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Production and Performance Evaluation of the Structural and Thermal Properties of Compressed Stabilized Earth Bricks (CSEB) Utilizing External Cullet (EC) and Polyethylene Terapthalete (PET)

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Abstract

Production and Performance Evaluation of the Structural and Thermal Properties of Compressed Stabilized Earth Bricks (CSEB) Utilizing External Cullet (EC) and Polyethylene Terapthalete (PET) was carried out in Makurdi, Benue State.This study was focus on the global challenge faced with the management of waste like polyethylene terephthalate and external cullet. The use of waste plastic bottles and glass for the production of compressed stabilized earth brick is an optimal method to solve the problem of storing waste materials and to optimize the cost for the production of building materials, which provides a friendly environment for both human and aquatic habitats. It was found that the highest and lowest thermal conductivity test falls between 0.251 and 0.165 W/mk respectively. While compressive strength EC/PET/Sharp sand and water in the ratio 30:18:45:7 using ASTM C67 (Standard 2014b). The highest and the lowest values of the compressive strength test are 3.85 and 2.00 respectively. This established that glass and plastic-derived CSEB are more rugged, more rigid, have low water absorption, high resistance to heat and are corrosion-resistant when compared to the convectional bricks produced from conventional cement and were found suitable for other engineering applications.

Keywords: External cullet, Polyethylene terephthalate, Polystyrene, CSEB.

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Introduction

Management of waste like polyethylene terephthalate and external cullet is a global challenge particularly in Nigeria. The industrial-scale production of plastic began in1950's,as of 2015; the world produced nine billion tons of plastic. Also,within 65 years, merely nine per cent of plastic waste were recycled, reused and twelve per cent was incinerated, then theremaining seventy-nine per cent has built up inlandfills or ended up elsewhere in the environment Statistically, the remaining seventy-nine per cent of plastic wastes can be recycled in more than 500 years (Ferris, 2017).

Building and construction material is expensive dueto the demand of the growing population with a lowsupply of the materials. However, sand is abundantlyavailable and the disposal of waste plastics is the biggest challenge (Manjarekar, et al., 2017). Glass has become indispensable in life due to such properties as its ability to take any shape with ease, its bright surface and resistance to abrasion, and its safety and durability. As the range of uses of glass increase, so does the amount of the waste glass. The United Nations estimates the volume of solid waste disposed of annually over the world to be 200 million tonnes, 7% of which is made up of glass, unlike other waste products; glass is imperishable and thus detrimental to the environment (Turgut, 2008).

Colombo et al. 2003 opined that the present trend is towards the use of glass obtainedfrom waste materials in the fabrication of marketable products such as glass–ceramics, tiles for flooring or lining, foamglass, insulating or reinforcing fibres, and glass or glass ceramic composites. The use of waste glass in the production of building materials has been successfully pursued as it can reduce both the consumption of natural resources and the cost of waste disposal, as well as protecting the environment from harmful effects. As glass is one of the predominant constituents of vitrified ceramic bodies, many authors have considered this to be the most suitable field for the potential recycling of waste glass (Manukyan and Davydova, 1996; Karamberi et al.. 2007).The use of waste plastic bottles and glass forthe production of compressed stabilized earth brickis an optimal method to solve theproblem of storing waste materials and to optimize thecost for the production of building materials,provide a friendly environment for both human and aquatic habitats.

The use of polyethylene terephthalate and external cullet will mitigate the municipal solid waste, water bodies-rivers, lakes, drains, lagoon and the ocean and improve the lives of the aquatic habitats.The use of waste glass and plastic bottles in the production of building materials will be used to replace the convectional bricks that use cement and clay.It can reduce both the consumption of natural resources and the cost of waste disposal, as well as protecting the environment from harmful effects.

