ASSESSMENT OF THE STRENGTH OF POLYSTYRENE MATERIAL USED IN BUILDING CONSTRUCTION IN MBORA DISTRICT, ABUJA

BY

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MATRIC NO: 2007/1/27275BT

DEPARTMENT OF INDUSTRIAL AND TECHNOLOGY EDUCATION,

SCHOOL OF SCIENCE AND SCIENCE EDUCATION,

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA,

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OCTOBER, 2012

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF

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IN PARTIAL FULFILMENT OF THE REQUIREMENT OF AWARD IN

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CERTIFICATION

I Bankole Oluwatosin Catherine, Matric No. 2007/1/27275BT an undergraduate of the department of Industrial and Technology Education, certify that the work embodied in this project is original and has not been submitted in part or in full for any other degree or diploma of this or any other institution.

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Name Signature & Date

APPROVAL PAGE

This project has been approved as meeting the requirement for the award of B.TECH degree in Industrial and Technology Education of the Department of Industrial and Technology Education, School of Science and Science Education, Federal University of Technology, Minna – Niger state.

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Project Supervisor	Signature & Date
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Head of Department	Signature & Date
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External Supervisor	Signature & Date

DEDICATION

This research project is dedicated to God Almighty for all his mercies towards me. Also, to my Parents Mr. & Mrs. P.O. Bankole for their love and support.

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First and foremost, my profound gratitude goes to Almighty God for His infinite mercy upon my life throughout the pursuit of this program. My most sincere gratitude goes to my Project Supervisor, Mr. Ibrahim Dauda who out of his tight schedule supervised this work. His immeasurable assistance, positive criticisms, source of inspiration, useful suggestions, time, knowledge, guidance on this work proved very helpful in the process of writing this research. I am also very grateful to his family for the time and care they showed to me while writing this research project. May God reward and bless them abundantly.

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ABSTRACT

This study was designed to assess the strength potentials of polystyrene material used in building construction in Mbora district, Abuja. Three research questions were formulated to guide the study. An experimental research design was employed for the study. The study was carried out in the building technology laboratory, Federal University of Technology, Minna Niger state and the construction site of Citec International estates Mbora District, Abuja. The findings of the study revealed among others that polystyrene material has good strength potentials in building construction. Based on the findings, it was also recommended that there should be a proper orientation on the use of Expanded Polystyrene (EPS) material for building construction since it posses the required quality for building material, the government and the people of Nigeria should make use of EPS material in the construction of houses since it is a strong and safe building material.

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CHAPTER I

INTRODUCTION

Background of the study

In life, the wealth of man is measured by his ability to acquire his basic needs of survival which are food, shelter, and clothing (Goodier, 1999). According to him, after man has eaten, the struggle for survival continues as he must protect himself from the various climatic conditions (such as cold/rain, heat/sun), wild animals and criminals and provide comfort which may be an aesthetic/luxury need. Goodier (1999) earlier stated that, from the very time of creation, man had always had a place to call home not minding what it looks like; starting with the Garden of Eden. This search for shelter has made man come across several materials ranging from tree branches, leaves, grasses, bamboo, clay/mud, metals, brick, block and even polystyrene.

Building materials are those materials out of which buildings are constructed (Hornby, 2006). Building construction is a major sector where a group of people or individuals invest their resources for optimal use. The use of building materials have changed from one material to another over the period of time due to technological advancement. This technological advancement has led to the production and use of polystyrene blocks in building construction.

Polystyrene is a thermoplastic material obtained by the polymerisation of styrene and it is used in packaging electronics, food items and building houses (Olasehinde,2009). Polystyrene which is a light synthetic material cannot be used in building houses unless polymerised to form a block. The polymerisation of styrene to form a block is called Expanded Polystyrene (EPS) (Olasehinde, 2009).

According to Olasehinde (2009), EPS is formed by a union of so many beads of polystyrene produced during a modelling process with a supply of heat which comes in form of steam until the following characteristics are obtained:-

- Normal density of 15kg/m³
- Thermal conductivity of 0.037w/mk
- Steam resistance of 0.15mmHgm² dia/gcm
- Compressive stress at 10% of strain is 50kpa.

The thickness of the EPS block may vary from 4cm to 25cm according to the requirements of the architectural design. Also, after the EPS block is produced, a base of reinforcement is placed against the sides with each side joined to another by means of electro-welded steel connectors. These steel connectors are usually called meshes. These results into a light weight three dimensional (3D) truss system with a high inherent stiffness.

Technological advancements in all phases of life have really helped life making it easy for man, but not all technological advancement can be accepted as their after effect may be too dangerous. Polystyrene as a building material has been used for over 30years (Kelvin 2009). According to him, the use of polystyrene is a technology with Italian origin that boasts more than 52 manufacturing lines installed all over the world in most countries such as Mexico, Guatemala, Costa Rica, Venezuela, Ecuador, Santo Domingo, Panama, Argentina, Russia, Italy, Ireland, Spain, Bosnia, Egypt, Eritrea, Nigeria, Mozambique, Libya, Saudi Arabia, Kurdistan(Iraq), Turkey, Reunion Islands, Malaysia, Republica Dominicana, Philippines, Qatar and USA. To this effect, the strength of polystyrene material used in building construction needs to be assessed to know if its use can be encouraged or not. Strength is a property of a material that makes it strong (Hornby, 2006). The strength of EPS as a building is a thing that must be determined to know how well it can serve as a building material. Assessment is the process by which the value of a building material's performance and quality is obtained. Keith and Kenneth (2002) viewed assessment as the process of examining carefully, thoroughly and as objectively as possible an individual, group of people, product or programme in order to ascertain its strength and weakness. From the foregoing therefore, assessment can be seen as the systematic process of judging the worth, desirability, effectiveness, potentials or adequacy of something according to a given criteria. According to Keith and Kenneth (2002), without a valid assessment, there would be an unreliable data to determine the strength of expanded polystyrene material used in building construction. Experience has shown that so many building materials have not been properly assessed before use as they really have caused a lot of damage on the building owners and loss of lives and properties on the part of the occupants. The question therefore is; Does polystyrene material used in building construction have the required strength to carry the dead and live load of a building? Is it safe and strong when used? How durable is it?

Statement of the problem

After man has met his basic need of survival (food, shelter and clothing) he begins to boast it, showing some luxury and aesthetic value to it. But man has failed to know how well this materials used in building construction would serve its protective value which every building should strive for. This protective value simply refers to its strength to resist the effects of the weather and all other forces applied to it. And to this effect, so many houses have collapsed wasting a lot of lives and properties. Experience have shown that, lack of an effective assessment of the strength of building materials has caused and imposed a lot of risk on so many lives and properties (Kelvin, 2009). This error has occurred in the past and should not be allowed to continue especially as polystyrene is being used as a building material in Mbora district in Abuja, Nigeria.

Hence, this study is designed to assess the strength of polystyrene material for building construction in Mbora district of Abuja, Nigeria. The strength to be assessed here would basically be on the compressive strength of EPS via crushing and axial loading in Mbora district Abuja as these test has being carried in other countries where EPS has being used but not in Mbora district.

Purpose of the study

The main purpose of this study is to assess the effectiveness of polystyrene material for building construction in Mbora district of Abuja, Nigeria. Specifically, this study is to determine the following:-

1. To find out the compressive strength of EPS via axial loading.
2. To find out the compressive strength of EPS block via crushing.
3. To find out the specific gravity of the materials (cement, plaster sand and stone dust) used in the shortcreting and plastering of the EPS walls.

Significance of the study

The occupants of the polystyrene structure would live in a safe house which is a monolithic structure that would be able to resist the effect of flood and other environmental disasters.

The Engineers would benefit from it as it would serve as a good alternative to other building materials since it has the required strength which a normal building material should have.

The government would be benefitting from it as it helps encourage mass housing for the citizens of the country; and at the same time help educate the general public on this material-polystyrene.

