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Sustainable Production of Building Blocks using A Recycled Plastic Waste

Ogunjiofor I. Emmanuel[1], Onwunduba C. Jude[2], Okpala I John[3]
[1]Lecturer, [2, 3]U.G Department of Civil engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra state, Nigeria

Abstract: Plastic waste is one of the materials that constitutes environmental nuisance and contribute to global warming. The global need to ameliorate the effect of global warming through waste reduction and recycling necessitated this research. The study involved using recycled plastic waste to produce building blocks. The low density plastic waste were collected from dump sites, cleaned and dried before melted and mixed with a fine aggregate at different ratios. The molten slurry formed by mixture of melted plastic waste and fine was poured into the metal mould and allowed to set. The result of the study showed that plastic sand blocks have a compressive strength ranging from 6.8N/mm^2 to13.15N/mm^2 which has a 3.3% higher than that of normal sand blocks. The water absorption rate, bulk density and Efflorescence results are within the acceptable limits. The exhibition favorable properties of blocks and need for sustainability of our environment should encourage the use of plastic waste produced blocks. This research indicates that bricks produced with plastics exhibit fine surface finishing, low porosity, and light weight, coupled with high compressive strength. Comparatively, these bricks surpass conventional clay bricks in both strength and weight reduction. The study recommends employing bricks produced with plastics for load bearing and framed structures, as well as in wet lands. Additionally, further investigations into different mix ratios are suggested to enhance quality and durability.
Keywords: Plastic waste reduction, global warming, recycling, building blocks, compressive strength, sustainability.

I. INTRODUCTION

Plastic is a strong, affordable, and lightweight material that can be moulded into a variety of objects with a broad range of uses. The amount of plastic produced has grown throughout time. However, there are several environmental problems brought on by the current level of their use and disposal. The majority of plastic generated each year is used to make packaging or other disposable items that are discarded after a year of usage. The enormous volume of plastic waste produced has made it a threat to survival, harming both the environment and the populace. Contaminated plastics can leak hazardous substances into the soil, which can then seep into nearby water sources, including underground ones. This could do major harm to the aquatic organisms who consume it. A concentration of plastics that is automatically more dangerous than that of sea water is formed when plastics are washed into the ocean by floodwaters during a period of severe rainfall. Humans can be exposed to this pollution through their tissues, skins, and aquatic life by consuming this polluted seafood. since they spend the majority of their time on land or at the water's surface close to the ocean.

Major Nigerian cities, such as Ibadan, Lagos, Kaduna, and Kano, are infamous for their smog and poor air quality due to the burning of solid waste, mostly plastics, as a waste management practice. These behaviors have continued because of a lack of knowledge, a lack of understanding of the effects, a lack of infrastructure for collecting waste, and occasionally the persistence of individuals. They are unaware of the possible hazards to human health and the environment posed by airborne particle emission (soot) and solid residual ash (black carbonaceous colour), which can travel thousands of kilometers and infiltrate our food chain depending on atmospheric conditions.

When used judiciously in the production of the different equipment used in homes and businesses, recycled plastic trash offers a plethora of advantages. In addition, one use for recovered plastic trash is the creation of building blocks, which are composite materials composed of coarse aggregates bound together by a binder that solidifies over time after the point of manufacture. They provide several advantages for house builders and businesses in the building sector and are utilised for dividing in new home construction. Some of the economical advantages are:

1) Cost effective: it can be extremely economical compared to other components used in producing cement based blocks.
2) It serves as means of controlling the environmental effect of plastic disposal.
3) It allows recycling of plastic waste.

It has been observed that one of the main non-biodegradable pollutants in landfills and waterways is plastic.

In light of the actions made to address the growing issue of plastic usage, this seminar work examines the literature on the use of plastic in the building and construction sector as a crucial first step in improving plastic recycling for the environment's safety for plant and animal systems in the future. Specifically, scope analysis articulates concerns related to plastic waste and identifies impending gaps for analysing the prospective market for recycling blocks. One of the operations intended to reduce substantial pollution to the environment is recycling and reuse through a number of procedures targeted at reducing plastic accumulation in the landfills.Plastic recycling is the process of turning discarded plastic into something useful.

