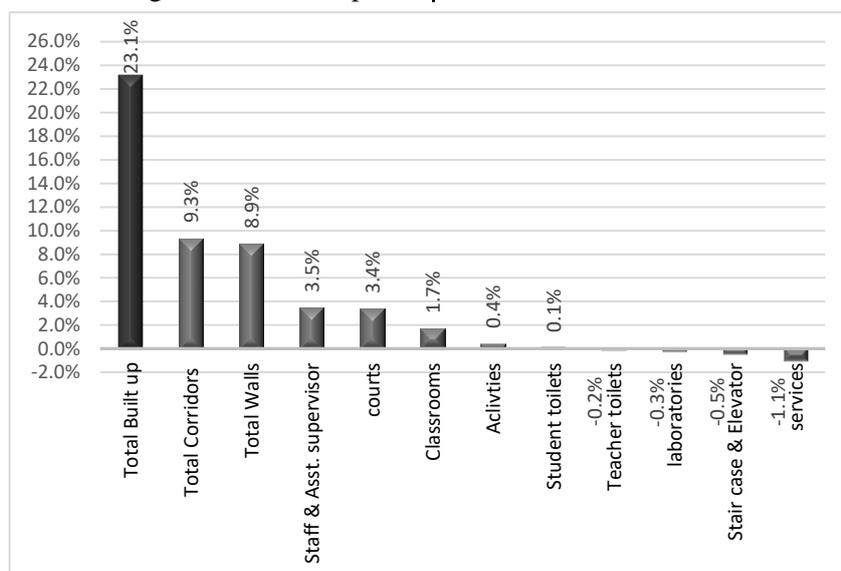


Fig. 9. The percentage of savings in the proposed school model, (Author, A design model developed with one of the companies that produce foam insulation panels reinforced with reinforcing wires, 2023)

## 5. Conclusion

In general, building with EPS insulated panels provides a set of advantages, which makes it an effective choice for various construction applications, especially semi-permanent buildings to deal with the negative effects of disasters, contribute to providing safe shelter for those affected by disasters and contribute to achieving a rapid recovery of society while achieving the appropriate level of services (health, education, entertainment, etc.).

- Provide excellent thermal insulation, reducing heat transfer between the interior and exterior parts of a building, thus reducing dependence on heating and cooling systems.
- Are prefabricated and therefore are able to be quickly assembled on site, resulting in faster construction times compared to traditional construction methods. This can be particularly useful for cases where the rapid provision of shelter (residential and community services) is required for those affected by disasters.
- Do not require a highly trained workforce, only a few moderately trained workers, and do not use heavy equipment for installation. They are lightweight yet structurally strong, making them easy to use and transport.
- Reduce the need for raw materials that need to be transported, stored, and handled (sand and bricks), as well as reduce the amounts of steel required for structural elements.
- Provide good sound insulation properties, which reduces outside noise pollution and enhances acoustic performance inside the building. This can be important for educational buildings where specific noise control measures are required.
- Often include environmentally friendly materials, such as recycled content or renewable resources. Their energy-efficient nature reduces the building's carbon footprint by lowering greenhouse gas emissions associated with heating and cooling.
- Can work as load-bearing walls, as it is a simplified structural system, and they can bear loads of two floors without structural elements such as (columns and beams), and they do not need concrete molds, but they can be reinforced with light elements until the cement screed is installed with plaster made by shoot concrete machine.

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