Scope of Study

This study is delimited to the assessment of the effectiveness of polystyrene material used for building construction in Mbora district of Abuja, Nigeria. The study hopes to determine the specific gravity of the materials (plaster sand, stone dust and cement) used in the shortcreting and plastering of EPS walls, the compressive strength of EPS materials through axial loading and crushing. This study would not be determining the tensile stress and strain of EPS there the materials required in carrying out the test are unavailable.

Research Questions

The following research questions are formulated to guide the study:-

1. What is the compressive strength of EPS via axial loading?
2. What is the compressive strength of EPS block via crushing?
3. What is the specific gravity of the materials (cement, plaster sand and stone dust) used in the shortcreting and plastering of EPS walls?

CHAPTER II

LITERATURE REVIEW

This chapter deals with the review of related literature to this study under the following sub-headings:

- An overview of building materials.
- The concept of expanded polystyrene, its properties and the manufacturing of polystyrene.
- The general application of expanded polystyrene material and the benefits of using polystyrene material as a building material in Mbora district, Abuja.
- The compressive strength of EPS.
- The specific gravity of the materials used.
- Summary of the reviewed literature.

An overview of building materials

Over the years, a lot of materials have being used in building construction ranging from stones, mud, timber, bamboo, glass, block, brick, grass, metal, cement, concrete and polystyrene among others. According to Hornby (2006), building materials are those materials that are used in building construction. He added that their use is very vital in all phases of life as no field of engineering is conceivable without their use as there is always a new technology to replace an outgoing technology due to mans' technological advancement. Chen et al (2005) also defined building materials as any material which is used for a construction purpose. According to him, many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings and that apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. He also added that the manufacture of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades, such as carpentry, plumbing, roofing and insulation work as they provide the make-up of habitats and structures including homes. Sandermann and Kohler (1994) listed some building materials and discussed briefly on them; they are:

Rock and stones - Rock structures have existed for as long as history can recall. It is the longest lasting building material available, and is usually readily available. Stone has been defined as the natural, hard substance formed from minerals and earth material which are present in rocks. Rock may be defined as the portion of the earth's crust having no definite shape and structure (Duggal, 2008). He added that Stone has been used for most of the important structures since prehistoric age. Most of the forts world over has used it in construction and examples are the Taj Mahal of India, the famous pyramids of Egypt, the Aztec pyramids, the remains of Inca civilization and the Great Wall of China are but a few examples.

Mud and clay - The use of mud and clay in building construction came to play shortly after the use of rocks and stones were discovered (Chen et al, 2005). According to him, the major source of building here is clay or mud and the choice of using clay or mud in place of rock and stone is that soil and especially clay has a good thermal mass and it is very good at keeping temperatures at a constant level.

Thatch - Thatch is one of the oldest of building materials known; grass is a good insulator and easily harvested. Many African tribes have lived in homes made completely of grasses year round. In the past, thatch roofs on homes were once prevalent but the material fell out of favour as industrialization and improved transport increased the availability of other materials (Chen et al,2005).

Wood - Wood is a natural material for building dwellings as it has being used for thousands of years. It has many advantages due to which it is preferred over many other building materials. Duggal (2008) said that since wood can be easily worked, repairs and alterations to wood work can also be done easily; owing to these mentioned advantages, wood is very widely used in buildings as doors, windows, frames, temporary partition walls, etc. and in roof trusses and ceilings apart from formwork.

Cement - Cements in a general sense are adhesive and cohesive materials which are capable of bonding together particles of solid matter into a compact durable mass (Duggal, 2008). John (2004) said Cement can be manufactured either from natural cement stones or artificially by using calcareous and argillaceous materials. Today cement finds extensive use in all types of construction works; in structures where high strength is required e.g. bridge piers, light houses, lofty towers, and large structures such as bridges, silos, chimneys and also in structures exposed to the action of water, e.g. reservoirs, dams, dock yards among others.

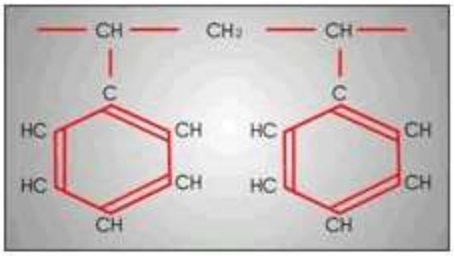
Concrete - Concrete is a composite building material made from the combination of aggregate (fine and coarse) and a binder such as cement (Duggal, 2008). He added that the most common form of concrete is Portland cement concrete, which consists of mineral aggregate (generally gravel and sand), Portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone-like material.

Metal - Metal is used as a structural framework for larger buildings such as skyscrapers, or as an external surface covering. Steel is a metal alloy whose major component is iron, and is the usual choice for metal structural building materials (Duggal, 2008). It is strong, flexible, and if refined well and/or treated lasts a long time.

Glass - Glassmaking is considered an art form as well as an industrial process or material. Clear windows have been used since the invention of glass to cover small openings in a building. They provided humans with the ability to both let light into rooms while at the same time keeping inclement weather outside. Glass is generally made from mixtures of sand and silicates, in a very hot fire stove called a *kiln* and is very brittle. Very often additives are added to the mixture when making it to produce glass with shades of colours or various characteristics (such as bulletproof glass, or light emittance).

Plastic - The term plastics covers a range of synthetic or semi-synthetic organic condensation or polymerization products that can be moulded or extruded into objects or films or fibres. Their name is derived from the fact that in their semi-liquid state they are malleable, or have the property of plasticity.

Polystyrene Foam - More recently, synthetic polystyrene or polyurethane foam has been used in combination with structural materials, such as concrete in building construction as it is light in weight, can be easily shaped and is an excellent insulator (Olasehinde, 2009). He added that, it is a material made from styrene which is a product of plastic. According to him, in the past, it has usually been used as part of a structural insulated panel where the foam is sandwiched between wood or cement or insulating concrete forms, where concrete is sandwiched between two layers of foam but in recent times, polystyrene foam is used basically as a building material and is shortcreted with a mixture of cement, stone dust, plaster sand and water. Below is a chemical structure of polystyrene material.

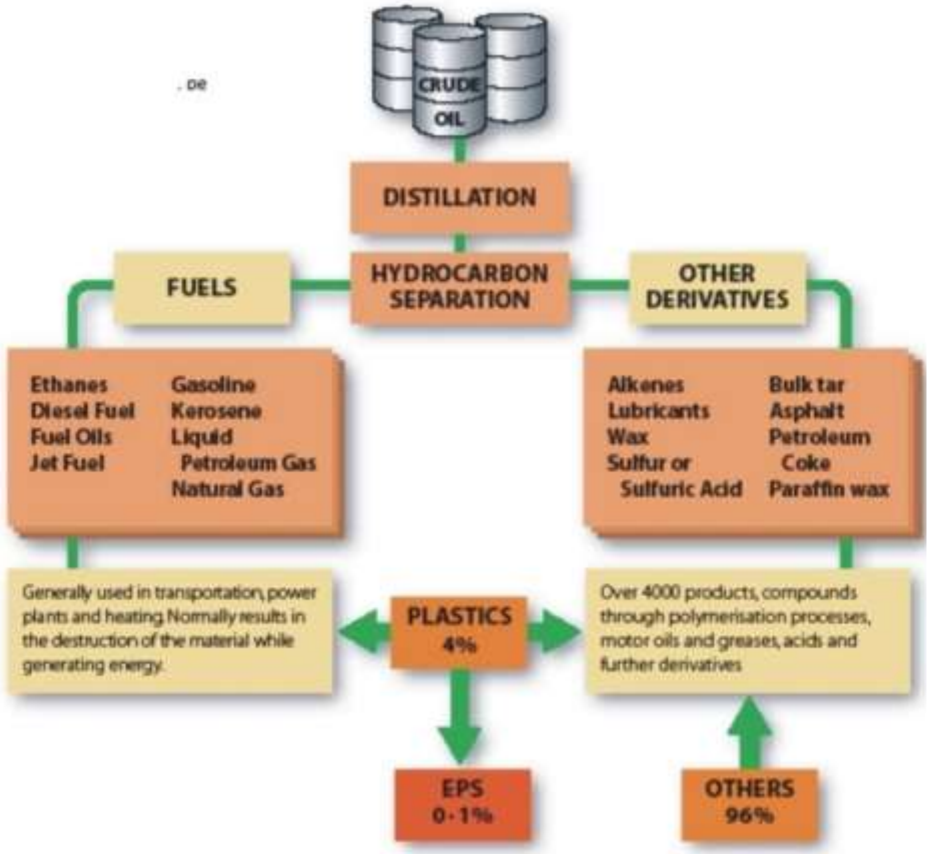


The above is known as poly(1- phenylethene-1,-2-diyl), it has a density of 1.06kg/m³ – 1.12kg/m³, thermal condition of 0.033w/m.k and a refractive index of 1.6.