II. LITERATURE REVIEW

A selection of the most relevant publications are reviewed, and various conclusions are drawn in light of the test findings.

A. Plastic Waste As An Environmental Hazard

In contrast to previous years, there has been a recent surge in the manufacture of plastic. Global demand for plastics increased to over 330 million tonnes in 2016 from over 320 million tonnes in 2015. 2017; Plastics Europe. This implies that the harm that plastic waste is causing to all living things and ecological systems is growing at a rapid pace. Plastics have always had an effect on human life, and the continued use and manufacturing of them is becoming more and more worrying since they might not be able to keep up with the most advanced techniques for managing plastic waste, especially in the majority of low-income nations (Uwaegbulam.2018).Furthermore, the characteristics of plastics that set them apart, including their durability and low weight, have also exacerbated the disposal problem. When utilised, plastic products remain a long time in the environment because they are robust, but because they are low in density, things dropped into water bodies continue to float on the surface. Because of this, these wastes are endangering ecosystems and life more severely, which raises the risk of major environmental problems like air, soil, and water pollution.

1) *Impact of plastic waste on land pollution:* Hazardous compounds that are released into the soil by contaminated plastics have the potential to infiltrate into neighbouring water sources, including subterranean ones. Because of this, the organisms consuming the water may sustain severe injuries. Because there are so many different types of plastic, landfills are always getting fuller. Numerous bacteria and diseases found in these landfills promote the biodegradation of plastics. Plastic waste clogs pipes, drainage systems, and other land features, resulting in pollution and land filling when improperly disposed of. Subsequently, this substance permeates the ground, contaminating crops. PETE bottles are visible blocking a drainage system in Nigeria in the picture below (Hakeem, & Aderuagba., 2018).
2) *Impact of plastic waste on air pollution:* Major Nigerian cities, such as Ibadan, Lagos, Kaduna, and Kano, are infamous for their smog and poor air quality due to the burning of solid waste, mostly plastics, as a waste management practice. These behaviours have continued because of a lack of knowledge, a lack of understanding of the effects, a lack of infrastructure for collecting waste, and occasionally the persistence of individuals. They are unaware of the potential hazards to human health and the environment posed by airborne particulate emission (soot) and solid residue ash (black carbonaceous colour), which can travel thousands of kilometres and enter our food chain depending on atmospheric conditions (Onwughara et al., 2015).
3) *Impact of plastic waste on aquatic life:* Water bodies such as rivers, streams, oceans, etc. are essential to the survival of all life on Earth because they provide most of the oxygen required for that species to exist. But the overwhelming negative effects of plastic waste are making people concerned about the state of life in general and marine life in particular. Estimates suggest that 5 trillion plastic bags, 10 million units, and more than a million plastic bottles are thrown away every minute worldwide. It is anticipated that each year, at least 8 million tonnes of plastic debris will enter the ocean (Darshan & Gururaja., 2017). In particular, the bulk of plastic particles may be resistant to natural breakdown processes, allowing them to linger for years in the aquatic environment and posing a huge threat to Nigeria's shoreline. Then, through terrestrial sources such groundwater runoff, combined sewage overflows, littering, industrial effluents, solid waste dumping, and landfills, these wastes are released into water bodies (Belttler et al., 2018).
4) *Impact of plastic waste on human life:* According to (Sigler., 2014), seafood is either poisoned, strangled, or killed when plastic waste gets into the ocean. Animals poisoned by plastic pollution can contaminate human food and water sources. Through skin absorption, those who come into contact with the chemicals used in the production of plastic may potentially become infected. Most of the plastic production methods involve the addition of synthetic compounds such as fire retardants, phthalates, and bisphenol A to give plastic its particular properties.

In the meantime, their additives (like plasticizers), monomeric building blocks (like bisphenol), or a combination of the two (like antimicrobial polycarbonate) may be harmful to human health. (Brazel & Rahman, 2004).

