American Journal of Engineering and Technology Management
2017; 2(5): 64-71
http://www.sciencepublishinggroup.com/j/ajetm
doi: 10.11648/j.ajetm.20170205.12
ISSN: 2575-1948 (Print); ISSN: 2575-1441 (Online)

Review Article

Use of Expanded Polystyrene Technology and Materials Recycling for Building Construction in Kenya

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To cite this article:

Hannah Nyambara Ngugi, James Wambua Kaluli, Zachary Abiero-Gariy. Use of Expanded Polystyrene Technology and Materials Recycling for Building Construction in Kenya. *American Journal of Engineering and Technology Management*. Vol. 2, No. 5, 2017, pp. 64-71. doi: 10.11648/j.ajetm.20170205.12

Received: September 15, 2017; **Accepted**: October 8, 2017; **Published**: November 3, 2017

Abstract: A growing population in Kenya demands expansion of housing facilities. Traditional burnt bricks, quarry stones, timber, and corrugated iron sheets remain the most commonly used construction materials in Kenya. Expanded Polystyrene (EPS) material derived from the distillation process of crude oil and is 100% recyclable, is an alternative construction material. Use of EPS material reduces the rate at which natural materials such as wood and stones are extracted from the environment, hence promoting sustainable development. EPS buildings are fast to construct, cost saving and have thermal characteristics that are suitable for areas with extreme weather conditions. Structurally, EPS materials have performed well for both low and high-rise buildings of up to ten floors. In Kenya, lack of governing standards and unawareness amongst industry players has hampered adaptability of EPS building materials. This paper discusses the potential of EPS as a construction material in Kenya. It is concluded that Kenya needs to develop strategies to promote use of environmentally friendly EPS materials.

Keywords: Expanded Polystyrene (EPS), Building Technology, Recycling, Sustainable Material

1. Introduction

Provision of decent and affordable housing remains a challenge in developing countries. Ede projected that the cost of construction materials will continue to escalate amidst the emerging environmental issues like climate change [1]. In 2017, Nairobi had an estimated population of 4.2 million people, having increased from 3.1 million people in 2009 [2]. Some 73% of Nairobians live below the poverty line and nearly 60% of houses are considered 'inadequate' and are in slums. Approximately 66% of houses in Nairobi County are stone and block walled while wood and corrugated iron sheet walling account for 31%. About 76% of the houses have cement floors while 14% have earthen floors, 7.5% have ceramic tiles and 2.5% have wooden floor (Figure 1). About 57% of homes in Nairobi are roofed with corrugated iron sheets, while those roofed with ceramic tiles and concrete constitute 12.4% and 27.9% respectively, of the homes. A 3-bedroom house in Nairobi costs about Ksh 4.5 million, which is beyond the reach of the majority [3]. The significance of shelter to man cannot be over emphasized as it is next in importance to air, water and food [4]. There is need to meet the ever-increasing need for decent and affordable housing in Nairobi, Kenya and beyond.

Faster and more affordable methods of construction are required to fill the housing gap [5]. Expanded Polystyrene (EPS) is a thermoplastic material manufactured from styrene monomer, using a polymerization process which produces translucent spherical beads of polystyrene. As a material, EPS is formed by union of so many beads of polystyrene produced during a modelling process with supply of heat as water steam until full formation of the desired properties. Research has shown that the unit weight of EPS embedded structure is up to 35% less than the conventional concrete structure and the pre-assembled units reduces the overall cost of structure significantly [6].