Manufacturing of polystyrene

Polystyrene which is a rigid cellular plastic contains an expansion agent which is obtained from crude oil that has styrene as one of its bye products in the production of petroleum and naphtha which boasts a ready and continuous source (Larry, 2001). His study also reported that styrene is naturally present in foods such as strawberries, coffee beans, beef, and produced in the processing of foods such as wine and cheese spices among others.

The diagram on the next page shows the production process of styrene from crude oil.



As shown in the diagram above, it is seen that EPS is gotten from a crude oil well through a chemical process. But before polystyrene can be used, it must go through some process/stages as stated by Olasehinde, (2009); these steps are:

- Pre-expansion
- Intermediate maturing
- Final stage

Pre-expansion

During this process, the raw materials which are in form of compact beads turn into cellular plastic beads with small closed cells that hold air in their interior.

The EPS raw material is heated in special equipment called pre-expanders using steam at temperatures between 80-100°C. During this process the beads are stirred continuously. Pentane, a liquid at room temperature, evaporates above 30º C and expands with the heat. Also, in this process of pre-expansion, the EPS compact beads turn into cellular plastic beads or pearls with small non-interconnecting closed cells. After cooling, the entrapped pentane condenses within the pearl creating a vacuum within the pearl. This vacuum is rapidly filled up with air. This process is called the conditioning of the EPS beads. The beads occupy approximately 50 times the original volume after expansion. In this process the final density of EPS is determined. The bulk density of the material drops from about 630 kg/m^3 to values typically between 10 and 35kg/m^3.

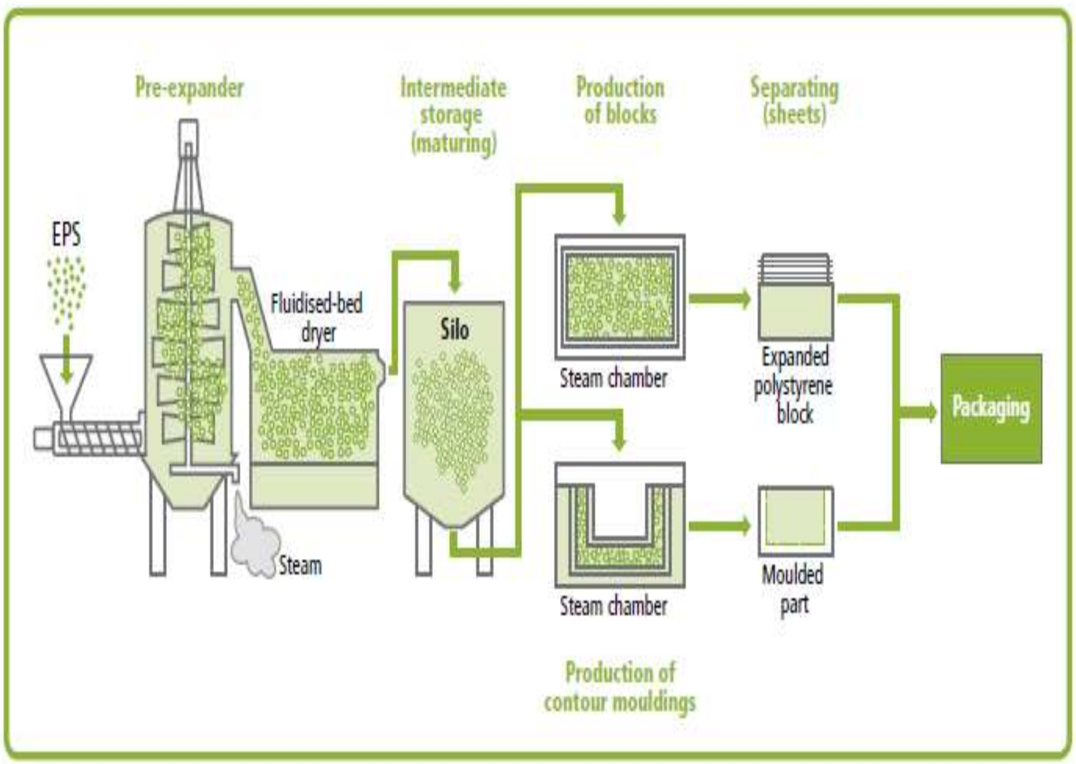
Intermediate maturing and stabilisation

After pre-expansion the expanded beads are cooled and dried in a fluidised 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 equalised. 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.

Expansion and final moulding

In the third stage of processing known as the moulding stage, the stabilised pre- expanded beads are transported to moulds, where they are heated again using steam. Under the influence of steam, the beads soften and start to expand again. However, as they are contained in a mould they cannot expand freely, and therefore create an internal pressure within the mould and the softened beads fuse together. Following fusion the mould is cooled and moisture is removed, usually under the influence of vacuum. The moulded product is ejected from the mould at the completion of the cycle. During processing, the pentane gas is depleted, so that the finished products contain little residual pentane. After a short time the residual pentane diffuses out of the material to make place for normal air in the cells. Enclosed air is known to be one of the best insulations in nature.

The diagram below shows an illustration for the production of EPS.



The manufacturing stages of EPS

There are generally two types of moulding processes for EPS. One is called block moulding and produces large blocks of EPS up to 10 metres in length. After a short cooling period, the moulded block is removed from the machine and after a further conditioning is cut into shapes or sheets using hot-wire elements or other appropriate techniques.

EPS is manufactured with pentane, a hydrocarbon blowing agent that is not harmful to the stratospheric ozone layer and which diffuses out during or shortly after the production process is complete (Cohen, 2002). He added that since the blowing agent is rapidly replaced by air, the installed insulation does not experience any significant off-gassing of pentane or other substances that may affect indoor air quality. The American Lung Association's (ALA) Health House guidelines are amongst the toughest in the world for indoor air quality. They acknowledge EPS as a safe material to insulate foundation walls and floors. Other ALA registered homes have incorporated EPS insulating concrete forms (ICFs) in order to meet their stringent requirements. Although ALA representatives do not promote specific materials or products, they cite that walls insulated with EPS release no lung damaging fibers.

The general application of expanded polystyrene material and the benefits of using polystyrene material as a building material in Mbora district, Abuja

Polystyrene as a material has various applications due to its unique nature and this unique nature has allowed it to stand the test of time and quality. According to Hillary (2009), EPS has a wide range of uses but its use is mainly categorised into 3; these are:

- Packaging
- General application
- Construction

EPS used for packaging

EPS as a packaging material is a very popular use of polystyrene as that is what virtually every person is familiar with. Examples of materials that are being packaged with polystyrene are; food items, electronics, pharmaceutical products, toys, horticultural materials and lots more. The use of polystyrene for this purpose helps protect these products from damage, contamination (food substance) and risk in transportation and handling (John, 2004).

Research has shown that apart from the fact that EPS is a non toxic material, it has a good shock absorption property and low weight; the following were discovered to be properties of polystyrene that enables it to be used in packaging (John, 2004).

- Retention of vitamin C
- Resistance to humidity
- Chemical resistance
- Display effect (promoting sales) and;
- Hygienic nature among others.

The use of EPS for packaging is often the best alternative in terms of cost, versatility and efficiency. It is easy for workers to handle with no sharp edges or staples and can work equally well with sophisticated machinery. For these packaging applications that we have seen, it is worth underlining the following properties of EPS.

