Assessment of Applicability of Expanded Polystyrene Technology in Addis Ababa Building Projects

Hable Firehun Gebremichael

A Thesis Submitted to

The Department of Civil Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies

Adama Science and Technology University

August, 2022

Adama, Ethiopia

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Declaration

I hereby declare that this Master Thesis entitled "Assessment of Applicability of Expanded Polystyrene Technology in Addis Ababa Building Projects" is my original work. That is, it has not been published and submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Hable Firehun	______________________	______________________
Students Name	Signature	Date

Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Assessment of Applicability of Expanded Polystyrene Technology in Addis Ababa Building Projects" prepared under my guidance by Hable Firehun submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Civil Engineering, the Graduate Program of the Department of Construction Engineering and Management, Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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Major Advisor	Signature	Date

Approval Sheet

I, the advisor of the thesis entitled "Assessment of Applicability of Expanded Polystyrene Technology in Addis Ababa Building Projects" and developed by Hable Firehun, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Bahiru Bewket (Ph.D.) ______ ______________________ _______________

Major Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Hable Firehun have read and evaluated her thesis entitled "Assessment of Applicability of Expanded Polystyrene Technology in Addis Ababa Building Projects" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and Management

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ABSTRACT

The key obstacles in construction for all parties involved, including owners, governmental organizations, home builders, and the general public, are the building industry cost, time, and quality. Even while the industry continues to use labor-intensive, complicated construction processes, the periodic swings in material costs present a significant obstacle. Delay in construction has been one common feature of the construction industry. As a result, alternative building supplies and techniques are required. An alternative building material is expanded polystyrene (EPS), which is made from the distillation of crude oil and is 100 percent recyclable. Utilizing expanded polystyrene material slows down the rate at which the environment is mined for natural resources like wood and stone, encouraging sustainable development. Construction of EPS structures is quick, economical, and they have thermal properties that make them suited for locations with harsh weather. The aim of this thesis is to assess the use of an expanded polystyrene (EPS) as a building construction material in Addis Ababa. It analyzes the benefits and challenges of using the technology and study how an expanded polystyrene panel is extracted from the raw material. It compares cost of wall and slab of expanded polystyrene technology and conventional method of construction. In order to achieve the listed objectives, data were collected using interview, questionnaire and focus group. Five different construction projects were selected through purposive sampling and a total of 60 questionnaire distributed and managed to collect 83.3%. Data were analyzed using excel and SPSS software as well as descriptions added from data gathered from interviews and focus group. It is found that the reduction in time or speed of construction is the main advantage of the technology. This technology faces the disapproval by the market as main challenge since the awareness among the different firms are low. It is found that the cost of slab is higher in case of conventional method but HCB walls are found to be less in cost than the expanded polystyrene panels. A sample of house with 100 m^2 slab and 107.03 m^2 of wall taken to compare the cost and using expanded polystyrene technology reduce total cost of slab and wall by 34.4 %. The completion time was also reduced by 46%.

Keywords: Expanded Polystyrene, EPS Technology, Conventional method, EDAB Homes

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LIST OF ACRONYMS AND ABBREVATIONS

ACI	American Concrete Institute
BASF	Baden Aniline and Soda Factory
CDW	Construction and Demolition Waste
CFCs	Chlorofluorocarbons
EPS	Expanded Polystyrene
EPSA	Expanded Polystyrene Australia
GDP	Gross Domestic Product
HCB	Hollow Concrete Block
HVAC	Heating, Ventilation and Air-Conditioning
ICFs	Insulating Concrete Forms
MMC	Modern Methods of Construction
PS	Polystyrene
PSW	Polystyrene Waste
PUR	Polyurethane
RII	Relative Importance Index
SIPs	Structural Insulated Panels
SPSS	Statistical Package for the Social Sciences

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

A building can be constructed using different methods and materials. Choosing the best amongst the various options is affected by factors such as availability, cost, and location of site. As an example, in most vernacular architecture indigenous materials are used as these are cheap, readily available, and have the most conformity with climate. Despite the effect of materials and climate on the choice of construction method, it is also affected by needs and aims of the building. For example, the choice might be different if the aim is to create an energy-efficient or zero energy building, or where time is the main constraint and the building has to be ready as quickly as possible (Bistouni et al., 2018).

Housing remains a big challenge for many governments, especially in the developing countries of the world. The problem is aggravated by fast increasing population, migration of rural masses into the city and industrial centers and demands for enhanced quality of life. It is difficult to meet this challenge with traditional building construction systems, as it is essential to fulfill the housing demand in a short time without sacrificing quality. Today, the Southern World seems to have largely overcome the housing shortage, but the problem remains intractable in the developing countries because of financial constraints and lack of appropriate technologies (Raju, 2017).

The Construction industry is one of the most important sectors that play a significant role in the GDP of a nation influencing other industry sectors in terms of social economic political developments. With the rapid growth of the industry, there is a shortage of resources (skilled workforce, material, etc.) and is challenged by sustainability and environmental regulation. Hence, there is a need to modify the housing design, advanced technologies, alternative materials and improved methods of construction to reduce cost, minimize CO_2, and provide a sustainable solution with lower energy consumption. In a developing nation like Ethiopia, the majority of constructions are still built using traditional technology and/or methods, which is labor intensive. However, in the last few years the use of modern methods of construction (MMC) for housing has increased, like prefabrication technology and using alternative local construction materials which is driven by a range of factors including demands for faster construction, shortage of skill and sustainability of construction. The use of expanded polystyrene sheet (EPS) is one of the materials introduced in the Ethiopian construction industry (Yemru, 2020).

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 3dimensional welded wire space frame provided with the polystyrene insulation core. Panel is placed in position and shotcrete on both the sides (Ministry of Housing and Urban Poverty Alleviation, 2017).

Expanded polystyrene (EPS) is one of the building materials capable of enhancing the design and structural integrity of the building. Since its recognition as conventional insulating material in 1950s, EPS has been experiencing swift progress in other new implementations. In recent years, there has been an explosive growth of interest in the application of expanded polystyrene (EPS) for construction industry (Ramli Sulong et al., 2019). EPS is a lightweight cellular plastic material consisting of small hollow spherical balls. It is an incredibly flexible material that is widely used for building and construction products. The technology has been found to be cheaper than the conventional method of construction using brick and mortar. The products consist of lightweight foam blocks made of EPS which are cut into panels (single or double depending on design requirements) prefabricated in the factory and are stacked together to make up the desired wall shapes which are then coated with cement mix or filled with concrete. These materials are used to build single level and multilevel walls, slabs, retaining walls and underfloor insulation panels for heating, cooling and sound insulation. EPS is a cost-effective material for thermal and sound insulation (Githuku, 2008).

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 five components. This are the outer layer of shotcrete, welded reinforcing mesh of high wire, the core of expanded polystyrene sheet, diagonal wire (stainless or galvanized wire), and the inner layer of shotcrete (Ministry of Housing and Urban Poverty Alleviation, 2017).

1.2 Statements of the Problem

In Ethiopia, construction is still practiced with old construction methods using the conventional construction materials like reinforced concrete, HCB and wood. These materials/methods take more time, cost and have quality problems. To reduce these problems, technology transfer is one means of adopting improved methods by investigating the time, cost, quality, durability, environmentally friendliness and sustainability of alternative construction materials (Yemru, 2020).

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 (Sherif et al., 2018).

Therefore, as stated in different studies of different countries regarding using EPS technology over the conventional method of construction, many researchers concluded that the use of EPS technology reduce cost and time of a project improving quality and safety along with creating a sustainable environment. In Ethiopia, the use of this technology is not very much common but there are still practices of using the technology in some areas. So, it is necessary to evaluate the performance of using the technology in Ethiopia.

1.3 Significance of the Study

This study is valuable for building contractors, governmental institutions and private builders to introduce EPS construction technology. In addition, the company, EDAB manufacturing and construction enterprise will be beneficial in improving the performance of this new construction technology. Furthermore, researchers can advance the research by taking this as a base study and incorporating other performance parameters to evaluate EPS construction technology and promote other alternative construction materials from this study as a promotion and creating awareness.

1.4 Research Objectives

1.4.1 General Objective

- ✓ The general objective of the research is to assess the applicability of prefabricated expanded polystyrene technology for building projects in Addis Ababa.

1.4.2 Specific Objectives

The specific objectives of the research are as follows:

- ✓ To assess the current application status of structural expanded polystyrene panel regarding to its benefits and factors affecting its adoption to building projects in Addis Ababa
- ✓ To investigate the critical challenges of using expanded polystyrene technology for building projects in Addis Ababa
- ✓ To make comparison analysis of performance between expanded polystyrene technology and conventional methods of construction for Addis Ababa building projects
- ✓ To study how expanded polystyrene manufacturing plant works at EDAB manufacturing and construction plc.

1.5 Research Questions

Within the view of accomplishing the above objectives, the research has posed the following questions, which are to be investigated by the selected research instruments:

- ✓ What is the application status of EPS technology in Addis Ababa building projects?
- ✓ What are the critical challenges faced while adopting EPS technology?
- ✓ How EPS panel is manufactured at EDAB manufacturing and construction plc?

1.6 Scope of the Study

The study took place on EDAB manufacturing and construction company. It evaluates building projects of EDAB homes located in Addis Ababa. It mainly focuses on evaluating the current performance of the technology along with its benefits and the challenges faced while adopting the technology which is new to our country. It includes the assessment of cost and time performance comparisons of expanded polystyrene with conventional building construction. It discusses the working of eps manufacturing plant in detail. The construction cost and time comparison between the expanded polystyrene panel and conventional method of construction will take place on HCB wall and solid slab structural elements only.

1.7 Limitation of the study

The major limitation of the study was lack of adequate references made on the area. We can find references or prior studies made on this topic but were limited in number. Also, no prior local published studies were made except one research made on Bezawit Schnell's home in Bahir Dar city.

Since the manufacturing and constructing works are made by the same company, it makes it difficult to get clear data stated in terms of cost and time and this made the journey to take more time than expected.

Another limitation of the study was the unwillingness of experts to complete and conduct the study. Returned surveys that took longer than expected forced series of briefings on the questionnaire was to motivate respondents to complete the questionnaire since results are for academic purposes.

1.8 Organization of the Study

This research report had five chapters that contain: -

Chapter one: Was composed the background of the study, statement of the problem, research objectives, and questions, scope of the study, the significance of the study, and limitation of the study were included in chapter one.

Chapter two: Was composed of the review of the relevant literature. Company documents, various books, and journal articles was reviewed to base the study on existing literature and discuss relevant issues to build an understanding of the subject matter.

Chapter three: Contains the details of the research methodology and the steps used to gather and analyze data from findings were drawn.

Chapter four: Contains the analysis of the data gathered through data collection methods and instruments indicated in the methodology part.

Chapter five: Discusses the conclusion and recommendation. The references used in the study are listed at the end. Tables, interview guides, and questionnaires used were included in the appendix part.

CHAPTER TWO
LITREATURE REVIEW

2.1 Definition

EPS is a closed cell lightweight cellular plastics material produced from polystyrene. The material has been modified by the addition of flame retardant additives. Polystyrene literally translated is “polymerized styrene”. That is, the single styrene molecules are chemically joined together to form a large molecule which is called the polymer. Styrene is produced from benzene and ethylene, and polymerization is accomplished in the presence of catalysts, usually organic peroxides. The expandable form is produced as small beads containing a blowing agent (Australian Urethane & Styrene, 2009).

EPS is a stiff cellular plastic that comes in a variety of shapes and uses. It's extensively utilized in electrical consumer products packaging and building insulation panels. One such technology is the usage of EPS sheets, which are produced from small polystyrene beads combined with pentane beads. In the construction of reinforced concrete buildings, the use of EPS introduces a pre-manufactured technology. This industrial method comprises the fabrication of a wavy/undulated polystyrene panel with electro welded zinc coated square mesh on both sides. Polystyrene panels come in two varieties: single and double. A single panel consists of a polystyrene sheet sandwiched between welded wire mesh on both sides, whereas a double panel consists of two single panels united by an intermediary hollow. The mesh is covered with a coat of shotcrete that is applied under pressure using a pneumatic device to build the walls. A single panel building can have up to four floors while a double panel structure can have up to fifteen floors (Nyambara et al., 2017).

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 panel is a versatile structural element designed for floors, walls, partitions, roof, and stairs. 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 (Ministry of Housing and Urban Poverty Alleviation, 2017).

2.2 History of EPS Technology

Polystyrene was discovered in 1839 by an apothecary in Berlin. From storax, the natural resin of the sweetgum tree (Liquidambar Styraciflua), that distilled an oily substance, a monomer which he named styrol. Several days later, it is found that the styrol had thickened, presumably from oxidation, into a jelly called styrol oxide (‘Styroloxyd’). It took more than 80 years before it was realized that heating of styrol starts a chain reaction which produces micromole- clues. This eventually led to the substance receiving its present name, polystyrene. In 1930, the scientists at BASF in Ludwigshafen, Germany developed a way to commercially manufacture polystyrene. They developed a reactor vessel that extruded polystyrene through a heated tube and cutter, producing polystyrene in pellet form. In 1954 foamed polystyrene was accidentally invented in the USA. A chemist trying to find a less brittle flexible electrical insulation based upon polystyrene, combined styrene with isobutylene, a volatile liquid, under pressure. The result was polystyrene foam, 30 times lighter than regular rigid polystyrene (EUMEPS, 2010).

The origin of expanded polystyrene (EPS) panels comes from an Italian project, developed in a region subject to earthquakes, in order to create a monolithic structure that did not collapse and aggregate thermal insulation elements in the early 1980s. Expanded polystyrene has been used in Brazilian civil construction in a growing way, using expansion joints, lost coffin, insulation and road foundation, gaining space in the construction of slabs. It has been used in several countries around the world for more than 40 years, safely and efficiently, among all the technologies used in civil construction. Contrary to the thought, of being a premature system, the construction system with walls raised from panels produced in EPS and steel mesh, arrived in Brazil around the year 1990. Polystyrene, or Styrofoam, as it is known in Brazil, is a synthetic aromatic polymer made with the styrene monomer, a liquid derived from the petrochemical industry, can be rigid or foamed, usually used in its white, hard and brittle shape. Taking into account its weight, it is a cheap resin, being widely used as an efficient barrier against oxygen and water vapor, having a relatively low melting point (Fernandes de Oliveira et al., 2019).

2.3 Properties of EPS

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 & 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 in infrastructures like roads bridges also making a sound proof room. EPS is made from styrene which is a byproduct of crude oil extraction (Yagnesh & Shrikant, 2016).

Expanded polystyrene (EPS) is found to be the most commonly used polymer core. This is because it is lightweight, resistant to moisture and also it has a long life. Pertaining to its low thermal conductivity, EPS acts as an excellent insulator for heat flow. Though, it works poorly in resisting fire due to its lower melting point temperature. Studies have concluded that softening of EPS starts when exposed to temperatures ranging from 100°C to 120°C. In the process of flashovers, EPS melted about 160°C and then vaporized, producing poisonous gases at a temperature of 275°C. EPS is an inert, low-density hydrocarbon-derived thermoplastic which contains several spherical beads with 2 percent polystyrene and 98 percent air (Ankesh et al., 2021).

2.3.1 Fire Behavior and Thermal Insulation Properties of EPS:

The fire behavior of fire-retarded EPS differs markedly from that of non-fire retarded EPS. When heated, fire-retardant EPS stretches away from the heat source. The likelihood of the substance igniting is lowered, and welding sparks or cigarettes will not typically ignite. In the construction sector, however, it is required to use a flame-retardant grade of EPS to decrease flammability and the spread of flame on the surface of EPS products. Without the integration of other fire-resistant materials, the use of EPS in compartmentalization or fire protection of structures is limited. This case was observed from previous studies where EPS was covered with gypsum and steel in order to address its fire behavior. As construction equipment, insulation material has to comply with parameters such as temperature, humidity, and overall assembly condition (Ramli Sulong et al., 2019).

EPS material prohibits a thermal conductivity in the range of 0.032 - 0.038W/(m·K) as compared to concrete that falls in the range of 0.4-0.7 W/(m·K). This is important since it is much lower helping to reduce the energy consumption. The material is therefore suitable to regulate extreme temperatures in a building. The unit weight of EPS embedded structure is up to 35% less than the conventional concrete structure. As a result of the reduced weight, the pre-assembled units reduce the overall cost of structure significantly. EPS embedded structure results in a sustainable and economical structure. Due to its closed air-filled cell structure that inhibits the passage of heat or cold, EPS has a high capacity for thermal insulation thus low thermal conductivity. EPS is a low weight material with densities of between 10 and 35kg/m2 allow light and safe construction works. The low weight properties of EPS make it easy to handle and to transport to site. It has excellent mechanical resistance properties making it good choice for load-bearing roof insulation, sub-pavement flooring, road-building and as loadbearing insulation (Nyambara et al., 2017).

EPS gains its exceptional insulating properties from the stabilized air trapped within its cellular structure. Since it contains no CFCs or any other gas that may leak out, it will not harm the ozone layer or decrease its insulation properties. As Australian Standard 1366 Part 3 is a minimum conformance standard the thermal resistances quoted will be achieved as a minimum in 97.5% of cases in a statistical sample, when tested at a mean sample temperature of 25°C (Australian Urethane & Styrene, 2009).

2.3.2 Production of Smoke:

Smoke is described as visible suspension of solid or liquid particles in the gas as product of combustion and pyrolysis. Production of smoke can be suppressed by restricting the ability of material to ignite and reducing the flame spread and heat released. The surface area of EPS insulation must be protected using noncombustible material in order to minimize smoke production during event of fire. EPS begins to soften at temperature above 100 C and upon further heat exposure, it will shrink, melt, and decompose to produce flammable gases which ignitable by spark or flame at certain condition and temperature (Ramli Sulong et al., 2019).

2.3.3 Strength of EPS:

In spite of its light weight, the unique structure of EPS brings the benefits of exceptional compressive strength. Wetting of the material will not result in settlement of the material or other performance characteristics. This means it is ideal for use in many constructions and civil engineering applications, particularly as a structural base infill, for example in road, railway and bridge infrastructures. Strength tests per- formed on EPS, after almost 30 years underground, showed that it routinely exceeded the original mini- mum design strength of 100kPa. EPS bridge foundations, which had been subject to many years of sustained loading, showed creep deformation of less than 1.3%: only half as much as had been theoretically predicted. Most importantly, EPS stability does not deteriorate with age. EPS has excellent mechanical properties making it good choice for the repetitive loading of roof insulation (walkability), sub-pavement flooring, road building and as a general load bearing insulation. With its flexible production process, the mechanical properties of EPS can be adjusted to suit every specified application (EUMEPS, 2010).