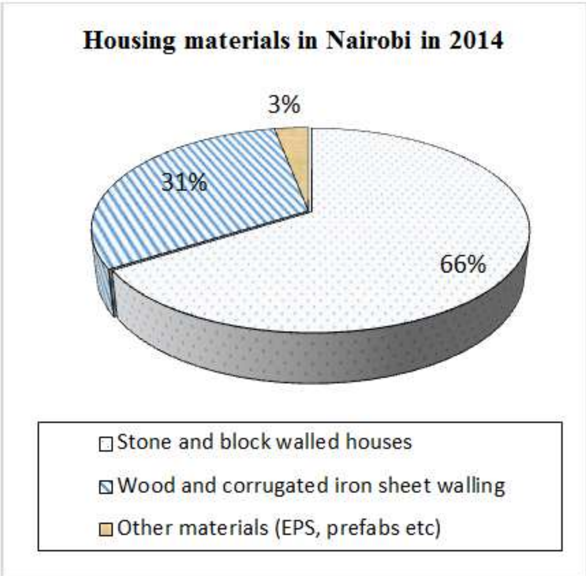

Figure 1. *Housing materials used in Nairobi houses [2].*

EPS is manufactured through 3 main stages namely Pre-expansion, Intermediate maturing and Final Moulding [7] and [8]. At Pre-expansion stage, the raw material is heated in special machines called pre-expanders with steam at temperatures of between 80-100°C. The density of the material falls from some 630kg/m^3 to values of between 10kg/m^3 and 35kg/m^3. During pre-expansion, the raw material's compact beads turn into cellular plastic beads with small closed cells that hold air in their interior. The objectives of this review are to assess the current trend and structural performance of EPS technology as a building material in Kenya.

2. Building Materials and Design Considerations

2.1. Overview

Building materials are required to provide adequate strength and ability to withstand the loading. The selected materials should be able to withstand collapse with an adequate factor of safety. The design of engineering structures must ensure that the structure is safe under the worst loading and that during normal working conditions, the deformation of members does not distract from the appearance, durability or performance of structure [9].

2.2. Concrete

A reinforced concrete structure is a combination of beams, columns slabs and walls rigidly connected to form a monolithic frame. Each of these members must resist the forces acting on each of them. The key design elements in design of a building include the foundation, floor slab, walling and the roof. Foundation is essential as it transfers and spread the loads from the columns and walls into the ground. The safe bearing capacity of the soil must not be exceeded to avoid excessive settlement which may result to damage of the building and its services facilities. Walls may take the form of structural or non-structural elements. The thickness of non-structural walls provides sound insulation and fire resistance requirements while nominal walls control cracking. Structural walls are designs to resist vertical and horizontal forces and moments. A typical structural wall is a vertical load-bearing member whose length is not less than four times its thickness. In design, a wall is designed as a series of columns with appropriate vertical load and transverse moments at its top and bottom. The wall is alternatively designed as a slab if it is predominantly subjected to lateral bending [9]. Walls thickness is usually governed by slenderness limitations, fire-resistance requirements and construction practicalities.

Slabs carry the loading exerted from occupation of the building. This comprise of both live and dead loads as analysed during design. Roof provide the covering for building structures to protect the building occupants from harsh weather conditions.

Concrete is one of mostly widely used construction material globally. Reinforced concrete provides tensile strength in reinforced structures. The key characteristics of concrete and steel entail high compressive and tensile strength respectively as shown in the table below.

Table 1. *Characteristics of Concrete and Steel [9].*

Properties	Concrete	Steel
Strength in tension	Poor	Good
Strength in compression	Good	Good, but slender bars will buckle
Strength in shear	Fair	Good
Durability	Good	Corrodes if unprotected
Fire resistance	Good	Poor, suffers rapid loss of strength at high temperatures

The tensile strength of concrete is about 10% of its compressive strength hence all reinforced concrete structures are designed on the assumption that concrete does not resist any tensile forces. Consequently, reinforcement are designed to carry tensile forces which is transferred by the bond between the interface concrete and reinforcement.

Concrete is made of cement, fine aggregates, course aggregates, water and admixtures. Although cement provides good bidding properties, the process of manufacturing of cements produces huge proportion of carbon dioxide thus making it unsustainable construction materials.