Shock absorption: the material has a high-energy absorption index should it fall or be knocked and this makes it the ideal material for protecting sensitive products during transport and storage.

Thermal insulation: protecting products, especially foodstuffs, from sudden changes in temperature.

Low weight: its low density reduces the packaging weight and consequently provides savings in transport.

Retention of vitamin c: recently studies have shown that fruit and vegetables when packed on EPS. Keep their content of vitamin c for a longer period.

Resistance to humidity: its excellent mechanical and thermal properties are maintained by the fact that it does not absorb water. This is significant because moisture can affect other packaging materials.

Compressive resistance: allows stacking of merchandise-filled packages and packs without any difficulties in storage, transport or at point of sale.

Chemical resistance: EPS allows many products to be packed without the goods being affected.

Display effect (promoting sales): given its appealing appearance and the ease with which it can be coloured, printed on, stacked and subjected to other product dressing techniques to attract customers.

Hygienic nature: since the material is inert, unalterable and innocuous it can come into direct contact with foodstuffs whilst complying with the laid down health and safety standards.

Adaptability: it is easy to adapt to any product or any design.

General applications of EPS

Due to its versatility, it can be moulded into almost any shape thereby allowing it to be used for a huge variety of different processes. Hillary (2009) listed the following as some general application of EPS;

- Chairs
- Book covers designed
- Snow sport helmet
- Infant car seater
- Air conditioning units
- Houses
- Load bearing structurally insulated panels.

Construction

This is the latest use of EPS that is yet to be accepted by every person. In construction, EPS is used as a building material in place of other materials used in building construction and road construction (Mihai, Huneault and Favis (2007)). Its construction use in building and road construction ranges from the erection of panels, stairways, slabs, kerbs, culverts, floor panels, road embankments, retaining wall or abutment backfill, slope stabilization, pavement insulation e.g. airports, basement constructions such as car parks and a lot more.

Polystyrene used for building construction are of various types and sizes with the common ones for wall panels and panels for slab. But these panels can not be erected without the use of some meshes. Olasehinde (2009) stated that the EPS blocks usually with a height of 3000mm, breadth of 1200mm and a thickness of 100mm are used as wall panels which also have a thin a layer of metal/ steel serving as a form of reinforcement. According to him, the panels being used for slabs are usually with a height of 6000mm, a breadth of 400mm and a thickness of 300mm. It is alongside reinforcements of Ø8mm, Ø10mm, Ø12mm, Ø16mm, Ø20mm which are used according to the bar bending schedule for the slab.

On the other hand, Kelvin (2009) noted that stair panels consist of a foam polystyrene block shaped according to designing requirements coated with two steel wire mesh assembled with electro welded wire. This panel is suitably reinforced and finished with casting on site in the suitable spaces. The stair panel is characterised by the extremely easy laying along with its special structural resistance and lightness. He also stated that polystyrene are used with panel splices which helps in keeping it firm. In his words, he said after the erection of the wall panel, all splices are overlapped by means of splice mesh. The idea behind this is to create continuous mesh reinforcement. Cengel (1997) gave a list of the panel splice and discussed on the areas to be covered with splice mesh as follows:

Straight panel joints - flat splice mesh

External/internal corners - L - shaped splice mesh

Window/door openings - U – shaped splice mesh.

British Reinforcement Mesh (BRC)

Straight mesh: this is a flat mesh that is used where two meshes meet.

External/internal corner mesh: this type of mesh as the name implies is used for external and internal corners. It is like letter L in shape.

Window/opening mesh: this type of mesh is used where there are openings. These opening include; doors, windows, arc and lintels. The meshes are like letter U in shape and fix into the edges of the opening like a cup.

British Reinforcement (BRC) mesh: this type of mesh is used as a cover mesh for panel slabs. It is thicker than the normal mesh used for wall panels. It comes in form if a flat mesh but this time like a mat.

Erecting panel walls

From experience, the walls of an EPS building starts from the upper edge of the foundation, preferably a load bearing slab or foundation strips as well. Starter bars with a diameter of 10mm are set at a distance of 500mm and are put on one side of the wall in order to put up the wall (Larry, 2001). These starter bars mainly serve as a means of easy erection of the panel walls and do not serve to carry horizontal forces of movements. Erection of panels always starts from the corner. This is necessary to give the construction work enough rigidity already from the beginning because only then it is possible to arrange the walls vertically and permanently fix them to the bars or the splice mesh. Fixing is done by tying the panels to the starter bars by means of a binding wire.

Benefits of using polystyrene material in building construction in Mbora district, Abuja

Edward & Joseph (2008) stated that the strength of polystyrene cannot be discussed without knowing its benefits as it also helps in viewing the effects of polystyrene from another angle.The benefits cannot be over emphasised as Bobby (2007) lamented that in using polystyrene, the following advantages are accruable. These benefits according to him includes: light weight, rapid assembling, termite resistance and resistance to damage by burglars and energy saving/ green building.

Light weight: due to its light weight, it can be carried in a large quantity thereby saving construction time, fuel in transport and energy.

Rapid assembling*:* due to its light weight and ease of handling, it can be assembled easily and fast with enough manpower and less skilled labour since there would not be any casting at every stage but only where you have a long span of lintel and this does not affect the work of the entire structure.

Termite resistance and resistance to damage by burglars*:* aside from the plastering and shortcreting, termite cannot go through polystyrene block as it does not provide any nutritional benefits to termites/vermin. Also, in block structures, burglars break through the walls to enter the house but in EPS structure, even if the shortcreting and plastering are removed, the meshes cannot be easily cut talk more of destroying the EPS panels.

Energy saving/green building: first, in the production of EPS blocks, there is no waste as it can be recycled and reused. The world is fighting the effect of green house as the ozone layer is being damaged everyday. EPS as a building material helps reduce the damage on the ozone layer since it can be recycled rather than burning it. It also saves energy (solar energy); in a normal block work, the wall absorbs heat during the day and discharges it at night but in the case of EPS walls, even with the heat and radiation of the sun, the walls on the inner side of the structure does not get hot.

In the same vain, John (2004) stated that the use of EPS has proven to be an excellent acoustic material, fire resistant, has a good choice of finish and a good resistance to earthquake and hurricane.

Excellent acoustics: this is similar to EPS being an energy saving material as sound does not go out of the building. EPS blocks serve as a sound proof material which prevents echoing or noise pollution in the environment.

Fire resistance: in the case of a fire outbreak, the EPS structure has a strength to say 120minutes before it becomes exhausted by the fire which is enough time to get the fire this is a characteristic unique to polystyrene structures as it gives a monolithic structure due to its assembling method.

Earth quake and hurricane resistance: This special characteristic of an EPS structure make the structure a single unit thereby making it difficult to be sunk or carried away by earthquake or hurricane (Hillary, 2009). Research has shown that earthquakes in the past have not being able to carry EPS structures as they have all read below 6.9 on the Richard scale which is what the Richard scale has not being able to resist.

Choice of finishes*:* polystyrene material with its 3D structure as well as it versatile nature makes it easy to be moulded into desired shapes and sizes thereby making the finishing of a building to meet the taste and desire of the occupants.

Another benefit of polystyrene is its recycling and disposal as well as it energy recovery property as stated by Larry (2007).

***Recycling and disposal**:* There are several options to treat EPS construction and demolition waste each with environmental, technical and economic implications to consider. Generally the most beneficial is direct re-use by grinding clean EPS waste and adding it to virgin material during production (Othman et al, 2008). This waste can also be used to improve soil condition. Alternatively, EPS can be melted and extruded to make compact polystyrene, for items such as plant pots, Coat hangers and a wood substitute. Medium toughened polystyrene from which sheets for thermoformed articles, such as trays, can also be made. As part of mixed plastic waste, EPS can be recycled to make, for example, park benches, fence posts and road signs, ensuring the plastic material has a long and useful second life (Eeydah Aminudah el al, 2011).