Table 2.1 Compressive Strength of EPS (Arun Solomon & Hemalatha, 2017)

S. No	**EPS Specification**	**Maximum Load (kN)**	**Compressive Strength (MPa)**	**Maximum Contraction (mm)**
1	4 kg Density 50 mm thick	1.5	0.15	36.9
2	4 kg Density 100 mm thick	3.6	0.18	123.7
3	8 kg Density 50 mm thick	1.5	0.15	33.4
4	8 kg Density 100 mm thick	4.1	0.205	128.9
5	12 kg Density 50 mm thick	2.1	0.21	40.9
6	12 kg Density 100 mm thick	3.7	0.185	132

Table 2.2 Flexural Strength of EPS (Arun Solomon & Hemalatha, 2017)

S. No	**EPS Specification**	**Maximum Load (kN)**	**Flexural Strength (MPa)**	**Maximum Contraction (mm)**
1	4 kg Density 50 mm thick	0.9	0.41	28.2
2	4 kg Density 100 mm thick	0.9	0.10	47.9
3	8 kg Density 50 mm thick	0.6	0.27	16.5
4	8 kg Density 100 mm thick	1.4	0.16	21.6
5	12 kg Density 50 mm thick	1.0	0.45	12.4
6	12 kg Density 100 mm thick	1.5	0.17	20.0

2.3.4 Water and Moisture Absorption:

The water absorption capacity of EPS is low, which further shows a remarkable reduction as the density increases. The EPS cellular arrangement is water resistant, vapor permeable and has zero capillary properties. Although neither liquid water nor water vapor affects its mechanical properties; however, owing to fine interstitial channels between shaped beads, there is still a higher chance of moisture absorption upon full immersion of EPS. A low temperature plasma treatment is used as a method to increase EPS surface energy. As a result, the EPS specimen's surface became highly hydrophilic (Ankesh et al., 2021).

EPS has very low water absorption, which decreases with density. EPS with a 9–12year utilization duration has 8–9% of its volume filled beneath the groundwater table. EPS's cellular structure is water resistant, vapor permeable, and has zero capillarity, even though neither liquid water nor water vapor impacts its mechanical characteristics. Due to the tiny interstitial passages between the molded beads, moisture absorption is still possible after complete immersion of the EPS. Moisture absorption in EPS geofoam causes degradation of thermal characteristics. During its lifespan, less than 10% of the volume of lightweight-fill geofoam is absorbed. Furthermore, high density EPS has a high water vapor diffusion resistance factor due to better moisture properties (Ramli Sulong et al., 2019).

EPS has low water absorption properties where EPS does not absorb moisture and its thermal and mechanical properties are unaffected by damp, humidity, or moisture. This makes it suitable for construction in cold, damp and swampy area as well as areas with high water table (Nyambara et al., 2017).

2.3.5 Chemical Resistance:

The reaction time, temperature, and applied stress all have an effect on the chemical resistance of EPS. It has the same resistance as polystyrene in general. Because of its thin cell walls and wide exposed surface, EPS is susceptible to solvent assault, which causes softening and cracking. Water, salt, or alkali solution do not react with EPS. The insolubility of EPS non most organic solvents impacts the choice of EPS adhesive, label, and coating. In general, substance compatibility with EPS is evaluated by exposing molded polystyrene to it at 120–140 F. Despite the fact that UV light caused surface yellowing and friability in molded polystyrene, its physical properties remained unaltered (Ramli Sulong et al., 2019).

EPS's chemical resistance make it completely compatible with other materials used in construction including cements, plasters, salt, fresh water and admixtures. Its versatility makes is easy to be cut into the shape or size required by the construction project. Its ageing resistance retains the properties listed above over the whole of the material's life and will last as long as the building itself. EPS is not altered by external agents like fungi or parasites as they find no nutritional value in the material. A life cycle analysis is a technique intended to quantify the total impact of a product during its production, distribution, use and recycling, treatment or disposal. Responsible organizations conduct the life cycle impact analysis which measures the energy consumption, air pollution, water pollution, global warming potential and volume of solid waste (Nyambara et al., 2017).

The following table shows chemicals that damage EPS panel as well as those resisted by EPS material.

Table 2.3 Chemical Resistance of eps Geofoam (Stark et al., 2012)

Eps Is Resistant To:	Chemicals That May Damage Eps:
• Alkalis • Dilute Inorganic Acids • Gypsum Plaster • Most Alcohols • Portland Cement • Silicone Oil • Solvent-Free Bitumen	• Hydrocarbons • Chlorinated Hydrocarbons • Organic Solvents • Ketones • Ethers • Esters • Diesel And Gasoline • Concentrated Acids • Vegetable Oils • Paraffin • Animal Fats and Oils

2.3.6 Lightweight:

Density is one of the important parameters which can control many physical properties in lightweight concrete. The previous studies indicate that the density of EPS concrete decreases with increase in volume of EPS aggregate. Since weight of a construction material is an important factor in transportation, application and processing, composite materials with low density are desired (Şahin & Karaman, 2012).

EPS is effectively 98% air captured within a 2% cellular matrix and so is very light weight. Densities of between 10 and 35kg/m² allow light and safe construction work. It is also easy to transport, and the low weight saves fuel in transport. The low weight of EPS also makes it easy to handle on the site, especially since lifting of heavy insulation products is becoming an increasingly important health and safety issue. EPS insulating boards can be laid quickly and in any weather conditions, since it is unaffected by moisture. The exceptional lightweight to insulating performance of EPS is of major benefit in low energy buildings where thicker insulation layers are required. The structural load needs to be considered since this has an important impact on the construction. For example, light weight flat roofs of industrial buildings based upon profiled metal sheet. At a U-value of 0.2 W/(m²K), a difference of nearly 40 kg/m² between EPS, with superior dynamic loading properties, and possible alternative insulation materials needs to be taken into account by the constructor of the building (EUMEPS, 2010).

EPS geofoam is manufactured in various unit weights that typically range from about 0.7 to 2.85 pounds per cubic foot (11.2 to 45.7 kilograms per cubic meter). As a result, they impart small dead load or stress to underlying soils, structures and utilities. This is especially advantageous where the existing soils are poorly suited to support additional loading (e.g., compressible clay, peats, etc.). In fact, existing loads can be significantly reduced by excavating and replacing native soils, which commonly weigh about 100 pounds per cubic foot (1,602 kilograms per cubic meter), with EPS geofoam. This can eliminate the need for specialized foundations or site preloading to reduce settlement and improve bearing capacity. The use of EPS geofoam over existing utilities can eliminate the need for utility relocation. The use of EPS geofoam behind earth retaining structures, such as bridge abutments, can reduce lateral stresses (Stark et al., 2012).

Table 2. 4 Properties of EPS (Ademović et al., 2017; Haile, 2018)

Sample No.	Characteristic			Results		
			EPS F	EPS 120	EPS 150	EPS 200
1.	Dimensions					
	Length	Min	99.70 cm	99.5 cm	99.0 cm	29.90 cm
		Max	100.0 cm	99.6 cm	100.0 cm	30.00 cm
		Average	99.85 cm	99.55 cm	99.95 cm	29.95 cm
	Width	Min	49.9 cm	49.70 cm	49.9 cm	29.90 cm
		Max	50.0 cm	49.90 cm	50.0 cm	30.00 cm
		Average	49.95 cm	49.80 cm	49.95 cm	29.95 cm
	Thickness	Min	4.90 cm	4.90 cm	5.0 cm	4.90 cm
		Max	5.00 cm	5.00 cm	5.0 cm	4.90 cm
		Average	4.95 cm	4.95 cm	5.0 cm	4.90 cm
2.	Bulk Density					
		Min	13.81 kg/m^3	18.86 kg/m^3	21.77 kg/m^3	28.30 kg/m^3
		Max	14.44 kg/m^3	20.38 kg/m^3	25.04 kg/m^3	32.60 kg/m^3
		Average	14.16 kg/m^3	19.62 kg/m^3	23.04 kg/m^3	29.90 kg/m^3
3.	Compressive Strength At 10 % Deformation					
		Min	104.15 kPa	122.80 kPa	179.55 kPa	260.90 kPa
		Max	108.84 kPa	131.31 kPa	182.82 kPa	272.50 kPa
		Average	105.85 kPa	127.52 kPa	181.04 kPa	263.90 kPa
4.	Bending Strength					
		Min	163.06 kPa	211.0 kPa	219.00 kPa	306.50 kPa
		Max	166.56 kPa	224.0 kPa	241.19 kPa	329.20 kPa
		Average	166.56 kPa	220.0 kPa	229.12 kPa	315.70 kPa
5.	Tensile Strength					
		Min	404.00 kPa	352.0 kPa	340.00 kPa	364.0 kPa
		Max	588.00 kPa	396.0 kPa	476.00 kPa	396.0 kPa
		Average	477.60 kPa	370.0 kPa	396.80 kPa	315.7 kPa
6.	Factor of Resistance to Water Vapor Diffusion μ		40	62	100	-
7.	Shear Strength					

	Min	25.84 kPa	53.2 kPa	53.15 kPa	58.49 kPa
	Max	37.06 kPa	55.4 kPa	62.07 kPa	69.69 kPa
	Average	31.67 kPa	54.0 kPa	58.41 kPa	65.11 kPa
8.	Lon-Term Water Absorption by Immersion				
	Min	3.501 %	1.82 %	2.892 %	2.854 %
	Max	3.606 %	2.46 %	3.522 %	4.043 %
	Average	3.550 %	2.16 %	3.130 %	3.420 %

2.4 Production Process of EPS Panel

2.4.1 Raw Material Production

The life cycle analysis of building products starts with the extraction of raw resources needed to make the products. In the case of EPS insulation this is crude oil. Overall, 83% of all the derivatives of crude oil are directly transformed into energy in one form or another, e.g., transportation fuel, electricity generation, heating. Only 4% is used as a raw material for making plastics and less than 0.1 % to produce EPS. Using oil to manufacture EPS for building insulation applications is an efficient use of this natural resource. Each kilogram of oil used to produce EPS insulation creates a saving of 150kg of oil used for heating buildings (calculated over a service life of a 50-year period). After its service life the embodied energy is still available and could be released, as an ultimate recycling option, by safely burning to recover the energy in ecological incinerators. Using oil to produce EPS therefore can be seen as borrowing oil with a high dividend. Future generations may well question why oil was used for fuel instead of using it to produce energy efficient light weight plastics (EUMEPS, 2010).

Styrene is produced by refinery and chemical processing. As part of the cracking of petroleum or natural gas, naphtha in a steam cracker is broken down into organic compounds. The by-products ethylene and benzene are used to produce ethylbenzene from which styrene is produced. Styrene, the monomer building block of polystyrene, is polymerized to form translucent spherical polystyrene pellets, about the size of sugar granules. EPS raw material is delivered to EPS processors usually in special boxes(octabins) or bulk bags, of up to 1100kg in weight (EUMEPS, 2010).

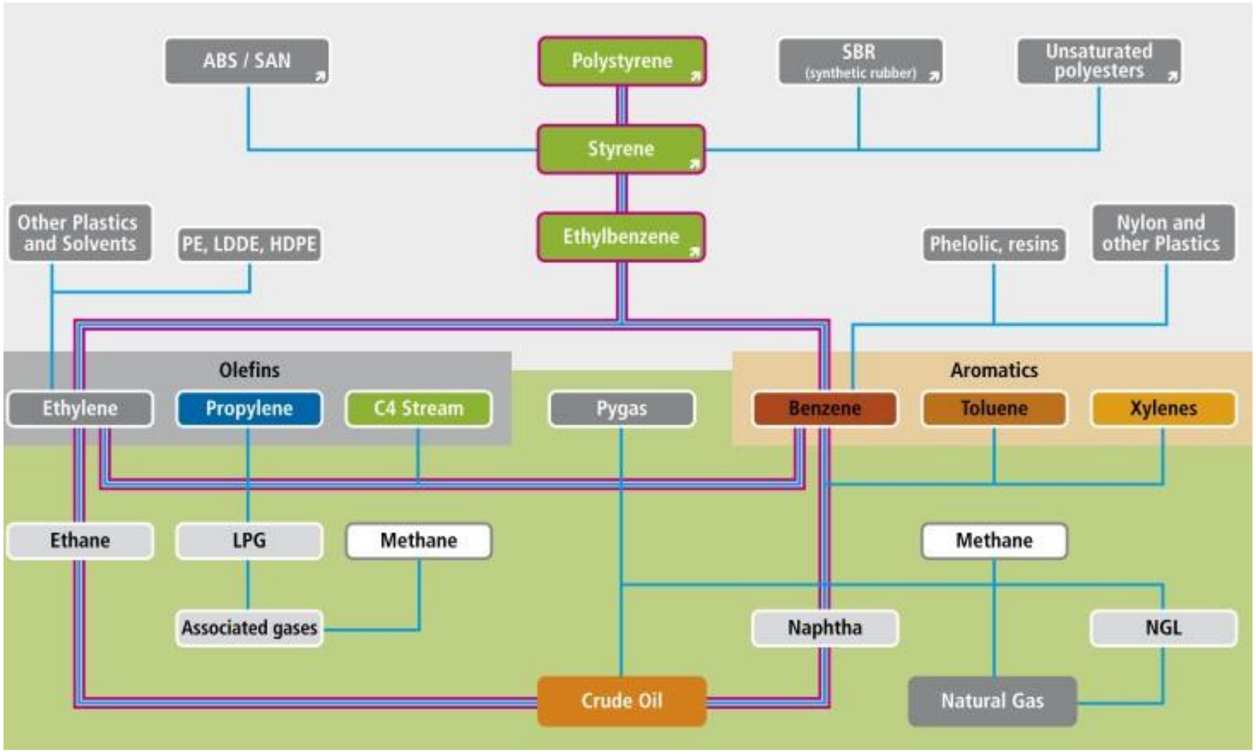


FIGURE 2. 1 Raw Material Extraction of EPS bid (EUMEPS, 2010).

2.4.2 Conversion of EPS

Pre-expansion

In the first processing stage the beads of EPS are expanded at a temperature of about 100 - 110 °C in a machine called a pre-expander, into which steam is fed. The high temperature softens the beads and the blowing agent they contain causes them to expand up to 50 times their original size. The final bulk density of the beads depends on temperature and steaming time. The bulk density at this stage will determine the density of the foam. The blowing agent within the beads is pentane, and it is quickly broken down into carbon dioxide and water in the earth's atmosphere. Pre-expansion can be done batch wise or continuously (Andersen & Jackson, 2018).

Intermediate conditioning and stabilization

After pre-expansion the expanded beads are cooled and dried in a fluidized bed drier, before being pneumatically conveyed to aerated storage silos for maturing, typically over a period of 24 hours. After expansion, the recently expanded beads still contain small quantities of both condensed steam and pentane gas. With cooling in the silos, a partial vacuum is created in their interior which must be equalized. Air gradually diffuses into the pores until equilibrium is reached replacing, in part, the other components until the beads contain up to 98% air. At this stage the beads achieve greater mechanical elasticity and regain expansion capacity - a very important factor in the subsequent transformation stage (EUMEPS, 2010).

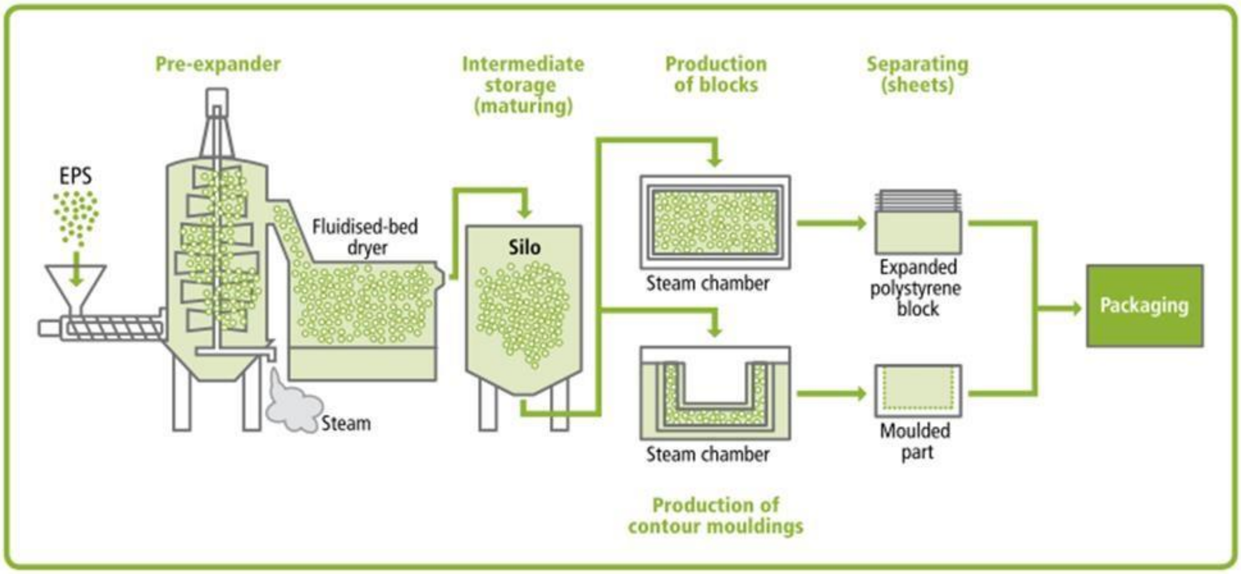


FIGURE 2. 2 Raw Material Extraction of EPS Panel (EUMEPS, 2010)

2.4.3 Moulding and Cutting Blocks

At this stage the beads are placed into a metal mould. The mould is closed, and steam is passed through it. Vacuum is introduced before and after the steaming. The residual blowing agent within the beads causes them to expand again and fuse together into a homogenous block of foam. After a short cooling phase, the foam block is removed from the mould and allowed to stabilize before being processed further. After some hours of ageing, the fresh moulded blocks may be cut into final dimensions with hotwire cutting equipment. Cutting is needed to split the block and to achieve better tolerances and flatness. One standard dimension is 600 mm x 1200 mm x length. Normally dimensions that make use of the total volume of the block are to be preferred (Andersen & Jackson, 2018).