The two main ways that individuals are believed to be exposed to BPA in their bodies are through food and breathing. Wilson and colleagues, 2007. Furthermore, research has demonstrated that bisphenol A increases the risk of conditions like discomfort, irregularities in metabolism, and malignancies of the breast and prostate. It can lead to a number of health issues in women when it is inhibited, including as obesity, polycystic ovarian syndrome, recurrent miscarriages, endometrial hyperplasia, and sterility. (Eskenazi et al, 2007)

B. Engineering Properties of Building Blocks

1) Compressive Strength: Cement-sand blocks have compressive strengths that can vary widely based on factors such as the mix ratio, curing conditions, and the quality of materials. Strengths can range from around 1 MPa to 5 MPa or more.
2) Density: Cement-sand blocks are generally lighter than concrete blocks, with densities typically between 1,800 to 2,200 kg/m³.
3) Water Absorption: The water absorption rate can vary but should be controlled to prevent excessive moisture penetration. Quality control is essential to maintain the desired absorption rate.
4) The specific engineering properties of cement-sand blocks can be influenced by local practices and materials availability. It's important to ensure that the mix ratios and properties of the blocks meet the requirements of your construction project and adhere to any relevant building codes or standards in your region. Additionally, proper curing and quality control during manufacturing are crucial for consistent and reliable performance of these blocks.

C. Use Of Plastic Waste As A Building Block.

PET bottles (plastic cans) and river sand (Fine aggregate) are the resources utilized to create the plastic sand block. PET plastic bottles were gathered and sorted for this purpose. PET bottles, which are typically used to package beverages, were also used to make building block. The PET bottles were cut into smaller, identically sized pieces for our usage because they cannot be used in their standard form and size. The bottles were first cleaned and dried to get rid of moisture. The plastic bottles used was then shredded into smaller bits using a shredder in this instance. Sand was added to the melted plastic in a drum to create the blocks. (Ipke &Owunna., 2017)

III. MATERIAL AND METHODOLOGY

A. Material and Tools Used

1) Metal mould of dimension 450mm x 150mm x 225mm.
2) Local furnace or oven for heating the recyclable plastic materials and sand.
3) Thermometer for noting the temperature of the thermoplastic during heating.
4) Tapping rod for compaction.
5) Hand trowel
6) Grease or condemned engine oil.
7) Sharp sand (locally mined silica sand as fine aggregate).
8) Processed recycled plastic waste materials (polythene bags, sachet water bags and plastic soft drink cans).
9) Flat surface for mixing the molten plastic and preheated sharp sand.

B. Method Of Sample Collection

The plastic wastes will be collected from surrounding waste dumping points in the municipal.These used plastics will be cut open, thoroughly washed to remove impurities.Finally dried in the open air until absolutely no moisture will be present.Admixture of sand will be collected from local surroundings, heated and mixed at a ratio of 1:2 and 1:3.Preparation of block mould :iron mould of 150mm^3 x150mm^3 and 100mm^3 x 100mm^3 were used . All the sides and surfaces of the mould should be even for the block to have better surface finish. Detachable cast iron mould was used for the purpose. Mould size of the sample is (450mm x 125mm x225mm). The recyclable plastic waste to be used will have thermoplastic properties, which means it can be moulded and remolded recursively when heated.

C. Experimental Procedure

1) A block mold having 450mm x 150mm x 225mm will be greased to prevent sticking of the consolidated block to the mould.
2) The thermoplastic will be packed into a container and heated to temperature of about 70^{o}C.
3) The admixture (sharp sand) will also be heated to same temperature with the thermoplastic (plastic waste) for easy mixing.

4) The two heated materials will be removed from the oven and hand mixed with the hand trowel.
5) The mixture will be poured into the mould (greased) and compacted using the tapping rod.
6) The mixture will be allowed to cool in natural air for about 20 minutes before it is removed from the mould.

D. Conversion Plastic Waste Into Molten State

Batching & Melting

Batching is the measurement of materials. After the waste bottles have been cleaned and rinsed with water, their weights were measured. Sand was sieved using a 600 micron sieve and was used to create building blocks. Blocks were made using various ratios of plastic bottles and sand. We applied the ratios 1:2 and 1:3. In this process, melting of plastic bottles was done. Plastic bottles were cut into pieces, and then these pieces were placed in furnace or oven for melting. In the first step, the melting drum was heated to remove moisture from it. The plastics was then put into the melting drum and allowed to melt.