To minimise and prevent emission of carbon dioxide to the environmental, researchers have explored alternative building technologies. EPS is one of the alternative building technologies aimed at providing affordable and sustainable building material for housing. Sustainability of buildings is a really important issue for the construction industry. Sustainable buildings are characterized by the lower construction costs for energy consumption and operations, they are environmentally friendly, able to save natural resources and they are comfortable and healthy for their users [10].

2.3. Polystyrene Materials Use Globally and in Kenya

A building material that meets the safety standards (including seismic resistance) and the dwellers 'comfort requirements must also be thermally insulating, light weight and inexpensive [11]. All these requirements are made possible using the Expanded Polystyrene (EPS) initiative which represents one of such new materials that have found their way into the previously conservative construction industry [12].

EPS is a multipurpose plastic material made available for a multiplicity of applications. It was initially mainly used for insulation foam for closed cavity walls, roofs and floor insulation [1]. Following continued research and innovation, EPS usage has extended in the building and construction industry in road construction, bridges, floatation, railway lines, public buildings, drainage facilities and family residences. EPS is a thermoplastic material manufactured from styrene monomer, using a polymerization process which produces translucent spherical beads of polystyrene.

EPS used for building construction are of various types and sizes with the most common ones being for wall panels and for slab that are erected with steel meshes. The steel mesh serves as reinforcement. The EPS 3D reinforced wall system usually transfers shear and compression forces along the wall plane. The wall system is completed by applying concrete layers of acceptable thickness on both sides to perform the dual functions of protecting the reinforcements against corrosion and for transference of compressive forces [12]. With the proven strengths of plastic materials used in commercial and residential construction in the past 30 years, the adoption of plastic in civil constructions is dramatically on the increase due to improved material performance, efficient use of technologies in new applications, and the need for lightweight, durable materials and insulation purposes [1].

Ede [1] carried out research aimed at studying the applications of this innovative plastic material in the Nigerian building industry with special regard to the performance perception by the clients and the end users. They carried out a case study for a building in Abuja. The study findings revealed great satisfaction verified among the clients and residents. It further ranked high performance of Expanded Polystyrene (EPS) materials as characterised by recyclability, reliability, versatility and moisture resistance characteristic of EPS building products.

EPS is a rigid cellular plastic found in a multitude of shapes and applications. It is commonly used for packaging for electrical consumer goods and for insulation panels for building. The use of EPS sheet which are made from small beads of polystyrene mixed with pentane is one of such technology. This research paper explored the usage of EPS technology in Kenya. EPS technology was introduced in Kenya in April 2013. National Housing Corporation (NHC) established an EPS factor in Nairobi at Mlolongo area, Machakos County [13]. The factory was pioneer in Kenya and in the East and Central African region. Construction using prefabricated materials including EPS is a relatively new method in Kenya, to get buildings up fast [3]. EPS technology had already been used in other countries including Mexico, Britain, Qatar, Nigeria, Mozambique and USA. EPS as a construction material provides environmental, technical, commercial and social benefits.

There are two types of polystyrene materials. Extruded Polystyrene (XPS) is plastic foam based on polystyrene that is formed by adding gas during extrusion not by expanding beads containing gas; which is how EPS is formed. A well-known use of XPS is the vac-formed polystyrene trays used for small portions of food found in the supermarket. The extruded polystyrene foam is a fine laminate that is only 2-3 mm thick. EPS is made from expandable polystyrene, which is a rigid cellular plastic containing an expansion agent.

2.4. Suitability of EPS in Construction

Use of EPS introduces a pre-manufactured technology in the construction of reinforced concrete buildings. This industrial system entails production of a panel of wavy/undulated shape of polystyrene which is covered on either side with electro welded zinc coated square mesh. There are 33 connectors of the square mesh per m^2 to form a three-dimensional reinforcement steel. There are two kinds of polystyrene panels, single and double [5]. A single panel has a polystyrene sheet sandwiched between welded wire mesh on either side while a double panel is made of two single panels which are joined with an intermediate cavity. To form the walls, the mesh is covered with a coat of shotcrete applied under pressure using a pneumatic system. A building can go up to four floors with a single panel and fifteen floors in double panel.

