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Examining the Impact of Molten Plastic Variation on the Strength of Interlocking Bricks Using Response Surface Methodology

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Abstract: This studied investigate the variation of molten plastic on the strength of plastic interlocking brick using response surface method and ANSYS FEM software. plastics, being one of the most commonly generated waste in today's culture and also one of the most easily recyclable materials that may be able to replace traditional clay and sand bricks Plastics interlocking brick s tests include compressive strength tests, in which the brick specimen is placed in a bricks testing machine that gradually increases the load until the specimen's resistance to the growing pressure breaks down and it can no longer tolerate any further strain. This increased from 10.5N/mm^2 to 14.0N/mm^2 by volume after 7days with a control specimen of M1. The maximum increase in flexural strength test for M5 and M6 was in order of 6.4N/mm^2 and 7.1N/mm ^{2} respectively.

Keywords: Variation, Interlocking Brick, Response, Compressive, Aggregates.

1. INTRODUCTION

One of the concerns that will continue to plague humanity in the near future is the obstacles of recycling waste materials. As a result, the use of plastic bottles and waste in the production of plastic sand brick has grown in importance in the recycling and construction industries. Plastics, being one of the most commonly generated wastes, are also one of the most easily recyclable materials that may be able to replace traditional clay and sand bricks. This work is motivated by plastic interlocking bricks tests such as compressive strength, flexural strength, tensile strength, water absorption test, and concrete shrinkage test, as well as simulation analysis using ANSYS finite element modeling tools.

According to Maneeth *et al.,* (2014) In recent years, there has been a significant disparity between the availability of traditional building materials and the demand for them. On the other hand, laterite quarry waste is plentiful, and disposing of waste plastics (PET, PP, etc.) is a major difficulty, as repeated recycling of PET bottles poses the risk of being changed into a carcinogenic material, and only a small percentage of PET bottles is recycled. Due to the high expense of traditional recycling methods, there has been a surge in demand for more scientific and inventive technologies that can successfully recycle these materials. One such effort is the efficient use of waste plastic and laterite quarry waste, combined with a small amount of bitumen, to develop an alternative building material, such as bricks, with minimal water absorption and comparable strength to Laterite stone, in order to meet the growing demand for traditional building materials Aciu et al. (2015).

Suji and Thivya (2020) conducted an experimental investigation in to the effects of Fly ash and Plastic waste – Poly Ethylene Terephthalate in compressive strength of interlocking concrete block used as a replacement of sand in interlocking concrete block respectively. Interlocking Blocks has gained rapid popularity in many countries as an alternative to conventional bricks for sustainable housing.

Sayanthan *et al.* (2013) conducted out research into the use of lightweight materials to reduce self-weight. Self-weight is a crucial component of the loads that a structure must withstand, hence reducing self-weight by using lightweight materials will substantially reduce the load as well as the construction cost. Furthermore, huge individual units would aid in building speed and cost savings. However, without qualified personnel, it is difficult to attain good workmanship in masonry work. The need for skilled employees can be decreased by using interlocking blocks.

To fulfill the above-mentioned objectives, an experimental inquiry was conducted to design interlocking lightweight cement blocks that are different from those now available. The created interconnecting hollow pieces are 600mmx200mmx200mm in size and weigh 20 kilogram. To lower the self-weight, expanded polystyrene beads were employed. The average compressive strength of the block was 4.91 N/mm2 and the strength of the wall panel was 2.13 N/mm2, indicating that it could be used for load bearing masonry walls. At the time of failure of the masonry wall panel, ductile load deformation behavior was also noticed, which is a plus

Geyer et al. (2019) Nestle's goal for recyclable and reusable programs in the manufacturing of construction materials from plastic waste was evaluated. Nestle, for example, has established a goal of using 100% recyclable or reusable packaging by 2025. Nestle has also realized that its contribution to building a circular economy extends beyond its own business. Nestle has partnered with local governments and Green Antz Builders, Inc. to create construction materials out of waste plastic.

2. MATERIALS AND METHODS

2.1 Materials

i. Plastic waste
ii. Cement
iii. Natural River Sand.

The plastic waste have less porosity and light weight with more compressive strength that make it very good material for the bricks. The cement acts as a good binding material for the component mixture while the natural river sand act as a fine aggregate material for the bricks.

