RECYCLING OF WASTE PLASTIC FOR THE PRODUCTION OF ROAD INTERLOCKING PAVING STONE IN NIGERIA

ABSTRACT

Each day, waste is produced in Nigeria, and these wastes are threats to the environment, coupled with the inexistence of proper and functional waste management systems at the moment. This study proffers an effective way of converting plastic wastes to wealth for use in the construction industry in Nigeria, by using waste plastic as the binder in the production of road paving stones, this solution is cost effective and also promotes recycling of waste to create a healthier environment. The procedure involved melting of waste plastics in heat and mixing in various ratios the melted paste with fine and coarse aggregates to make interlocking paving stones, the samples formed from this mix were cured and crushed then the strength determined. From the results given by this research, one of the mix ratios had a strength of about $25N/mm^2$ which can serve as pavements for some aspects of roads expected to carry light traffic, as; Pedestrian ways, Cycle tracks, unimportant roads and some local roads.

KEYWORDS
Waste plastic, interlocking paving stone, recycling.

1. INTRODUCTION

Nigeria is one of the most densely populated countries in Africa, with approximately 216.7 million people in an area of 923,768 km2 (356,669 sq mi), and is also the country with the largest population in Africa and the seventh largest population in the world.[1] Nigeria's huge population implies that there will be a commensurate amount of waste produced by her populace, which there currently are no fully functional waste collection and management systems in place.

Waste can be a curse to a community, because of the harmful effects it causes to inhabitants when it is not properly managed. However, wastes can also be a blessing to a community when effectively collected, managed and recycled.

Waste

Unwanted or useless materials are referred to as wastes. Waste is also defined as any substance that has served its original purpose but is now worthless, defective, or useless. Waste materials can be either liquid or solid, and their components can have dangerous or inert impacts on human health and the environment. Solid waste, sewage (wastewater), hazardous waste, and electronic waste are all commonly referred to as trash.

Municipal liquid waste is channeled through sewage systems in developed countries, where it is treated as wastewater or sewage before it enters groundwater aquifers or surface waters like rivers, lakes, estuaries, and seas, this procedure eliminates most or all the contaminants. Refuse, also known as municipal solid waste, is nonhazardous solid waste that must be collected and transported to a processing or disposal facility. Garbage and waste are examples of refuse. Garbage consists primarily of decomposable food waste and dry materials such as glass, paper, cloth, or wood. Garbage, on the other hand, is extremely putrescible and decomposable, whereas trash is not. Bulky goods such as old refrigerators, couches, and massive tree stumps, as well as building and demolition waste (e.g., wood, drywall, bricks, concrete, and steel rod), all of which require special collection and processing, are considered trash. Refuse is frequently disposed of in sanitary landfills, which are pits or other locations with impermeable synthetic bottom liners that segregate garbage from the rest of the environment.

Hazardous waste, both solid and liquid, is defined as waste that is dangerous to human health and the environment. Toxic, reactive, ignitable, corrosive, infectious, or radioactive wastes are examples of hazardous wastes. Toxic waste is defined as toxic waste generated by industrial, chemical, or biological activities that can cause injury or death when swallowed or absorbed through the skin. Chemically unstable, reactive wastes react violently or explosively with air or water. Infectious wastes are materials that may contain germs, such as old bandages, hypodermic needles, and other materials from medical and research facilities. Radioactive wastes (such as spent fuel rods containing fissionable elements used in nuclear power generation and cobalt and iodine isotopes used in cancer treatment and other medical uses) produce ionizing energy, which can harm living creatures. Hazardous wastes provide unique issues in terms of management, storage, and disposal, which vary depending on the material. [2]

Plastic Waste

Polymers are the primary component of a wide variety of synthetic or semi-synthetic materials known as plastics. Plastics can be moulded, extruded, or pressed into solid objects of diverse shapes thanks to their plasticity. Its widespread use is a result of its versatility, as well as a variety of other qualities, including being portable, strong, flexible, and reasonably priced to create. Typically, human industrial systems are used to make plastics. However, more recent industrial processes use variations created from renewable materials, including derivatives of corn or cotton. The majority of modern plastics are made from chemicals based on fossil fuels, such as natural gas or petroleum. Between 1950 and 2017, it is projected that 9.2 billion tonnes of plastic were produced. Since 2004, more than half of this plastic has been produced. 400 million tonnes of plastic were created in 2020. By 2050, it is predicted that yearly worldwide plastic production will exceed 1,100 million tonnes if current trends in plastic demand hold. Due to the slow pace of breakdown of plastics in natural ecosystems, their popularity and dominance since the early 20th century have led to significant environmental issues. The plastics industry pushed recycling toward the end of the 20th century in an effort to allay environmental worries while continuing to make virgin plastic and shifting the blame for plastic pollution onto the customer. At the time, the major plastics-producing businesses had doubts about recycling's economic sustainability, and those doubts have never been dispelled.