Glass

The main component of glass is sand which is mostlymade of silica sand, and quartz sand. Sand melts at anextremely high temperature about 1700°C or 3090°Fthrough the fusion process and it is amorphous in theliquid state. However, it is hard, transparent, and brittlein the solid state. Glass does not display the orderedcrystalline structure as compared to other ceramics butthen it has a disorderly amorphous structure. Glass canbe recycled repeatedly because of its workability to bereheated. In a commercial glass plant, sand is mixed withwaste glass from recycling collections, soda ash that issodium carbonate, and limestone or calcium carbonateand heated in a furnace (Woodford, 2018). Glass iswidely used as building and construction material in anengineered structure.

External cullet

The recycling of glass from external cullet (glass waste)reduces the solid waste population and improveswaste management in the environment. Glass material can be easily melted down and remade into different kinds of shapes. Drinking glasses, moulding sculptures and glass fibre were most of the noble materials used in the world today. Once collected, it is broken into small pieces, crushed, soldered and cleaned. They can be molten into with another constituent like sound which can be moulded into the desired shape (Ostwal, 2004).

Solid Waste

Solid waste refers to the range of garbage arising from animal and human activities that are discarded as unwanted and useless. It is a waste produced from residential, commercial, and industrial activities. Also, it can be categorized based onmaterial, such as plastic, paper, glass, metal, and organicwaste and classification may also be based on hazard potential, including radioactive, flammable, infectious,toxic, or non-toxic (Leblanc, 2018). Waste is anysubstance that is discarded after primary use, or it is worthless, defective and of no use. In building and construction industry, if large number of waste materials were utilized instead of natural materials, then the natural resourceswill be conserved, unappealing waste materials will belessen, and land will be converted to valuable use (Nishikant et al. 2016). Municipal Solid Waste (MSW) is usually described as non-hazardous solid waste from a certain localityincluding private residences, commercial establishments,and institutions that requires the routine collection toprocessing or disposal site. MSW is also called trash orgarbage which does not include wastes from industrialprocesses, construction, and demolition debris, sewagesludge, mining waste or agricultural wastes.

Polyethylene Terephthalate (PET)

The generation of Polyethylene Terephthalate (PET) is higher than recovery and due to this large gap, an innovative approach to encourage high recycling of the material is recommended. PET has a property of low modulus synthetic fibres along with other fibres sharing the similarity such as polyethylene, nylon, and polyester. However, PET bottles are being experimented to produce a non-load bearing product and partition walls in many parts of the world (Chowdhury et al. 2013). The possibilities of PET plastic bottles to be used as building material exist and it is also significant for sound insulation (Joravia and Parikh, 2015).

Plastic bottles are made up of thermoplastic polymer known as Polyethylene Terephthalate (PET). It is one of the largest and most problematic sources of waste as it is affordable, lightweight and sturdy material, which can be moulded into a wide range of products. As a result, the generation of plastic waste has expanded significantly in the recent years. Dumping plastic wastes in the landfills is not encouraged due to its bulk and slow degradation rate (Hopewell et al. 2009). However, other than the land-filling and stockpiling, incineration processes can be conducted to break down plastic to generate energy, but the high temperature can produce high-calorie energy, where its combustion generates harmful gases which affect both human health and the environment. In addition, the vast amount of plastic produced yearly is used for packaging disposable items or other fleeting items which are discarded within a year of manufacture. This scenario causes accumulation of discarded plastic as debris in landfills and oceans. These two perceptions alone demonstrate that our present utilization of plastic is not economical (Saikia et al. 2014). Recycling the plastic is one of the most prominent methods to diminish these effects by constructing various useable objects (Hopewell et al. 2009).

Plastic bottles infilled with sand, soil, fly ash or any other material gives higher compressive strength as compared to the convectional bricks but requires binding material, mainly cement to form a structure (Sharma 2017; Shoubi et al. 2013). Due to the low cost and effectiveness, masonry infill has been extensively utilized as construction material (Vincent Sam Jebadurai et al. 2019). The engagement of compressed stabilized earth brick is developing notoriously around the world due to the mortarless brick construction concept, the interlock between bricks provides a very accurate assembly and a neat finishing during construction of buildings. The installation is continued similar to an ordinary clay brick but does not use mortar because these bricks are shaped with projected parts, which fit exactly into depressions in the bricks placed above and automatically aligned vertically and horizontally (Malahayati et al. 2018).In the study, glass waste and plastic bottles is been used in making the interlocking brick (CSEB) which will not change its properties.