The data of the physical properties of plastic aggregates produced mainly from waste bottles, data of natural river sand aggregate and data of the physical characteristics of cement collected from Olasuru Bricks Nigeria Limited, Lekki express way, Lagos, respectively as well as ANSYS finite element modeling and simulation software.

2.1.1 Plastic Aggregate Specification

The plastic aggregates were made primarily from PET bottles that had been discarded. A crushing machine was used to crush and cut the plastic bottles into little bits. The plastic aggregates were thoroughly cleansed to remove any dust particles and verify that they were clean.

2.1.2 Fine and Coarse Aggregates Specification

Fine aggregate was made from readily available natural river sand with a Fineness Modulus of 1.97. As a coarse aggregate, brick chips were employed. The sieve analysis method was used to grade fine and coarse particles.

Fine and coarse aggregates were tested for specific gravity and water absorption according to ASTM C127 and C128 standards. Table 3.1 shows the physical parameters of fine and coarse aggregates.

Table 2.1: Physical Properties of Aggregates

Properties of Aggregates	Fine Aggregate	Coarse Aggregate
Bulk specific gravity (oven dry)	1.22	1.42
Bulk specific gravity (SSD condition)		1.45
Apparent Specific Gravity	1.19	1.50
Water absorption (%)		9.30
Size Range (mm)	<4.75	4.75-9.5
Fineness modulus	1.97	

2.2 Response Surface Methodology (RSM)

RSM was employed in this work to create a mix design of interconnecting bricks that used PET as a variable. After entering the data into the RSM, six mix designs were created, each with a different amount of PET, as shown in Table 2.2. The data were put into the RSM once the experimental results were obtained to create a model for the optimal amount of PET. Modeling and analysis employing a combination of statistical and mathematical approaches for constructing empirical models, enhancing, and optimizing process parameters are all part of RSM's capability. It can also be used to determine how various things interact. Response surface models are a type of basic linear regression that adds the second-order effect of non-linear interactions.

2.2.1 Waste Plastic and it's Availability

Plastics are widely utilized materials that are present in practically every area of our lives.

Because of the extensive creation of plastic garbage, proper end-of-life management is required. Containers and packaging contain the greatest amount of plastic (i.e. bottles, packaging, cups etc.).

Table 2.2 Types of Plastic and Its Uses

Waste plastic	Available as
Poly-ethylene terephthalate (PET)	Drinking water bottles etc
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.

Low Density Polyethylene (LDPE)	Milk pouches, sacks, carry bags, bin linings, cosmetics and detergent bottles.
Poly propylene (PP)	Bottle caps and closures, wrappers of detergents, biscuit etc.
Urea formaldehyde	Electrical fittings, handles and Knobs.
Polyester resin	Casting, bonding fibers (glass, Kevlar, carbon fiber)

Table 2.3: General Value of Plastic

Properties	**Standard Values**
Density At23˚C	0.958
Elastic Modulus	9 3
Tensile Creep Strength	8 4
Bending Creep Modulus	1
Tensile Strength At23˚C	2
Elongation At Break (%)	> 600
Thermal Conductivity	0.8
Ignition Temperature	3

The cement used in this investigation is ordinary portland cement. The mechanical properties of used cement are given in Table 2.3. Tap water was used in all concrete mixes.

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A horizontal rotating counter flow mixer pan with a capacity of 0.09 cubic meter and a rotational speed of 13 revolutions per minute was used to mix the concrete components. The pan mixer was wetted before rotation, and only half of the sand, gravel, and polypropylene particles were introduced to the mixer and mixed for 2 minutes. The cement was added to the mixer while it was rotating, followed by the remaining sand, gravel, and polypropylene aggregates, and the mixture was mixed for 2 minutes. For homogeneity, further 3 minutes of mixing was undertaken with the addition of water. The mixing procedure was followed in line with ASTM C. (192-81). To inhibit the establishment of a bond between the mould and the concrete, the internal surfaces of the interlock brick moulds were treated with a thin layer of mineral oil before casting directly. Using a blunted trowel, fresh concrete was removed from the mixer and poured into the molds in three levels. To ensure a symmetrical distribution of the concrete and reduce coarse aggregate segregation, the trowel was moved around the top edge of the cube. The third layer of concrete was compacted by a mechanical vibrator after each layer was compacted using a normal compacting rod. The top surfaces of interlock brick molds were then finished and leveled with a metal trowel, and the specimens were retained in the cubes and covered with plastic sheets for 24 hours to prevent quick moisture evaporation and plastic shrinkage.