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 [6]. The material is therefore suitable to regulate extreme temperatures in a building. The unit weight of EPS embedded structure is upto 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.

Numerous laboratory tests performed in different parts of the world have highlighted the high load resistance of the panels which after compression testing with centred load performed on a single finished panel, 2700mm high, have shown that they withstand a maximum load of up to 1530 kN/m ≈ 153 ton/m. The Monolithic joints of the building system provide a high level of structural strength to buildings. Compressive strength and axial loading for EPS compares well with concrete strength. In EPS in Kenya has been used to build houses [14] while in South Africa EPS has been used for construction of boundary walls, suspension floors and roofs, pillars, and swimming pools.

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/m^2 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. 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 [15]. This makes it suitable for construction in cold, damp and swampy area as well as areas with high water table.

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 organisations conduct the life cycle impact analysis [15] which measures the energy consumption, air pollution, water pollution, global warming potential and volume of solid waste.

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 labour and transport building costs. The light weight 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 [5].

EPS provided flexibility in design and enables choosing various options on fascia of panels and colours. 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

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 off-cuts 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.

3. Recycling of Building Materials for Enhanced Sustainability

Bolden [16] observed researchers have studied the use of acceptable waste, recycled band reusable materials and methods. These recyclable construction materials include use of swine manure, animal fat, silica fume, roofing shingles, empty palm fruit bunch, citrus peels, cement kiln dust, fly ash, foundry sand, slag, glass, plastic, carpet, tire scraps, asphalt pavement and concrete aggregate in construction is becoming increasingly popular due to the shortage and increasing cost of raw materials. In some countries like Japan, the government through the Ministry of Lands, Infrastructure and Transport, aimed to recycle 95% of the waste from concrete, wood and asphalt waste in 2010 [17].

EPS is 100% recyclable and thousands of tonnes are recycled every year in developed countries likes the United Kingdom (UK). This compacted material can be transformed into recycled polystyrene pellets. These pellets are used to manufacture coat hangers, picture frames, replacement hardwood and CD-ROM cases. Some of the members of the EPS Packaging Group have set up consumer recycling points on their sites so that local people and small businesses can recycle their used polystyrene.

3.1. Recycling of Concrete

Nowadays steel scraps from demolished reinforced concrete is recycled by innovative transportation and highway industry construction [18]. Course aggregates are recycled for use in low strength concrete for making pavements and paving blocks. Concrete can be crushed and recycled while steel and bricks can be reusable and recyclable [19].

The application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries. Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate [20].

Recycling of concrete debris can contribute to reduction in the total environmental impact of the building sector [21]. For most construction sites, construction and demolition debris is typically disposed, recycled, or incinerated. The debris may be recycled at a recycling facility, where it replaces a natural resource or other competitive material in a new market. It can also be directly reused from the construction site.

