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Research Article

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

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## 1. Abstract

The cost of materials for construction, as well as the natural resources needed to manufacture these materials in an enabling environment, 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 percent, 75 percent, 50 percent and 25 percent by mass. The 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/mm2. There was no significant difference in mass after soaked in different acid, salt and base solutions for seven days. Finally, as tile products, Polyethylene plastic tiles have good strength, chemical tolerance, low water absorption, and are environmentally friendly. This possibility would not only reduce the cost of construction materials, but it would also serve as a waste diversion, reducing the environmental impact of plastic waste disposal.

**2. Keywords**: Plastic wastes; Polyethylene; Mechanical properties; Tiles; Kaolin; Durability

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## 3. Introduction

Plastic is a synthetic solid and hydrocarbon polymer. There are different types of plastics which are widely used: thermoplastics and thermo-setting plastics. These categories of polymer are differentiated based on their behavior in the presence of heat. Among these, thermoplastics can be cheaply and easily molded and re-molded to various usable forms. They have low processing cost, low melting point, durability, strength and chemical resistance. Thermoplastics constitute about 80% of all plastic that are commonly used while thermosetting plastics constitute about 20% [1]. The plastics industry is a new industry since the mid-nineteenth century, it began with the introduction of mixture of camphor and nitrocellulose. Since the 20th century, people created a series of synthetic resin that was consistent with properties of natural resin using chemical synthesis technique. Since then, the plastics industry begun to flourish and had become an indispensable material in many aspects of daily life.

Currently, the plastics industry is one of the fastest growing industries globally. Plastics are carcinogenic as they contain chlorine and other carcinogens. The burning of this waste produces toxic gases such as phosgene, chlorine, carbon monoxide, nitrogen oxide, sulphur dioxide, and other deadly dioxins that are harmful to the environment.

The world's plastic production was 1.5 million tons in 1950, 6.9 million tons in 1960, 30 million tons in 1970, and in 1979 it had doubled to 63.44 million tons. It was estimated that, by 1985, the world's total output of plastic would rise up to 100 million tons and to greater than 350 million tons by 2000. In the foreseeable future, the world would massively produce fine plastic with volume and weight greater than steel. The future world will be 'a world of plastic'. Plastic packaging accounts for about half of the plastic waste in the world. Most of this waste is generated in Asia while America, Japan and the European Union are the world's largest producers of plastic packaging waste per capita. If current consumption patterns and waste management practices continue, then by 2050 there will be around 12 billion tonnes of plastic litter in landfills and the environment. By this time, 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 dumped into water bodies contributes to about 5.25 trillion estimated pieces of plastic debris in the oceans currently [2]. The rate of increase of waste plastics in municipal solid waste is estimated to be doubling every 10 years. This is owed to the rapid urbanization, population growth, and changes in developmental activities and life style. According to recent studies, waste plastics are estimated to remain on earth surface for about 450 to 500 years without degradation [3,4]. Since plastic wastes account for the highest percentage of waste produced globally, there is a need to ensure proper management of such waste [5]. Presently, recycled plastic wastes are gradually replacing natural materials such as fiber, metal, wood/timber, and sand, thereby preserving the natural environment. Proper management of solid wastes through recycling into new products will help to promote a sustainable environment, conservation of natural resources, and cheap raw materials [6,7]. The only means to adequately taken care of several tonnes of plastic wastes being disposed is through the adoption of recycling process, and this process of recycling contributes to a cleaner environment [8]. Recycling of Plastic waste is a process of recovering the wastes and turning the scrap plastics into useable products that can be sent back to the manufacturing chains. The large volume of materials required in the manufacturing industries as feedstock is potentially a major area for the recycle of waste plastic materials [9]. Recycling of waste plastics has the benefits of reducing environmental impacts that may arise as a result of indiscriminate burning of plastics materials. Reuse of waste plastics in industrial construction has been embraced by many researchers [10,11]. Cement is generally used as a binder in the construction industry; however, the high cost of cement has prevented many people from building their houses and has hindered the advancement of the construction sector [12]. Hence, it is important to find a suitable replacement for this expensive and essential building material [13-15]. Polyethylene terephthalate (PET) bottles are now used as binders in the manufacture of a wide range of building materials, including tiles [16]. Reported that high-density polythene (HDPE) plastics can be used to make roof tiles when combined with sand. The results of their study revealed that composite tiles made with 70% HDPE had better performance and quality after analysis. Polyethylene has an excellent low-temperature resistance, a great chemical resistance, an outstanding power insulation, a good pressure resistance and a marvellous radiation resistance. Since polyethylene is composed only of carbon and hydrogen, there is no polar element present hence it comes with good water resistance.

