ISSN No:-2456-2165

Polymer Tiles from Polyethylene Wastes and Kaolin: Mechanical Properties and Durability

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Abstract:- The recent cost of materials for construction, likewise the resources needed in manufacturing these materials in an enabling situation, is affecting the world's construction industry, which is expanding at an unprecedented pace. Plastic wastes are a significant environmental concern due to their widespread use, non-biodegradability, and contamination from incineration and landfill, recycling these wastes into tiles would be a significant benefit. The mechanical qualities of tiles made from Polyethylene wastes, and kaolin sand aggregates becomes the insight of this study. Polyethylene wastes were added to other aggregates in various percentages of 100%, 75%, 50% and 25% by mass. Assessment of physical and mechanical properties reveals that, in terms of material density, mass, and chemical resistance, the tiles labelled PEK 4 outperforms the other proportion of waste. The composite tile PEK 3 demonstrated good % water absorption and enhanced compressive strength of 16.51100 N/mm^2. There was no significant difference in mass after soaked in different acid, salt and base solutions for seven days. Finally, as tile products, Polyethyleneinterlock tiles have better strength, chemical tolerance, low water absorption, and are friendlyenvironmentally. This possibility will not only reduce cost of construction materials, but it will also serve as a waste diversion, reducing the environmental impact of plastic waste disposal.

Keywords:- *polyethylene, mechanical properties, plastic wastes, tiles, durability,kaolin*

I. INTRODUCTION

Plastic is aninorganic solid and polymer which are hydrocarbon in nature. There are diverse types of plastics which are commonly used: thermoplastics and thermo-setting. These categories of polymer can be distinguished based on their performance in the presence of heat. Among these, thermoplastics are cheaply and easily molded and re-molded to various utilizable forms. They have low processing cost, low melting point, durability, strength and chemical resistance. Thermoplasticcomprises about 80% of all plastic that are usually used while thermosetting comprises about 20% (Gawande et al., 2012).

The plastics industry is an entirely new industry since the mid 19thcentury; it started with the introduction of mixture of camphor and nitrocellulose. Since the 20th century, people produced a series of synthetic resin that was steady with the properties of natural resin using chemical synthesis technique. Ever since then, the plastics industry begun to growand flourish and had become a vital material in many aspects of daily life.

Currently, this industry is one of the rapidly growing industries globally.

Plastics are carcinogenic in nature as they contain chlorine and other carcinogens. The burning of these wastes produce toxic gases such as chlorine, phosgene, carbon monoxide, nitrogen oxide, sulphur (iv) oxide, and other harmful dioxins that are dangerous to the environment.

In 1950, the world's plastic production was 1.5 million tonnes, 6.9 million tonnes in 1960, 30 million tonnes in 1970, and it had doubled to 63.44 million tonnes in 1979. It was calculated that, by 1985, the world's total production of plastic would rise up to 100 million tonnes and to greater than 350 million tonnes by 2000. In the near future, the world would in abundance produce fine plastic with volume and weight greater than steel. The future world would be 'a world of plastic'. Packaging using plastic material accounts for almost half of the plastic waste in the world. Most of these wastes are generated in Asia while America, Japan and the European Union are the world's largest producers of plastic packaging wastes per capita. If current consumption patterns and waste management practices continue, by 2050 there will be about 12 billion tonnes of plastic litter in landfills and the environment. Consequently, if the growth in plastic production continues at its current rate, then the plastics industry may account for 20 per cent of the world's total oil consumption. (WEDO, 2018).

It is estimated that 15–40% of waste plastic accumulation into water bodiescontributes to around 5.25 trillion estimated pieces of plastic wastes in the oceans currently (Alexander et al., 2018). The rate at which waste plastics are increasing in municipal solid waste is estimated to be doubling almost every 10 years. This is due to the rapid urbanization, growth in population size, and changes in developmental activities and lifestyle. Based on recent studies, waste plastics are estimated to remain on earth surface for about 450 to 500 years without degradation (Shinde et al., 2018; Thirugnanasambantham et al., 2017).

