Education & Science Journal of
Policy Review and Curriculum Development
Hard Print: 2315-8425 Online: 2354-1660

November, 2016

Vol. 6, No. 1

Investigation into the Suitability of used Water Sachet (Polyethylene) as a Binder in the Production of Building Blocks

[1]**Dunu Williams,**
[2]**Albert Idowu,**
[3]**Adaji Ahmadu Adejoh &**
[4]**Ibiyemi Bankayode Sunday**
[123&4]*Department of Building Technology*
Kogi State Polytechnic, Lokoja

Abstract

In recent years the use of polymers is expanding and the demand is increasing in construction industry as material that can partially or fully replace cement to combat the increasing cost of cement and also since alternative form of waste disposal system such as incinerators are not popular and have environmental implications landfills are filling up fast also burning of waste produce greenhouse gasses. Nevertheless, recent trend in research shifted its attention to recycle more rubbish such as polymers waste informs of polyethylene bags which constitute disposal problems. This study investigated the suitability of used water sachet (polyethylene) as a binder in the production of building blocks with a view to converting waste to wealth. Thus to solve these problems, this research focused on this five areas which are necessary to obtain, clean and sort polyethylene waste, to melt the polyethylene waste into its binding form, to produce polymer-sandcrete blocks, to determine compressive strength, water absorption capacity and density of polyethylene mortar cubes, and to recommend the usefulness of polyethylene for use in making poly-sandcrete blocks. In order to achieve these, Samples of polyethylene were sorted, washed and cut into sizes and then melted and mixed with fine aggregates to produce 70×70×70 mm mortar cubes, the cubes were cured in air and crushed at 7, 14, 21 and 28 days; for compressive strength, water absorption capacity and density. Ordinary cement mortar was also produced with nominal mix of 1:6 with a 0.55 w/c ratio was used and its properties evaluated and compared with the polyethylene mortar. The strength of the polyethylene mortar after 28 days surpasses those of ordinary cement mortar after 28 days. The compressive strength of polymer mortar was 20.62 N/mm^2 while the compressive strength of cement mortar was 14.22 N/mm^2 and the percentage difference of the compressive strength was 45.0%.the polymer mortar has less sorptivity than cement mortar (control) specimens with 0.15% for polymer mortar against 9.55% for cement mortar at 28 days. In conclusion polyethylene has shown a great potential in term of strength and less sorptivity than ordinary cement mortar. Hence it can be used to produce a strong and durable mortar blocks.

Keywords:
Environmental implications, Water sachet and Disposal problems

Corresponding Author:
Dunu Williams

Background to the Study

Polymers consist of numerous monomers which are linked together in a chain-like structure. There are different definitions of polymers as given by different authors. Polymers have been defined as a natural synthetic chemical compound or mixture of compounds formed by polymerization and consisting essentially repeating standard units. It has also been defined as long molecular built of simple units called monomers. Monomers are more generally organic compounds which can be converted to polymer either by heat radiation (gamma or ultra violet), catalyst. Neville & Brooks (2010).A look in our street in Nigeria today is an eye sore. The amount of waste substances which are predominantly synthetic fabrics, scrap metals waste glass found on our streets refuse dumps are gradually taken over the streets. Since alternative form of waste disposal system such as incinerator are not popular and have environmental implications."Landfills are filling up fast, also burning of waste produce greenhouse gasses" Izam and Ameh (2011). Developing countries are making efforts to recycle more rubbish such as polymers waste in the form of plastic bottles, polyethylene bags which constitute disposal problems.

The thermoplastic polymer waste can be recycled into a binding substance which could then be mixed with other minerals such as clay, sand, coarse aggregate, to produce polymer products without using cement. Polymer as a binding material is relatively new breed of materials in the construction industry. They can sometimes act as ideal alternative to the traditional Portland cement because of the properties exhibited by polymer products such as high strength, high chemical resistance and durability. These properties made polymer to have vast number of application in modified concrete and mortar. In recent years the use of polymers is expanding due to the increasing demand from construction industry. They are used as substitutes or a partial substitute for cement and as effective repair material both individually and in combination with cement. The very high porosity of concrete, formation of void, capillary, capillaries, disintegration due to formation of free lime as a hydration reaction products in concrete are disadvantages severely limiting strength, durability and toughness of concrete under severe service condition. These shortcomings in Portland cement can significantly be improved by incorporating polymers in various forms.