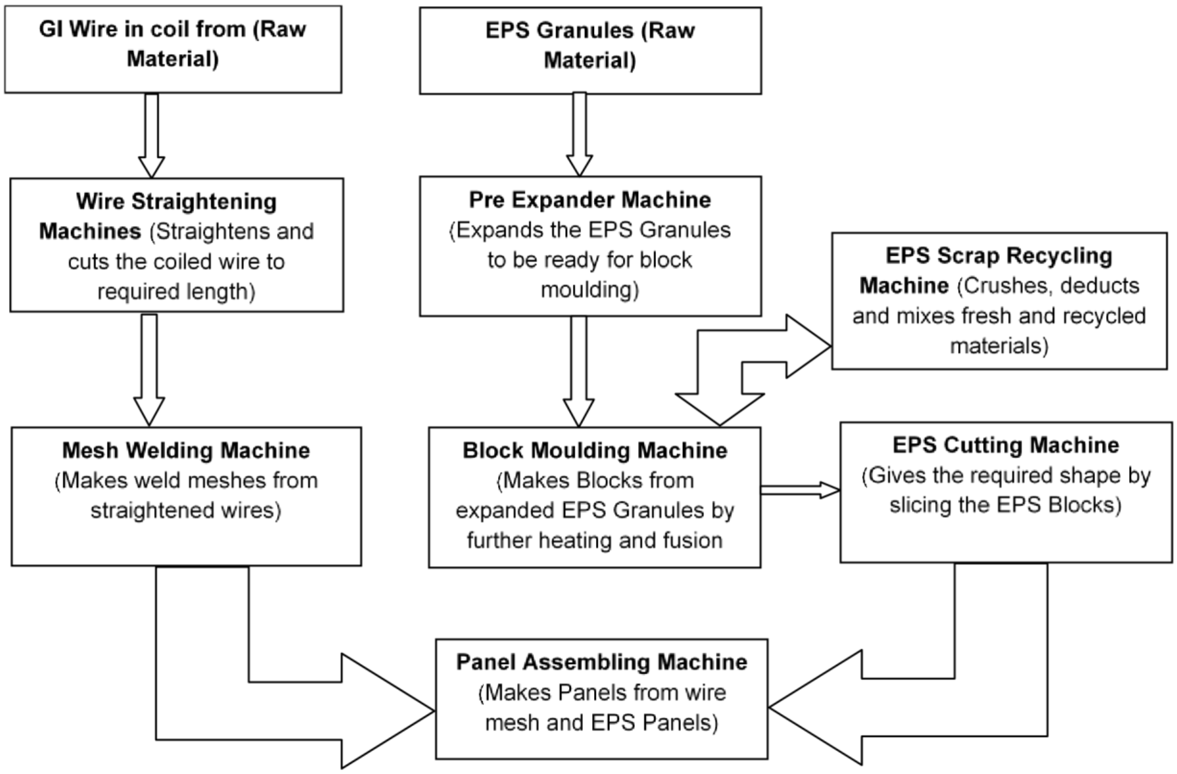
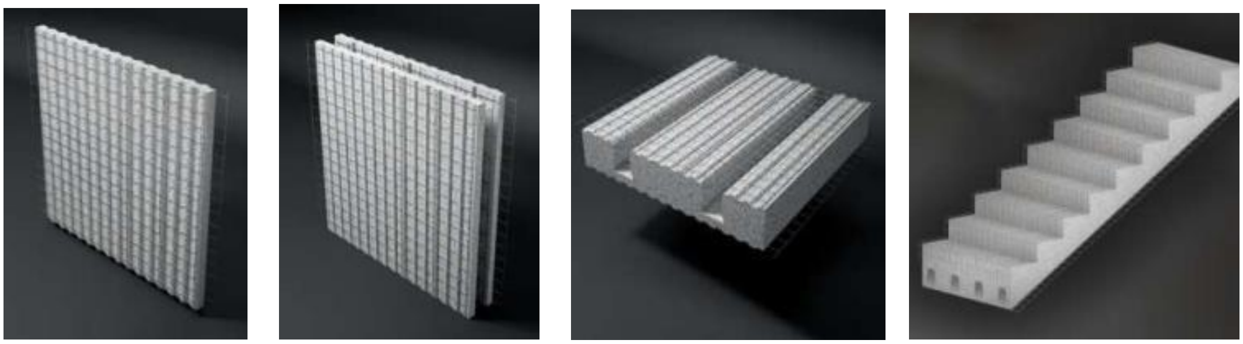


FIGURE 2. 3 Production Process of EPS Panel (Centre, 2015)

2.5 Types of EPS Panel

Single panel consists of a sheet of polystyrene sandwiched between two mats of welded wire mesh. The polystyrene sheet can be shaped as required and the thickness can vary according to needs. The Single Panel can be used for the construction of single and multistory buildings according to the local building regulations. Double panel consists of two single panels joined together with an intermediate cavity. The thickness of the polystyrene and the width of the cavity can be varied according to the performance required. The external faces of the panel are usually finished in plaster. Floor/roof panel is used for the construction of floors and roofs. The thickness and geometry of the panel can be varied according to the span and project requirements. The placement of the reinforcement and the concrete pour can be made totally on site or partially in the production plant. Stairs panel is constituted by a suitably shaped polystyrene core, wherein the rise and tread may vary according to the needs of the project. The polystyrene core is covered by two electro-welded meshes joined by connectors. This element must be reinforced and completed on site (Homes, 2018).



a) single panel b) double panel c) roof/floor panel d) stair panel

FIGURE 2.4 Types of Eps Panel (Homes, 2018)

2.6 Installation Procedure

Expanded polystyrene panels are anchored to the foundation bars using pliers and steel wires. To ensure continuity among the components, panels are equipped with an overlapping mesh wing on both sides to enable the operators to join proper heat insulation; no empty spaces should be left between the joints of adjacent panels. Assembling of doors and balconies should be done carefully to ensure there are no openings that expose the panels. The main and short procedures of polystyrene assemblage are anchoring of rebar to the foundation, assembling the panels, alignment and plumb setting out of panels, installation of plumbing and electric system, installation of the roof panel and application of shotcrete (Yemru, 2020).

2.6.1 Foundation

Foundations for the EPS Core Panel system whether strip or raft is conventional. If strip foundations are used, they should be level and stepped as this makes panel positioning easier. For EPS Core panels, parallel sided timber or metal template of the width of panel shall be required to mark the position of the wall panels on the foundation and the spacing of the starter bar holes (Ministry of Housing and Urban Poverty Alleviation, 2017).

2.6.2 Wall Panel Erection

2.6.2.1 Anchoring rebar’s to foundation

Mark out and profile line wall positions. Starter bars should be either φ6mm or φ8mm, 500mm long with 100mm drilled into the foundations and 400mm above the foundations (Sneha & Tezeswi, 2016).

a) Electrical drilling machine

b) Drilled holes in the foundation Drilled holes in the foundation

FIGURE 2.5 Installing Anchor Bars into Foundation (Sneha & Tezeswi, 2016)

2.6.2.2 Assembling of Panel

The assembly of self-supporting panels is not complex, but requires care and standards to avoid misunderstandings in construction. They must be aligned with the iron guides of the contra piso and mounted on the plumb, where the fixation is made by clamps and annealed wires. The panels will be numbered by the manufacturer of the construction system and the mesh tabs of each panel must overlap the tabs of the next panel for composition of the monolithic assembly. All corners and wall joins must be reinforced with right angled wire mesh to the with right angled wire mesh to the full height of the wall (Fernandes de Oliveira et al., 2019).

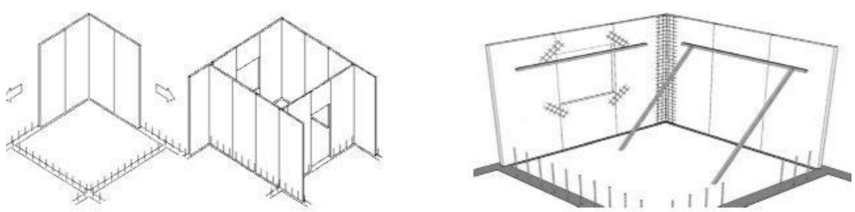


FIGURE 2.6 Alignment of Panels (Sneha & Tezeswi, 2016)

2.6.3 Roof/floor Panel

After the vertical panels are assembled, verticality of the walls shall be checked and the bending meshes positioned on all the corners. Thereafter, horizontal bending meshes shall be placed to connect the floor/roof to the vertical panels. The bending meshes shall be fixed throughout the perimeter of the floor/roof, at the level of intrados. When the horizontal bending meshes are fixed and checked, floor/roof panel shall be placed on these. The lower mesh of the panel shall be fixed by steel wire to the bending meshes. Between the edges of floor/roof panel and vertical panel, gap of 35 mm should be left to ensure structural continuity. The plaster applied on the walls shall be continued from one level to another level. Placing of the EPS Core Panel elements for the floor and/or roof should be done before the application of the external layer of plaster on the walls. Casting of concrete on the floor/roof panels (after placing the additional reinforcing bars, if required) should be done after the walls are plastered and a number of props shall be put to limit the deformation of the panel (Ministry of Housing and Urban Poverty Alleviation, 2017).

2.6.4 Plumbing and Electrical Fittings

Plumbing and electrical conduits shall be behind the panel wire mesh before plastering. The space behind the wire mesh shall be opened up by using a blow torch to partially melt the EPS along the lines of the conduits. As the EPS used in the panels is fire retardant, it will melt under the flame but not burn. The wire mesh shall be cut with wire clippers to make space for DB boards, switches and plug boxes. For the installation of HVAC suitable strengthening measures (in form of mess size and no.) should be provided as and when required. At the time of installation of HVAC suitable additional reinforcement mess should be provided to take care of HVAC unit as per the strength requirement. of the panel (Ministry of Housing and Urban Poverty Alleviation, 2017).

2.6.5 Application of Shotcrete

Application of shotcrete is done on both sides of the single or double panel till a thickness of 17-20mm is achieved. After about 30 minutes, mortar of 15mm thickness is applied (Sneha & Tezeswi, 2016).

FIGURE 2. 7 Shotcreting of EPS Panel (Homes, 2018)

2.7 Benefits of using EPS technology

EPS as a construction material provides environmental, technical, commercial, and social benefits. Use of EPS material for construction yields numerous benefits to the users, investors and to the environment. EPS yields construction time saving and reduce construction periods. It is very quick to erect because of its lightness and the availability in any length. It further leads to reduction in direct and indirect labor and transport building costs. The lightweight panels which is easy to lift and erect at any height inside the plant or any other place. EPS material is resistant to fire and earthquakes. It is an all-weather proof construction and maintenance free. Construction pre-engineered and fewer components internationally accepted and meets the building code. Modular in nature and pre-engineered for precision and simplified construction.

Environmental benefits e.g., reduce use of natural resources including stones, uses less water. It is thermal regulating for areas with extreme weather and has higher energy savings due to low thermal conductivity. It is insect resistance and does not require chemical pre-treatment before construction begins. Its good acoustical properties make it a sound choice for high density townhouses. Since EPS panels are made from small beads of polystyrene mixed with pentane as the blowing agent, they can be used to minimize the production of cement and to benefit the environment (Australian Urethane & Styrene, 2009).

EPS provided flexibility in design and enables choosing various options on fascia of panels and colors. It enables design and construction of walls of different height, yet sturdy and strong construction. It enables frameless construction and ease of design, supply and erect for any types of construction. It supports the innovative insulated panels and saves the energy. These insulated panels' gives long lasting value with controlled quality. Accuracy and speed of construction and caters for better functionality and application (Andersen & Jackson, 2018).

EPS exhibit minimal energy consumption as steam is used as energy in the manufacturing process. The steam itself is produced in boilers mainly using natural gas as fuel. Water consumption used in the manufacture of EPS is very low. The water is reused many times in the process. There is no solid waste generated during the EPS manufacturing process. Waste and offcuts are easily put back into the production process. No material is wasted, and clean used packaging can be recycled into new product using this method. There is no pollution to the surface or underground water supplies near an EPS plant because atmospheric and liquid emissions are very low during the manufacture of EPS (Nyambara et al., 2017).

The Expanded polystyrene (EPS) fascia offers wide range of advantages over the conventional concrete fascia. The observed advantages from sampled cases include flexibility of design. The EPS fascia affords the designer the flexibility of design and improved aesthetics. Uncommon shapes and slanting installations which are difficult to achieve in concrete fascias are easily achieved with EPS fascias. For example, EPS fascia can be installed transversely or in any direction along the gable end of a façade for an improved aesthetics, which ordinarily could be cumbersome if concrete fascia is to be used. Also, smaller grooves as small as 10mm in fascias are easily achieved in EPS fascias. Another advantage of EPS is the absence of formwork for installation. EPS fascia is a precast module which requires no formwork during installation. The construction of formwork inevitable in the construction of concrete fascia is totally avoided during the installation of EPS fascia. Thirdly, fewer numbers of laborers are required for the installation of EPS fascia compared to conventional concrete fascia. The engagement of specialized services such as carpenter and iron benders, which is inevitable in the construction of concrete fascia, is not required in the EPS fascia installation. Besides, faster construction is achievable as a great deal of time is saved in the construction of fascia using expanded polystyrene. Much time expended in the construction of formwork and iron bending for the construction of concrete fascia is absent. The long duration of time observed before striking off the formwork after the concrete fascia has set is avoided. These merits give EPS fascia short duration advantage over the concrete. Added, firmness and rigidity characterize the use of EPS. It has been observed that poorly designed and poorly constructed concrete fascias are prone to sagging, falling off the grid or falling off completely. The EPS fascia after proper installation and alignment is firm and rigid. All alignment problems associated with the concrete fascias may not be easily corrected without attracting wastes, demolition, extra cost and extra time. In the case of EPS fascias, there is no risk of fall-off and sagging. Alignments of the slightly off-grid fascias can easily be done without marring the aesthetics at no extra cost and time. Other advantages are deconstruction and material re-use. Despite EPS fascia firmness and rigidity in full installation which is a good structural attribute, the material can easily be disassembled and the materials can be re-used, either on the same project during remodeling or on another project (Ogundiran & Adedeji, 2014).

Some of the advantages of the EPS Core panel systems are to reduce the cost of construction, to reduce construction period, to reduce transport cost, Light weight panels which do not requires cranes and other heavy construction equipment (A Standard panel of size (1.2×3) m without shotcrete weighs 20 kg), installation does not need heavy construction equipment, ensure high levels of thermal insulation, sound insulation, as well as sanitary and 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, and Strength and durability used extruded polystyrene virtually inert and does not absorb moisture, is durable and resistant to decay (Ministry of Housing and Urban Poverty Alleviation, 2017).

2.8 Challenges of using EPS Technology

Depending on market changes and current trends where the focus on sustainable construction swells is growing significantly, the use of methods that reduce waste creation and energy expenditures, becoming increasingly frequent in construction occupying more and more space, showing that the monolithic system of EPS is an advantageous option for those looking for innovative constructions. It was observed that the method of monolithic polystyrene panels (EPS), is a new and innovative system in Brazil, replaces conventional walls, because it is a prefabricated, modular, lightweight system composed of expanded polystyrene EPS, enabling a new and advanced construction system, by synthesizing the advantages of the traditional system and prefabricated, dispensing beams and pillars, and towed in structural mortar (Fernandes de Oliveira et al., 2019).

However, adopting new technology is not simple and the implementation may face a lot of challenges. Below is table that illustrates different challenges faced while adopting eps technology in construction projects.

Table 2. 5 Challenges of Using E Technology (Sherif et al., 2018)

Resource	Critical resources may not be available when required
Technical	• Failure to effectively mix internal and external expertise • Shortage of qualified workers in this type of construction • Lack of training readily available in using EPS • No technical standard for EPS safety and manufacturing • Absence of civil engineers specializing in planning, design and supervision of this type of construction • No quality standard on the use of EPS • Lack of integration between process and planning • Inexperienced workforce and staff turnover
Economical	• Sudden change of foreign exchange rate
Managemental	• Weak support from stakeholders in the use of EPS as construction materials • Lack of available project management skill • Change in organizational management • Team members not familiar with the task(s) being automated • Failure to comply with contractual quality requirements
Design	• No design guide for using EPS in building and construction especially in high-rise buildings • No design manual for using EPS in building and construction • Design errors and omissions • Stakeholders request late changes • Failure to carry out the works in accordance with the contract
Installation	• Cut parts of steel wire mesh to place switch boxes, electrical ducts, tubes, etc. this may weaken the wall • Forgetting to place parts of the drainage system and electrical works • Errors in cutting and molding • Errors due to improper use of the hot air gun
Others	• Transport cost for sites far away from factory

	• Not accepting people to use EPS in building • Construction cost overruns • Technology changes

2.9 Comparison Between Conventional and EPS Method of Construction

The construction system is characterized by an alternative for replacing materials such as conventional masonry. Thus, we sought to understand the advantages of EPS in relation to the conventional (Fernandes de Oliveira et al., 2019)

Table 2.6 Comparison of Conventional Masonry and EPS Panel (Fernandes de Oliveira et al.,2019)

Characteristics	Conventional Masonry	EPS Panels
Mechanical Resistance	Excellent mechanical strength, however, lower than the system in EPS panels. It drives more heat, but spends more energy	Low thermal conductivity, reduction of energy and air conditioning expenses
Fire Resistance	Excellent. For a wall with a 9 cm block and mortar of 6 cm thick, one has a time of 150 min	Low. For a wall with 9 cm thick panel and 6 cm thick mortar one has a time 40 min. Flame retardation
Thermal Insulation K (W/m.K) Thermal Transmission Coefficient (CCT)	It is constituted by good insulation, but the ceramic block has a lower resistive capacity than the EPS. Its coefficientranges from 0.9 to 1.2	Main features, high ability to resist heat passage, its cell structure closed. Its coefficient ranges from 0.035 to 0.042
Soundproofing. Rw (Db) Sound Resistance	For a wall of 15 cm (9 tij. + 6 arg.) you get a Rw=38 db	For a wall of 14 cm (8 EPS + 6 arg.) you get a Rw=38 db

Storage	Its storage takes up a lot of space, reducing the mobility rate in the work	It can be stacked horizontally superimposed with a maximum of 20 panels. Reduces space occupancy
Weight	Larger, so that in the same dimensions that the panel with a thickness of 15 cm can reach 250kg/m²	Reduces the structural weight of the work, as the EPS is 98% composed of air. The finished panel with 15 cm thickness has its weight around 120kg/m3
Manpower	Does not need a specialized workforce	For its simplicity of execution does not require specialized labor, but a qualification through training
Speed Of Application (Productivity)	Because of its fully artisanal system, it is characterized by a much slower and less productive method	Due to the easy handling and simplified application characterized by modularity, it presents high executive productivity
Price	Low initial unit cost, due to the abundance of its materials and simple manufacture	Higher initial unit cost, however, if taking into account the entire context involved the price may become lower
Durability	Larger than any other material, being can exceed 100 years	The age limits of the EPS are not known, but understands that the material has great durability, as it keeps its properties unbeaten over the years.
Execution Of Complementary Installations	Less efficient due to the need for rework to perform	Facilitated due to no need for cutouts of the walls
Wasted Material	Because it is a totally handmade concept, where the executive process is totally geared towards an almost always disqualified workforce, to a huge waste rate in this system	Due to their modular character, where the parts already come ready according to dimensional needs, it is possible that there is a reduction of almost 100% in waste

Plaster Adhesion	Its adhesion capacity is much higher, due to a greater porosity that the material presents	There is difficulty in joining this material, due to its very high impermeability
Market	There is a better acceptance by its users	Limited due to factors such as ignorance of the material regarding its advantages
Pavement Limitation	There are no limitations and can be checked in the most diverse quantities	There is a limitation of up to 4 floors. Since to obtain larger numbers, it is necessary to resort to auxiliary structures such as beams and pillars
Sustainability	Large amounts of debris are used for further dumping, using a lot of water and energy from its manufacture to execution.	Expanded polystyrene 100% recyclable and reusable. With its use decreases the consumption of water and energy from its manufacture to its execution and decreases the generation of waste to nature.

2.10 Limitation of EPS as a Building Material

According to Ministry of Housing and Urban Poverty Alleviation (2017), some of the limitations of using EPS as building materials are; the Panel construction system may only be used in the construction of foundation walls supporting 4 storey or less, unless designed by a professional engineer, Concrete must be applied by either the “shotcrete dry” or “shotcrete wet” process in accordance with ACI 506 R-85, “Guide to Shotcrete,” by the American Concrete Institute, and Compressive strength of concrete shall not be less than 20 MPa. iv. The steel reinforcement shall have a minimum allowable stress (fy) of 415 MPa. The figure below shows the limitation eps technology face in kanya which is pushing the construction method backward.