ISSN No:-2456-2165

As plastic wastes account for the highest number of percentage of waste produced worldwide,hence proper management of such waste must be ensured (Wahid et al., 2015).

Currently, plastic wastes that have been recycled are gradually replacing natural materials such as fibre, wood/timber, metal and sand, thereby preserving the natural environment. Adequate management of solid wastes via recycling into new products will aid in promoting a sustainable environment, conservation of natural resources, and cheap raw materials (Sadiq and Khattak, 1999).The only means to adequately take care of numerous tonnes of plastic wastes disposed is through the adoption of recycling method, and this practice of recycling contributes to a safer environment (Temitope et al., 2015).

Recycling of polymeric waste is a process of improvingon the wastes and turning the debris plastics into useable products that can be sent back to the manufacturing chains. The large amount of materials required in the manufacturing industries as feedstock is a major area for the recycle of waste plastic materials (Dinesh et al., 2016).

Recycling waste plastics has thebenefits of reducing environmental hazards that may occur as a result of arbitrary burning of such materials. Reuse of plastic wastes in industrial construction has been held with high esteem by many researchers globally (Nitin and manisha, 2016; Maneeth et al., 2014).

Cement is well known in the construction industry; however, the daily inflation of the price of cement has prevented many people from building their houses and in turnhindered the advancement of the construction sector (Konin, 2011). Therefore, it is imperative a suitable replacement for this expensive and essential building material is found(Ramaraj and Nagammal, 2014; Veluman and Karthik, 2017).Polyethylene terephthalate (PET) materials are recently used as binders in the manufacture of a largevariety of building materials, including tiles.

Harini, 2015 reported that high-density polythene (HDPE) plastics can be used to make roof tiles when combined with sand. The results revealed that composite tiles made with 70% HDPE possessed better performance and quality after analysis. Polyethylene possesses atremendous low-temperature resistance, with a great chemical resistance, and excellent power insulation; an outstanding pressure resistance and a spectacular radiation resistance. Because polyethylene is made up of only of carbon and hydrogen, it has no polar element present hence itsreason for the good water resistance nature.

A. Most Common Plastic Types

Classification of plastics isdone based on the basis of the polymer from which they are composed of Plastictypes which are mostly reprocessed are polyethylene (PE), polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC) and polyethylene terephthalate (PET).