Energy recovery

This involves the recovery of energy, usually in the form of heat from incineration. This gives EPS waste a genuine post-consumer use. The calorific value of EPS available for heat recovery is slightly more than that of coal by weight. In a modern incinerator EPS releases most of its energy as heat, aiding in the burning of municipal solid waste and emitting only carbon dioxide, water vapour and a trace of non-toxic ash. The fumes are non toxic and are not harmful to the environment as no dioxins or furans are emitted. The energy gained can be used for local heating and generation of electricity.

Landfill: although currently a large proportion of EPS waste is disposed of in landfill, it is least preferred option since it does not create a “second life” and is therefore not an optimal use of natural resources. However, landfill-using EPS does bring advantages. EPS waste is inert and non-toxic, so the landfill site becomes more stable. EPS aerates the soil, encouraging plant growth or reclaimed sites. EPS does not degrade and will not leach any substances into ground water, nor will it form explosive methane gas.

***Durability*: this is the process of being hard to wear or a property of a material that makes it able to stand the test of time. Due to its termite, lack of nutritional value and water resistant property, it makes it much more durable and free from fungi attack and any other microorganism's attack.**

Affordability: this is a property of EPS which makes it relatively cheap when compared to its value and benefit. Research, has shown EPS is relatively cheap when compared to sandcrete block. See appendix for a cost comparism of EPS panel and sandcrete block used in building a 3-bedroom semi detached bungalow.

Availability: this is a property of a material that makes it to be easily obtained. Availability is also a property that tells how long a property would last because no matter how affordable and strong a material is, if there is no continuity in its production, its use may not be encouraged or appreciated since it is a material to be embraced by everybody in the construction field. Presently in Nigeria, EPS is new but has spent over hundred years in most Asian countries including the US. In Nigeria, Citec International estates limited produces EPS panels for use.

Variety: this is the property of a material that allows for the creation of different or varied shape and design. This property also allows for uniqueness of design thereby increasing the flexibility of the material.

An interaction with the occupants, Engineers and panel erectors of Mbora district was positive and in line with the findings of Bobby (2007).

The compressive strength of polystyrene material used in building construction.

The strength of the use of polystyrene as a building material is something that used to give the occupants of polystyrene structures and other people not in the construction line and even construction workers who have not used polystyrene in building construction a cause to doubt its use. John (2009) stated that any write up or awareness done to make people know of the use of polystyrene as a building material would be incomplete without discussing the strength of polystyrene as a building material. He added that so many people think that the physical and simple knowledge of polystyrene makes it a material not strong enough to carry the dead and live load of a building while serving as shelter to man. As stated in the benefit of polystyrene by Hillary (2009), it shows that polystyrene has much benefit that can withstand the effect of earthquake and hurricane since it produces a monolithic structure and its ability to maintain a good temperature. From his study, he said there is no negative effect in the use of polystyrene on its occupants, the erectors and the producers/ manufacturers which makes it a safe material to work with and live in.

The monolithic structure of EPS does not only make it a safe material but a strong material. While working with EPS in building construction, the concern of so many people is on its strength properties and to this effect, the following tests were carried out to check the strength of EPS alongside other findings;

- The compressive strength test of EPS via axial loading
- Compressive strength test of EPS via crushing and;
- Fire resistance

Axial loading

In spite of the lightweight nature of EPS, its structure brings the benefits of exceptional compressive strength which has made it suitable for use in areas of construction and civil engineering applications (James, 2008). In order to prove the strength of EPS, several research institutes across the globe have carried out several tests whose results have shown that EPS panels can serve as wall panels for multi-storey buildings and as slab panels for residential buildings, office buildings and industrial buildings (Larry, 2001) and as structural base infill in roads (Arellano & Stark, 1999), railway and bridge infrastructure (James, 2008).

Larry, 2001 stated that a test was carried out on EPS 3-dimensional slab by the Insteel Construction Systems of Brunswick, GA., USA where 52 bags of cement weighing above 4000kg were placed on a 150mm x 1200mm x 2700mm slab. The total load including dead weight of the slab amounts to more than 1400 kg/m^2 which is at least twice the load in usual residential buildings. In another test performed on a block-moulded EPS specimen with a density of $21kg/m^3$ to check the typical uniaxial compression stress-strain response of an EPS – block specimen, Arellano and Stark (1999) also stated that, to determine the compressive strength of any used for construction, the materials must be subjected to loading within a time frame to ascertain the failure rate or sagging of that material as EPS did not typically exhibit failure like other solid materials used in construction (metals, concrete, wood) by a physical rupture of the material when uniformly loaded.

Compressive strength test

The compressive strength test is a test that have being used over the years to determine the strength of most building materials used especially for sandcrete block and concrete mix used in building construction. For the compressive strength test being carried out on most polystyrene materials, research has shown that the results gotten are usually in units of psi ie pound/square inch instead of the regular Newton/metre square used. As stated by ASTM (American Society for Testing and Materials) D1621-10 that shows standard tests methods for the compressive properties of rigid cellular plastics. In this, it states that

1psi = 0.000689475728N/mm²

For normal calculation; compressive strength =

$$\frac{applied\ load}{cross\ sectional\ area} \times 100\%$$

It is measured in Newton per meter square (N/mm²).

Compressive stress/strain characteristics of EPS insulation are determined using ASTM D1621, Standard Test Method for Compressive Properties of Rigid Cellular Plastics, or ASTM C165, Standard Test Method for Measuring Compressive Properties of Thermal Insulations. The most important mechanical property of EPS insulation and building products is its resistance to compressive stresses, which increase as the density becomes higher. EPS has a compressive resistance between 10 - 60 psi for most construction applications (Reuben, 2012). Within that range EPS can be produced to meet specific strength requirements.

Kopchikov & Romanenkov (1987) noted that the mechanical property of EPS depends on two primary factors: the density of the materials and the fusion, or integral bonding of the expanded polystyrene beads. Although density plays a key role in defining the mechanical properties as density alone does not adequately define the important characteristics and should not be the sole criteria used to specify the product. The degree of fusion achieved in the forming process is a critical factor. EPS's ongoing investment in state-of the- art manufacturing equipment and controls results in the highest quality material available as not all expanded polystyrene products are created equally. Care should be taken to make certain the manufacturer is able and willing to certify the mechanical properties of their product will meet those prescribed for the project.

Also in support of the above is ASTM C578, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation is the generally accepted document used to define the physical properties of expanded polystyrene used in the United States as the values in this specification are the minimum properties recommended for each material type. These properties are determined using ASTM C203, Test Method for Breaking Load and Flexural Properties of Block-Type Thermal Insulation, ASTM C165, Test Method for Measuring Compressive Properties of Thermal Insulations and ASTM D1621, Test Method for Compressive Properties of Rigid Cellular Plastics. Compressive Strength is required to support or resist dynamic loads (e.g. foot and construction traffic) as well as static loads (e.g. mechanical fasteners) to which typical roof systems will be exposed during the construction process and while in service as this permits the use of EPS in the construction of roof for building structures.

Fire Resistance

The property of fire resistance in an EPS structure is another thing that gives a fear as well as doubts the strength properties of an EPS structure. It is to be noted that an EPS structure shortcreted and plastered are some measures of preventing the structure from any fire accident as polystyrene is combustible. Short & Kinniburgh (1963) reported that the ability of a structure or element to resist fire is no property of the material it is made of but the function of the assembly of material stored inside it. Though the combustibility of a material may be important, the severity of the fire depends not so much on the fabric of structure as from the contents. The material may not be good in fire protection and its resistance can be improved by suitable protection.

Some researchers have discovered that using a 9mm thick plasterboard or plaster of minimum 10mm has been shown to provide resistance to ignition, if the protective facing is mechanically supported. An unsupported coating, applied directly on the expanded Polystyrene materials, with adequate insulation to maintain the interface temperature below 100°c for a specified time will provide protection, as long as the integrity of the facing is preserved. Thin finishes, such as plaster Skim coat, aluminium film, flame retardant paints or tumescent coatings applied directly on to the expanded Polystyrene materials can delay ignition to a limited extent, but once the underlying material softens under the effect of heat, penetration and progressive failure of the coating may occur.