E. Mixing Of Molten Plastic With Sand To Produce Building Block

Plastic pieces were put to a melting drum until we reach the desired proportion. During mixing, sharp sand was added. Sand was added to the drum once the melted plastic within has reached a temperature of between 130 and 250 °C. Continuous stirring ensures that the melted plastic and fine aggregate form a flawless connection. The mixture needed to make block were produced as the plastic bottles melt and begin to combine with the sand particles.

F. Moulding of The Plastic Block

When moulding, the prepared mixture was poured into the mould and tamped down using a tamping rod. The tampering rod exerts pressure so that the mixture fills the mould appropriately. In order to make it easier to remove the block at the end, oil was applied to the mould's walls before filling it with the mixture produced. Therefore, it was necessary to properly grease the mould before adding the mixture. The blocks moulded were taken out of mould after 24hours.

IV. RESULT AND DISCUSSIONS

A. Water Absorption Test

Overall, the water absorption test results indicate that both mix ratios (1:2 and 1:3) showed low moisture absorption rates, especially in the short term (up to 24 hours). This suggests that the block mixtures used in this experiment have good resistance to moisture penetration, which is a desirable characteristic for block structures, as excessive moisture ingress can lead to deterioration and reduced durability.

Table 1: Test results of 1:2 after curing at 60 sec., 24 hrs., 7 days and 14 days

S/N	Time	Before curing (A) (Kg)	After curing (B) (Kg)	Moisture content (C=B-A) (Kg)	Absorption rate ((C/A) x 100) (%)
1	60 Sec	6.65	6.65	0.00	0.00
2	24 Hrs	6.65	6.70	0.05	0.75
3	7 Days	6.65	6.80	0.15	2.26
4	14 Days	6.65	7.10	0.45	6.77

Table 2: Test results of 1:3 after curing at 60 sec., 24 hrs., 7 days and 14 days

S/N	Time	Before curing (A) (Kg)	After curing (B) (Kg)	Moisture content (C=B-A) (Kg)	Absorption rate ((C/A) x 100) (%)
1	60 Sec	2.05	2.05	0.00	0.00
2	24 Hrs	2.05	2.05	0.00	0.00
3	7 Days	2.05	2.07	0.02	0.98
4	14 Days	2.05	2.07	0.02	0.98

The results also suggest that the 1:3 mix ratio exhibited slightly lower absorption rates compared to the 1:2 mix ratio. However, both mixtures showed relatively low absorption rates throughout the curing period.These findings can inform decisions regarding the choice of mix ratio for specific applications, taking into consideration the desired moisture resistance properties of the block.

B. Compressive Strength Test

In the compressive strength test experiment, we utilized a total of 12 plastic cubes as test samples. During the experiment, we observed a slight variance in the weight of these cubes. This variance can be attributed to the presence of air holes or honeycombs that formed during the thermal cooling process of the molten plastic mixture containing fine aggregate. This occurrence was primarily due to inadequate compaction during the molding process.

Here is a summary of the weights of the plastic cubes for different mix ratios and cube sizes:

Table 3: Table Showing The Average Weight Of 12 Samples Of Plastic Cubes Having 1:2 And 1:3 Mix Ratios.

S/N	1:2 MIX RATIO 150mm^3 (KG)	1:3 MIX RATIO 100mm^3 (KG)
1	6.65	2.08
2	6.01	2.10
3	5.04	2.07
4	6.35	1.99
5	5.87	2.07
6	6.80	2.09
AVERAGE WEIGHT OF PLASTIC CUBES	6.12	2.07

These weight measurements provide insights into the characteristics of the plastic cubes used in the experiment. The variation in weight highlights the presence of air voids and the importance of adequate compaction during the molding process. These factors can influence the overall performance and compressive strength of the plastic cubes in subsequent tests.