- **Polyethylene (PE) -** Thereare two main types: low-density polyethylene (**LDPE**) and high density polyethylene (**HDPE**). LDPE is flexible, soft and simple to cut, with a candle wax feel. When thin, it is very transparent and when thick, it is milky white, except a pigment is added. LDPE is applied in the manufacture of film bags, sheeting and sacks, food boxes, blow-moulded bottles, flexible piping and hosepipes, household articles such as bowls and bucket, toys, telephone cable sheaths, etc. HDPE is stiffer and tougher than LDPE. Its colour is always milky white. It is used for bags, soft drinks bottles, industrial wrappings, detergents and cosmetics containers, crates, toys, jerry cans, dustbins and other household items.
- **Polystyrene (PS) -** Incrude form, polystyrene is transparent and brittle. It is frequently blended with other materials to obtain the desired properties (copolymerization). High impact polystyrene (HIPS) is prepared by adding rubber. Polystyrene foam is mostly produced by integrating a blowing agent during the polymerization process. Polystyrene is used for cheap, light fittings, bottles, transparent kitchen ware, toys, food containers, etc.
- **Polypropylene (PP)** – Polypropylene possesses more rigidity than Polyethylene, and can be bent sharply without breaking. It is used for chairs and stools, high-class home ware, strong moldings such as housings of car battery and other parts, suitcases, domestic appliances, wine barrels, pipes, crates, woven sacking, fittings, rope, netting, carpet backing, surgical instruments, food containers, nursing bottles, etc.
- **Polyvinyl chloride (PVC) -** Polyvinyl chloride is a rigid and hard material on application of plasticizers. Application of PVC include:thin sheeting, bottles, transparent packaging materials, window frames, water/irrigation pipes, building panels, gutters, etc. If plasticizers are applied, the product is called plasticized polyvinyl chloride (PPVC), which is flexible, soft and rather weak, and is used to make inflatable items such as shoes, footballs, hosepipes and cable coverings, flooring, raincoats, furniture coverings, shower curtains, bottles, automobile linings, etc.
- **Polyethylene Terephthalate (PET)** – Polyethylene Terephthalate exists as semi-crystalline (opaque and white) and amorphous (transparent) thermoplastic material. It often has good resistance to mineral oils, solvents and acids but not to bases. The semi-crystalline PET has good strength, stiffness and hardness, ductility while the amorphous type has better ductility but less stiffness and hardness. PET possesses good barrier properties against oxygen and carbon dioxide. Therefore, it is utilized in bottles for mineral water. More applications of these materials include food trays for oven use, audio/video tapes, roasting bags, mechanical components and synthetic fibres.
- Other plastic extensively used in our daily lives are as follow:
- **High Impact Polystyrene (HIPS) –** used in food packaging, fridge liners, vending cups**.**
- **Acrylonitrile butadiene styrene (ABS) –** used in electronic equipment cases, e.g. drainage pipe, computer monitors, keyboards, printers.
- **Polyester (PES) –** used in textiles, fibres.

- **Polyamides (PA) (Nylons) -** used in toothbrush bristles, fibres, fishing line, under-the-hood car engine mouldings.
- **Polyurethanes (PU) -** used in thermal insulation foams, surface coatings, cushioning foams, printing rollers.
- **Polycarbonates (PC) -** used in eyeglasses, CDs, security windows, riot shields, traffic lights, lenses.
- **Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) -** Blending of Polycarbonate and Acrylonitrile Butadiene Styrene creates a stronger plastic. It is used in car exterior and interior parts and mobile phone bodies.

B. Thermoplastics and Thermosets

Synthetic and semi-synthetic plastics are divided into two major categories: thermoplastics and thermosets.

- **Thermoplastics** are the plastics that could be repeatedly melt and soften when heat is applied and they harden into new shapes or new plastic products when cooled. Thermoplastics include Low Density Poly Ethylene (LDPE), Polyethylene Terephthalate (PET), High Density Poly Ethylene (HDPE), Poly Vinyl Chloride (PVC), Polystyrene (PS) and Polypropylene (PP) among others.
- **Thermosets or thermosettings**are plastics that can melt and soften but take shape onlyonce. They are not fit for repeated heat treatments; hence if heat is reapplied, they would not soften again but they stay permanently in the shape that they solidified into. Thermosets are generally used in automotive and electronics products. Thermosets contain epoxy, alkyd, melamine formaldehyde, ester, phenolic formaldehyde, urea formaldehyde, silicon, polyurethane, metalised and multilayer plastics etc.

Of the total post-consumer plastic wastes in India, thermoplastics constitute 80% and the remaining 20% correspond to thermosets. Similar percentages are also representative in the rest of the world.

II. MATERIALS AND METHOD

The following items were used in the experiment: a metal mold, a gas cylinder, a burner, a measuring scale, a measuring cup, lubricating oil, a plier, a metal bowl, a screwdriver, a brush, a fire source, a stirrer, and protective clothing such as a hand glove, a nose mask, a boot, an eye shield, and so on.

The shredded wastes and kaolin used in this study were collected from a waste site and a quarry site respectively.

Different chemical reagents of analytical grade such as sodium carbonate (Na_2CO_3), acetic acid, hydrochloric acid (HCl), acetone, nitric acid (HNO_3), benzene, and sodium chloride (NaCl) are needed to evaluate composite tiles' chemical resistance.