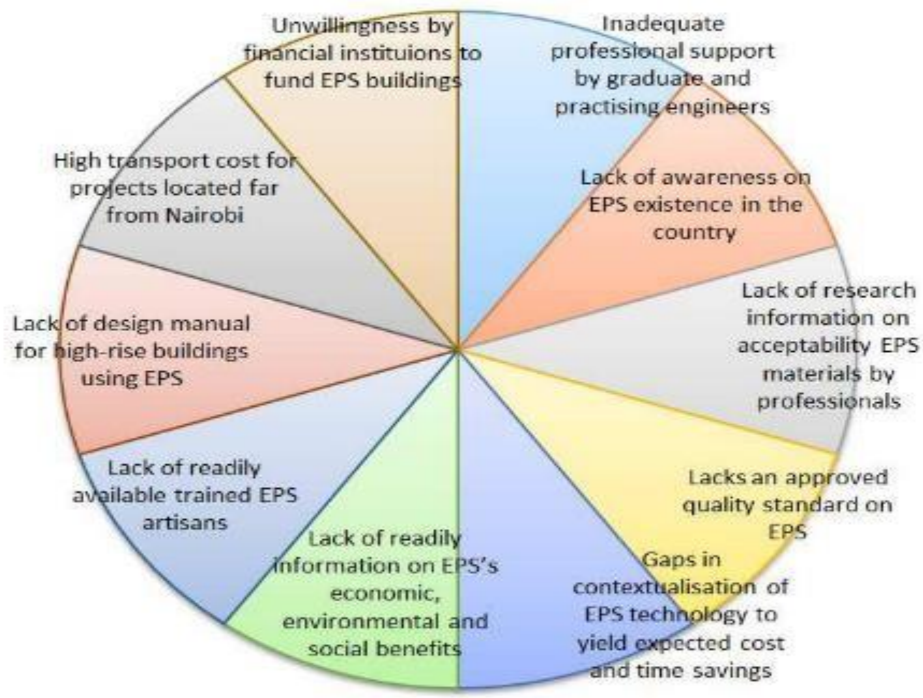


FIGURE 2.8 Factors attributing to slow uptake of EPS for building construction in Kenya (Nyambara et al., 2017)

According to Fernandes de Oliveira et al., (2019) the limitation of eps panels are: Due to the nature of the board itself, its strength is not high, the bearing capacity is low, and the external facing brick needs to be strengthened, The board has to go through a period of maturity before leaving the factory, it needs to be placed for a period of time before it can be used. If the curing time is insufficient, the quality of the sheet cannot be guaranteed, and the sheet shrinks after construction, causing the system to crack, Poor combustion performance, EPS material causes it to remain at an abnormal level, Beijing Radio's fire is caused by the extremely low combustion performance of EPS, Low thermal conductivity, reduction of energy and air conditioning expenses, resulting in not meeting the current 75 energy-saving standards promoted in China, basically EPS belongs to the insulation materials being eliminated, Higher initial unit cost, however, if taking into account the entire context involved the price may become lower, Limited due to factors such as ignorance of the material regarding its advantages, and There is a limitation of up to 4 floors. Since to obtain larger numbers, it is necessary to resort to auxiliary structures such as beams and pillars expanded.

2.11 Application of Expanded Polystyrene in Building Construction

EPS is one among the world's most important commodity polymers. It is a rigid foam with a unique set of properties such as lightweight, superior thermal insulation, strong shock absorption, high compressive strength, and moisture resistance. EPS is utilized in a variety of applications, including food packaging, valuable goods cushioning, and building and other construction panels (Githuku, 2008).

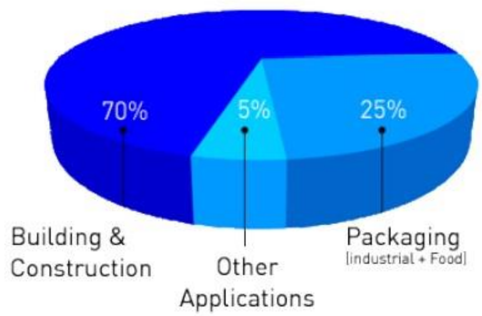


FIGURE 2.9 EPS Applications (Githuku, 2008)

Expanded polystyrene (EPS) is a synthetic material that is widely used to manufacture disposable utensils and for product packaging. Most applications of EPS involve a short service life and one-time use with virtually no recycling. EPS is not a readily biodegradable waste product. There appears to be a good deal of interest in reducing EPS solid waste. EPS has peculiar characteristics that would be desirable for subsurface construction applications. It is very light compared with soil and concrete and has energy absorption and insulation properties. EPS has been used as super lightweight fill and for foundation insulation to reduce frost cover requirements. Reported applications of EPS in subsurface construction have mostly been related to roads. There have been some large and small unpublished applications in the United States. Norway has been the pioneer in EPS applications, and much of the experience to date has been guided more by rule of thumb and field observation (Negussey & Jahanandish,1993).

EPS is used in the building and construction sector in large numbers to create insulation foam for walls, roofing, and floor insulation. EPS has also been used in the building of roads, bridges, swimming pools, retaining walls, basements, and soundproof rooms. Prefabricated structure includes EPS panels. Only the foundation is built using traditional stone and mortar methods in this technique, while the sections of walls, floors, and roof are prefabricated and assembled in a factory before being delivered to the site, set in position, and cemented together (Nyambara et al., 2017).

EPS technology is used for various purposed in the construction industry. Soils modified with expanded polystyrene (EPS) particulates could be used as lightweight fill in a variety of installations including slopes for improved stability, embankments over compressible soils, and to reduce earth pressures next to structures. Polyvinyl chloride and polystyrene were the most used plastics and they are applied in pipes, finishes, ceiling, wall panels, windows and doors while advanced fiber reinforced polymers are not widely used. Polystyrene was also used for expansion joints. EPS comprise of about 98% air and 2% polystyrene and can be used as partial replacement of coarse aggregates. Further increase in the EPS beads content in concrete mixes reduces the compressive and tensile strength of concrete (Nyambara et al., 2017).

EPS geofoam is inherently multi-functional, which makes it effective to use in a wide variety of applications. It offers special advantages for construction on soft ground, slope stabilization and retaining walls. EPS geofoam has been used in road and airfield pavements and railway track systems, beneath refrigerated storage buildings, sports arenas and storage tanks to prevent ground freezing and heaving and in below-ground building segments to reduce seasonal heating and cooling requirements. EPS geofoam enables engineers, architects, and builders to design for key geosynthetic functions and select the best combination of products to achieve project goals. With unprecedented strength and flexibility, EPS geofoam also offers innovative solutions to a range of problems, including protection from earthquake shock and noise and vibration dampening (Stark et al., 2012).

The purpose of decorative molding is to improve the overall aesthetic aspects of a building by concealing transition and gaps between surfaces. Currently, EPS has replaced stone as material for decorative molding as observed in North America and other countries where EPS is embedded with reinforcing mesh before polyurethane (PUR) or polymer modified cement coating is applied. Polymer foams are popular materials for decorative tiles and molding (Ramli Sulong et al., 2019).

The growing need for new roads may, in many cases, require construction over soft or loose soils that are incapable of supporting additional loads. Designers must identify innovative materials and construction techniques to address the problem of building on soft soils or where sensitive existing utilities or wetlands are present while, at the same time, accelerating project schedules. EPS geofoam can be used to replace compressible soils or in place of heavy fill materials to prevent unacceptable loading on underlying soils and adjacent structures. The high compressive resistance of EPS geofoam makes it able to adequately support traffic loadings associated with secondary and interstate highways. Construction with EPS geofoam also saves time because EPS geofoam is easy to handle without the need for special equipment. Because EPS geofoam is an engineered product it arrives on site already having undergone rigorous Q&A testing, unlike other fill materials that require time consuming QA/QC testing. A description of a typical road construction, from bottom to top, is as follows: compact a layer of sand at the base of the roadway excavation to provide a level and free draining construction surface. Place the EPS geofoam to the desired height, staggering the vertical joints in each course so as not to create continuous vertical seams. If required, a separation layer may be placed between the top of the EPS geofoam and the overlying pavement system. A separation layer can have two functions: to enhance the overall performance and life of the pavement system by providing reinforcement, separation and/or filtration and to enhance the durability of the EPS geofoam both during and after construction. Choices for the separation layer include geotextile, hydrocarbon resistant geomembrane, geogrid, geocell with soil fill, soil cement, pozzolanic stabilized materials or a reinforced concrete slab (Stark et al., 2012).

It is generally utilized as free fill protection in workmanship development where it improves imperviousness to fire, decreases clamor transmission, don't spoil and termite obstruction, It is utilized underway of warmth protected light divider board, Used in the scaffold to forestall freezing, Environmentally nurseries are the structures which are less unsafe to condition. Green house is comprised of the materials which produces less CO_2 and are reusable. To lessen the measure of plastic on the earth utilization of plastic as EPS dots is a smart thought for ecologically green tasks. It gives warm protection to building which forestalls the vitality misfortune in structures so it is valuable in earth green tasks, as street bedding EPS concrete is utilized as street bedding in inflexible asphalts. It very well may be utilized in base course of unbending asphalt, and EPS concrete can be used in geo-stabilization projects to improve load bearing capacity of sub grade. It can be used to support pavements and foundations (Moon & Patel, 2021).

2.12 EPS as a Sustainable and Recycling Material

2.12.1 Sustainability

The choice of environmentally friendly materials and techniques is very relevant. To ensure a better-quality life and guaranteeing the health and safety of the building occupants and users, the construction materials and process must preserve unique ecosystem and local landscapes. It was also mentioned that several studies have identified the key environmental issues associated with construction materials and processes, which include the embodied energy of building materials and greenhouse gas emissions. Sustainable construction materials are defined as those that outperform set requirements in terms of overall performance. The criteria are as follows: locally produced and sourced materials, transportation costs and environmental impact, thermal efficiency, occupant needs and health considerations, financial viability, recyclability of building materials, waste and pollution generated in the manufacturing process, energy required in the manufacturing process, use of renewable resources, toxic emissions generated by the process To be considered sustainable, materials must have minimal energy consumption throughout manufacturing, transit (embodied energy), and usage. The materials used in the design of a building have a significant impact on its long-term sustainability, resulting in improved energy savings and occupant comfort. Building materials that fulfill safety regulations and prisoners' comfort needs must also be thermally insulating, low weight, and cheap. EPS is one of the outcomes of creative research that has resulted in substantial cost reductions for building affordable dwellings in sophisticated nations (Hassan et al., 2017).

Various environmental challenges posed by the application of non-sustainable construction materials and techniques and higher cost of same in the recent time have made the search for better and cheaper alternatives a crucial task in the provision of housing. Modern eco-friendly building materials are currently emerging to satisfy the requirements of sustainable developments and mitigate environmental challenges. One of such materials is the expanded polystyrene or EPS (Hafizah et al., 2019).

It is no longer news that the combat against environmental challenges has called for energy efficient materials. In as much as buildings in developed and developing nations account for 40% of the energy demand, over 60% of this being for heating and cooling purposes, appropriate thermal insulation is recognized as one of the most rapid and cost-effective ways of reducing energy demand whilst simultaneously reducing greenhouse gas emissions. Effective insulation method of walls, roofs and floors is a strategy to improve the efficiency of buildings and ultimately reduce monthly utility bills. As a product of research and technological advancements, modern eco-friendly building materials are currently emerging to satisfy the requirements of sustainable developments and mitigate environmental challenges. One of such materials is the expanded polystyrene or EPS, a readily available local energy efficient material, which offers 'best' practice of construction, unique modular design, high strength, good thermal and acoustic properties, reduction of labor, cost and time, in addition to the satisfaction of the green building requirements (Ogundiran & Adedeji, 2014).

2.12.2 Recycling

EPS is 100% recyclable, and hundreds of tons of it are recycled each year in developed countries such as the United Kingdom (UK). This compressed substance has the potential to be recycled into polystyrene pellets. These pellets are utilized in the production of coat hangers, picture frames, hardwood substitutes, and CD-ROM casings. Some members of the EPS Packaging Group have installed consumer recycling stations on their premises so that nearby households and small businesses may recycle their used polystyrene. EPS is an environmentally friendly project that is completely recyclable. The method of recycling EPS materials for increased sustainability consists of five major stages: mechanical crushing, dissolving of recovered EPS, slurry filtration, and polystyrene precipitation. The recovered EPS is crushed and split into smaller bits during mechanical crushing. In the first stage of the procedure, the tiny particles are dissolved. The unique solvent guarantees that only polystyrene is dissolved, leaving all other plastics and contaminants in the slurry in solid phase. The slurry goes through a multistage filtering process to remove solid contaminants from the liquid. Only the solvent and dissolved polystyrene (PS) make it to the next step of recycling. After that, the PS gel is separated from the solvent. Both the precipitant and the solvent are collected and reintroduced into the process circuit. High-quality recycled PS granules are the end result. The finished product (PS) has been authorized independently by the appropriate European authorities. When compared to other methods of disposing of EPS, such as burning and landfill dumping, this recycling technique provides a more cost-effective alternative. Polystyrene waste (PSW) disposal can be difficult due to its bulky form and highly mobile characteristics, as EPS is composed of 98% air and 2% polystyrene. He claims that dissolving EPS in supercritical solvents can liberate the air content in EPS. This dissolving method is one of the most cost-effective and efficient EPS waste treatment procedures. Because these materials do not contain chlorofluorocarbons and are unlikely to contribute to ozone depletion, using dissolved EPS as a building material is a sustainable and ecologically beneficial alternative. One potential application of dissolved polystyrene waste was to use it as wood adhesive instead of use of the traditional popular furniture adhesives. EPS waste can also be used enhancement the performance properties of hot mix asphalt. Addition of EPS waste resulted in improvement of workability and enhanced the resistance to deformation of the asphalt concrete mixture. Addition of EPS waste to the Construction and Demolition Waste (CDW) results in a 34% reduction of density and an 8% improvement (Nyambara et al., 2017).

Expanded polystyrene, or EPS, is a hard cellular plastic manufactured from expandable polystyrene including an expansion agent, pentane. It is an organic insulator with a positive eco balance. As a building material, EPS has found use in a variety of construction projects, including huge constructions such as highways, bridges, railway lines, and public buildings. In addition to being environmentally benign, EPS has low thermal conductivity, is lightweight, has mechanical resistance, moisture and chemical resistance, is easy to handle and install, and is versatile, making it more suited for building construction than the traditional sandcrete method. Insulating concrete forms (ICFs) and structural insulated panels are two energy-efficient solutions that rely on EPS in the building industry (SIPs). Both are regarded as unique product solutions for building envelopes that are gaining widespread support among leaders in sustainable design. Expanded polystyrene has been proven to provide significant environmental benefits through energy savings and reduced greenhouse gas emissions, making it perfect for the development of ecologically friendly new construction projects (Ogundiran & Adedeji, 2014).

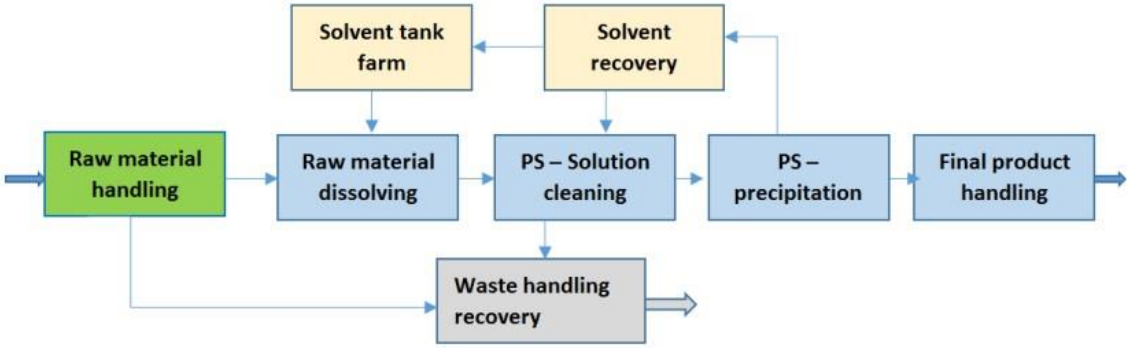


FIGURE 2.10 Recycling Process of EPS Materials (Nyambara et al., 2017)

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. This study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them. Researchers also need to understand the assumptions underlying various techniques and they need to know the criteria by which they can decide that certain techniques and procedures will be applicable to certain problems and others will not. All this means that it is necessary for the researcher to design his methodology for his problem as the same may differ from problem to problem (Pandey, 2015).

This chapter of the paper discuss the type of method the researcher used while doing the thesis. It describes the research area along with the adopted study design. The population and sampling techniques are also described. Their exist different kinds of sources for the data to be gathered and in this chapter the sources from which the data is collected are elaborated. This data can be collected using different techniques and the techniques we used are discussed in this part of the study. It also includes the techniques used to analyze the collected data and also with its validity and reliability measures.

3.2 Description of Study Area

The research is made on building projects which are located in Addis Ababa, Ethiopia. It focuses on building projects that uses EPS technology and conventional construction method. In case of EPS technology, there is only one construction company called EDAB manufacturing and construction which uses this technology and is involved actively in building projects in Addis Ababa. EDAB has made 1780 classrooms for school expansion projects within three months during the covid pandemic. Even if the study area lies in Addis Ababa, EDAB manufacturing division is found around the city Gelan, Oromia region. Other building constructions in Addis Ababa uses the conventional method of construction.

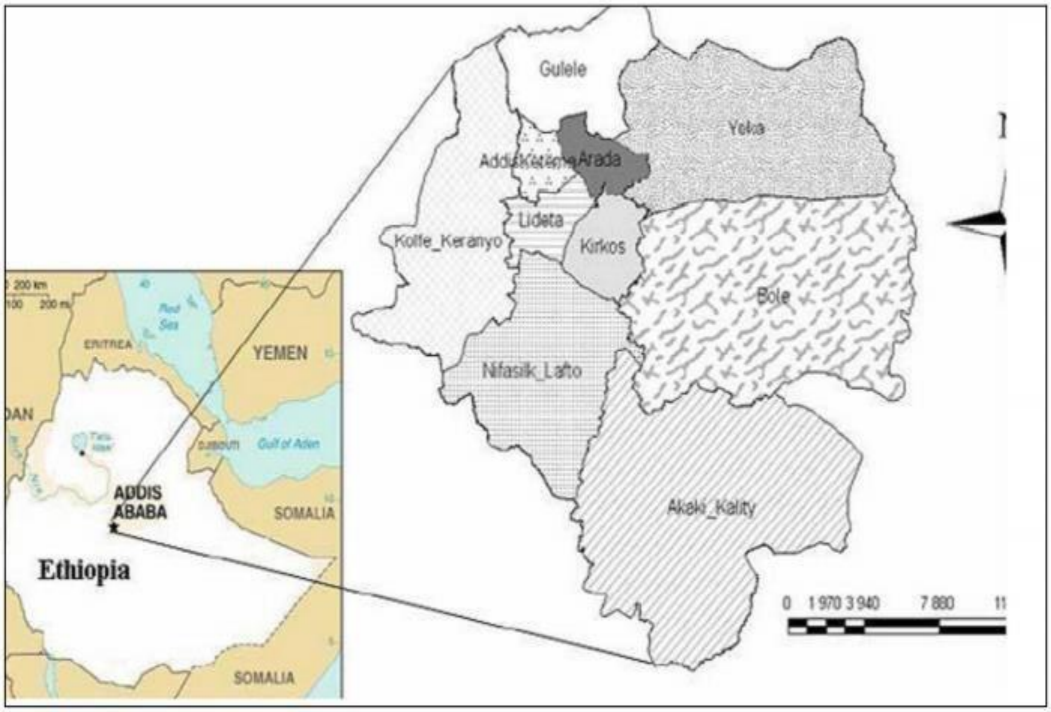


FIGURE 3. 1 Map of Addis Ababa (Yeshineh, 2021)

3.3 Study Design

This research aims to evaluate the current performance of using EPS technology by comparing it with the conventional method of construction. In order to do that, the collection of data from different sources is necessary. For the purpose of this research, data were collected from aforementioned projects through focus group, questionnaire survey and interviews. In addition to this, a series of literature review was made which helps to understand the technology as well as the experience of foreign countries in eps technology. The research design used for this thesis was largely both exploratory and descriptive.