"Adding small amount of Natural clays to plastic changes some of their physical properties. Addition of clays can make plastic less permeable to liquid and gasses, more flame retardant and toughness" (Okafor, 2005). Raw polymers can also be processed into solid form with smooth outer layer for ease of handling, transportation and storage. Polymers are today used as a product, specifically to enhance some properties of concrete and clay such as tensile and flexural strength, enhance chemical resistance, toughness, bond and impermeability. They are also used over concrete for varied purposes such as improved bonding, crack filling or pore sealing, reducing permeability to chemicals, dust proofing and self -levelling. Because of this varied application of polymers in the construction industry, the properties of such polymer products such as compressive strength, water absorption and density, bending and setting time needed to be studied in order to assess their suitability for such applications.

Need for the Study

"Waste is defined as materials of solid or semi-solid matters that the processor no longer considers of sufficient value to retain Nwaubani and Poutos (2013). Virtually all waste generated in the environment by man and his activities have turned out to be hazardous and may affect man directly or indirectly" Dahiru, Zubairu and Abdullazeez (2009). The effect of this waste could be immediate or delayed, depending on their characteristics and origin. Waste pollutes the air, land, surface and underground water. Failure to effectively manage the waste generated has given rise to various environmental hazards with great threat to human health. In this era of polysynthetic technology; we have an environment littered with garbage, much of which consists of synthetic fabrics and membranes which are non-bio-degradable materials. Such materials are dumped indiscriminately around houses, on the streets and in farmlands, to the extent that they render farmland infertile. Lands that are ordinarily for food production are rapidly becoming wastelands being unable to support life or growth (Djokoto and Dadzie, 2013). This emphasizes the need for us to exercise caution about the use and disposal of used polythene bags and broken plastic containers. They are remarkable source and cause of land degradation.

Among the various types of waste, polymer waste such as plastics, polyethylene (pure water sachet) are difficult to work on when it comes to recovering it because of its weight and strength. Recycling is one of the most promising approaches to waste management of both disposable and durable product types (MALHUTRA, 2004). Used polyethylene materials are found virtually everywhere partly due to its light weight, strength and their unlimited use. Polymer waste such as polyethylene have gain a wide range of application in the construction industry in the recent times, such polymer waste has been successfully recycled and used in the production of polymer products. The choice of this product for application is dependent upon effluent and chemical environment due to their superior strength, durability and impermeability.The need to build structures capable of withstanding high stresses and severely environment accompanied with the limitation in space, money and time have led to several researches been carried out in the application of different polymer products due to their improved properties. Therefore there was the need to investigate the suitability of pure water sachet (polyethylene) as a binder for the production of building block. Details of the experiment undertaken are presented as follows:

Materials and Methods

Materials

The materials used in this study are; Ordinary Portland cement, OPC, fine aggregate, polyethylene (pure water sachet) and water. Details of these materials are presented as follows:

Cement

OPC manufactured by Dangote Cement Company in Nigeria was obtained from local dealers in Zaria and used throughout the cubes specimens. Test were undertaken so as to ensure that it complies with the British standards BS 12 (1996) and EN 197-1 (2000).

Fine Aggregate
The fine aggregate used in this research was clean and saturated surface dried sharp river sand obtained from samara Zaria. It was sieved through 5mm sieve to take away any impurities and large size aggregates away in accordance to BS EN 933-1 (1997).

Polyethylene
The binder used in the production of polymer sample specimen, was polyethylene (pure water sachet). It was sourced from Ahmadu Bello University pure water factory located within campus, washed, sun dried and cut into desired sizes using scissors.

Water
The water used to produce mortar samples was clean, fresh water, free from injurious oils, chemicals and vegetable matter or other impurities as it was obtained directly in the laboratory. It is portable water.

Tools / Apparatus used
The tools and apparatus used for the experiment tests were
Weight scale, mixing board, metallic hand scoop, 300mm tapping rod, hand trowel, head pan, measuring cylinder, stand sieves [20mm-pans], 0.5mm thick fabricated mould (75mm×75mm×75mm), cast iron mould (75mm×75mm×75mm), steel pot, locally fabricated stove, crushed value testing machine, damp sack, shovel and mould oil.