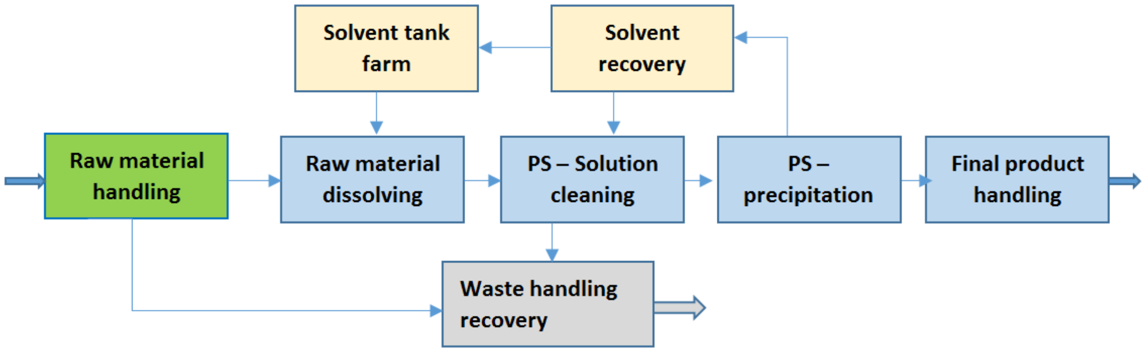

Figure 2. *Recycling Process of EPS Materials [22].*

3.2. Recycling of Wood

Abimaje and Baba [23] urges that a sustainable building material must be environmental friendly, affordable, flexible in usage and durable and wood possess these characteristics. Wood can be recycled and renewed, again and again and only few other materials can match the unique combination of benefits; strength, affordability and environmental sustainability of wood.

Kralj and Markič [19] observed that wood is reusable, recyclable and biodegradable. To minimise waste in wood construction, use of advanced framing techniques, trusses for roof or floor framing, finger jointed studs and trim, and engineered wood products as well as use of wood frame wall panels prefabricated off-site as some of applicable initiatives.

3.3. Recycling of EPS

EPS is an environmental friendly project and is 100% recyclable. The process of recycling EPS materials for enhanced sustainability comprise of 5 main stages namely, Mechanical Crushing, Dissolving of recovered EPS, Slurry Filtration, Polystyrene precipitation and Final Product as illustrated in Figure 2 below [22].

The waste EPS material is gathered up together. At mechanical crushing, the recovered EPS is crushed and broken into smaller pieces. The small pieces are then dissolved in the first stage of the process. The special solvent ensures that only the polystyrene is dissolved and therefore all other plastics and impurities remain in solid phase in the slurry. In order to separate solid impurities from the liquid, the slurry passes a multistage filtration. Only the solvent and dissolved polystyrene (PS) continue through to the next recycling stage. The PS gel is then separated from the solvent. Both, precipitant and solvent, are recovered and led back into the process circuit. The final product is high quality recycled PS granules. The end product (PS) has been independently approved by the relevant European authorities. This recycling process provides an economical feasible solution compared to disposing of EPS include combustion and landfill dumping resulting in damaging environmental impacts.

Mwasha, [24] recognised that disposal of polystyrene waste (PSW) can be problematic due to its bulky nature and highly mobile properties since EPS, comprises of 98% air and 2% polystyrene. He argues that the air content in EPS can be released by dissolving EPS in supercritical solvents. This dissolution method is one of the cheapest and most efficient processes for EPS waste management. The use of the dissolved EPS as construction material can be considered as a sustainable and environmentally friendly option since these materials do not contain any chlorofluorocarbons and most likely will not contribute to the depletion of the ozone layer. 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 [25]. Addition of EPS waste resulted in improvement of workability and enhanced the resistance to deformation of the asphalt concrete mixture. Gonzalez et al (2015)'s research findings established that addition of EPS waste to the Construction and Demolition Waste (CDW) results in a 34% reduction of density and an 8% improvement of thermal behaviour of gypsum composites.

4. Limitations of EPS as a Building Construction Material

EPS technology is used for various purposed in the construction industry. Rocco [26, 2, 13] argues that 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.

Ede [27] assessed the acceptability of plastic materials for structural applications in Nigerian buildings and established that the level of acceptability is not very good. Polyvinyl chloride and polystyrene were the most used plastics and they are applied in pipes, finishes, ceiling, wall panels, windows and doors while advanced fibre reinforced polymers are not widely used. Polystyrene was also used for expansion joints. Many construction industry professionals interviewed in Nigeria had had very minimal knowledge on the use of plastic materials in building construction and it is expected that this scenario still holds in Kenya and most developing countries.

EPS comprise of about 98% air and 2% polystyrene and can be used as partial replacement of coarse aggregates [18]. Further increase in the EPS beads content in concrete mixes reduces the compressive and tensile strength of concrete.