Weight of plastic cubes, maximum compressive strength load and compressive strength of cube samples at 7, 14 and 21 days

Table 4: Seven (7) days test on 100mm^3 cube

Mix ratios	Weight of sample (Kg)	Maximum compressive load (KN)	Compressive strength (N/mm^2)
1:3	2.08	77.56	7.18
1:3	2.10	80.27	7.04
AVERAGE	2.09	78.92	7.11

Table 5: Seven (7) days test on 150mm^3 cube

Mix ratios	Weight of sample (Kg)	Maximum compressive load (KN)	Compressive strength (N/mm^2)
1:2	6.65	163.80	7.2
1:2	6.01	143.62	6.3
AVERAGE	6.33	153.71	6.8

Table 6: Fourteen (14) days test on 100mm^3 cube

Mix ratios	Weight of sample (Kg)	Maximum compressive load (KN)	Compressive strength (N/mm^2)
1:3	2.07	71.16	6.70
1:3	1.99	110.77	10.50
AVERAGE	2.03	90.97	8.60

Table 7: Fourteen (14) days test on 150mm^3 cube

Mix ratios	Weight of sample (Kg)	Maximum compressive load (KN)	Compressive strength (N/mm^2)
1:2	5.04	151.56	6.70
1:2	6.35	169.60	7.50
AVERAGE	5.70	160.58	7.10

Table 8: Twenty-one (21) days test on 100mm^3 cube

Mix ratios	Weight of sample (Kg)	Maximum compressive load (KN)	Compressive strength (N/mm^2)
1:3	2.07	140.38	13.30
1:3	2.09	137.50	13.00
AVERAGE	2.08	138.94	13.15

Table 9: Twenty-one (21) days test on 150mm^3 cube

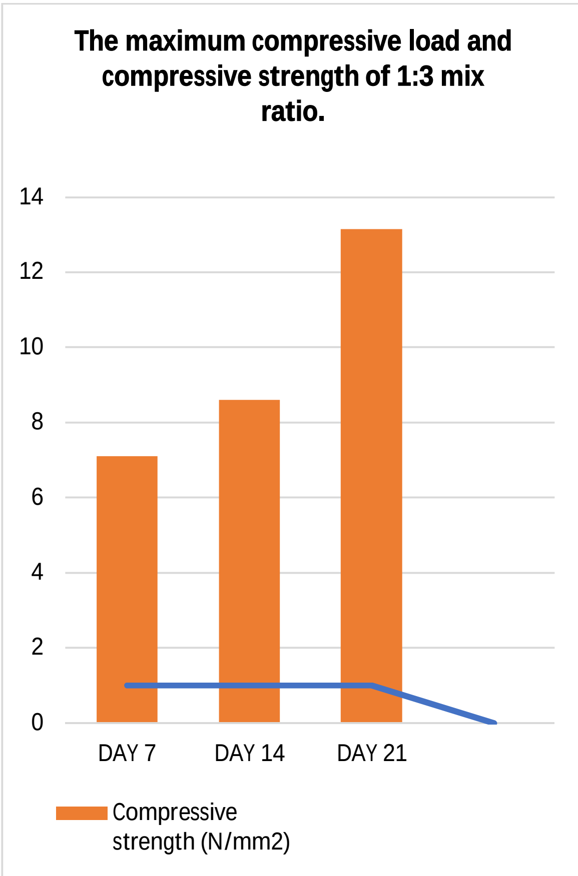
Mix ratios	Weight of sample (Kg)	Maximum compressive load (KN)	Compressive strength (N/mm^2)
1:2	5.87	157.20	6.90
1:2	6.80	181.03	8.00
AVERAGE	6.34	169.12	7.45