Methods
In this research various test were conducted and these can be categorized into:

Preliminary tests of material (fine aggregates)
The preliminary tests of fine aggregates that were carried out were; sieve analysis, bulk density, specific gravity and moisture content were carried out.

Sieve Analysis
In accordance to BS EN 933-1 (1995) 1.2kg of fine aggregates was weighed and then poured on different sizes of sieves passing through 5mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and pan. Fineness modulus of fine aggregates was determined as sum of cumulative percentage of aggregates retained on each of a series of sieves (each sieve having a clear opening that is half of the preceding one) and the total divided by 100.

Bulk Density
The test of bulk density of fine aggregate was carried out in accordance with BS 812.2 [1995]. The apparatus used were density wooden cube, trowel, rammer and weighing balance. The bulk density for aggregate sample was computed using the equation:

$$D = \frac{m}{v} \qquad ------- \qquad (1)$$

D = the density of the aggregate specimen in kg/m^3
m = the mass of the aggregate specimen in kg
v = the volume of the aggregate specimen in m^3

Moisture Content

One kilogram of fine aggregate was weighed as (A) using weighing balance, the aggregate was then poured on wide metal container, spread and put inside an electric oven for 24hours at 105°C. After 24 hours the aggregate was removed from the oven and allowed to cool down at room temperature and the aggregates was weighed again as (B). the moisture content was determined in accordance to BS 812-109 (1990) using the equation:

$$\text{Moisture content} = \frac{A - B}{B} \text{ X } 100 \quad \text{-------------} \quad (2)$$

A = weigh before oven dry

B = weigh after oven dry

Specific Gravity

Specific gravity of fine aggregate was determined using pyknometre method, the procedure used where in accordance with BS 812-2 (1995). The apparatus used during the test include density bottle and stopper, funnel, spatula and weighing balance. The specific gravity of fine aggregate was calculated using the following formula:

$$Gs = \frac{C-A}{(B-A) - (D-C)} \quad \text{-------------} \quad (3)$$

A= the weight of empty density bottle and it is stopper which it was clean and dried

B= the weight of empty density bottle plus water

C= the weight of empty density bottle plus aggregate sample

D= the weight of empty density bottle plus water plus aggregate sample

Mortar Production

Mixed Design

The final mix entails the batching of the polymer mortar material was done by weight using 60% polyethylene and 100% by weight of sand while that of cement mortar were produced to serve as control by absolute volume batching with nominal mix of 1:6 and a water- cement ratio of 0.55. the polyethylene (pure water sachet) was melted in a steel pot for 8 minutes. Heat was applied using specially fabricated stove which was later replace with heat supplied using local aluminum smelters equipment. The mixing was done by adding the fine aggregate gradually to the molten polyethylene in the pot while on fire and the mixture was thoroughly stirred for 2 minutes and transferred immediately into a 75mm × 75mm × 75mm mould in three layers using trowel and each layer tamped 25 times and the mould was levelled using a trowel. After casting, the polymer mortars were cured in the open air for 28 days and the cement mortar was cured in water for 28 days.

$$\text{Absolute volume of material (a.v)} = \frac{\textit{ratio of material in mx X density of material}}{\textit{specific gravity of material X 100}} \quad \text{-------} \quad (4)$$

$$\text{Quantity of material (kg/m3)} = \frac{\textit{ratio of material in mx X density of material}}{\textit{total absolute volume}} \quad \text{-------} \quad (5)$$

Testing of Hardened Mortar

Tests carried out on the hardened mortar were the determination of the density of the hardened mortar, the compressive strength and water absorption capacity.

Density of Mortar

The density in kg/m^3 was determined by firstly air drying the cured cubes, weighing and computing the density using the relationship;

$$\text{Density of mortar} = \frac{\textit{mass of cube in kg}}{\textit{volume of cube in } m^3} \quad \text{----------------} \quad 6$$

Compressive Strength

The specimen were weighed and placed centrally in the load frame of manual crushing machine. Each specimen was placed on the center of the square plate in the machine and the load was applied until the mortar cube fails. The failure load and compressive strength was computed in conformity with BS EN 12390-3 (2002) using the equation:

$$f = \frac{F}{A} \quad \text{--------------------------} \ (7)$$

Where f is the compressive strength, in KN/m^2

F = the maximum load at failure, in KN

A = the cross-sectional area of the specimen on which the compressive force acts calculated.