The scrapped polyethylene wastes were heated in the aluminium pot to 230°C before adding the kaolin to the plastic wastes that was melted. The mixture were homogenized, poured into an iron mold lubricated with engine oil for quick removal; the mold's edge was bashed continuously for a few minutes to ensure proper compassion. After an hour, the samples were de-molded, cooled, and cured for 48 hours at room temperature before testing.

III. RESULT AND DISCUSSION

S/N	Sample	Mass yield (kg)	Density (kg/m^3)	Load (N)	% Absorption	Compressive Strength (N/mm^2)
1	PEK1	0.085	426.8692	2600	0.00000	0.783368
2	PEK2	0.185	929.0682	46400	0.010695	13.98011
3	PEK3	0.245	1230.388	54800	0.008097	16.51100
4	PEK4	0.260	1305.717	49700	0.011407	14.97439
5	PEK5	0.285	1431.267	7700	0.003497	2.319976

Table 1: Mass, Density, load, % absorption, and compressive strength of the Polyethylenecomposite tiles of different Polyethylene and kaolin contents

A. Water absorption

PEK 4 tile achieved the highest value (0.011407%) while PEK 1 occupiedthe lowest value. This implies that water absorption of the tiles is directly a function of the polyethylene quantity but inversely related to the kaolin quantity.

B. Density

The density of the tiles were determined, and the PEK 1 had thelowest density (426.8692 kg/m^3) whilePEK 5 had the highest density (1431.267kg/m^3). Therefore, increase in the polyethylene mass decreases the density of the composite tile.

C. Compressive strength

Polymer composite which contains 100% polyethylene(PEK 1) displayed the lowest compressive strength value (0.783368 N/mm^2) and PEK 3 exhibited the highest compressive strength value (16.51100 N/mm^2). The results show that increasing the polyethylene waste content reduces thecompressive strength of the composite.

D. Resistance to Chemical Reagents

Chemical resistance tests were performed on the samples in accordance with ASTM D543-14 guidelines. The tile samples were prepared using length of 20mm, width of 20mm and thickness of 10mm. they were weighed and immersed in variouschemicals: hydrochloric acid (HCl), sodium carbonate (Na_2CO_3),sodium chloride (NaCl), benzene,acetone, acetic acid and carbon tetrachloride (CCl_4). The experiment was prepared at room temperature for 168 hours. After the soaking time, the tiles were all removed and rinsed with distilled water, air-dried before measuring the mass andthe dimensions of the soaked tiles

ISSN No:-2456-2165

and evaluate them with the mass and size of the non-soaked samples. Comparativeassessment showed that no considerablechanges in sample masses or measurements after seven days of soaking in differentchemicals; this finding is consistent with Dhawan et al., 2019.

IV. CONCLUSION

From the experimental results, the conclusions reached were as follows:

- A high polyethylene content presence in the tile will reduce water absorption. The percentage of water absorption decreases with increased polyethylenewaste.
- Samples with 100% polyethylene content had the lowest average density hence density increasesgraduallywith increasing kaolin content but decreases with an increasing percentage of polymer waste.
- The compressive strength of the tiles decreases as the polyethylenewaste content increases.
- Polyethylene tile tolerance in different chemical solutions was demonstrated, with no significant changes in mass or dimensions found after seven days of soaking in different chemicals.

These results indicate that polyethylene wastes can be used to manufacture long-lasting, minimalwater absorption,good strength, eco-friendly tiles for both commercial and residential applications. This development of tile productionusing polyethylene (PE) waste and kaolin will not only minimize the cost of building products but would also act as a waste diversion to mitigate environmental pollutionoften caused by plastic waste disposal.

Funding: no specific financial support was received on this study from anyone.

Competing interests: the authors affirm that they have no competing interests.

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