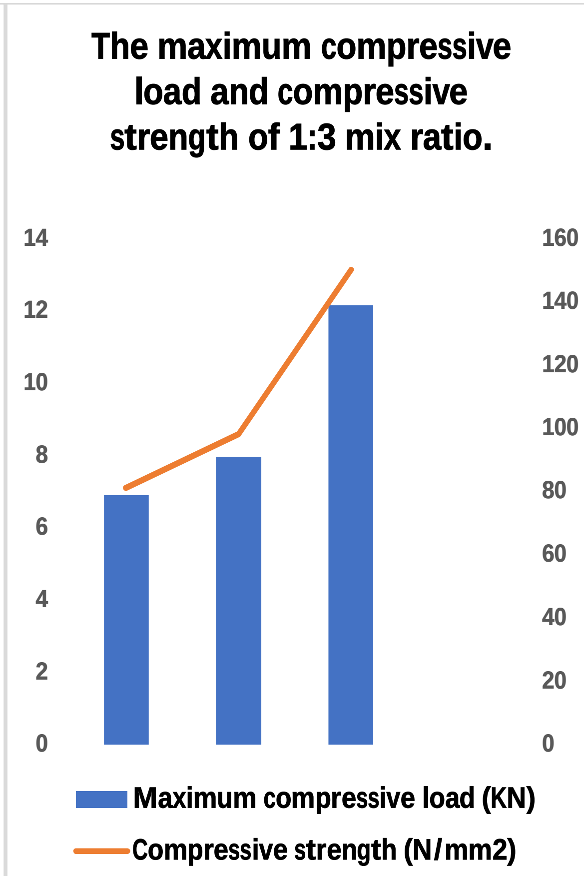
Based on the provided data, it appears that we have conducted a series of compressive strength tests on concrete cubes at different ages (7 days, 14 days, and 21 days) and with different mix ratios (1:3 and 1:2). Here are some observations and discussions based on the results:

The compressive strength of concrete is a crucial parameter that determines its ability to withstand axial loads or pressure. In this test, we have measured the compressive strength in N/mm^2.The mix ratios of 1:3 and 1:2 represent the proportions of cement to aggregate in the concrete mix. The first number is the amount of cement, and the second number is the amount of aggregate.We have tested two different cube sizes, 100mm^3 and 150mm^3. The larger cube size typically results in higher compressive strength due to the increased volume of the mixture. Testing concrete at different ages (7 days, 14 days, and 21 days) allows us to assess how the compressive strength develops over time. Generally, concrete becomes stronger as it matures.For both mix ratios and sample sizes, the compressive strength tends to increase from 7 days to 14 days, indicating that the block gains strength as it ages. However, there is some variation in the results.The 14-day test results show a significant increase in strength compared to the 7-day results, especially for the 1:3 mix ratio samples. This is expected as block continues to hydrate and gain strength over time. At 21 days, the block samples generally exhibit the highest compressive strength. This is consistent with the normal behavior of block, which continues to cure and strengthen with time. It's important to note that the mix ratio significantly affects the compressive strength. Generally, the 1:2 mix ratio samples show higher strength compared to the 1:3 mix ratio samples. This is because a higher cement-to-aggregate ratio usually results in stronger block. Larger cube sizes tend to exhibit higher compressive strength, as seen in the 150mm^3 cubes compared to the 100mm^3 cubes. There is some variation in the test results, which is common in block testing. Factors such as mixing, cooling effect, curing, and sample preparation can influence these variations.Overall, the data suggests that the concrete samples with a 1:2 mix ratio and 150mm^3 size cubes have the highest compressive strength, especially at 21 days. However, block strength depends on various factors, including the specific materials and curing conditions used. These results provide valuable insights into the performance of the concrete mixtures we tested under different conditions and ages.

Table 10: The maximum compressive load and compressive strength of 1:3 plastic cubes of $100mm^3$

Days	Maximum compressive load (KN)	Compressive strength (N/mm^2)
7	78.92	7.11
14	90.97	8.60
21	138.94	13.15





From the plot shown above, compressive strength increased uniformly from day 7 till day 14; followed by a sharp increase from day 14 to day 21. Same trend was observed for maximum compressive load.

In summary, the data demonstrates that the 1:3 plastic cubes of $100mm^3$ exhibited a substantial increase in compressive strength and maximum load-bearing capacity from day 14 to day 21. This suggests that the block was still in the process of curing and developing its structural integrity. The uniformity in the trends between maximum compressive load and compressive strength indicates a direct relationship between the two, where an increase in strength leads to a higher load-bearing capacity. These results are consistent with the typical behavior of block, which continues to strengthen over time.