Due to the complexity requirements for cleaning and classifying post-consumer plastics for efficient reuse, plastic collecting and recycling is largely inefficient. The majority of plastic generated has not been recycled; instead, it has either ended up in landfills or continues to pollute the environment as plastic waste. All of the world's major water bodies are affected by plastic pollution, which damages terrestrial ecosystems and causes waste patches in all the oceans. Less than 10% of the plastic that has been thrown out thus far has been recycled, while 14% has been burned. [3]

Plastics make up over 10% of the content of municipal rubbish by weight. Plastic containers, bags, and other household items are increasingly being recycled, and they, like paper, must be sorted at the point of collection before being processed. Remelting and reforming thermoplastics into new products is possible. Before they can be remelted, thermoplastics must be separated by type. In contrast, thermosetting polymers such as polyurethane and epoxy resins cannot be remelted; instead, they are crushed or shredded for use as fillers or insulating materials. Starches in so-called biodegradable plastics dissolve when exposed to sunshine (photo degradation), yet a thin plastic residue remains, and the degradable additives prevent these products from being recycled. [2]

Plastic accounts for 2.5 million tons of Nigeria's annual trash production, which totals over 32 million tons. Nigeria, according to research by the United Nations Industrial Development Organization (UNIDO), Nigeria is one of the top 20 countries responsible for 83 percent of all land-based plastic garbage that ends up in the oceans. According to a World Bank study, each Nigerian generates 0.51 kg of garbage every day, with that number anticipated to rise to 107 million tons by 2050, offering both a risk and an opportunity. [4]

Recycling

In Nigeria, recycling is carried out by few companies, as collection of waste is still not optimal but is done majorly by scavengers who try to make a living by scouring for valuable materials such as paper, plastic, glass, metal, and e-waste. According to a study on solid waste led by C. C. Ike, a lecturer at the Department of Political Science, University of Nigeria, Nsukka, this method, albeit being informal, has contributed to reduce the volume of rubbish disposed of. Scavengers working at landfills, legal and illegal rubbish dumps, and itinerant bottle and cart pushers typically recover materials to sell to small buyers/middlemen. Small buyers/middlemen form a cartel, making it nearly impossible for new entrants to enter the market while fending off competition. Large buyers with a lot of money sell directly to the industries they're interested in. They may have contractual relationships with small buyers/middlemen who gather and supply materials to ensure that an acceptable number and quality of materials is supplied. [4, 11]

Roads

Highway/Roads are paths that aid the movement of people, animals or vehicles, from one location to another. Roads can be classified in various ways, as; function of the road, material composition of the road, rigidity of the road, traffic type and traffic volume, as seen in the table below: [5]

Table 1 : Road function statistics

Function of the road:	*Material composition of the road:*	*Rigidity of the road:*	*Traffic type:*	*Traffic volume:*
• Express way • Free way • Highway • Collector roads • Arterial roads • Local streets	• Earthen roads • Gravel roads • Murram • Kankar • Water bound macadam • Bituminous road • Concrete roads.	• Rigid pavement • Flexible pavement	•Light traffic •Medium traffic •High traffic	•Pedestrian ways • Cycle tracks • Motor way

One of the major developmental indexes of any economy is its highway infrastructure. An increased and improved road network of a country makes travel easier, faster and cheaper; this also encourages trade within and outside the country.

Highway/road construction is generally capital intensive throughout the world, as funding can be a huge challenge for any country. In Nigeria about 60,000km of its estimated 195,000km road network is paved. [6,12]

Interlocking paving stone

Pavements can either be flexible or rigid, where flexible pavement is made of bituminous material while rigid is made of cementitious concrete material. However, in the case of interlocking paving stones, it is made of cementitious materials, but functions as a flexible pavement due to the sand filled joints between each stone.

Interlocking stones, when properly made, can serve the test of time, and are durable in areas with high water table, as it enables quick draining of surface water. Its construction is relatively faster than that of asphalt or concrete pavement, and as such could be said to be much easier to construct. It is also much cheaper than the asphaltic or cementitious concrete.

More and more roads in Lagos, especially in the Island regions of Lagos recently, are constructed with interlocking paving stones, and many collector roads, arterial, and local streets in Lagos as well. [7,8]

Recycling waste plastic to make paving stones

This study explores the recycling of waste plastics for the production of interlocking paving stones. Owing to the thermoplastic property of plastic, that is, its ability to soften or melt when heated and solidify on cooling, it can serve as a good binder, and this property can be employed in the production of interlocking paving stone. Partial and complete replacement of the cement in paving stone can be done using waste plastic.