Water Absorption Test

The sample (cubes) were removed from the curing tank and allowed to dry, then placed in the electronic oven to oven dried at 105^0C at 24 hours. The samples were removed from the oven and allowed to cool at room temperature then weighed to determine the initial weights. The final weights were determine after immersing the mortar samples in the curing medium for 24 hours then removed to cloth dried and re-weighed again. The values obtained were recorded and the results were calculated to assess the rate of absorption of the mortar specimens in accordance to BS 1881-122 (1983).

Method of Data Analysis

The results obtained for different tests carried out in this research work was analysed using simple statistical tools (mean and percentage). According to Tavakoli (2012) mean also called arithmetic mean, represented by M, X is the most commonly used measure of central tendency which is the sum of scores divided by the total number of scores, often represented by the following formula:

$$X = \frac{\sum x}{N} \quad \text{--------------------------} \ (8)$$

Where:

X= the symbol for the mean

∑x= summation of the specimen

N= number of the specimen

A percent or percentage is a proportion multiplied by hundred. It is used in this research to anlysed the results of water absorption.

Presentation of Results

The results of various test carried out are presented under the following headings:

Physical properties

The results of physical properties tests are presented in Table 1

Table 1: Physical Properties of fine Aggregate

Material	Specific Gravity [kg]	Bulk Density [kg/m³]	Moisture content [%]
Sand	2.65	1600	2.88

Source: Laboratory Research Work, (2015)

The Table 1 present specific gravity and bulk density of fine aggregate used for the research. The test carried out has satisfied the requirements according to Shetty, (2005) which specified the range for light weight aggregates between 2.3 to 2.9kg for specific gravity and 300 to 1850 kg/m^3 for bulk density. According to ACI E1-99 moisture content for fine aggregate should be within 0 to 10% which denotes that the test on the aggregate has being satisfied.

Grading of the Aggregate

Result of the sieve analysis carried out on the fine aggregate is presented in Table 2

Table 2: Result for Sieve Analysis of fine Aggregate

BS Sieve Size	Weight Retain [kg]	Weight Passing [kg]	PercentagePassing [kg]
5mm	0.008	1.192	99.3
2.36mm	0.125	1.067	88.9
1.18mm	0.293	0.774	64.5
600μm	0.443	0.331	27.6
300μm	0.245	0.086	7.2
150μm	0.052	0.034	2.8
Pan	0.018	0.016	1.3

Source: Laboratory Research Work (2015)

The Table 2 shows results of sieve analysis of fine aggregate which has been used to determine the fineness modulus and determined as 2.92. According to Garba (2008) the fineness modulus of fine aggregate should be within the range of 2.0 - 3.5 (± 0.2) and hence it has fell within the range.

Hardened Mortar

The results of various tests carried out on hardened mortar, are presented and discussed under the following headings:

Table 3: Average Density of Cement Mortar Samples

Density of Cubes [kg/m³]			
7 days	**14 days**	**21 days**	**28 days**
1585	1635	1682	1737

Source: Laboratory Research Work (2015)

Table 4: Average Density of Polymer Mortar Samples

Density of Cubes [kg/m³]			
7 days	**14 days**	**21 days**	**28 days**
1481	1502	1535	1557

Source: Laboratory Research Work (2015)

The Table 3 and 4 present the average densities of cement mortar cube samples cured in water and polymer mortar samples cured in air and weighed 7, 14, 21 and 28 curing days respectively. Density obtained from cement mortar cube samples range from 1585kg/m^3 to 1737kg/m^3 and it increase with increase in curing periods, while Density obtained from polymer mortar cubes range from 1481kg/m^3 to 1557kg/m^3. Mortar samples with density higher than 2600kg/m^3 are called higher weight mortar samples and lesser than 2600kg/m^3 are called light weight mortar (Kazjonovos, 2010). It can be observed that the densities of both cement mortar cube samples and polymer mortar cubes samples are lesser than 2600kg/m^3 so they are both regarded as light weight mortar.