Therefore, this study aims to produce and evaluate the structural and thermal properties of compressed stabilized earth bricks incorporating external cullet and polyethylene terephthalate collected from Makurdi metropolitan and adopting the Response Surface Methodology (RSM), as glass and plastic wastes take a longer time to decompose.

Materials and Method

External Cullet and Polyethylene Terephthalate the EC and PET was collected from two public waste dumps after NASME Barracks and along the old bridge road in Makurdi LGA, Benue State Nigeria. Other materials to be used include the followings:

i. Shredded plastics
ii. Shredded styro (polystyrene)
iii. Used cooking oil
iv. Crushed glass
v. Cement
vi. Sand
vii. Valve
viii. Hose
ix. Gas cylinder12Kg (filled)
x. Turrets (burner gas stove)
xi. Gauge thermometer
xii. Paints
xiii. Mild steel plate
xiv. Galvanized pip
xv. Mold boxes
xvi. Angle iron

Preparations of CSEB

The raw materials (glass and plastic wastes) will be collected and screened to remove impurities. The crushing and shredding process will be done and categorized into three, based on the macrons of the samples; sample A (EC), sample B (PET) and sample C (EC and PET). The EC will be mixed with sand, conventional cement and water poured into the mould and allowing it to cure. The shredded PET will be mixed with styro (polystyrene) and waste cooking oil heated to molten at a temperature of 150^{o}C for one hour. The densified PET will be poured into the desired mould and allowed to cool naturally for three hours. The EC and PET will be mixed with sand, cement and water and moulded using compressed brick machine. The

procedure will be repeated respectively to produce the CSEB for different macrons of A, B and C samples.

Characterization

The structures of the samples will be characterized by TCT using thermo gravimetric Analyzer (TGA). The morphology of the samples will be analyzed using Field Emission Scanning Electron Microscope (FESEM). The amount of H_2O absorbed under optical conditions will be analyzed using (ASTM D570). The mass will be determined using a digital weighing balance (DWB). The Izod Impact Strength Test will be analyzed to determine the impact resistance using the standard method of American Society for Testing Standard Materials (ASTM).The force required to bend the CSEB will be analyzed using the 3-point flex method and the amount of compressive load it can bear before fracturing, the asphalt binder low temperature fracture properties will be analyzed using Compressive Strength Test (CST) and Direct Tensile Test (DTT) respectively.

Result and Discussion

The Compressed Stabilized Earth Bricks (CSEB) was produced using external cullet and polyethylene terephthalate; the structural and thermal properties were evaluated. Tables 1 and 2 showed the compressive strength test and the thermal conductivity test results.

Table 1: Compressive Strength Test

Run	Mixture	Compressive test reading (Mpa)
0	Control	31.50
1	First	2.05
	Second	2.00
2	Third	2.10
	Fourth	3.50
	Fifth	3.70
3	Sixth	3.45
	Seventh	3.85
	Eighth	3.60

From table 1 it was discovered that the highest and the lowest values of the compressive strength test is 3.85 and 2.00 respectively.

Table 2: Thermal Conductivity Test

Run	Mixture	Thermal conductivity (W/mk)
0	Control	0.39
1	First	0.251
	Second	0.238
2	Third	0.205
	Fourth	0.192
	Fifth	0.195
3	Sixth	0.182
	Seventh	0.175
	Eighth	0.165

Conclusion and Recommendation

Four tests (Mechanical, Physical, Thermal and Field Emission Scanning Electron Microscope) wasused to determine the quality of the bricks. The study will established that glass and plastic-derived CSEB are more rugged, more rigid, have low water absorption, high resistance to heat and are corrosion-resistant when compared to the convectional bricks produced from conventional cement and was found for other engineering applications.

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