Plastic insulation used to be associated with increased fire risk as some researchers also discovered. This was discovered in large agricultural buildings where non-fire retardant insulation was used unprotected. In practice, EPS burning behavior depends upon the conditions under which it is used. The best way to avoid fire spread is by appropriate protection of the insulation from any ignition source. Any insulation material should not be used uncovered, not only for fire performance but also for mechanical and long-term insulation properties. It is recommended by the industry that EPS is used with a covering material like brick, concrete, gypsum, etc An example is by rendering with gypsum plaster. Gypsum plaster is a non-combustible material. Gypsum plaster is produced by heating gypsum to about 300°F (150°C)

$$CaSO_4.2H_2O + \text{Heat} \rightarrow CaSO_4.{}^{1}/_{2}\,H_2O + 1{}^{1}/_{2}\,H_2O \text{ (released as steam)}$$

The removal of water in gypsum by heating is known as hem-hydrated gypsum or Plaster of Paris (POP). It is a class A plaster as stated in BS 1191.

Safety: this is simply a condition of being protected from danger, risk or harm (Hornby, 2004). A report of June 28, 1992 in an area of California was struck twice by earthquakes measuring 6.5 and 6.9 on the Richter Scale (the second quake was the worst recorded in over forty years). The epicenter of these quakes was located only 80-110 kilometers from the research facility site.

According to Dr. Phillippe Cohen who resides at the site, the facility was subject to continuous shaking at one point for over one full minute. Incredibly, the four buildings in the facility, some with walls over 7.3 meters in height, showed no signs of any damage despite the existence of large areas of glass. A full structural analysis of the building was ordered and the findings, testimony to the remarkable strength and integrity of Insteel 3-D Panels. Of particular significance is the sentence which reads, “There was no sign of any crack or damage of any kind to the superstructures and foundations” (Nancy, 1992). The monolithic nature of EPS makes it a safe material as curled from Cricket Diane’s report of 2012 on the earth quake and hurricane that occurred in Chile in January, 2012. In his report, he said m**any experts say the high death toll of the Jan. 12 earthquake, which claimed the lives of nearly 217,500 people according to the latest government figures, was largely preventable because earthquakes kill and injure people only if they cause buildings to collapse. “The lethality of an earthquake comes from poor construction, not from the shaking of an earthquake,” he added by saying** while no structure is 100 percent quake-proof, engineers say, buildings can be made more rigid to help them withstand an earthquake’s rocking forces. At the very least, buildings can be built to keep standing for longer, giving occupants potentially life-saving seconds to flee to safety. In addition to this, a **United Nations’ staff Wahlstrom added that “building a home, a box, where all the elements of the box are connected and tied together with bolts and steel mesh in corners is one guiding principle in making buildings safer,” as such features are relatively cheap, experts say, and add less than 10 percent on average to building costs. “The difference in cost between a building that is safe and one that is not safe is not that big”.**

Specific gravity test

Specific gravity is defined as the density (mass of unit volume) of a substance to the density (mass of the same unit volume) of a reference substance usually water (David, 2003). It is common to use the density of water at 4°C (39.2°F) as reference - at this point the density of water is at the highest. It has no dimension or unit and varies from substance to substance, aggregate to aggregate as well as gas to gas. Below is a list of the specific gravity for common materials used as aggregates in building construction.

Building material	**Specific gravity**
Alumina	3.4 - 3.6
Aluminium min.	2.55
Aluminium max.	2.8
Asphalt	1.1
Brick, common red	1.75
Brick, fire clay (firebrick)	2.4
Brick, hard	2.0
Brickwork, in cement	1.8
Brickwork, in mortar	1.6
Cement	1.2 - 1.5
Cement, Portland	2.8 - 3.2
Chalk	2.3
Clay min.	1.8
Clay max.	2.6
Concrete, light	1.4
Concrete, stone	2.2
Earth, dry	1.4
EPS	1.03-1.05
Granite min.	2.4
Graphite	2.07
Gypsum, solid	2.8
Gypsum, board	0.8
Limestone	2.6
Plaster, light	0.7
Plaster sand	2.46 – 2.96
Plaster of Paris	1.8
Polyurethane	1.05
PVC	1.39
Salt	2.2
Sand, silica	2.6
Sand, Quartz	7.0
Sandstone min.	2.0
Sandstone max.	2.8

Sawdust	0.15
Water	1.0

Summary of the Reviewed Literature

The review revealed that the use of polystyrene as a building material serves as a good and strong building material. It further pointed out the uses and benefits of polystyrene material while discussing on the various building materials used in building construction.

This study also tells the effect of the use of polystyrene as a building material. This effects being discussed helps to give more emphasis on the use of polystyrene since its effects are of no negative impact on its occupants, erectors and producers.

From all that have been discussed above, the following conclusions have being made:

- EPS is a good example of an efficient use of natural resources.
- The manufacture and use of EPS do not generate any risk to health or to the EPS does not damage the ozone layer since it does not and never has used CFCs or HCFCs in the manufacturing process.
- The transformation process consumes little energy and does not generate waste.
- The use of EPS for thermal insulation as seen in cavity walls means significant energy savings on heating and cooling buildings and a drastic reduction in the emission of polluting gasses (CO2 and SO2). It therefore contributes to alleviating the greenhouse effect and acid rain.

Also, the above shows that the compressive strength of EPS via axial loading is high and good since it can carry both dead and live load applied on it.

It also shows that the compressive strength of EPS via crushing is usually calculated in pound per square inch (psi) and not in Newton per square millimetre (N/mm^2) as the compressive strength of most building materials are usually calculated.

It also showed the specific gravity of common building materials including the specific gravity of the materials (cement, plaster sand and stone dust) used in the shortcreting and plastering of EPS walls including the specific gravity of EPS bead.

CHAPTER III

MATERIALS AND METHODS

This chapter describes the research design, area of study, materials used, test carried out and the procedures adopted for the collection of data for the study.

Research Design

The research design employed for the study was experimental. Thus, an experimental study is a study that requires a practical test work to be carried out, which can then be used to collect data, organize data, analyze data and discuss their result to find out or prove something (Suleiman, 2004).

Area of the Study

The study was conducted at Citec International Estates, Mbora district, Abuja.

Materials Used

The materials used for the research work are:

i. Plaster sand: these consist of natural sand particles passing through a 3/8 inch (0.05mm) sieve. The plaster sand used for this work was gotten from Mekunkele in Niger state of Nigeria.

ii. Stone dust: this consists of a fine powderof stones used for mixing mortar. The stone dust used for this work was gotten from a quarry in F-layout of Bosso local government area of Niger state.

iii. Cement: this is a fine, soft, powdery –type substance that is made from a mixture of elements such as limestone, clay, sand and /or shale found in natural materials. It is also made of calcium, silicon, aluminium and iron. It basically serves as a binding material. The cement used for this work was ordinary portland cement.

iv. Expanded Polystyrene (EPS) this is the major material used for this work. It is a polymer of styrene used in building construction in several parts of the world but seems to be a new material here in Nigeria. The sample used for this test was obtained from Citec International Estates, Mbora district, Jabi- airport road Abuja Nigeria.

Tests Conducted

The following tests were carried out; they are:

- Compressive strength test of expanded polystyrene material through axial loading
- Compressive strength test of expanded polystyrene material through crushing
- Specific gravity test of the cement
- Specific gravity test of plaster the sand
- Specific gravity test of stone the dust

Procedures for determining the compressive strength of an EPS material through axial loading

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. When the compressive strength of a material is reached, it crushes. Also, Axial loading is a pure tension on compression load acting along the long axis of a straight structural member.

Procedure

1. Cast the EPS slab like a normal hollow pot slab.
2. Allow the slab to set properly.

3. Load the slab with about 200 bags of 50kg cement and observe for failure and if there is no structural failure, the slab is continuously loaded until the slab sags.

The compressive strength of a material cannot be determined unless the material is moulded in form of a block and then tested but before that, I would like to define the following terms which would serve as key words in this research:

- Crushing: this simply means to bruise and break by pressing.

  Before a polystyrene block can be tested, it must be moulded as stated earlier after which it would be cured. The question then is what is curing?