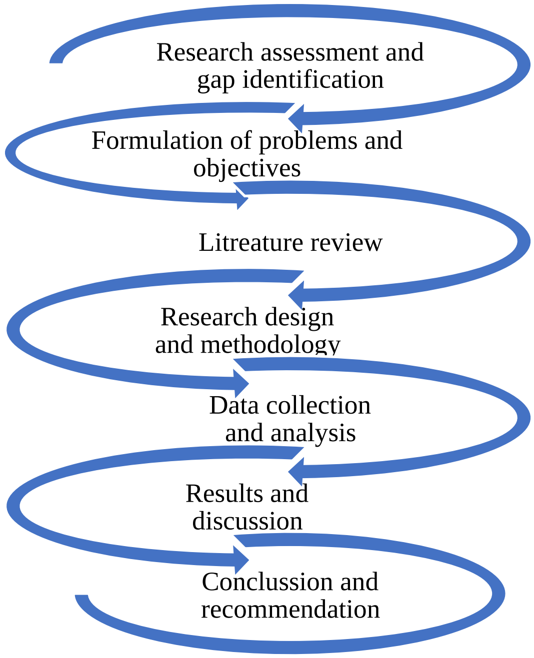


FIGURE 3.2 Study Design

3.4 Population and Sampling Technique

3.4.1 Target Population

The target population in this study is projects that are located in Addis Ababa which uses EPS technology as their method of construction as well as those projects that uses the conventional method of construction. In case of using EPS technology as their method of construction, currently there is only one company called EDAB manufacturing and construction. So, EDAB manufacturing and construction is the target population of the study.

3.4.2 Sampling Technique

For this study, the census method of sampling technique was used in case of EDAB manufacturing and construction company. The Census method is the method of statistical enumeration where all members of the population are studied. In this study, five building projects are used. One is EDAB homes and the other four are construction companies that uses conventional method of construction. Samples that uses conventional method of construction are selected by deliberate or purposive sampling techniques due ease of access and grade of contractors. All selected projects are undertaken by grade 1 contractors.

3.5 Sources of Data

In order to get sufficient and relevant information, Primary and secondary data are the two categories of data for research. For this specific research, both primary data and secondary data were collected. Primary sources were used to collect enough information in the study area and primary data are collected from the above mentioned samples through focus group, questionnaires and interviews. The study was also collected relevant information from the secondary data which were described or preprinted in different books, reports, and company documents to draw the primary data collection instruments and case studies.

3.6 Data Collection Techniques

In order to collect data which are needed for the study, focus group, questionnaire, and interview were used as means of data collection method.

3.6.1 Focus Group

Focus group is one technique used as means of collecting data. By selecting skilled professionals and forming a focus group, areas related to cost, time, quality as well as the manufacturing plant in EDAB manufacturing works. A focus group was made both in the manufacturing as well as constructing segment of EDAB homes. This helps the study get more supporting ideas that helps compare eps technology with the conventional method of construction. In addition to this, it insights the critical factors that differentiate eps technology related to cost and time. It clarifies those information's raised on the interview in a detailed manner and provides document that was further used in the study.

3.6.2 Questionnaire

Another data collecting techniques used in this research is questionnaire. It is the most common way of collecting data and again is used in this study as major source of data for the study. In this research a total of 60 questionnaires were distributed to the selected samples from the given populations. Questionaries were delivered by hand to all the respondents on site and plant. From a total of 60 questionnaires distributed, 50 questionnaires were collected. 40 questionnaires were distributed to those four projects that uses conventional method of construction and from 40 questionnaires 30 of them were collected and 20 out of 20 questionnaires were collected from

EDAB manufacturing and construction company. From the 20 questionnaires given to EDAB homes, 15 of them were given to the construction team and 5 of them were collected from the manufacturing or the plant professionals.

3.6.3 Interview

Face to face interview was one of the data collecting technique used while doing this research. The interviewees were EDAB manufacturing and construction professionals. The interview takes place both in the construction site and in the manufacturing area where the plan is located which is around Gelan city, Oromia region. An interview helps to get more detailed information in order to answer the research problems and address all the raised objectives of the study. Therefore, questions related to how the plan in EDAB homes work were asked in detail in order to evaluate how eps panel is manufacturing. It also includes questions related to cost, quality as well as time it takes for the plan to manufacturing a specific area of panel. It assesses the long- and short-term plan of the company and also the market challenges and acceptability of current situations.

3.7 Data Analysis Techniques

In this study, Analysis of data collected by questionnaire survey were undertaken using Statistical Package for Social Science (SPSS) version 20 to display findings and helps to make it easier. In addition to this Microsoft Excel 2016 was used for supporting the data analysis. For factors related to benefits and challenge questions, the Likert Scales had been used to rank the responsive element. The five-point scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree) was transformed to relative importance index (RII) for each factor as follows: Table 3. 1 Respondents' Demographics

Scale	**Level of Preference**	**RII**
1	Strongly Disagree	$0.0 \leq RII \leq 0.2$
2	Disagree	$0.2 < RII \leq 0.4$
3	Neutral	$0.4 < RII \leq 0.6$
4	Agree	$0.6 < RII \leq 0.8$
5	Strongly Agree	$0.8 < RII \leq 1.0$

According to Rosil et al., (2012), the rating scales used for the result of the questionnaire in this research and the average index is calculated based on the Equation 3.1 as follows; Average Index,

$$I = \frac{\sum ai\, xi}{\sum xi} \qquad \text{Equation 3.1}$$

where ai = Constant which represents the weight of I;

xi = Variable that represents the respondent frequency for I;

i = 1, 2, 3, 4, 5…probability of occurrence rating scale (integer values between 1and 5) Results from focus group and interviews were analyzed differently and incorporated with the results from the questionnaire.

3.8 Data Validity and Reliability

3.8.1 Validity

According to Kothari, (2004), validity refers to the extent to which the instrument measures what the researcher(s) wishes to measure. A validity test indicates the degree to which an instrument measures what it is supposed to measure. There are different ways of testing the validity of the research. In the case of this research, a content validity test is utilized. Content validity is the extent to which a measuring instrument provides adequate coverage of the topic under study. The validity of this research was measured through a pilot study on the project which means a questionnaire was distributed to five project managers and two project research and development heads to evaluate the quality of the questionnaire before data collection. By modifications based on the opinions of those experts before collecting the data and also based on opinions of academicians the quality of the questionnaire was measured.

3.8.2 Reliability

Reliability is concerned with whether the procedures of data collection and analysis generate the same results on all occasions and whether others can also make similar observations and arrive at the same conclusions from the same given raw data. In other words, it is an attribute in which data collection procedures can be repeated with the same results (Yeshineh, 2021). In this research internal consistency was used which involves correlating the responses to each question in the questionnaire with those to other questions in the questionnaire. It, therefore, measures the consistency of responses across either all the questions or a subgroup of the questions from the questionnaire. There are a variety of methods for calculating internal consistency, of which Cronbach's alpha was used for this study to measure the consistency of respondents that were computed with SPSS software.

The minimum advisable level is 0.7 although it may be reduced to 0.6 in exploratory research and anything less than 0.6 is usually eliminated (Kothari, 2004). The formula used for the

Cronbach's alpha measurement present on Equation 3.2:

$$\alpha = \frac{Nc}{v + (N-1)c} \text{ --Equation 3.2}$$

Here N is equal to the number of items, c¯ is the average inter-item covariance among the items and v¯ equals the average variance.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter focus on analyzing and interpreting the result gathered from the respondents through focus group, questionnaire, and interview. Based on the gathered data from the respondent 's current performance status of EPS technology in Addis Ababa building construction and its comparative advantages were analyzed.

In order to analyze the data gathered from the respondents, analyzing methods such as SPSS and excel were used. Results were presented using descriptions, tables, figures, charts and other forms of data presenting techniques.

Cronbach's Alpha (Reliability Test)

The reliability taste was made by Cronbach's alpha coefficient scale through SPSS (Statistical package for social science) on different parameters. The result of the test taken from the respondent response present under the following table 4.1.

Table 4. 1 Cronbach's Alpha coefficient (Reliability Statistics)

Reliability taste made on	Factors	Cronbach's Alpha	N of items
Benefits of using EPS technology	No material waste	0.936	50
	Cost effective	0.920	50
	Speed of construction time	0.905	50
	Lightness	0.963	50
	Versatility	0.869	50
	Integration with other building systems	0.906	50
	Wide choice of finishing	0.941	50
	Earth-quake resistance	0.960	50
	Fire resistance	0.933	50
	Load resistance	0.842	50
	Less no. of laborers	0.842	50

Challenges of using EPS Technology	Lack of suitable transportation	0.941	50
	It may face connection problem	0.878	50
	Error in cutting and molding	0.953	50
	Lack of practice and experience	0.874	50
	Shortage of qualified workers	0.973	50
	Lack of industry knowledge	0.897	50
	Lack of training	0.934	50
	Shortage of critical resources	0.936	50
	Sudden changes of foreign currency	0.965	50
	Higher average cost	0.945	50
	Design errors and omissions	0.848	50
	Lack of design guide	0.942	50
	Weak stakeholders support	0.94	50
	Persist change in organizational management	0.878	50
	Disapproval by the market	0.953	50
Factors affecting using EPS technology	Shortage of skilled man power on the area	0.891	50
	Shortage of supply of prefabricated elements	0.789	50
	Lack of information about the existing potential.	0.898	50
	Lack of awareness about the technology	0.856	50
	Lack of willingness of professionals	0.923	50

The minimum advisable level is 0.7 although it may be reduced to 0.6 in exploratory research and anything less than 0.6 is usually eliminated (Kothari, 2004). As shown in Table 4.1 all factors were beyond the minimum advisable level.

4.2 General Information of the Respondent

Respondents are people participating in a survey, an interview, or offer information to be used in an analysis for a research study. Respondents must give their informed consent in order to participate, and their age can vary depending on the study's parameters. Depending on the position they possess, respondents that were selected and participated in this research are categorized under five groups. This are project managers, office engineers, designers, site engineers and those working on manufacturing site at EDAB homes. From a total of 50 respondents, below is Figure 4.1 presenting the position the respondents have on their company.

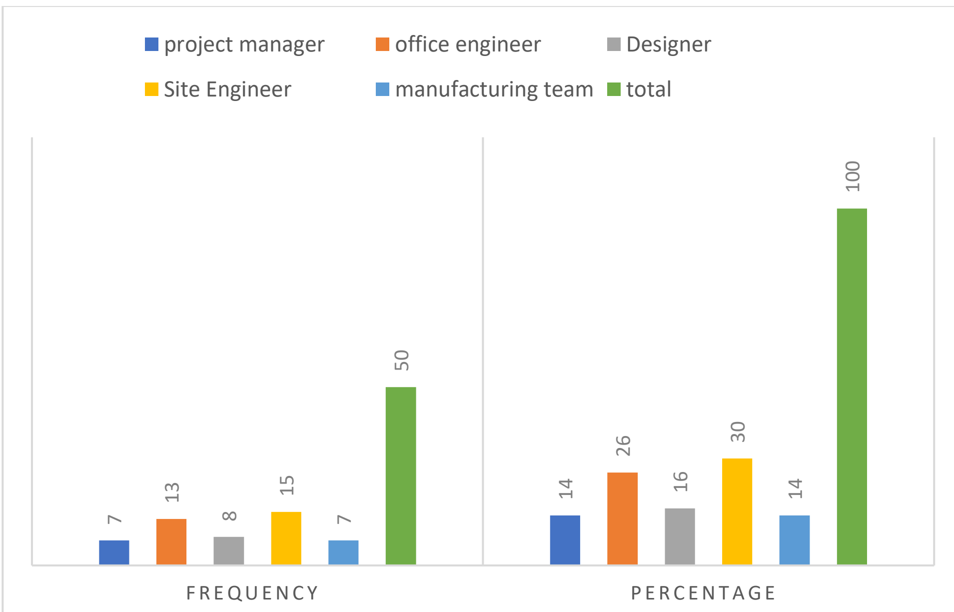


FIGURE 4. 1 Position of Respondents

The questionaries were distributed among construction professional such as office and site engineers, project managers, designers, or architects as well as EDAB manufacturing plant workers as stated above. As it is presented in the above chart, 30% the respondents are site engineers. It means from the collected 50 questionaries; 15 questionaries were responded by site engineers. 13 respondents where office engineers which makes it 26% of the total collected questionaries. Designers were also part of the research and are found to be 7 in number which makes it to be 16% of the total response. A total of 7 questionaries were collected from project managers and manufacturing team members each. This makes it 14% from the respondents were project managers and EDAB manufacturing plant workers each.

The experience of professional in construction plays a significant role in effectiveness of the projects. Prior experience helps manage and reduce upcoming risk and helps to increase productivity.

EDAB manufacturing and construction plc first launched in 2018. The first EPS panel was produced in august 03, 2019. Including the plant manager, majority of the manufacturing staff members started working since the beginning of the plant. The construction team workers relatively have less duration in the company as compared to the manufacturing plant workers. The following Table 4.2 shows the year of experience of respondents.

Table 4. 2 Year of Experience of Respondents

Year of experience	Frequency	Percentage %
Less than 5 years	9	18
5 to 10 years	29	58
More than 10 years	12	24
Total	50	100

The above table shows the experience of respondents involved in this research. As it shows, more than 50% of respondents have five to ten years' experience and 24% of the respondents have an experience of more than 10 years. The other 18%of the responds have less than five years' experience. From this data, we can see that professionals involved have grater experience which increases the reliability of the research.

The educational background of respondents was analyzed and the majority of them were found to be first degree holders. 6% of the respondents were found to be PhD holders. From a total of 50 respondents, 9 of them were found to be MSc degree holders. At last, those with diploma are found to be 8% of the total. Below is Figure 4.2 that illustrates the result.

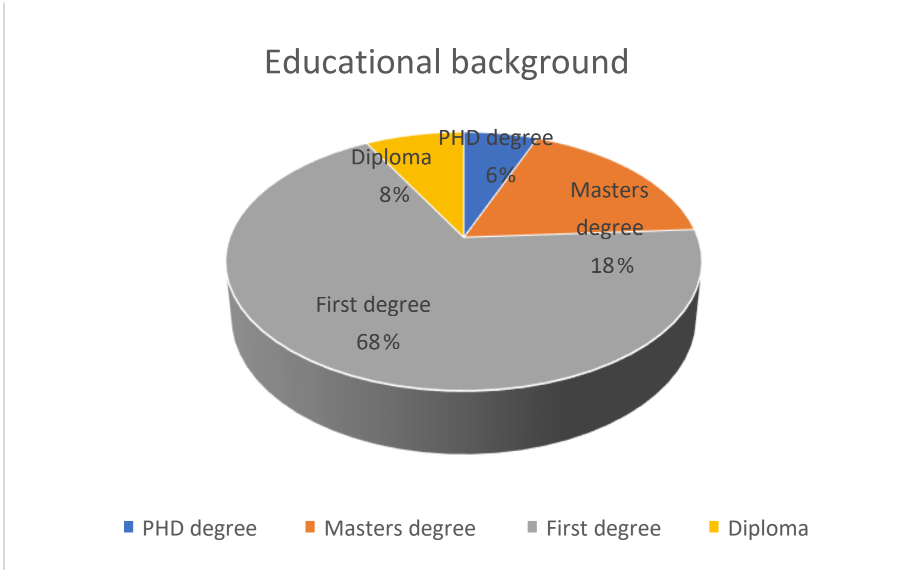


FIGURE 4. 2 Educational Background of respondents

As of being new to our country, EPS technology needs better attention and awareness from main construction firms. The chart Figure 4.3 ranks the potential that different construction firms have on improving the application of eps on building projects.

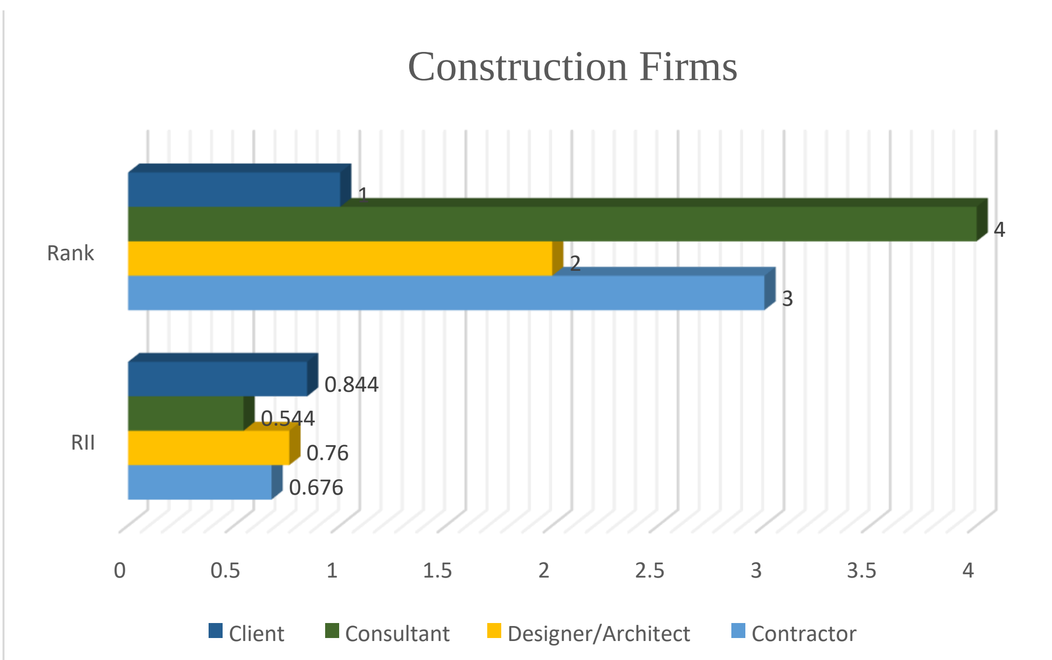


FIGURE 4. 3 Potential of construction firms in improving EPS application.

As the chart indicates, majority of the respondents believed that the client has more potential to increase the application or adoption of eps technology as the new construction method in building projects. The designer/architect is given the second priority with RII value of 0.76. with RII value of 0.544, the consultant is believed to have the last impact from the listed firms.

4.3 The Application Status of EPS Technology:

4.3.1 Benefits of using EPS technology

A versatile plastic material made available for a variety of purposes is expanded Polystyrene (EPS). Due to its light weight, stiffness, and thermal and acoustic insulating qualities, EPS has a wide range of uses. Initially, closed cavity walls, roofs, and floor insulation were the primary uses for EPS insulation foam. In the end, however, the usage of EPS in the building and construction sector has greatly expanded, and it is currently utilized in the building of roads, bridges, floatation devices, and drainage systems.

Currently, EDAB homes is building house made of EPS panel in Ethiopia. The company produces panels to be used in different building parts. According to the thickness of the panel, the function differs. Panels for floor/roof slab and wall are produced. Eps panel stair structures are also manufactured in the company.

We can use the technology for high rise buildings but not up to now that the company built with more than five stores but the design stage for G+12 house is completed in ledeta sub city. Up to now, the maximum story built is four.

The following Table 4.3 describes the major benefit of EPS technology through multiple response analysis method. Multiple response analysis method is a method one respondent can select more than one option and the result of respondent was based on the response rate by the respondent.