After the components are extracted and reprocessed for manufacture, the post-consumer plastic material can either be used directly or undergo chemical treatment after being physically treated, such as grinding, melting, and reforming. The interlocking brick's dimensions are given in Fig.
2.1.

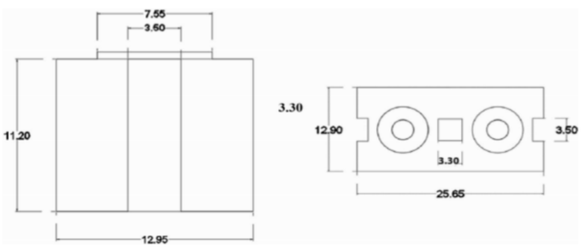

Figure 2.1 Typical Dimensions of the Interlocking Brick in cm (Side View and Top View)

3. RESULTS AND DISCUSSION

3.1 Results

The compressive strength, tensile strength, flexural strength, percentage of water absorption, and shrinkage of the plastic interlock brick concrete were all measured in this study. This chapter discusses the maximum compressive strength of concrete after 7, 14, and 28 days as a function of the polyethylene terephthalateplastic aggregates content by volume of concrete, as well as the flexural strength, percentage of water absorption, and shrinkage concrete. The British (DOE) approach was used to design the concrete mix. The aggregates were saturated and surface-dry (SSD), meaning that all of their pores were full and they couldn't absorb any water from the fresh mix. The coarse aggregate was replaced with 0 percent, 10%, 20%, 30%, 40%, and 50% volume of concrete mix with plastic particles. The concrete examples were made with the same 0.45 water-to-cement ratio.

Table 3.1: Concrete Mixes for Interlock Bricks with Plastic Aggregates

3.1.1 Compressive Strength Results of Plastic Interlock Brick

The compressive strengths of six 150x150x150 mm specimens were tested using a universal testing equipment with a capacity of 100 tonnes. Cube specimens were evaluated at a loading rate of 14 N/mm2/min according to ASTM C39 at 7, 14, and 28 days after casting. Table 3.2 shows the compressive strength, which is defined as the stress generated as a result of compression load per area of specimen.

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The plastic interlock brick specimens show an increase in compressive strength when compared to the control sample, as shown in Table 3.2. Furthermore, increasing the volume of plastic particles has a direct impact on compressive strength.

The compressive strength of the specimens increased from 10.5N/mm2 for the control specimen (M1) with no plastic aggregate content to 14.0N/mm2 for specimen M6 with 50% plastic aggregate by volume after 7 days of curing, as shown in Figure 3.1. Compressive strength increases from 18.2N/mm2 to 21.7N/mm2 for M1 and M6 specimens after 14 days of curing, whereas compressive strength increases from 22.2N/mm2 to 32.7N/mm2 for M1 and M6 specimens after 28 days of curing.

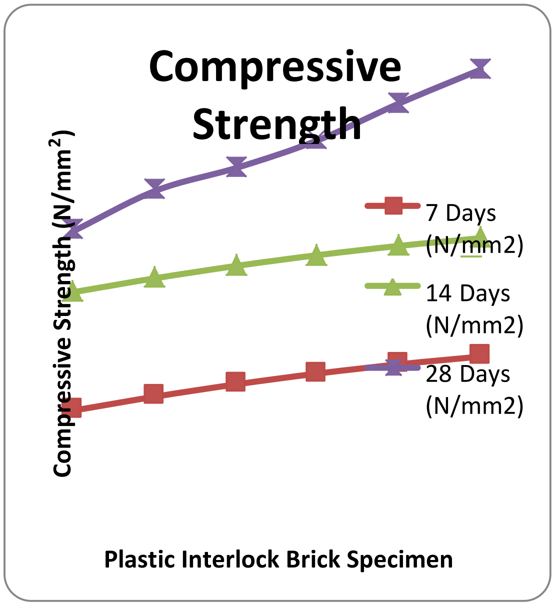

Figure 3.1: Compressive Strength of Plastic Interlock Brick Specimens.