Table 11:The maximum compressive load and compressive strength of 1:2 plastic cubes of $150mm^3$

Days	Maximum compressive load (KN)	Compressive strength (N/mm^2)
7	153.71	6.80
14	160.58	7.10
21	169.12	7.45

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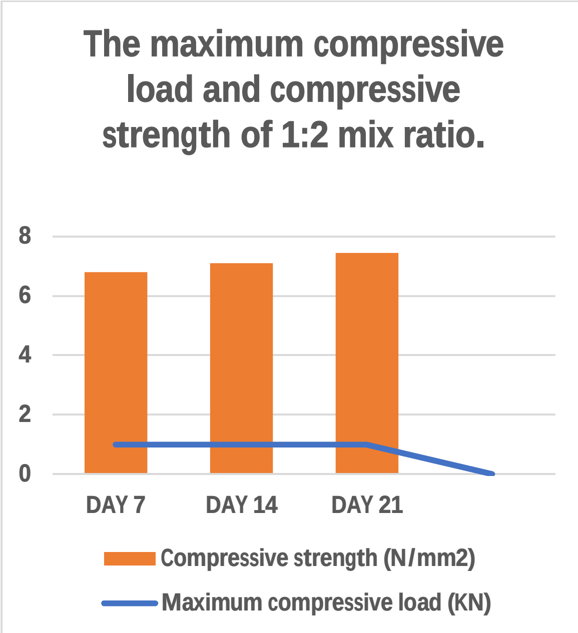

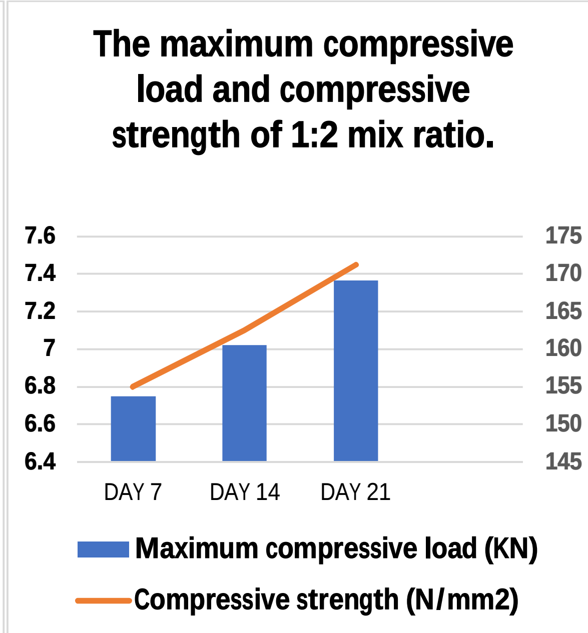

From the plot shown above, compressive strength increased uniformly from day 7 till day 21; followed by a uniform increase in maximum compressive load from day 7 to day 21.

In summary, the data demonstrates that the 1:2 plastic cubes of 150mm^3 showed a consistent and positive increase in both compressive strength and maximum load-bearing capacity over the 21-day testing period. The uniformity in these trends indicates that the block was continuously maturing and strengthening, which is a desirable characteristic for structural applications. These results are in line with the typical behavior of block and suggest that the 1:2 mix ratio used in this experiment was effective in producing a robust and reliable block mixture.


(a)


(b)


(c)

Figure 1: (a) melting of the plastic. (b) Mixing of melted plastic with fine aggregate. (c) After moulding the block

V. CONCLUSION

From the experiments carried out, a compressive strength of 6.8 N/mm^2 (minimum) and 13.15 N/mm^2 (maximum) were recorded as seen at section 4.1.3 and 4.1.2 of chapter four respectively which were higher than the recommended 3.5 N/mm^2 by (BS EN 771-3) for solid blocks. From the further experiment as recommended by (BS EN 771-3) for a good quality solid blocks, the water absorption should be less than 20% of it's own weight.

Therefore, the experimental research showed 0.75% after 24hrs which is not greater than 20% of it's original weight (6.65kg) as shown in section 4.2 of chapter four.The average bulk density for 1:2 and 1:3 mix ratio recorded is within the standard for building block which is 1800 - 2100kg/m^3. Plastic Sand Bricks offer cost and resource efficiency, among other benefits. They are created from plastic wastes that would have polluted the environment in any other case. The bricks were lightweight, had a smoother surface, reduced porosity, and had a higher compressive strength. By experimenting with different mix ratios and plastic types, further study may enhance the durability and quality of plastic sand bricks. The findings we obtained demonstrated that these bricks had a higher compressive strength than traditional clay bricks of the same size, and they also weigh less, which will reduce the structure's dead weight. These bricks also absorbed relatively little water.