Table 4. 3 Benefits of Using EPS Technology

		Responses		Percent of Cases
		No	Percent	
	No material waste	38	9.3%	76.0%
	Cost effective	38	9.3%	76.0%
	Speed of construction time	100	24.6%	200.0%

BENEFITS OF EPS	Lightness	50	12.3%	100.0%
	Versatility	26	6.4%	52.0%
	Integration with other building systems	24	5.9%	48.0%
	Wide choice of finishing	38	6.1%	50.0%
	Earth-quake resistance	38	7.6%	62.0%
	Fire resistance	12	2.9%	24.0%
	Load resistance	24	5.9%	48.0%
	Less no. of laborers	38	9.3%	76.0%
Total		408	100.0%	812.0%

From Table 4.3, most response of respondent was EPS technology has more advantage than conventional construction method with speed of construction time (200%). Next to speed of construction time lightness of panels was second advantage with (100%). cost effective, less number of laborers and no material waste with (76%) were next benefits of EPS technology that conventional construction method doesn't have. EPS is resistant to earth-quakes because it reduces the mass of the building. In Table 4.3 earth-quake resistance of EPS technology get most response following cost effective, less number of laborers. In general EPS technology has major advantage than conventional construction method with many aspects.

The following figure 4.4 prioritize the benefit of EPS technology by ranking. From different benefits of EPS common and some of benefit were listed and prioritize below.

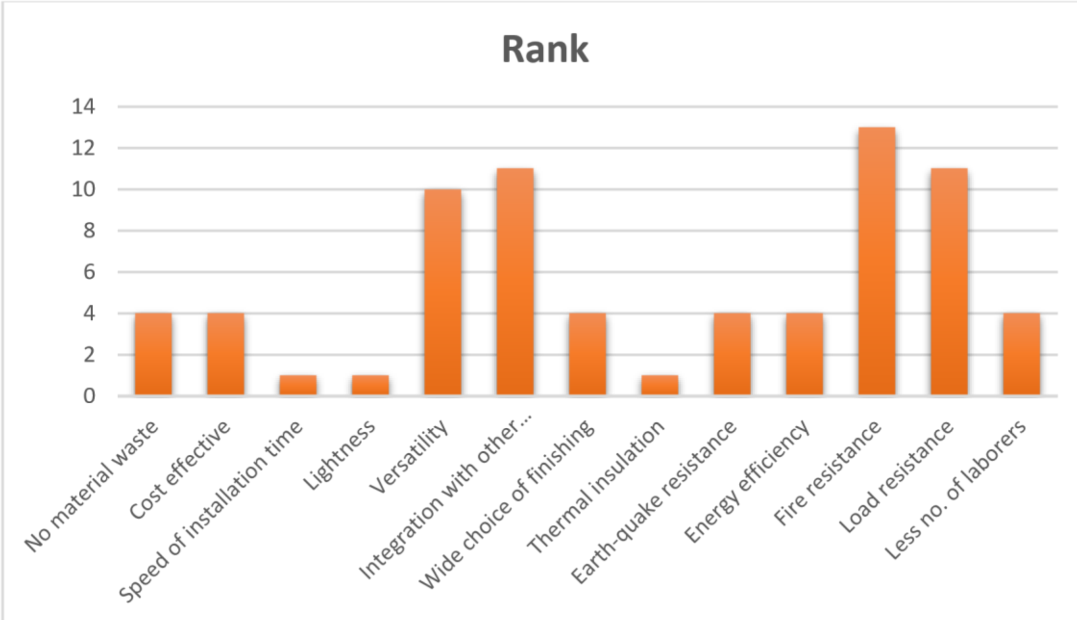


FIGURE 4. 4 Benefit Rank

As shown on the above figure speed of installation (construction) time, lightness of material and thermal insulation was rank first this shows they were major benefits of EPS technology than conventional one. With less material waste, cost effectiveness earth quake resistance, wide choice of finishing and energy efficiency EPS technology had a great benefit since there was on the fourth rank but in case of fire resistance it had limitation because of its material it made up of.

EDAB adapts the technology with the design and constructions are performed as per the world standards of using EPS panel as the building element. In fact, the technology is registered and standards are specified in Ethiopian building codes. Some tests like fire test were made by applying fire on the wall for one hour and found to have no effect. Since eps is coated with concrete, at first it doesn't have the ability to surpass the concrete but the nature of eps is not flammable as we think. It melts when fire or heat is directly applied but the action does not propagate if we stop heating the material like other plastic materials. Leakage test was made on one side of the wall for a week and no leakage encountered on the opposite side of the panel. The authority does not give other building construction companies to use this technology by purchasing the panel from EDAB manufacturing and construction. currently, it is only EDAB which has the authority to build homes to avoid quality problems since it is new technology in the country.

Prior built projects include 20 G+1 apartments for destitute finished in two-month, unity park projects finished within a week, Debora foundation finished in 38 days, and 1780 class for school expansion projects within three months.

Currently, EPS panels are not sold to the market for sale but the manufacturing company is trying to have the right to sale allowing other construction firms to use the technology and supervising them. If this is possible in the near future, the company is profitable and produce up to its capacity but till now, the company is not producing with its maximum ability. It has the ability to manufacture three time the current panel produced daily.

4.3.2 Factors that affect the use EPS technology in construction

Due to lack of proper understanding, it is clear that use EPS in building of in Ethiopia has not been fully integrated. EPS is a multipurpose plastic material made available for a multitude of applications because of its light weight, speed of construction and ability to effectively insulate sound. However, despite its proclamation of its overwhelming properties and the compatibility of its use in the construction industry, it is clear that this use has not been fully integrated.

Now the question is: Why does the acceptance of ESP's use not equate to its declaration as a viable building material for the region? The following are the main factors that affect using EPS technology taken from different literatures and compute under the following Table 4.4

Table 4. 4 Factors that affect the use EPS Technology

Factors	Mean	RII	Rank
Shortage of skilled man power on the area	1.35	0.27	4
Shortage of supply of prefabricated elements	1.15	0.23	5
Lack of information about the existing potential.	4.8	0.96	2
Lack of awareness about the technology	4.85	0.97	1
Lack of willingness of professionals	3.4	0.68	3

The result from the survey Table 4.4 shows that EPS technology mainly affected by lack of awareness about technology and its potential that produce in Ethiopian construction industry. This is due to the EPS technology is new in the country there is a lack of information about this technology features. Lack of willingness of professionals and shortage of skilled man power on the area were next factors that affect adaptation of EPS technology. Those two factors mainly related to manpower need and skill. This is due to a fear of new technology and adaptation we seen in construction industry most of the time, the cost is still there. The EPS technology doesn't need skilled manpower. But most of the time new technology consider as difficult and it seems only constructed by skilled manpower. The EPS technology only needs short-term training on manufacturing and installation of the panels. Shortage of supply of prefabricated elements was last factor that affect use of EPS technology compared to other. Since it is manufactured in our country and the factory itself has a potential to supply the respondents didn't think it is an obstacle in using this technology.

4.4 Challenges of Using EPS Technology in Construction Industry

The construction industry has been living through an exciting phase of its life, growing nonstop and facing many challenges at the same time. Some of these challenges are relatively new; others are as old as the industry itself in case of new technology appears in industry. There are different challenges of EPS technology stated in different literatures. The following challenges are major challenges that are direct relationship with EPS technology in construction industry.

Table 4. 5 Challenges of Using EPS Technology

Factors		Mean	RII	Rank
Transportation	Lack of suitable transportation	1.8	0.36	15
	It may face connection problem	1.9	0.38	13
Installation	Error in cutting and molding	2.05	0.41	12
	Lack of practice and experience	4.4	0.88	2
	Shortage of qualified workers	3.95	0.79	6
	Lack of industry knowledge	4.3	0.86	3
Technical	Lack of training	3.75	0.75	9
Resource	Shortage of critical resources	3.6	0.72	10

Economic	Sudden changes of foreign currency	4.1	0.82	4
	Higher average cost	1.85	0.37	14
Design	Design errors and omissions	3.85	0.77	8
	Lack of design guide	4.1	0.82	4
management	Weak stakeholders support	3.95	0.79	6
	Persist change in organizational management	3.55	0.71	11
market	Disapproval by the market	4.5	0.9	1

In Table 4.5, the first challenge in using EPS technology was disapproval by the market and the second was lack of practice and experience in the industry as per respondent response. Lack of industry knowledge as third rank. The above three major challenge was due to it is crucial to understand the benefits of the technology used in construction as to the extent of problem solving because on the contrary. As such, problems always persist and processes continue in a less efficient manner. Sudden changes of foreign currency and lack of design guide were next to lack of industry knowledge as a challenge. The next challenge were weak stakeholders support and Shortage of qualified workers due to its new technology it needs training on it. Higher average cost and transportation problems was last challenge as respondent response.

According to the respondents, connection problems ranked on the 13th position. Joints and connections in eps technology are simple. Wall panels are first supported by anchor bars since they are placed prior putting the panels in place. EPS panels are easy so we can easily place them and join them in different parts of the building. The anchor bar from front and back supports the wall throughout and shotcrete firms the structure. At evert openings, u and flat mesh are placed to increase the strength of the structural element. L mesh is used at corner areas which make right angle or ninety degrees. It is also used as a surface to place roof slabs tied to the wall.

4.5 Comparison analysis of performance

4.5.1 EPS technology performance analysis on cost

The overall expenditures involved in developing a constructed asset, such a building, include construction costs. In general, construction costs are the expenses related to the actual construction activity itself. A rising middle class with increased housing needs presents a difficulty for developing nations. More than ever before, construction techniques that are quicker and cheaper are being sought for emergency response. More innovation is being incorporated into building and construction techniques in an effort to lower construction costs and produce affordable housing. In order to decrease the negative features of in-situ building, including theft, an unreliable supply of labor, unpredictable weather, unheard-of changes in material prices, and high energy usage, prefabricated components have been introduced employing assembly line techniques.

When employing expanded polystyrene for construction, the biggest cost benefits are attained through lower labor, transportation, and operating and maintenance expenses. By carefully estimating the quantities of materials and labor costs used to create both buildings, the costs associated with construction were examined.

In this section of the study, the cost of slab and wall of EPS technology and conventional method of construction ae compared. The comparison is made only on slab and wall regarding material, labor and equipment cost of the structural elements. In case of wall, eps panel is compared with HCB wall excluding the column and also the slab without the beam. The following tables describe the unit cost of slab in both methods of construction. Here is the unit cost of slab components that sum up to form the total unit cost of slab in EPS as well as conventional method in Table 4.5, 4.6, 4.7, 4.8, 4.9, 4.10 and 4.11:

Table 4. 6 EPS Panel unit cost (EPS technology)

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** Providing , Assembling and laying SINGLE FLOOR PANEL PCSS with 160 mm thick Expanded Polystyrene (EPS) Core Panel reinforced on both sides using welded mesh made of 3 mm Steel Wire

LABOUR HOURLY OUTPUT: 1.49254 m^2/ hr.

WORK ITEM: (4.5) **Footing,Beam and slab**

EQUIPEMENT:

TOTAL QUANTITY OF WORK ITEM: 1 m^2 Sub structure

RESULT: 952.80 Birr/m^3

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
SINGLE FLOOR PANEL PCSS wit	m2	1.00	770.66	770.66	Foreman	1.00	0.10	40.00	4.00	Tools	1.00	12.00	12.00
with 160 mm thick					Steel Fixer	1.00	1.00	23.75	23.75				
including steel wire mesh					Gang Lead	1.00	1.00	16.25	16.25				
					D/L	1.00	1.00	15.00	15.00				
					Carpenter	1.00	0.25	37.50	9.38				
									0.00				
									0.00				
Total (1:-01)				770.66	**Total (1:02)**				68.38	**Total (1:03)**			12.00

A= Materials Unit Cost 770.66 Birr/m^3

B=Manpower Unit Cost 45.81 Br./m^3
Total of (1:02)
Hourly Output

C= Equipment Unit Cost : 8.04 Br./m^3
Total of (1:03)
Hourly output:

Direct Cost of work item = A+B+C = 824.51 Birr/m^3

Overhead Cost: 8% 65.96 "

Profit Cost: 7% 62.33 "

Total Unit Cost : 952.80 Birr/m^3

Remark ____________________

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

From table 4.6 The unit cost of a single 160 mm thick panel to be used for slab is 142.92 $Birr/m^2$

Table 4. 7 Concrete unit cost for Shotcreting of lower side floor slab (EPS technology)

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** Shotcreting of lower rside of floors using non structral plaster

WORK ITEM: (4.5) a) In lower side of slab with 25mm thickness with minimum strength of 15 N/mm²,

TOTAL QUANTITY OF WORK ITEM: 1 m^3

LABOUR HOURLY OUTPUT: 5.71429 m^3 / hr.

EQUIPEMENT:

RESULT: 3481.98 Birr/m^3

87.05 Birr/m^2

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Cement(opc)	Qnt.	3.50	573.00	2005.50	Foreman	1.00	0.10	40.00	4.00	Mixer	0.25	91.46	22.87
Sand	m^3	0.99	900.00	891.00	Mason /plaster	2.00	1.00	37.50	75.00	Manual plaster machi	0.75	62.50	46.88
water	m^3	0.20	100.00	20.00	Gang Lead	1.00	1.00	16.25	16.25	Tools	1.00	12.00	12.00
					D/L	2.00	1.00	15.00	30.00	Air compressor	1.00	284.88	284.88
					Carpenter	1.00	0.25	37.50	9.38				
					Steel Fixer	1.00	0.25	23.75	5.94				
					pump operator	1.00	1.00	37.50	45.00				
Total (1:-01)				2916.50	**Total (1:02)**				185.56	**Total (1:03)**			366.63

A= Materials Unit Cost 2916.50 Birr/m^3

B=Manpower Unit Cost 32.47 Br./m^3 = Total of (1:02) / Hourly Output

C= Equipment Unit Cost : 64.16 Br./m^3 = Total of (1:03) / Hourly output:

Direct Cost of work item = A+B+C = 3013.13 Birr/m^3

Overhead Cost: 8% 241.05 "

Profit Cost: 7% 227.79 "

Total Unit Cost : 3481.98 Birr/m^3

Remark ______________________________

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

From the table 4.7 The unit cost of shotcrete of lower side slab of 25mm thick is 522.3 $Birr/m^2$

Table 4.8 Concrete unit cost for Shotcreting of upper side floor slab (EPS technology)

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** LABOUR HOURLY OUTPUT: 1.25 m^3 / hr.

WORK ITEM: (4.6) C-25 Concrete 5 cm upper side of floor salb (Mechanical Mix) 1:2:3 EQUIPEMENT: Mixer & Vibrator

TOTAL QUANTITY OF WORK ITEM: 1 m^3 Super structure RESULT: 4289.19 Birr/m^3

214.4595992 Birr/m^3

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Cement	Qnt.	3.78	573.00	2165.94	Foreman	1.00	0.10	40.00	4.00	Mixer	1.00	91.46	91.46
Sand	m3	0.55	900.00	491.40	Mason I	2.00	1.00	37.50	75.00	Vibrator	1.00	54.40	54.40
Gravel (02)	m^3	0.82	630.00	515.97	Gang Lead	1.00	1.00	16.25	16.25	Tools	23.00	1.00	23.00
Water	m^3	0.21	100.00	21.30	D/L	23.00	1.00	15.00	345.00				
Eucalyptus wood support	Ml	2.10	10.60	22.26	Carpenter	1.00	0.25	37.50	9.38				0.00
									0.00				0.00
									0.00				0.00
Total (1:-01)				3216.87		**Total (1:02)**			449.63	**Total (1:03)**			168.86

A= Materials Unit Cost 3216.87 Birr/m^3

B=Manpower Unit Cost 359.70 Br./m^3
Total of (1:02)
Hourly Output

C= Equipment Unit Cost : 135.09 Br./m^3
Total of (1:03)
Hourly output:

Direct Cost of work item = A+B+C = 3711.66 Birr/m^3

Overhead Cost: 8% 296.93 "

Profit Cost: 7% 280.60 "

Total Unit Cost : 4289.19 Birr/m^3

Remark ______________________________

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

From the table 4.8 The unit cost of shotcrete of upper side slab of 25mm thick is 643.4 $Birr/m^2$

Table 4.9 Reinforcement bar unit cost (EPS technology)

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT : REINFORCEMENT BARS LABOUR HOURLY OUTPUT: 22.2 kg/hr.
WORK ITEM: (4.32) dia. 6,8 & dia. 10 mm. plain bars super structer EQUIPEMENT:
TOTAL QANTITY OF WORK ITEM: 1 kg. RESULT: 72.45 Birr/kg.

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Dim 6mm to 10mm	Kg	1.05	48.15	50.5575	Foreman	1	0.17	40.00	6.80	tools	2	1.00	2
1.5 mm black anneald wire	Kg	0.02	56.15	1.123	Barbender	4	1	31.25	125.00	Bar cutter	1	30.3	30.3
				0	D/L	2	1	15.00	30.00	Bar Bending	0.25	30.3	7.575
				0					0.00	Hosting Equipment	0.4	106.8	42.72
				0					0.00				0
				0					0.00				0
				0					0.00				0
Total (1:-01)				51.68	**Total (1:02)**				161.80				0
													0
													0
										Total (1:03)			82.60

A= Materials Unit Cost 51.68 birr/kg B= Manpower Unit Cost 7.29 Birr/kg. 3.72
Total of (1:02)
hourly output:
Direct Cost of Work Item = A+B+C = 62.70 Birr/kg.
Over head cost : 8% 5.02 "
Profit Cost: 7% 4.74 "
Total Unit Cost : 72.45 Birr/kg.

Remark ______________________________
UF: UTILIZATION FACTOR
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

- For 229.6 m^2 floor slab they use 1042.4 kg of 8mm bar and 633.7kg of 10 mm bar. Therefore, in 1 m^2 slab we use 4.54 kg of 8mm bars and 2.76 kg of 10mm bar which is 329 and 200 Birr respectively.