- Curing: this is a process of providing a proper surrounding condition for cement to harden correctly and resist more forces than it meets. It may also be defined as a process of keeping concrete moist and warm enough so that hydration of cement may continue. There are four basic types or methods of curing; they are:

  (i) Water curing
  (ii) Membrane curing
  (iii) Application of heat and;
  (iv) Miscellaneous curing

The type of curing used for this work is water curing. Water curing is a type of curing involves the covering of concrete with a layer of water for a period of time and the evaporation of moisture is from the surface of the water.

Apparatus and materials used

- 10 EPS blocks cut into a size of 450mm×225mm×150mm, sprayed and plastered
- Trowel
- Shovel
- Wooden float

Procedure

1. Spray (shortcrete) the EPS blocks with a mix of cement; plaster sand and stone dust with a mix ratio of 1:2:4 and leave for a day to dry.
2. Plaster the shortcreted EPS block with a mix of cement; plaster sand and stone dust to ratio 1:4:2.
3. Allow the plaster shortcreted EPS block to dry.
4. Cure the plaster shortcreted EPS block for 7 days, 14 days and 28 days respectively. The EPS blocks can be cured using the water curing method via spraying.

Compressive strength test via crushing

Apparatus and materials

Compression testing machine

A measuring scale

Theory:

Compressive strength = $load\ of\ failure \div\ cross\ sectional\ area\ of\ the\ EPS\ block$(kN/m)

Procedure

1. Remove surface grit and projecting lips and note the dimensions and weight.
2. Clean the bearing surface of the testing machine and place the EPS blocks in the machine in such a way that the load is applied to other than the top and bottom of the EPS block.
3. Align the axis of the EPS block carefully with the centre of the thrust of the machine.
4. Apply the load without shock and increase continuously at a rate of 15N/mm2 per minute until no greater load can be sustained.

Procedure for finding the specific gravity of cement, plaster sand and stone dust used

Specific gravity is defined as the ratio of mass (or weight in air) of a unit volume of material to the same volume of water at a stated temperature. Specific gravity depends on the amount of voids and the specific gravity of the materials of which it is composed.

Materials and apparatus

- Density bottle
- A measuring scale
- Water
- Sample of material (cement, plaster sand and stone dust)
- An electric oven

Procedure for specific gravity of cement

1. Dry the cement thoroughly to be free of moist.
2. Weigh the empty density bottle and note the weight W1.
3. Fill the density bottle with 1/3of cement and weigh it. Note the weight as W2.
4. Fill the density bottle with 1/3 of cement with water and weigh. Note the weight as W3.
5. Fill the density bottle with clean water and weigh. Note the weight as W4.

According to David (2003), the stated that the specific gravity of any material used for building construction can be expressed as:

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)} =$$

Where:

W1= weight of the empty density bottle

W2= weight of density bottle and cement sample

W3= weight of density bottle, cement sample and water

W4= weight of water

Procedure for specific gravity of stone dust

1. Dry the stone dust thoroughly to be free of moist.
2. Weigh the empty density bottle and note the weight W1.
3. Fill the density bottle with 1/3of stone dust and weigh it. Note the weight as W2.
4. Fill the density bottle with 1/3 of stone dust with water and weigh. Note the weight as W3.
5. Fill the density bottle with clean water and weigh. Note the weight as W4.

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_{2)}}$$

Where:

W1= weight of the empty density bottle

W2= weight of density bottle and sample of stone dust

W3= weight of density bottle, sample of stone dust and water

W4= weight of water

Procedure for specific gravity of plaster sand

1. Dry the plaster sand thoroughly to be free of moist.
2. Weigh the empty density bottle and note the weight W1.
3. Fill the density bottle with 1/3of plaster sand and weigh it. Note the weight as W2.
4. Fill the density bottle with 1/3 of plaster sand with water and weigh. Note the weight as W3.
5. Fill the density bottle with clean water and weigh. Note the weight as W4.

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_{2)}}$$

Where W1= weight of the empty density bottle

W2= weight of density bottle and sample of plaster sand

W3= weight of density bottle, sample of plaster sand and water

W4= weight of water

CHAPTER IV

PRESENTATION AND DATA ANALYSIS

This chapter analyzed the data collected through the practical test carried out for the study. A total of five (5) tests were carried out in the building laboratory of the department of Building, Federal University of Technology Minna, Niger state Minna and in Citec International estates Mbora district Abuja. The analysis is arranged according to the research question posed for the study.

Research question 1

What is the compressive strength of EPS via axial loading?

To determine the compressive strength of EPS via axial loading, the axial loading test was carried out on the expanded polystyrene (EPS) slab in order to determine the strength and the sag.

Result of EPS test via axial loading

The EPS slab was loaded with 50bags of 50kg Dangote Portland cement each to give a load of 2500kg. It was observed that there was no sag on the slab, this load was later increased to 100 bags that is 5000kg, there was no sag. It was found out that the compressive strength of an EPS slab via axial load is good and high enough to carry the dead and live load of a building since the total load including dead weight of the slab amounts to more than 1400kg/m^2 which at least twice the load in a usual residential building.

Research question 2

What is the compressive strength of an EPS block via crushing?

In determining the compressive strength of an EPS block through crushing, nine (9) EPS blocks were cut into a dimension of (450×225×10)mm and were shortcreted and plastered while it was left for 24 hours to set properly in the building laboratory of the department of Industrial and Technology Education, Federal University of Technology Minna Niger state .The EPS blocks were cured with water for 7days, 14days and 28 days respectively and were crushed (3 EPS blocks each) on the 7^{th}, 14^{th} and 28^{th} day respectively at the building laboratory, School of Environmental Technology (SET), Federal University of Technology Minna Niger state of Nigeria. Table 2below shows the data obtained from the crushing of the EPS blocks at 7days, 14 days and 28 days respectively.

Table 2

S/No	No.of curing days	Mass of EPS block (kg)	Volume of the EPS block (mm³)	Density of the EPS block	Load applied on the EPS block (N)	Compre-ssive strength Of the EPS block(N/mm)	C. S in psi
1.	7days	14.38	450×225×10		10.0	0.10	145.14
2.	7days	12.39	"		24.0	0.24	348.33
3.	7days	12.98	"		21.0	0.22	319.30
4.	14days	12.93	"		15.0	0.15	217.71
5.	14days	14.53	"		30.2	0.30	435.41
6.	14days	10.62	"		17.0	0.17	246.73
7.	28days	12.78	"		32.6	0.32	464.44
8.	28days	14.73	"		44.3	0.44	638.61
9.	28days	12.27	"		19.8	0.20	290.28

Standard deviation for the compressive strength

Table 3

S/No	Compressive strength (x)	Deviation from mean $(x - \bar{x})$	Square of deviation $(x-\overline{x})^2$
1.	0.10	-0.138	0.019044
2.	0.24	0.002	0.000004
3.	0.22	-0.018	0.000324
4.	0.15	-0.088	0.007744
5.	0.30	0.062	0.003844
6.	0.17	0.068	0.004624
7.	0.32	0.082	0.006724
8.	0.44	0.202	0.040804
9.	0.20	0.038	0.001444

Where $\bar{x}$ = mean

$= \frac{\sum x}{n} = \frac{2.14}{9}$ = o.238

$$\sum(x - \overline{x}) = -0.02$$

$$\text{Variance} = \frac{\sum(x-\overline{x})}{n} = \frac{0.084556}{9} = 0.009395$$

$$standard\ deviation = \frac{\sqrt{(\sum(x - (x)))}}{n}$$

$$S.D = \frac{\sqrt{0.009395}}{9} = 0.0969 \approx 0.1$$

The analysis of the data presented in table 4.1 revealed that the compressive strength of EPS is high. This signifies that the EPS material has the required strength to withstand the load of a building.

Research question 3

What is the specific gravity of the materials (cement, plaster sand and stone dust) used?