Table 5: Water absorption test hardened mortar samples

Specimen	Average weight before immersion	Average weight after immersion
Polymer mortar	0.646	0.647
Cement mortar	0.670	0.734

Source: Laboratory Research Work (2015)

Table 5 presents the average water absorption test of polymer and cement mortar cube specimens cured and tested at 28 curing days. The degree of sorption of polymer mortar has satisfied the assertion made by Pitroda and Shah (2014) which state that the average absorption of test specimens shall not be greater than 5%. The level of sorptivity of polymer mortar samples has a negligible absorption of 0.15% while that of cement mortar absorbed 9.55% at28 days. This mean that polymer mortar absorbed less amount of the curing agent than cement mortar.

Compressive Strength test of hardened mortar samples

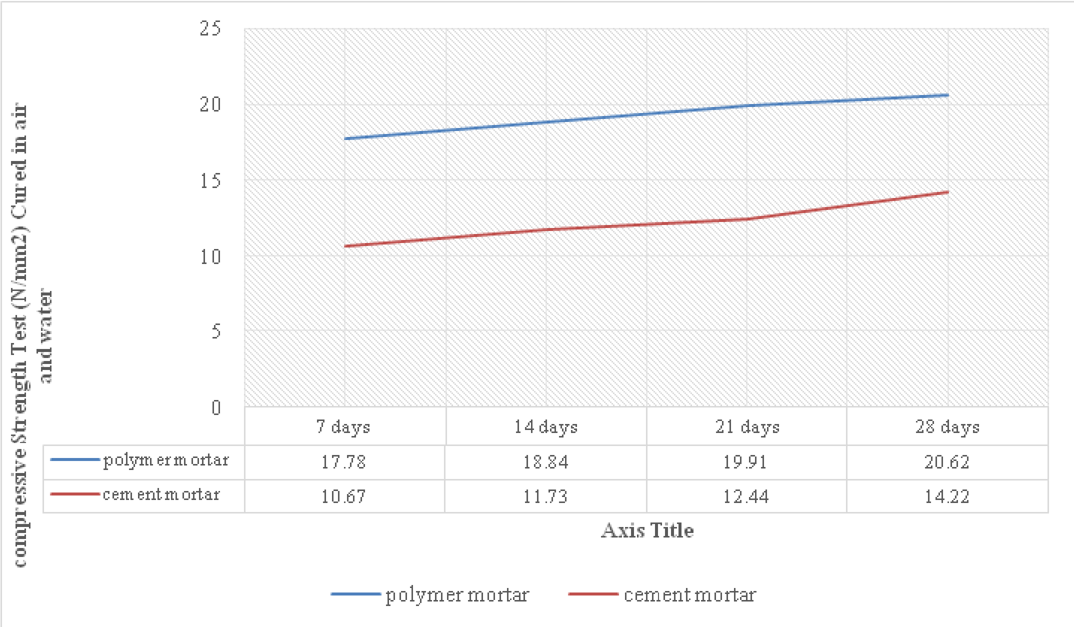

Figure 1 Compressive Strength of cement mortar and polymer mortar samples cured in water and air respectively.

The figure 1 shows compressive strength of cement and polymer mortar specimens cured in normal water and air and crushed at 7, 14, 21 and 28 curing periods. Cement mortar samples achieved 14.22 N/mm^2 while Polymer mortar samples achieved 20.62 N/mm^2 at 28 days which represent 45.0% increase in compressive strength of polymer mortar.

Summary of the Research Findings

The study investigates the suitability of polyethylene (pure water sachet) as a binder in the production of building blocks with a view to converting waste to wealth. Highlights of the major findings are as follows:

i. The aggregate has specific gravity 2.65kg with bulk density of 1600kg/m^3 based on saturated surface dried sample as compared with the light weight aggregate with specific gravity of 2.3 to 2.9 and bulk density of 300 to 1850kg/m^3 which is classified as light weight aggregate.

ii. Water absorption capacity of cement mortar 9.55% indicate high porosity while that of polymer mortar 0.15% shows very low porosity.

iii. The density mortar produce with cement ranges 1585 to 1737kg/m^3 while polymer mortar ranges from 1481 to 1557kg/m^3.

iv. The compressive strength test result after 28 days shows that mortar produced with cement as control is 14.22N/mm^2 while the polymer mortar sample has a higher strength of 20.62N/mm^2.