Table 4.10 Concrete unit cost for slab (Conventional construction)

PROJECT: Concrete Work
WORK ITEM: Reinforced concrete C-25 to 150mm floor slab, 150mm roof slab and water tank slab
TOTAL QUANTITY OF WORK ITEM: 1m2 0.15 m3

Labour Hourly Output: 0.79 m2/hr
Equipment Hourly Output : 0.79 m2/hr
Result: 814.21 Birr/m2

A) MATERIAL					B) MANPOWER					C) EQUIPMENT			
TYPE	UNIT	QTY PER UNIT WORK	RATE (BIRR)	COST PER UNIT (BIRR)	SKILL	NO.	U.F.	HOURLY RATE (BIRR)	HOURLY COST (BIRR)	TYPE	NO.	RENTAL RATE/hr (BIRR)	HOURLY COST (BIRR)
OPC Cement	qtl	3.65	573.00	2,091.45	Forman	1	0.5	40.00	20.00	Mixer	1	400.00	400.00
Sand	m3	0.46	900.00	414.00	Mason	2	1	30.80	61.60	Vibrator	1	37.50	37.50
Gravel (01 & 02)	m3	0.81	630.00	510.30	DL	18	1	22.00	396.00	Benzine	3	15.20	45.60
Water	m3	0.24	100.00	23.70	Gang Chief	1	1	23.50	23.50				
					Mixer Operator	1	1	18.75	18.75				
					Viberator Operator	1	1	22.65	22.65				
Total(A)				3,039.45	Total(B)				542.50	Total (C)/			483.10
Material Unit Cost				3,039.45	Manpower Unit Cost				689.24	Equipment Unit Cost			613.77

A=Materials Unit Cost 3,039.45 **70.0%**

B=Manpower Unit Cost 689.24 **15.9%**

C= Equipment Unit cost 613.77 **14.1%**

Direct Cost of Work Item =A+B+C=		4,342.46
Overhead Cost :	15%	651.37
Profit :	10%	434.25
Total Unit Cost:		**5,428.08**

From table 4.10 The unit cost of concrete (c-25) of 150mm thick floor slab is 814.2 $Birr/m^2$

Table 4.11 Formwork unit cost (conventional construction)

PROJECT: Concrete Work
WORK ITEM: Formwork for floor beam, floor slab, roof slab, toptie beam, stair case, RC gutter and water tank slab
TOTAL QUANTITY OF WORK ITEM: 1m^2

Labour Hourly Output: 3.24 m^2/hr
Equipment Hourly Output : 3.24 m^2/hr
Result: 523.20 Birr/m^2

A) MATERIAL					B) MANPOWER					C) EQUIPMENT			
TYPE	UNIT	QTY PER UNIT WORK	RATE (BIRR)	COST PER UNIT (BIRR)	SKILL	NO.	U.F.	HOURLY RATE (BIRR)	HOURLY COST (BIRR)	TYPE	NO.	RENTAL RATE/hr (BIRR)	HOURLY COST (BIRR)
Eucalyptus dia 8mm to dia 12mm	m	0.30	50.00	15.00	Forman	1	0.25	40.00	10.00	Hand Tools	1	2.00	2.00
4x5 cm batten	m	0.80	31.43	25.14	Carpenter	1	1	32.00	32.00				
Nails	kg	0.05	41.10	2.06	Carpenter Helper	1	1	22.50	22.50				
2.5cm thick timber	pcs	1.23	288.00	355.38	0	2	1	0.00	-				
Mold oil/fromwork releasing agent	lit	0.05	10.00	0.45									
Total(A)				398.03	Total(B)				64.50	Total (C)/			2.00
Material Unit Cost				398.03	Manpower Unit Cost				19.92	Equipment Unit Cost			0.62

A=Materials Unit Cost	398.03	B=Manpower Unit Cost	19.92	C= Equipment Unit cost	0.62
	95.1%		4.8%		0.1%
				Direct Cost of Work Item =A+B+C=	418.56
				Overhead Cost : 15%	62.78
				Profit : 10%	41.86
				Total Unit Cost:	**523.20**

From the table 4.11 The unit cost of formwork in one meter square is $523.2\ Birr/m^2$

Table 4.12 Reinforcement bar unit cost(conventional construction)

PROJECT: Concrete Work		**Labour Hourly Output:**	7.91 kg/hr
WORK ITEM:	Reinforcement dia. 8mm to dia. 24mm	**Equipment Hourly Output :**	7.91 kg/hr
TOTAL QUANTITY OF WORK ITEM:	1kg	**Result:**	83.50 Birr/kg

A) MATERIAL					B) MANPOWER					C) EQUIPMENT			
TYPE	UNIT	QTY PER UNIT WORK	RATE (BIRR)	COST PER UNIT (BIRR)	SKILL	NO.	U.F.	HOURLY RATE (BIRR)	HOURLY COST (BIRR)	TYPE	NO.	RENTAL RATE/hr (BIRR)	HOURLY COST (BIRR)
Rebar dia 8 to dia 24	kg	1.05	48.15	50.56	Forman	1	0.25	40.00	10.00	Hand Tools	1	2.00	2.00
Black wire 1.5mm	kg	0.02	56.15	1.12	Bar Bender	2	1	31.25	62.50				
					Helper	2	1	22.50	45.00				
Total(A)				51.68	Total(B)				117.50	Total (C)/			2.00
Material Unit Cost				51.68	Manpower Unit Cost				14.86	Equipment Unit Cost			0.25

A=Materials Unit Cost	51.68	B=Manpower Unit Cost	14.86	C= Equipment Unit cost	0.25
	77.4%		22.3%		0.4%
				Direct Cost of Work Item =A+B+C=	66.80
				Overhead Cost : 15%	10.02
				Profit : 10%	6.68
				Total Unit Cost:	**83.50**

For 229.6 m^2 floor slab they use 50.57 kg of 8mm bar and 83.2kg of 10 mm bar. Therefore, in 1 m^2 slab we use 14.07kg of 8mm bars and 16.5 kg of 10mm bar in this case of conventional construction which is 1175 and 1378 birr respectively.

In the above listed tables, unit cost of each element of slab on both method of constructions is calculated. So, in order to compare the total unit cost of slab, we need to sum up to get the total unit cost of slab. All units are converted in Birr per meter square. The total unit cost is the sum of each unit costs. The unit cost of single panel of 160 mm thickness, unit cost of shotcrete of both upper and lower side of the panel and the unit cost of reinforcement bar in one-meter square area sum up the total unit cost of slab for EPS panel slab. This are (142.92+522.3+643.4+200+329) birr/m^2. This is 1837.62 Birr/m^2. And as u can see, the same process is undertaken for conventional method and the sum of c-25 concrete unit cost, formwork unit cost and reinforcement bar unit cost give us the total unit cost of slab. the next step is to add all the listed components. This are (814.2+523.2+13781175) birr/m^2. This is 3890.4 Birr/m^2.

Table 4.13 Total unit cost of slab and wall per meter square of conventional and EPS technology.

Structural Member	Total unit cost for item of work birr/m^2	
	Conventional	EPS Technology
Wall	634	1083.84
Slab	3890.4	1837.62

The above table illustrates the total unit cost of slab and wall for both EPS technology and conventional method of construction. Check Appendix A to see unit costs related to wall on both cases. Below is Figure 4.5 showing slab and wall total unit cost.

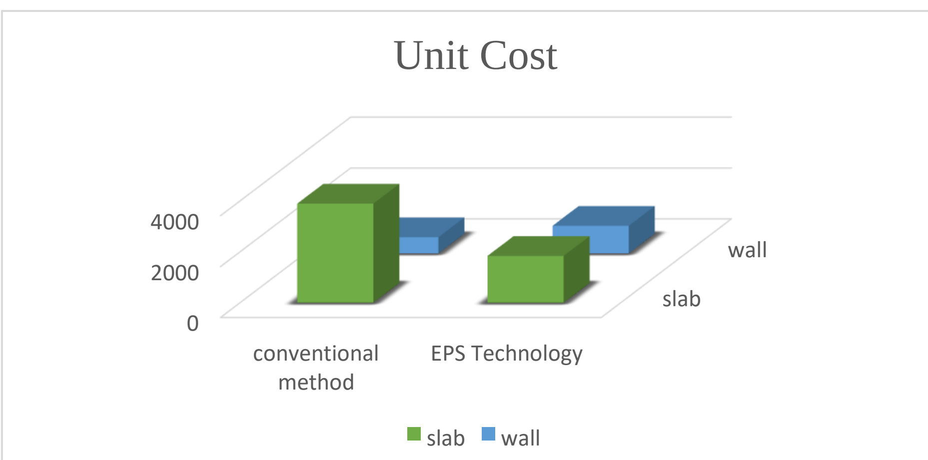


FIGURE 4. 5 Total unit cost of slab and wall

The total unit cost of wall in case of HCB is less than the cost of EPS panel cost but the unit cost of slab in conventional method is greater than that of the EPS slab panel. Let us see the difference by taking an example of a sample house. Let's consider a house of 10-meter width and 10-meter length with 2.75-meter height. Assume the door is 0.9 meter wide and 2.1 meter high and the window is 0.9 meter wide and 1.2 meter high. In this case, slab area of the house is 10m * 10m = 100 m^2 and wall area is 4(10m * 2.75m) = 110 m^2. We then subtract the area of window and door for the wall. The area of window is 1.08 m^2 and area of door is 1.89 m^2. The new area of wall becomes 107.03 m^2. For a house with slab area of 100 m^2, since the unit cost of slab for conventional method is 3890.4 birr/m^2, the total cost of slab is 3890.4 birr/m^2 * 100 m^2= 389,040 Birr. For eps technology, the unit cost is 1837.62 birr/m^2 and for 100 m^2 of slab, the total cost is 1837.62 birr/m^2 * 100m^2= 183,762 Birr. For 107.03 m^2 of wall, total cost for conventional method is 634 birr/m^2 * 107.03m^2= 67,853.02 birr. For EPS technology, the total wall cost is 1083.84 birr/m^2 * 107.03m^2= 116,003.4 birr. From this, we can see that the total cost of wall of HCB is lower that of EPS panel walls but the cost of conventional concrete slab is greater than that of the EPS panel slab. for a house with 100 m^2 slab and 107.03m^2 wall, the total cost of wall and slab is 456,897.02 birr for conventional method and 299,765.4 birr for using EPS technology. The result is more illustrated in the Figure 4.6 below.

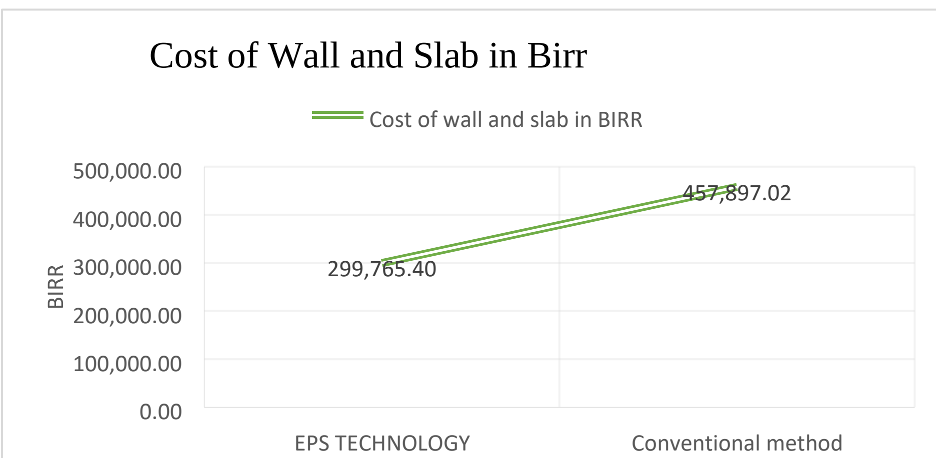


FIGURE 4. 6 Cost of wall and slab

4.5.2 EPS technology performance analysis on time

Keeping the project on schedule is one of our construction's challenges. The likelihood that the project will be completed on time or earlier is increased by the shorter construction period. In case of EDAB homes, no delay is faced by the manufacturing plant. The plant always manufactures panels exceeding the daily requirement and up to now, no delay issue is encountered by the manufacturing team. The plant manufactures 1600 m^2 eps panels daily with only one shift or eight working hours.

Additionally, the time value of money provides a cost advantage when the construction period is shorter. Under this section, the time taken to construct member of structure (wall and slab) were compared by taking two construction methodology. one conventional the other is EPS technology. Since this EPS technology is a wall-slab system technology the comparison made on those structure member only. Under time taken to construct each member of construction the time consume by two methods were compared inm^2 in order to compute equally. The following Table 4.14 shows the time consumed to construct floor slab and wall through both conventional and EPS method.

Table 4. 14 Construction time for slab and wall

Structural member	Construction time in m^2/hr.	
	conventional	EPS technology
Floor slab	1.3	2.5
Wall	1.8	3.2

In the above table, the amount of work done in meter square done within one hour is stated by analyzing data from focus group and observation. It can be seen that using EPS technology has better time advantage than using the conventional method of construction. using the previous sample house of 100 m^2 of slab and 107.03 m2 of wall, we can compare the time it takes to complete the wall and slab of a building considering the other works to be done takes same amount of method and time. In case of conventional method, 1.3 m^2 area of slab is completed within one hour. Considering this, it takes 76.9 hour to complete 100 m^2 slab. this means it takes 9.6 days to complete the slab if one uses conventional method to construct 100 m^2 of slab. in case of using

EPS technology, since it takes one hour for 2.5 m^2 of slab, it takes 40 hours to complete 100 m^2 of slab. this means, 5 days are required to complete 100 m^2 of slab while using EPS technology as means of construction. for constructing HCB wall, it takes relatively one hour for completing 1.8 m^2 area. So, to complete 107.03 m^2 of wall, it will take 59.46 hour. This means 7.43 days to complete the wall. For construction that uses EPS panel, it takes an hour to complete 3.2 m^2 of wall. Taking this into account, it takes 33.44 hours or 4.2 days to complete 107.03 m^2 of wall.

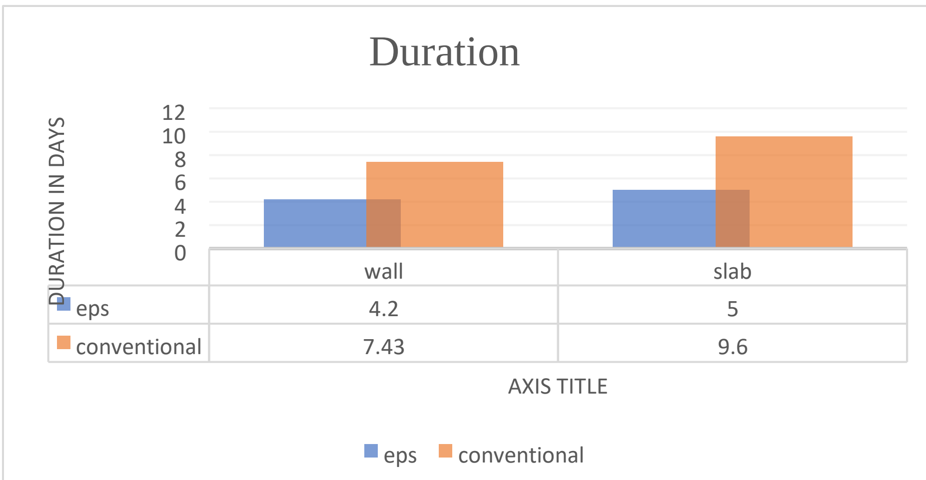


FIGURE 4. 7 Duration of wall and slab construction

4.6 EPS Manufacturing Plant

4.6.1 Raw Material

In order to produce EPS panel, we need to have two main raw materials. This are eps bid and a wire. Both materials are imported from China and Dubai.

a) EPS bid

b) Wire

FIGURE 4. 8 Raw Materials of EPS panel

4.6.2 Production of wire mesh

As it can be seen in the above diagram (b), the wire is imported in a coiled format so the first thing to do is to straighten the coiled wire. It is 3mm in diameter and weight abbot 700 kilogram. The strength of the wire is 700 Mpa.The wire is placed in a machine where it can be straightened and directed to be cut in the appropriate or needed size. The machine is automated and work according to the encoded data. It can cut up to six-meter length of wire. If we need 200 pieces of a one meter and twenty-centimeter length of wire, we will log the length and the number of pieces we want and then start the machine so that it will deliver the encoded length of wire with the required quantity. Below is the wire straightening machine.

a) Wire straightening machine b) straightened wire

FIGURE 4. 9 Wire Straightening Machine and Straightened Wire

There is also another machine that reduces the diameter of a bar. This machine reduces the diameter of the local bar up to 12 mm diameter to the required diameter in three stages. Once you insert the bar into the machine, it will first reduce it to a lower diameter in the first chamber and forward it to the next chamber so that it can be reduced more. The last part is where the required diameter obtained. This machine can also rib the body of the bar if required.

After straightened the wire with the required length, the next step is to produce the mesh. The mesh welding machine is the machine that welds the prepared wires to form a wire mesh.

In this machine, a wire mesh is created by welding the long vertical and horizontal wires in the programed spacing. The vertical wires are placed in the appropriate standard format and the machine will weld the horizontal wires in the needed spacing. This machine also has a programming part so if we need a 100 mm spacing between the horizontal meshes, encode the data and the machine will weld according to the recorded data. The short horizontal wires are added from the top of the machine and are first adjusted in a proper way manually. When the welding is over, the mash will be withdrawal at the back of the machine and be manually removed from the machine and directed to the desired use.

a) Wire Welding Machine b) Welded Mesh

FIGURE 4. 10 Wire Welding Machine and Welded Mesh

4.6.3 Production of EPS panel

The raw material we use to produce an eps panel is called eps bid which is imported from Dubai and China. It is commonly known as polystyrene salt. The bid is up to 95% gas and this gas is called polystyrene gas. The first step is to expand the bids by using stem. In order to do this, there is a boiler that boils water at 116 °C. The boiler can contain up to 1500 liter of water. It converts the water into gas or stem. The stem is stored in a condenser and can also be use directly from the boiler.

FIGURE 4. 11 EPS Manufacturing Plant

The above picture shows a large pneumatic machine where eps panel is formed. Fifteen to sixteen kilogram of eps bid is expanded in one cycle. The bids are expanded using stem which were initially formed by boiling water at 116 ℃. Stem is released from the boiler for 80-90 second. The stem will expand the bid to 85% of their expansion ability.

FIGURE 4. 12 Expanded EPS Bid

Once they are expanded, bids are driven in to silos. The machine contains four silos in which three of the silos are used to store virgin expanded bids for about 24 hours. The fourth silo is where the recycled bids are stored. The wasted panels are crushed in a machine and then directed into the fourth silo using the same method. Since the bids are expanded using stem, it has moisture contain. So before casting the bids, it should dry first. The bids are driven into the silos using compressed air so the use of air will help us remove the moisture. In addition, we will let the bid stay up to a full day so that it can dry completely. After the bids are completely dry, the bids are dragged into a smaller silo. The three silos that contain the virgin bids are connected underneath by a single tube and directed into one silo and the recycled bid are dragged by another tube and dragged in to a different silo. Now the dried virgin and recycled bids are places in two different silos and from, bids are forwarded into one single silo. It means both the virgin and recycled bids are going to be mixed and put into the same silo. The mixture is composed of up to a minimum of 70% of virgin bid and a maximum of 30% of recycled bid. The percentage of the recycled bid cannot exceed 30% of the total amount because at the first stage of expansion, the bids expand at 85% of their total expansion and the rest 15% is going to take place inside the mold making machine. It's a confined area so without any additives, the bids will fuse. So fusion is needed and since the recycled bid finished its expansion ability, it will not bring the needed fusion if its more than 30%. So the next part is the mold making machine. First step is to place the bids into the machine. It's a confined area. It has spaces from left and right side in which stem is released. At this stage, we need high volume of stem for only 30 seconds and the boiler doesn't produce the required volume of stem at once. So, stem is contained in the condenser and from the condenser stem is released with higher volume in to the molding machine for only 30 seconds. we then let the bids mold or fuse for up to four minutes. At this time the bids will expand and fuse. Width and length of the panel is standard. It is one meter and twenty centimeters of length by sixty centimeters of width. The height of the machine is two meter and thirty centimeters but the height of the panel can be adjusted up to two meters because of the piston at the upper part of the molding machine. So, after 4 minutes in the molding machine, the panel is ready to be removed.

Now, after the panel is removed from the molding machine, the next step is to cut the mold into the desired thickness. In order to do this, we are going to use the slating machine. slating machine cuts the mold into different sizes.

a) Mold cutting machine b) EPS Panel

FIGURE 4. 13 Mold Cutting Machine and Slated Mold (Eps Panel)

As you can see from the diagram, the mold is going to be placed in the slating machine and at the middle of the machine, their exists three strings which cuts the mold according to the encoded data by the use of heat. The machine has data encoding part in which you log the way your mold wants to be cut. It adjusts the spacing and the shape of the mold. As you can see from the above diagram, the machine is logged to cut the mold in a zigzag shape. In order to have sharp endings, first the machine cuts five centimeters of the panel from all sides. The strings can be reduced in number if needed. This means, if the required shape is going to be made using one string, we can remove the others and cut the mold into the desired shape. Since we use eps panel for different structural parts, it is obvious that the size varies. The thickness of the panels varies according to their purposes. We use up to sixteen centimeters of panel for slab, eight centimeters thick panel for wall and six centimeters thick panel for partition wall. So, this means that the molds are cut in to different thicknesses according to their functions. This time, the molds are of the required thickness and are ready for the next process.