In determining the specific gravity of the material used, the specific gravity of the cement, plaster sand and stone dust used were carried out. The result for the test is presented below;

Specific gravity of cement

- The cement was thoroughly dried to make it free of moist.
- The empty density bottle was weighed and noted as W1.
- The empty density bottle was filled with 1/3of cement and weighed. It was noted as W2.
- Water was added to the density bottle containing 1/3 of cement and was noted as W3.
- The density bottle was emptied and filled with water and then weighed. This was noted as W4.

It is calculated as;

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_{2)}}$$

Where;

W1 = 110g

W2= 157g

W3 = 273g

W4 = 247g

Specific gravity = $\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_{2)}} = \frac{157 - 110}{(247 - 110) - (278 - 157)} = \frac{47}{137 - 121} = \frac{47}{16} = 2.93 \approx 3.0$

The analysis of the data shown above revealed that the specific gravity of cement used was 3.0. This shows that the cement used was good. This is because according to David (2003) that noted that for a cement to be used for a construction work, the specific gravity of that cement must be within the range of 2.80-3.20.

Specific gravity of plaster sand

- The plaster sand was thoroughly dried to make it free of moist.
- The empty density bottle was weighed and noted as W1.
- The empty density bottle was filled with 1/3of plaster sand and weighed. It was noted as W2.
- Water was added to the density bottle containing 1/3 of plaster sand and was noted as W3.
- The density bottle was emptied and filled with water and then weighed. This was noted as W4.

It is calculated as;

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)}$$

Where;

W1 = 28g

W2 = 70g

W3 = 103g

W4 = 77g

Specific gravity = $\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)} = \frac{70 - 28}{(77 - 28) - (103 - 70)} = \frac{42}{49 - 33} = \frac{42}{16} = 2.625 \approx 2.6$

The analysis of the data shown above revealed that the specific gravity of the plaster sand used was 2.6. This shows that the plaster sand used was good as stated by David (2003) who said the specific gravity for plaster sand ranges from 2.46 – 2.96.

Specific gravity of stone dust

- The stone dust was thoroughly dried to make it free of moist.
- The empty density bottle was weighed and noted as W1.
- The empty density bottle was filled with 1/3of stone dust and weighed. It was noted as W2.
- Water was added to the density bottle containing 1/3 of stone dust and was noted as W3.
- The density bottle was emptied and filled with water and then weighed. This was noted as W4.

It is calculated as;

$$\frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_{2)}}$$

Where;

W1 = 28g

W2 = 67g

W3 = 102g

W4 = 77g

Specific gravity = $\frac{w_2-w_1}{(w_4-w_1)-(w_3-w_{2)}} = \frac{67-28}{(77-28)-(102-67)} = \frac{39}{14} = 2.786 \approx 2.8$

The analysis of the data shown above revealed that the specific gravity of the stone dust used was 2.8. This shows that the stone dust used was good as stated by David (2003) who said the specific gravity for stone dust is 2.0- 2.8.

Findings

Based on the test carried out, the following findings were made according to the research question posed for the study:

a. The findings of the study on the compressive strength of EPS via axial loading revealed that the strength of an EPS slab was good and can carry both the dead and live load of a building which is basically what every building should strive for.

b. The findings of the study on the compressive strength of EPS via crushing shows that the compressive strength of EPS panels was high and good as the compressive strength of EPS is measure in pound per square meter (psi) and according to EVG 2004, that says that the strength of an EPS structure determines to a large extent how well it is able to keep its monolithic nature which makes it an outstanding building material.

c. The findings on the study on the specific gravity of cement shows that the test carried out is in relation to what is being conducted as the specific gravity of cement.

d. The findings on the specific gravity of plaster sand shows that the test carried out is in relation to what is being conducted as the specific gravity of Plaster sand.

e. The findings on the specific gravity of stone dust shows that the test carried out is in relation to what is being conducted as the specific gravity of stone dust.

Discussion of findings

The discussion of findings is based on the research questions posed for the study and from the above,

Research question one dealt with the compressive strength of EPS via axial loading. The findings as discussed above revealed that after the EPS slab had been loaded with the bags of cement, it was still standing properly without sagging. It showed that the compressive strength of EPS via axial loading was high and is able to carry almost twice the dead and live load of a building which makes it a good material since that is one of the major requirement of a slab.

Research question two dealt with the compressive strength of EPS blocks via crushing. The findings as discussed above revealed that after the EPS blocks had been crushed on the 7^{th}, 14^{th} and 28^{th} day, the compressive strength of the EPS blocks were still high enough. It showed that the compressive strength of EPS is high as the result of the test was in line with that agreed upon by ASTM that says that the compressive strength of EPS should not be less than 65psi of which the least compressive strength from the result in table 4.1 is 145.14psi. Research has also shown that what actually gives the EPS block most of its strength is the mortar used in shortcreting and plastering as John (2004) in his work says EPS is a lightweight material.

The findings also indicated that the compressive strength of EPS block either via axial loading or crushing is high and good which means that it is a good material to be encouraged in the construction industry since it meets the basic requirements of a building material.

Also, the findings have also reviewed that the specific gravity of the materials used for the work are in line with the accepted specific gravity for cement, plaster sand and stone which means that, the results given have no negative or imposing strengths on the compressive strength of the EPS material. As the specific gravity of the cement used was 3.0, that of the plaster sand 2.6 and that for the stone dust 2.8. this results shows that the materials used for the shortcreting and plastering of the EPS walls were of the required quality and standard.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the Summary of the study, Conclusions, Recommendations and Suggestions for further studies.

Summary of the study

The main purpose of the study is to assess the effectiveness of expanded polystyrene material used in building construction in Mbora district, Abuja based on the information obtained from the previous chapter. To achieve this objective, three (3) research questions were formulated to guide the study. A total of five tests were carried out to achieve this.

These tests were carried out at the building laboratory of the School of Environmental Technology, Federal University of Technology, Minna – Niger State and the construction site of Citec International Estates, Mbora district, Abuja. The result of the test gave a positive result on the effectiveness of an EPS material used in building construction.

Implication of the study

The findings of this study have far reaching implications for the occupants of EPS building as it makes them feel and know they are safe in their houses. Also, the findings would have an implication for the government, construction workers, the environment and the society at large. The result of the study will give a better awareness on EPS used in building construction since its use is not dangerous to the erectors, occupants or the environment. It would also encourage the government to go into mass housing which would help the masses.

Conclusion

It is glaring from the research made that expanded polystyrene (EPS) has all it takes to be used as a building material in Mbora district, Abuja for the construction of houses either as load bearing walls, non-load bearing walls, slabs, culverts, stairways and other uses of the EPS panels since it passed all the tests it passed through.

Recommendations

Based on the findings of this study, the following recommendations were drawn:

1. There should be a proper orientation on the use of EPS material for building construction since it posses the required quality for a building material.
2. The government should make use of EPS material in the construction of mass housing since it is safe and strong.
3. Areas liable to flooding and river over flowing should make use of EPS in the construction of their buildings as it leaves the building standing not minding flow of the river or water due to its box like nature.

Suggestion for further study

The following suggestions have been made for further research:

1. Comparison on the effects of EPS on the environment and sandcrete block on the environment.
2. An investigation into the minimum standard size of an EPS bead to be used for building construction.

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APPENDIX I

An EPS wall erected with conduit pipes fixed
pipe fixed in it.

An EPS wall erected with water
in it.

An EPS structure under construction.

An EPS structure after shortcreting and plastering.

An EPS structure during shortcreting

An EPS structure ppreparing to take a decking.

APPENDIX II

EPS panels fixed on slabs.

Reinforcement being fixed for an EPS slab

An EPS slab before casting

A cast EPS slab

APPENDIX III

The underneath of an EPS slab


An EPS slab being tested via axial loading in Mbora district.


An EPS structure on completion.

APPENDIX IV

An EPS block being crushed with a crushing machine.

Doing the specific gravity test for the materials used.

APPENDIX V

Myself while shortcreting.

The ITE building laboratory where the EPS blocked were shortcreted and plastered.

APPENDIX VI

My Supervisor (Mr. Ibrahim Dauda) explaining to me.


My Supervisor and I while doing the shortcreting and plastering of the EPS block.