Ibrahim [28] assessed the strength properties of polystyrene material used in building construction in Mbora District of Abuja, Nigeria and found out that the compressive strength of expanded polystyrene through axial loading was high and could carry 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. The study further revealed that the compressive strength of expanded polystyrene via crushing showed that the compressive strength of expanded polystyrene panels is high and good as the compressive strength of expanded polystyrene is measure in pound per square meter (psi). They concluded that the government should make use of EPS material in the construction of mass housing since it is cheaper, has a faster erecting time and safe and that EPS should be used in areas liable to flooding and river over flowing as EPS leaves the building standing not minding flow of the river or water due to its box like nature. Use of EPS as green materials (Ling and Teo, 2013) enables production of rice husk ash and EPS concrete blocks as used in Malaysia by mixing agricultural and industrial wastes with concrete.

The construction of fills for roads and other applications in an urban environment often present many technical and socioeconomic challenges [29]. To provide solution to such challenges, use of expanded polystyrene (EPS) blocks as a type of geofoam lightweight fill material has seen growing use worldwide in urban areas in the U. S. A. Besides road application, use of EPS-block geofoam has numerous other uses as a lightweight fill in urban environments. This include use in transportation earthworks involving railways and airfields, landscaping as well as direct support to shallow foundations of lightly loaded buildings and small bridges. In general, it has been and can be used in any application where the long-term applied stresses do not exceed approximately 100 kPa (2000lb/ft^2).

In Kenya, there is inadequate professional support in use of EPS material for construction. Most graduate and practicing engineers are not conversant with new building technologies and therefore often design housing using the traditional stone and mortar technology. There lacks research information on the acceptability of use of EPS materials by professionals in Kenya's construction industry. The slow uptake of EPS as a construction material in Kenya is has further attributed to lack of awareness of EPS existence in the country, lack on readily information on EPS's economic, environmental and social benefits, lack of trained readily available EPS artisan, lack of design manual for high-rise buildings using EPS and high transport cost for projects located far from Nairobi.

There lacks an approved quality standard on use of EPS in Kenya. The Kenya Bureau of Standards has the mandate to develop and update the quality standards in Kenya. Literature shows that some African countries have started using EPS and Cameroon adopted EPS standards in 2014. Standardisation of EPS to protect consumers is required to put in place safety requirements

Technology for manufacturing the prefabricated EPS materials is quite new to the Kenya Bureau of Standards hence many developers are not aware of availability of alternative construction technology. EPS technology need to be contextualised in Kenya to generate the expected cost reduction.