The 3-dimensional response surface plot for compressive strength of the plastic interlock brick specimens is shown in Figure 3.2. However, in terms of compressive strength, there is a difference in performance of the plastic interlock brick concrete when a higher proportion of plastic aggregate is used in the sample and the curing period is increased by n days. The performance of the interlock brick concrete combination can be attributed to good cohesion with plastic particles, which improves the interlock brick concrete's mechanical qualities.

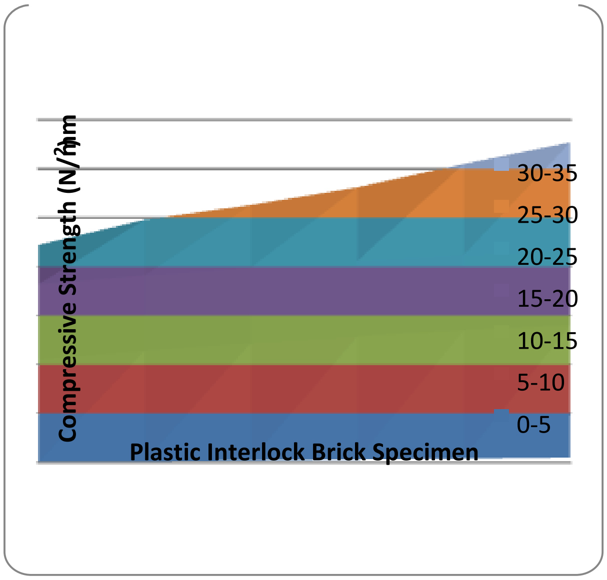

Figure 3.2: 3D Response Surface Plot for Compressive Strength of Plastic Interlock Brick Specimens

3.1.2 Flexural Strength Results of Plastic Interlock Brick

The flexural strength of three 100 x 100 x 500 mm beams under third-point loading on a simply supported span of 400 mm was tested according to ASTM C 1609 criteria after 28 days of cure. The results of the flexural strength test are interpreted according to ASTM standards by calculating flexural stress, as indicated in Table 3.3.

All plastic-reinforced concretes demonstrated a significant increase in flexural strength when compared to control interlock brick concrete without plastic. Additionally, an increase in the percentage volume of plastic aggregates content demonstrates improved performance.

Table 3.3: Flexural Strength of Plastic Interlock Brick Specimens

Specimen	%ofplastic aggregates by volume of concrete	Flexural Strength @ 28 Days (N/mm^2)
M1	0.00	3.9
M2	0.10	4.2
M3	0.20	5.0
M4	0.30	5.7
M5	0.40	6.4
M6	0.50	7.1

The specimens with the highest proportion of PET plastic aggregates (M5 and M6) had the highest flexural strength of all the plastic aggregate reinforced concretes. The largest increase in flexural strength for M5 and M6 was in the order of 6.4N/mm2 and 7.1N/mm2, respectively, as shown in figure 3.3. This is owing to the fact that more plastic particles contribute to the tensile load before the samples shatter. Furthermore, the increased availability of plastic aggregates makes it more effective in delaying the onset of micro fractures and so improving ultimate tensile stress capacity.