Conclusion

i. The study has conclusively revealed that polymer can be used for the production of strong and durable building blocks.

ii. Mortar made with polyethylene is almost impermeable compare with the cement mortar.

iii. The average density of mortar cubes made with polyethylene is less dense than cement mortar therefore polymer mortar is lighter than cement mortar.

Recommendations

Based on the results of this study, the following recommendations were made;

i. As a viable way of optimizing resources and keeping our environment clean, it is recommended that polyethylene (water sachet) may be used as a complete binder in the production of building blocks.

ii. A machine should be devised for melting, mixing and compacting the polyethylene mortar to achieve homogenous mixture.

iii. Since polyethylene is impermeable, it could be suitable to use it as an impervious membrane on roof to prevent it from leakage.

iv. It is recommended that this waste that litters the street should be collected and recycle into wealth.

References

British Standard European Norm, (1997). *Tests for geometrical properties of aggregates; Determination of Particle size distribution-Sieving method.* BS EN 933-1, BSI, Linfordwood, Milton Keynes MK146LE, U.K.

British Standard European Norm, (2002). *Testing hardened concrete; Compressive strength of test.* BS EN 12390-3, BSI, Linfordwood, Milton Keynes MK146LE, U.K.

British Standard Institute BS 812: 109 (1990). *Method for determination of moisture content of aggregate*. BSI, Linfordwood, Milton Keynes MK146LE, UK

British Standard, (1983). *Testing concrete; Method for determination of water absorption.* BS 1881-122, BSI, Linfordwood, Milton Keynes MK146LE, U.K.

British Standard, (1995). *Testing aggregates; Methods of determination of density*. BS812-2, BSI, Linfordwood, Milton Keynes MK146LE, U.K.

Dahiru D., Zuabiru I.K & Abdulazeez A. D (2009). An Assessment of the Properties of Concrete made with Rice Husk Ash as a Partial Replacement of Cement. *Journal of Engineering and Technology,* 3(1)

Garba, M. M. (2008). *Concrete Technology*. Unpublished Lecture Note, Department of Building Faculty of Environmental Design Ahmadu Bello University, Zaria, Nigeria.

Izam, Y.D. & Ameh, O.S. (2011). The concept of construction sustainability and its implication on the training of builders in nigerian universities. In Sourcing, Development And Utilization of Appropriate Building Material for Sustainable Environment. Fourty One Annual Conference of the Nigerian Institute of Building 1-3.

Kazjonovs, J., Bajare, D. & Korjakins, A. (2010). Designing of High Density Concrete by Using steel Treatment Waste. Paper Presented on Modern Building Materials, Structure and Techniques International Conference May 19-21, 2010. Vilnius, Lithuania, 138-142.

Malhutra, V. M. (2004). Role of Supplementry Cementing Materials and Superplasticizers in Reducing Greenhouse Gas Emission. Proceedings of ICFRC International Conference on Fiber Composites, High- Performance Concrete and Smart Materials, chennai India, Jan, 489- 499

Neville, A. M & Brooks, J.J. (2010). Concrete Technology. 2nd edition. Long man Group United Kingdom Limited, 30-269

Nwaubani, S. O. & Poutos, K. I. (2013). Influence of Waste Glass Powder Fineness on the Properties of Cement Mortar. International Journal of Application or Innovation in Engineering and Management, 2(2), 110-116. Retrieved from http://www.ijaem.org

Okafor, J. O., (2005). Design and Construction of Polyethylene Recycling Equipment for Waste Management. Nigeria Journal of Applied Arts and Sciences (NIJAAS), Maiden Edition.

Pitroda, J. & Shah, D. S. (2014). An Experimental Study on Durability and Water Absorption Properties of Pervious Concrete. International Journal of Research in Engineering and Technology, 3(3), 439-444. Retrieved from http://www.ijret.org

Shetty, M. (2005). Concrete Theory: Theory and Practice. New Delhi 110055, India: S. chad and Company Ltd, Ram Nagar.

Tavakoli, H. (2012). A Dictionary of Research Methodology and Statistic in Applied Linguistics. Tehran, Iran: Rahnama Press, 346-347.