A. Recommendations

The experiment showed that plastic wastes had higher compressive strength and lower water absorption rate; we recommend its use for:

1) Load bearing structures,
2) Framed structures
3) Wet lands
4) Also further research should be carried out on other mix ratios to know their effects too.

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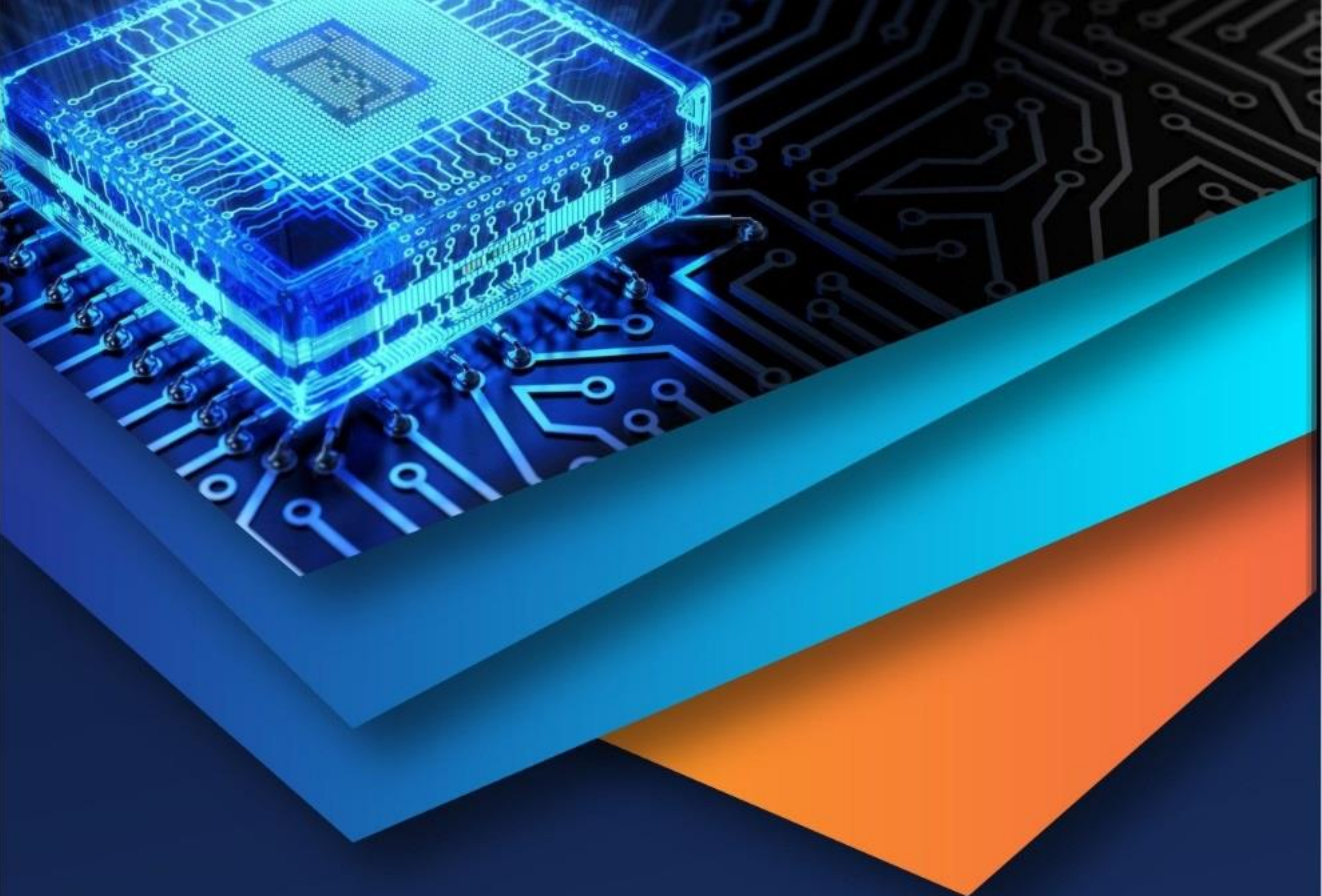

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