This research considered complete replacement of the cement in interlocking paving stones with waste plastic. The waste plastic used for this experiment is waste cement bags, made from polypropylene, although other types of waste plastics can be used such as low density polyethylene, this concept will significantly reduce the cost of road construction and also create a healthier environment by recycling waste plastic.

2. METHODOLOGY

Materials used for this work include: sand, granite, waste plastic (empty cement bags),

Tools: steel mould, tamping rod, trowel, shovel, weighing scale, steel drum, head pans and fire setup.

Procedure

Granite, sand and waste plastic are measured into the various quantities as required by the mix ratio, after which the fire setup is made and the steel drum placed on it to heat up. Then the waste plastic bags are placed in the drum to melt, after which the sand and the granite are added, then the mixture is mixed thoroughly till it forms a molten paste. The paste is then placed in steel moulds that have been oiled, then it is compacted, and left for a few hours before demoulding. [9]

Batching

Batching of the materials for the paving stone was done using a digital scale, and three different mix ratios were batched.

Curing

This was allowed to air dry for about 3 days, although it actually attains optimum strength when it cools completely. [10]

Compressive Strength Test

Compressive strength was achieved by subjecting the interlocking paving stone to crushing, with a concrete crushing machine. This was done in the Federal Ministry of Works and Housing, materials, geotechnics & pavement evaluation unit, 15, Awolowo Road, Ikoyi, Lagos.

3. ANALYSIS OF RESULTS

Table 2: compressive strength results

Label	Mix Ratio	Weight (KG)	Size (mm)	Compressive strength (N/mm^2)
Sample A	1 : 1 : 1	3.05	200 x 100 x 80	25.7
Sample B	1 : 1 : 1.5	3.95	200 x 100 x 80	10.6
Sample C	1 : 1.5 : 2.5	4.03	200 x 100 x 80	7.9

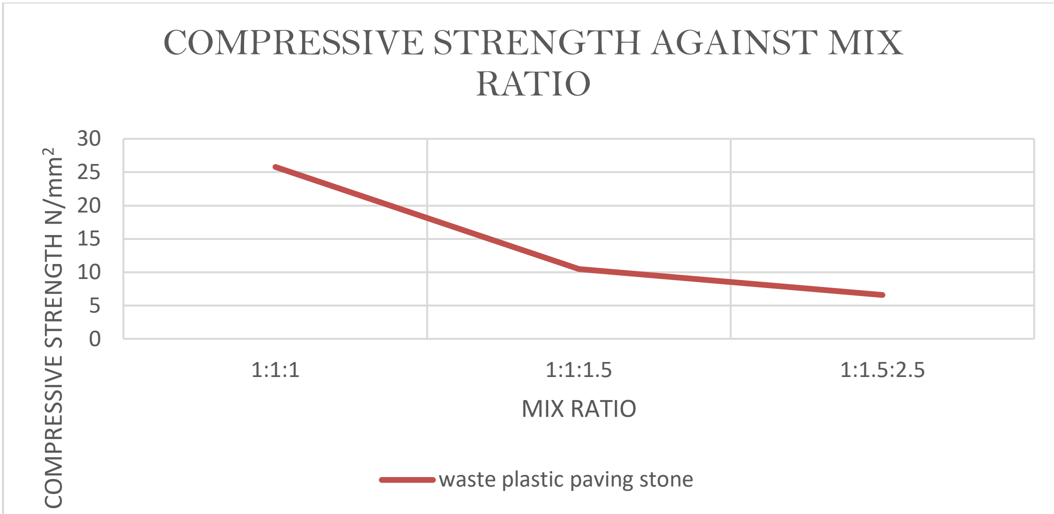

Fig. 1: compressive strength against mix ratio

The results revealed that sample A, which is 33% waste plastic and 66% aggregates, gave the highest compressive strength of 25.7 N/mm^2, while sample B, containing 29% of waste plastic and 71% aggregate, gave a result of 10.6N/mm^2, finally sample C containing 25% waste plastic and 75% aggregates, had a strength of 7.9 N/mm^2.

4. CONCLUSION

From the experimental results of this research, waste plastics can be recycled to produce interlocking paving stones. Although the strength given by this sample is less than required for standard roads or highways, especially roads expected to carry high volume traffic, it will function adequately as pavements for pedestrian ways, cycle ways, and possibly unimportant roads expected to have light traffic, as in streets.

The suitable mix ratio for this type of interlocking paving stone should be around 33% of waste plastic and 66% of aggregate if the production is carried out in similar conditions, that is using sand, granite chippings and plastic bags from polypropylene however other thermoplastic materials may require a different mix ratio to achieve this strength.

With this, waste plastic can easily be recycled for the production of interlocking paving stones used for road construction.

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