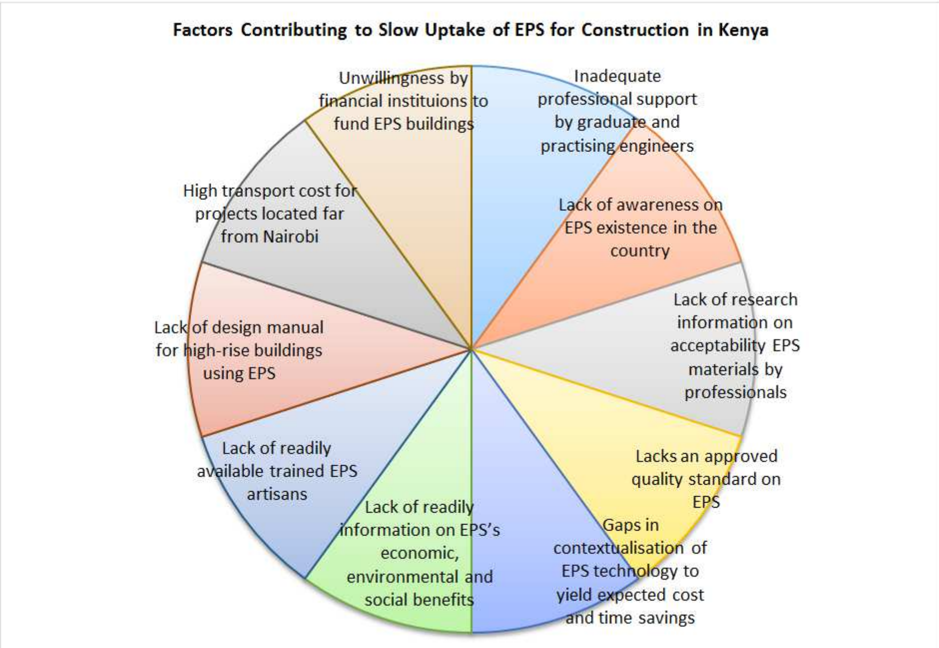

Figure 3. *Factors attributing to slow uptake of EPS for building construction in Kenya.*

5. Conclusion

The research reveals that decent housing remains a big challenge for the larger populations in Kenya and other developing countries. Although EPS technology was invented 30 years ago, it is still underutilised in Kenya where use of stones, stone block and corrugated iron sheet walling comprise of 97% of all houses in Nairobi.

EPS construction materials are sustainable in the sense that they can be re-used, thus reducing the rate of extraction of natural resources. However, there lacks quality control standards to guide production and use of EPS construction materials in Kenya.

Recommendations

To address the existing housing gaps in Kenya, use of EPS technology should be promoted. There exists an urgent need for research to develop standards to govern [3] production and use of EPS materials in Kenya.

References

[1] A. N. Ede, V. Alegiuno and P. Oluwa, "Use of Advanced Plastic Materials in Nigeria: Performance Assessment of Expanded Polystyrene Building Technology System.," American Journal of Engineering Research (AJER), vol. 03, no. 04, pp. 301-308, 2014.

[2] Nairobi Couty Government, Nairobi County Government Development Plan, Nairobi, 2014.

[3] L. K. Githuku, "Use of Expanded Polystyrene as a Solution to Low Cost Housing in Kenya.," Nairobi, 2014.

[4] A. N. Ede, "Measures to Reduce the High Incidence of Structural Failures in Nigeria..," Journal of Sustainable Development in Africa., vol. 13, no. 1, pp. 153-166, 2011.

[5] K. Sneha and T. P. Tezeswi, "A Comparative Study of Construction Using Schnell Concrewall® Pre-Cast Sandwich Composite Panel and RC Moment Frame with Brick Infill.," International Journal of Civil Engineering and Technology (IJCIET), vol. 7, no. 5, pp. 110-110, July-August 2016.

[6] R. Raj, M. K. Nayak, M. A. Akbari and P. Saha, "Prospects of Expanded Polystyrene Sheet as Green Building Material.," International Journal of Civil Engineering Research. Volume 5, Number 2 (2014, vol. 5, no. 2, pp. 145-150, 2014.

[7] O. Medne, "Research on Expanded Polystyrene Product Manufacturing Process," Riga Technical University, Riga, 2011.

[8] M. X. Calbureanu, E. Albota, D. Tut, D. Tutunea, S. Dumitru, R. Malciu and A. Dima, "Contributions above the dew-point problem in civil building EPS insulated walls modelling with finite element the convective heat transfer.," International Journal of Mechanics., vol. 4, no. 3, pp. 53-62, 2010.

[9] W. H. Mosley, J. H. Bungey and H. Ray, Reinforced Concrete Design, 5th Edition ed., 1999.

[10] P. Mesaros, M. Spisakova, L. Kyjakova and T. Mandicak, "Expanded polystyrene as the bearing building material of low energy construction.," in IOP Conference Series: Materials Science and Engineering, TSU, 2015.

[11] J. A. Lee, H. Kelly, A. Rosenfeld, E. Stubee, J. Colaco, A. Gadgil, H. Akbari, L. Norford and H. V. Burik, "Affordable, safe housing based on expanded polystyrene (EPS) foam and a cementitious coating.," Springer, J Mater Sci 41, p. 6908–6916, 2006.