Now, we have both the eps mold of the required thickness and the wire mesh ready. The next part is forming the eps panel which comprises the mesh sandwiching the eps mold. In order to do this, we need a welding machine which weld a short vertical wire which helps join the mold with the mesh. So, we put the meshed panel on the machine and start welding it with vertical wires from the top to bottom throughout. Sometimes there are shapes other than rectangle that cannot be welded in the machine. This time we use manual to cut the short vertical wires and weld them. Once it is done, the panel is ready to be used in the construction site.

a) Mesh and panel welding machine b) manual welding

FIGURE 4. 14 Mesh and panel manual and machine Welding

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The goal of this study, as stated above, is to assess the effectiveness of EPS technology in Addis Ababa building projects by contrasting the price and timeline of a wall and slab with a traditional method of construction while taking into account the advantages and difficulties it presents as well as how EPS panel is produced from the raw material. The following conclusion is reached from the study's findings based on the study's objectives, previous results, and analyses: -

EPS technology is a new means of construction adopted in our country. It uses panels made from expanded polystyrene by extracting it from a raw material called EPS bid and sandwiching the panel with a wire mesh. The raw materials are imported from Dubai and China. It works by expanding the bid by means of steam from a boiler or condenser. The machines are pneumatic which uses compressed area for the motion if objects. Straightening the imported wire mesh and sandwiching the panel with the mesh, a complete meshed EPS panel is produced with different thickness. EDAB manufacturing and construction plc planted its manufacturing site around Gelan city and manufacture 1600 m^2 of panel daily in one shift.

EPS technology has many benefits and, in this study, we can conclude that the completion time of construction can be concluded to be the major benefit of EPS technology over the conventional method of construction. the light weight of EPS panel which makes it easy to handle during construction as well as transportation from the manufacturing site to the construction site makes it favorable among the construction workers since transportation of HCB wall or any other concrete structure is not easy to handle in site. The other benefit of using EPS technology is its cost effectiveness. Cost reduction is selected as being third among the top benefits of using the technology. Since EPS is recyclable material, it is best to reduce waste. This is why the reduction of waste in construction ranked third among the other benefits of EPS'S technology.

Any kind of construction method might face different kinds of challenges and as being a new method, using EPS technology as means of construction has many challenges. Different possible challenges were studied and the challenge faced by the market is found to be prior to all. This shows that the market opposing to accept eps as a building material. The lack of practice and experience is ranked second from all the challenges. The third rank was given to lack of industrial knowledge. As we can see all the top three challenges faced, it is cleared that the cause of all of them was because it is new method of construction and people are not accepting the market because there is lack of knowledge and experience. This shows that a series of awareness building in the industry is mandatory.

EPS technology has better cost performance in case of wall and slab as compared to the conventional method. In fact, cost comparison took place only for wall and slab and unit cost in meter square was calculated. Taking a sample house of 100 meter square slab area and 107.03 meter square of wall area, the cost of slab for both construction methods were calculated. It is found that the total sum cost of wall and slab in EPS technology reduces cost by 34.4 % from the conventional method. From this we can conclude that the sum total cost of wall and slab is lower when using EPS technology than conventional method.

Among many advantages of using EPS technology, the reduction in construction time is unbeatable. Construction time of wall and slab were compared in both methods of construction. When 1.8 meter square area of wall is constructed within one hour in case of conventional method, 3.2 meter square wall is constructed per hour in case of EPS technology. When 1.3 meter square of slab is constructed in an hour using conventional method, 2.5 meter square slab is constructed per hour by using EPS technology. From this, it can be concluded that EPS technology reduces the construction time by 46%.

5.2 Recommendation

I'd like to recommend the ideas and comments below based on the study's findings and conclusion.

- ✓ There isn't enough research on this type of technology, we know less about it than we should, and we're afraid to adopt new technologies since we only look at it from the outside. This is what the majority of contractors do, but instead of concluding that the technology is difficult, contractors ought to become involved and conduct study on it. The contractors should be informed of and keep up with technological advancements in the building industry.

- ✓ Awareness creating conferences to be organized by EDAB manufacturing and construction plc to different clients, designers, engineers and contractors to penetrate the market as well as to share experience is recommended.
- ✓ Government funding for the contractors who bring this kind of technology is nonexistent. It is challenging to transform the building sector from conventional to current technologies because the contractors try it themselves. Therefore, in order to modernize our building industry, the government should encourage the contractors by offering promotions and tax breaks. It should also take into account the current highly volatile foreign exchange market since raw materials are imported from other nations.
- ✓ Since there are not many researches in this area in our country, this research will serve as reference for the coming researches. Apart from this, It is recommended to study the overall building cost and time of buildings because this research only compares cost and time of wall and slab. I recommend to study on quality and safety of adopting this technology in detail and also to make practical tests on laboratory.

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Appendix A: Costs of Wall

Table A- 1 Panel cost (EPS technology)

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** Providing , Assembling and laying Load bearing wall of SINGLE PANEL PCSP with 80 mm thick Expanded Polystyrene (EPS) Core Panel reinforced on both sides using welded mesh made of 3 mm Steel Wire

LABOUR HOURLY OUTPUT: 3.03 m^2/ hr.

WORK ITEM: (4.5)

EQUIPEMENT:

TOTAL QUANTITY OF WORK ITEM: 1 m^2 Super structure

RESULT: 595.00 Birr/m^3

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
SINGLE PANEL PCSP	m2	1.00	484.73	484.73	Foreman	1.00	0.10	40.00	4.00	Tools	23.00	1.00	23.00
including steel wire mesh					Steel Fixer	1.00	1.00	23.75	23.75				
					Gang Lead	1.00	1.00	16.25	16.25				
					D/L	1.00	1.00	15.00	15.00				
					Carpenter	1.00	0.25	37.50	9.38				
									0.00				
									0.00				
Total (1:-01)				484.73	**Total (1:02)**				68.38	**Total (1:03)**			23.00

A= Materials Unit Cost 484.73 Birr/m^3

B=Manpower Unit Cost 22.57 Br./m^3

Total of (1:02)

Hourly Output

C= Equipment Unit Cost : 7.59 Br./m^3

Total of (1:03)

Hourly output:

Direct Cost of work item = A+B+C = 514.89 Birr/m^3

Overhead Cost: 8% 41.19 "

Profit Cost: 7% 38.93 "

Total Unit Cost : 595.00 Birr/m^3

Remark ______________________

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 2 Shotcret cost

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** Shotcreting walls using

LABOUR HOURLY OUTPUT: 11.4286 m^3 / hr.

WORK ITEM: (4.5) a) In Load Bearing walls with 35mm thickness on both sides with minimum strength of 2 EQUIPEMENT:

TOTAL QUANTITY OF WORK ITEM: 1 m^3

RESULT: 3641.59 Birr/m^3

254.91 Birr/m^2

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Cement	Qnt.	3.50	573.00	2005.50	Foreman	1.00	0.10	40.00	4.00	Mixer	0.25	91.46	22.87
Sand	m3	0.52	900.00	466.56	Mason /plaster	2.00	1.00	37.50	75.00	Shotcrete Pump	0.75	507.10	380.33
Gravel (<6mm)	m^3	0.78	531.25	413.10	Gang Lead	1.00	1.00	16.25	16.25	Tools	1.00	12.00	12.00
Water	m^3	0.17	70.80	11.72	D/L	2.00	1.00	15.00	30.00	3phase generator	1.00	284.88	284.88
Superplasticizer, BASF RHEO BUILI	lt	2.64	67.00	176.88	Carpenter	1.00	0.25	37.50	9.38				
					Steel Fixer	1.00	0.25	23.75	5.94				
					pump operator	1.00	1.00	37.50	45.00				
Total (1:-01)				3073.76	**Total (1:02)**				185.56	**Total (1:03)**			700.08

A= Materials Unit Cost 3073.76 Birr/m^3

B=Manpower Unit Cost 16.24 Br./m^3

Total of (1:02)

Hourly Output

C= Equipment Unit Cost : 61.26 Br./m^3

Total of (1:03)

Hourly output:

Direct Cost of work item = A+B+C = 3151.26 Birr/m^3

Overhead Cost: 8% 252.10 "

Profit Cost: 7% 238.24 "

Total Unit Cost : 3641.59 Birr/m^3

Remark ______________________

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 3 Extra strengthening U- mesh cost

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** Extra for strengthening around wall openings on the perimeter of the opening sides, using U-mesh 3mm Hard Drawn Steel Wire mesh of size 449 mm including straightening, cutting, bending, placing in position and binding all complete as per direction of the Engineer-inCharge (The measurement is to be done in length of openings).

LABOUR HOURLY OUTPUT: 20 m/ hr.

WORK ITEM: (4.5)

EQUIPEMENT:

TOTAL QUANTITY OF WORK ITEM: 1 m Sub structure

RESULT: 89.36 Birr/m

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
U-mesh of size 449 mm	m	1.00	73.78	73.78	Foreman	1.00	0.10	40.00	4.00	Tools	1.00	12.00	12.00
					Steel Fixer	1.00	1.00	23.75	23.75				
					Gang Lead	1.00	1.00	16.25	16.25				
					D/L	1.00	1.00	15.00	15.00				
Total (1:-01)				73.78	Total (1:02)				59.00	Total (1:03)			12.00

A= Materials Unit Cost 73.78 Birr/m^3

B=Manpower Unit Cost 2.95 Br./m^3

Total of (1:02)

Hourly Output

C= Equipment Unit Cost : 0.60 Br./m^3

Total of (1:03)

Hourly output:

Direct Cost of work item = A+B+C = 77.33 Birr/m

Overhead Cost: 8% 6.19 "

Profit Cost: 7% 5.85 "

Total Unit Cost : 89.36 Birr/m

Remark ____

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 4 Extra strengthening Flat mesh cost

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: ***CONCRETE WORK*** Extra for joining two sheets/ corners strengthening on both sides using 3mm Hard Drawn Steel Flat Wire mesh 225 mm wide, including straightening, cutting, bending, placing in position and binding all complete as per direction of the Engineer-inCharge (The measurement is to be done in running metres).

LABOUR HOURLY OUTPUT: 20 m/ hr.

WORK ITEM: (4.5)

EQUIPEMENT:

TOTAL QUANTITY OF WORK ITEM: 1 m Sub structure

RESULT: 46.73 Birr/m

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Flat Wire mesh 225 mm	m	1.00	36.89	36.89	Foreman	1.00	0.10	40.00	4.00	Tools	1.00	12.00	12.00
					Steel Fixer	1.00	1.00	23.75	23.75				
					Gang Lead	1.00	1.00	16.25	16.25				
					D/L	1.00	1.00	15.00	15.00				
Total (1:-01)				36.89	Total (1:02)				59.00	Total (1:03)			12.00

A= Materials Unit Cost 36.89 Birr/m

B=Manpower Unit Cost 2.95 Birr/m

Total of (1:02)

Hourly Output

C= Equipment Unit Cost : 0.60 Birr/m

Total of (1:03)

Hourly output:

Direct Cost of work item = A+B+C = 40.44 Birr/m

Overhead Cost: 8% 3.24 "

Profit Cost: 7% 3.06 "

Total Unit Cost : 46.73 Birr/m

Remark ____

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 5 Anchor Bar Cost

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT : REINFORCEMENT BARS — LABOUR HOURLY OUTPUT: 12.0 pcs/hr.
WORK ITEM: (4.30) Anchor bars of ø8mm round or processed steel bars with 50 cm maximum length whicl — EQUIPEMENT:
TOTAL QANTITY OF WORK ITEM: 1 pcs — RESULT: 24.46 Birr/pcs.

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Dim 6mm to 10mm	Kg	0.248582	48.15	11.96922	Foreman	1	0.17	40.03	6.81	tools	2	0.50	1
1.5 mm black anneald wire	Kg	0.02	56.15	1.123	Barbender	1	1	23.75	23.75	Bar cutter	1	30.3	30.3
				0	D/L	2	1	12.50	25.00	Bar Bending	0.25	30.3	7.575
				0					0.00	Drill with 8mmdrillbit	0.25	10	2.5
				0					0.00				
				0					0.00				0
				0					0.00				0
Total (1:-01)				13.09	**Total (1:02)**				55.56				0
													0
													0
										Total (1:03)			41.38
												3.45	

A= Materials Unit Cost 13.09 Birr/pcs. B= Manpower Unit Cost 4.63 Birr/pcs.
Total of (1:02)
hourly output:
Direct Cost of Work Item = A+B+C = 21.17 Birr/pcs.
Over head cost : 8% 1.69 "
Profit Cost: 7% 1.60 "
Total Unit Cost : 24.46 Birr/pcs.

Remark ______
UF: UTILIZATION FACTOR
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

There will be 4 pcs of anchor bars in 1 m2 wall in order to increase the strength of the wall. The cost for anchor bar is 24.46 birr/ pcs since it has 4 pcs of anchor bar in 1m2 wall the total cost of anchor bar in 1m2 EPS wall will be 97.84birr/m2.

Table A- 6 HCB Wall cost of conventional

BLOCK WORK

PROJECT: Masonry Work — **Labour Hourly Output:** 1.00 m^2/hr
WORK ITEM: 200mm thick class-B HCB — **Equipment Hourly Output :** 1.00 m^2/hr
TOTAL QUANTITY OF WORK ITEM: $1m^2$ — **Result:** 634.00 Birr/m^2

A) MATERIAL					B) MANPOWER					C) EQUIPMENT			
TYPE	UNIT	QTY PER UNIT WORK	RATE (BIRR)	COST PER UNIT (BIRR)	SKILL	NO.	U.F.	HOURLY RATE (BIRR)	HOURLY COST (BIRR)	TYPE	NO.	RENTAL RATE/hr (BIRR)	HOURLY COST (BIRR)
HCB 20cm thick	pcs	13.00	18.20	236.60	Forman	1	0.5	40.00	20.00	Hand Tools	4	2.00	8.00
PPC Cement	qtl	0.21	563.00	118.10	Mason	1	1	30.80	30.80				
Sand	m3	0.03	900.00	25.20	Helper	1	1	22.50	22.50				
Water	m3	0.02	100.00	2.00	DL	2	1	22.00	44.00				
Total(A)				381.90	Total(B)				117.30	Total (C)/			8.00
Material Unit Cost				381.90	Manpower Unit Cost				117.30	Equipment Unit Cost			8.00

A=Materials Unit Cost 381.90 (**75.3%**) B=Manpower Unit Cost 117.30 (**23.1%**) C= Equipment Unit cost 8.00 (**1.6%**)

Direct Cost of Work Item =A+B+C= 507.20
Overhead Cost : 15% 76.08
Profit : 10% 50.72
Total Unit Cost: 634.00

Appendix B: Questionnaire

Questionnaire

Dear Respondent;

I am Hable Firehun, student of Adama Science and Technology University and currently working research on "Evaluation of Performance of Expanded Polystyrene Technology in Addis Ababa Building Projects." This research survey is intended to fulfill an academic requirement for a Master of Civil Engineering in program of Construction Engineering and Management. Therefore, it is believed that your participation in this research will contribute to achieving the objectives of the research. Thus, the quality of your response towards the question items determines the quality of the research results. Therefore, please answer the questions as thoroughly, objectively, and honestly as possible according to the instructions contained in the body of the questionnaire.

All information provided in this survey will be treated as strictly confidential, no companies or individuals will be identified in any subsequent research report, and all information collected will be used purely for the purposes of academic research.

Name of Construction Company: ________________________________ (optional)

Full Name of Interviewee: ________________________________ (optional)

Part I. General Information

Please kindly respond to the following questions by ticking (√) the appropriate box or writing your answer in the space provided.

1. What is your position in a company?

☐ Project Manager ☐ office engineer ☐ Designer

☐ Site Engineer ☐ Project Manager

☐ Manufacturing team

Other ______________________________

2. How many years of experience do you have?

☐ Less than 5 years ☐ 5-10 years ☐ More than 10 years

3. What is your highest educational Level?

☐ PHD degree ☐ Master‘s degree ☐ First degree ☐ Diploma

4. Do you have any previous work experience in using EPS technology?

☐ Yes ☐ No

5. In your opinion which firms have more potential to improve the application of eps technology in housing projects of Addis Ababa?

Firms	Negligible 1	Low 2	Moderate 3	High 4	Very high 5
Contractor					
Designers/Architect					
consultant					
Client					

Part II. Application Status of Eps Technology

6. Below are outcaste benefits of using eps panel than in-situ method. Level from strongly disagree to strongly agree according to your experience.

Benefits	Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5
No material waste					
Cost effective					
Speed of construction time					
Lightness					
Versatility					
Integration with other building system					
Wide choice of finishing					
Earth quake resistance					
Fire resistance					
load resistance					
Less number of laborers					

7. In your opinion to what extent do the following factors affect the use of eps structural elements in Addis Ababa housing projects?

Factors	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
Shortage of skilled man power on the area					
Shortage of supply of prefabricated elements					
Lack of information about the existing potential.					
Lack of awareness about the technology					
Lack of willingness of professionals					

8. In your opinion, what are major benefits that eps construction method has that in-situ construction does not? Choose from the list below.

   A. No material wastes
   B. Cost effective
   C. Speed of installation time
   D. Lightness
   E. Versatility
   F. Integration with other building systems
   G. Wide choice of finishing
   H. Thermal insulation
   I. Earthquake resistance
   J. Energy efficiency
   K. Fire resistance
   L. Load resistance
   M. Less number of laborers

9. From the benefits of eps panels for construction you choose in question number 8, rank the benefits from most to least beneficiary.

Part III. Challenges of EPS Technology

10. Below are challenges of using eps technology. Level from strongly disagree to strongly agree according to your experience?

Factors		Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5
Transportation	Lack of suitable transportation					
Installation	It may face connection problem					
	Error in cutting and molding					
Technical	Lack of practice and experience					
	Shortage of qualified workers					
	Lack of industry knowledge					
	Lack of training					
Resource	Shortage of critical resources					
Economic	Sudden changes of foreign currency					
	Higher average cost					
design	Design errors and omissions					
	Lack of design guide					
management	Weak stakeholders support					
	Persist change in organizational management					
market	Disapproval by the market					

Appendix C: Interview

Interview

Interview Questions to EDAB manufacturing and construction Staff Members 1.

How long have you been working at EDAB manufacturing and construction?

2. What is your position in the company?
3. What are the raw materials for manufacturing EPS panel?
4. What are the building parts that the enterprise prefabricates?
5. Describe how elements are joined and connected.
6. Is there any failure of joints and connections you face during assembly? If yes, in which structural components do the failure occur.
7. can we use the technology for high rise buildings? are there any buildings more than five stories built by your company? If not, will there be in the future?
8. Does your manufacturing face any delay problem claimed by your construction team? If yes, what was the reason for the delay to occur?
9. What are your previous building work experiences?
10. In your opinion, is EDAB functioning up to its capacity?

Appendix D: Focus Group

Focus group

Focus group discussion area: (EDAB)

A. Manufacturing plant

- ✓ How is eps pane extracted from the eps bid?
- ✓ Elaborate the process from raw material to end product production

B. Cost

- ✓ What is the cost of eps wall in one meter square?
- ✓ What is the cost of eps slab in one meter square?
- ✓ Is it cost reducing?

C. Time

- ✓ How much time does it takes to complete one-meter square area of wall and slab?
- ✓ Is it time effective?

D. Quality

- ✓ What possible tests do u make in order to check the quality of each construction elements?
- ✓ what can you say about the quality standards of the technology?

Appendix E: Figures

FIGURE D-1 EPS Panel Built House