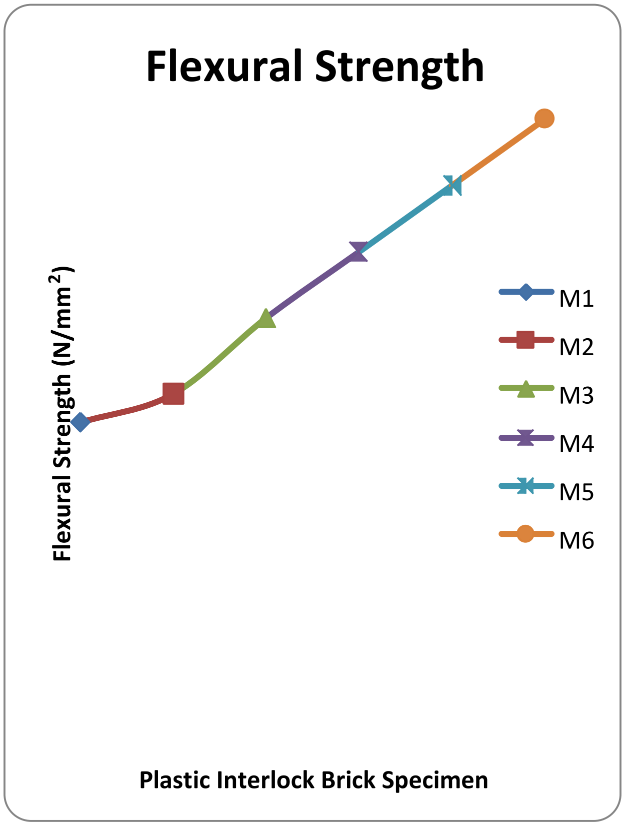

Figure 3.3: Flexural Strength of Plastic Interlock Brick Specimens

Figure 3.4 shows the 3-dimensional response surface plot for flexural strength of the plastic interlock brick specimens. In addition, specimens with more PET plastic aggregates had higher flexural strength than specimens with less plastic aggregates. The high aspect ratio of plastic aggregates employed in the M5 and M6 specimens, which produces a high reinforcing index, could be the reason.

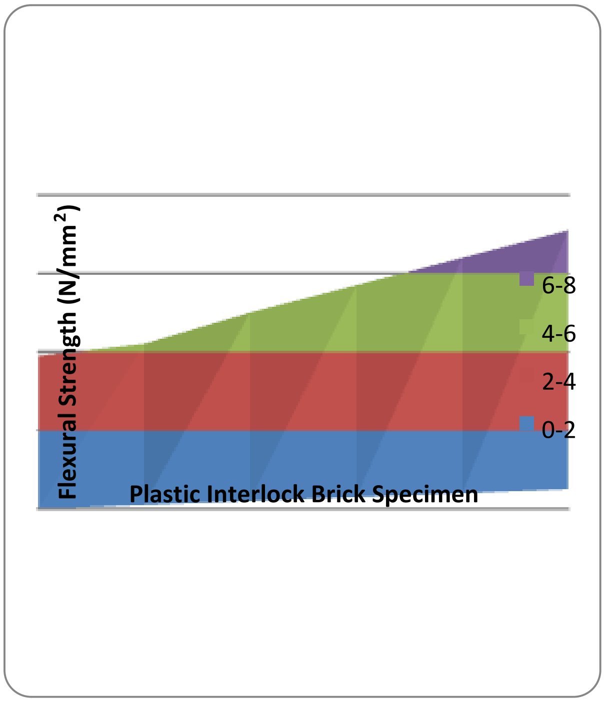

Figure 3.4: 3D Response Surface Plot for Flexural Strength of Plastic Interlock Brick Specimens.

4. CONCLUSION

The compressive strength of waste plastic fibers used for interlocking bricks was determined using a universal testing equipment with a capacity of 100 tonnes, which was utilized to test the compressive strengths of six specimens of molten plastic cube for 7, 14, and 28 days. After 7 days of curing, the compressive strength of waste plastic fibers used for interlocking bricks rose from 10.5N/mm2 for the specimen M1 with no plastic aggregate content to 14.0N/mm2 for the specimen M6 with 50% plastic aggregate by volume.

For the investigation of the flexural strength of the waste plastic fibres with different ratio that is durable for interlocking bricks, the flexural strength of the interlocking bricks containing good volume of molten waste plastic fibers with different ratio most especially specimen (M5 and M6) showed maximum flexural strength.

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REFERENCES

Aciu, C., Manea, D. L., Molnar, L. M., &Jumate, E. (2015). Recycling of polystyrene waste in the composition of ecological mortars. Procedia Technology. *International Conference of Interdisciplinarity Engineering, Tirgu-mures, Romania*, 9 – 10.

Geyer, R.,Jambeck, J.R. & Law, K.L. (2019). Production, Use, and Fate of All Plastics Ever Made. Science. Advancement. (Calif.) the Veolia Institute Review

Maneeth, P. D., Pramod, K., Kishor,K.&Shanmukha, S. (2014). Utilization of Waste Plastic in Manufacturing of Plastic-Soil Bricks

Sayanthan, R., Ilamaran, S., Rifdy, M. &Nanayakkara, S. (2013). Development of interlocking lightweight cement blocks. In: Special Session on Construction Materials & Systems 4th International Conference on Structural Engineering and Construction Management, Kandy, Sri Lanka. 194–202.

Suji, U. &Thivya, J., (2020) Experimental Investigation on Concrete Blocks using Flyash and Recycled Plastic Waste with Interlocking Mechanism.