[12] A. N. Ede and A. Ogundiran, "Thermal Behaviour and Admissible Compressive Strength of Expanded Polystyrene Wall Panels of Varying Thickness," Current Trends in Technology and Science, vol. 3, no. 2, pp. 110 -117, 2014.

[13] N. H. Corporation, "National Housing Corporation EPS Factory in Athi River," National Housing Corporation, Nairobi, Kenya, 2015.

[14] L. G. Kageni, "Use of Expanded Polysterene as a Solution to Low Cost Housing in Kenya," University of Nairobi, Nairobi, 2014.

[15] E. P. Group, "EPS Packaging Group," EPS Packaging Group, 2014.

[16] J. Bolden, T. Abu-Lebdeh and E. Fini, "Utilization of Recycled and Waste Materials in Various Construction Applications.," American Journal of Environmental Science, vol. 9, no. 1, pp. 14-24, 2013.

[17] M. Tonosaki, T. Fujii, Y. Hiramatsu, Y. Tsunetsugu and M. Karube, "Present State of Wood Waste Recycling and a New Process for Converting Wood Waste into Reusable Wood Materials," Special Issue on Environmentally Benign Manufacturing and Material Processes Towards Dematerialisation. The Japan Institute of Metals. Material Transactions., vol. 43, no. 3, pp. 332-339, 2002.

[18] P. V. Khole and M. V. Mohod, "Application of Smart Materials in Civil Engineering for Better Tomorrows: A Review," International Journal of Engineering Research, vol. 5, no. Special 3, pp. 665-668, 2016.

[19] D. Kralj1 and M. MariČ, "Building Materials Reuse and Recycle," WSEAS Transactions on Environment and Development, vol. 4, no. 5, April 2008.

[20] T. R. Sonawane and. S. S. Pimplikar, "Use of Recycled Aggregate Concrete," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), pp. 52-59, 2015.

[21] T. U. Ganiron Jr, "Recycling Concrete Debris from Construction and Demolition Waste," International Journal of Advanced Science and Technology, vol. 11, pp. 7-24, 2015.

[22] C. Klaus, "EPS Recycling Technology," EPC Engineering Consulting GmbH, Germany, 2014.

[23] J. Abimaje and A. N. Baba, "An Assessment of Timber as a Sustainable Building material in Nigeria.," International Journal of Civil Engineering, Construction and Estate Management, vol. 1, no. 2, pp. 39-46, September 2014.

[24] A. Mwasha, "Dissolved EPS Wastes as Wood Adhesive," Advance Recycling Waste Management (ARWM) an open access journal, vol. 1, no. 1, pp. 1-8, 2016.

[25] I. M. Nassar, K. I. Kabel and L. M. Ibrahim, "Evaluation of the Effect of Waste Polystyrene on Performance of Asphalt Binder.," ARPN Journal of Science and Technology., vol. 2, no. 10, pp. 927-936, January 2012.

[26] N. T. Rocco, "Characterization of expanded polystyrene (EPS) and cohesive soil mixtures.," Missouri, 2012.

[27] A. N. Ede, "Acceptability of Plastic Materials for Structural Applications in Nigerian Buildings," International Journal of Innovative Research in Advanced Engineering (IJIRAE), vol. 2, no. 3, March 2015.

[28] D. Ibrahim, O. Bankole, S. A. Ma'aji and E. Ohize, "Assessment of The Strength Properties of Polystyrene Material Used in Building Construction in Mbora District of Abuja, Nigeria.," International Journal of Engineering Research and Development., vol. 6, no. 12, pp. 80-84, May 2013.

[29] H. L. Riad, A. L. Ricci, P. W. Osborn and J. S. Horvath, "Expanded Polystyrene (EPS) Geofoam for Road Embankments and Other Lightweight Fills in Urban Environments.," in Soil and Rock America 2003 - 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering/39th U. S. Rock Mechanics Symposium Cambridge, 22-26 June 2003, Massachusetts, U. S. A., 2003.