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

| 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 |

## 4. Most Common Plastic Types

Plastics are classified on the basis of the polymer from which they are made, therefore the variety of plastics it is very extensive. The types of plastics that are most commonly reprocessed are polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). Polyethylene (PE) - The two main types of polyethylene are low-density polyethylene (LDPE) and high density polyethylene (HDPE). LDPE is soft, flexible and easy to cut, with the feel of candle wax. When it is very thin it is transparent; when thick it is milky white, unless a pigment is added. LDPE is used in the manufacture of film bags, sacks and sheeting, blow-moulded bottles, food boxes, flexible piping and hosepipes, household articles such as buckets and bowls, toys, telephone cable sheaths, etc. HDPE is tougher and stiffer than LDPE, and is always milky white in color, even when very thin. It is used for bags and industrial wrappings, soft drinks bottles, detergents and cosmetics containers, toys, crates, jerry cans, dustbins and other household articles. Polypropylene (PP) - Polypropylene is more rigid than PE, and can be bent sharply without breaking. It is used for stools and chairs, high-quality home ware, strong moldings such as car battery housings and other parts, domestic appliances, suitcases, wine barrels, crates, pipes, fittings, rope, woven sacking, carpet backing, netting, surgical instruments, nursing bottles, food containers, etc. Polystyrene (PS) - In its unprocessed form, polystyrene is brittle and usually transparent. It is often blended (copolymerized) with other materials to obtain the desired properties. High impact polystyrene (HIPS) is made by adding rubber. Polystyrene foam is often produced by incorporating a blowing agent during the polymerization process. PS is used for cheap, transparent kitchen ware, light fittings, bottles, toys, food containers, etc. Polyethylene Terephthalate (PET) – PET exists as an amorphous (transparent) and as a semi-crystalline (opaque and white) thermoplastic material. Generally, it has good resistance to mineral oils, solvents and acids but not to bases. The semi-crystalline PET has good strength, ductility, stiffness and hardness while the amorphous type has better ductility but less stiffness and hardness. PET has good barrier properties against oxygen and carbon dioxide. Therefore, it is utilized in bottles for mineral water. Other applications include food trays for oven use, roasting bags, audio/video tapes as well as mechanical components and synthetic fibers.

Polyvinyl chloride (PVC) - Polyvinyl chloride is a hard, rigid material, unless plasticizers are added. Common applications for PVC include bottles, thin sheeting, transparent packaging materials, water and irrigation pipes, gutters, window frames, building panels, etc. If plasticizers are added, the product is known as plasticized polyvinyl chloride (PPVC), which is soft, flexible and rather weak, and is used to make inflatable articles such as footballs, as well as hosepipes and cable coverings, shoes, flooring, raincoats, shower curtains, furniture coverings, automobile linings, bottles, etc.

Other plastics extensively used in our daily lives are as follow:

High Impact Polystyrene (HIPS) – used in fridge liners, food packaging, vending cups.

Acrylonitrile butadiene styrene (ABS) – used in electronic equipment cases (e.g., computer monitors, printers, keyboards, drainage pipe.)

Polyester (PES) – used in fibers, textiles.

Polyamides (PA) (Nylons) - used in fibers, toothbrush bristles, fishing line, under-the-hood car engine mouldings.

Polyurethanes (PU) - used in cushioning foams, thermal insulation foams, surface coatings, printing rollers.

Polycarbonates (PC) - used in CDs, eyeglasses, riot shields, security windows, traffic lights, lenses.

Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) - A blend of PC and ABS that creates a stronger plastic. Used in car interior and exterior parts and mobile phone bodies.

1.2 Thermoplastics and Thermosets

Synthetic and semi-synthetic plastics can be divided into two broad categories: thermoplastics and thermosets.

Thermoplastics are plastics that can be repeatedly soften and melt when heat is applied and they solidify into new shapes or new plastics products when cooled. Thermoplastics include Polyethylene Terephthalate (PET), Low Density Poly Ethylene (LDPE), Poly Vinyl Chloride (PVC), High Density Poly Ethylene (HDPE), Polypropylene (PP) and Polystyrene (PS) among others.

Thermosets or thermosettings are plastics that can soften and melt but take shape only once. They are not suitable for repeated heat treatments; therefore if heat is reapplied they will not soften again but they stay permanently in the shape that they solidified into. Thermosets are widely used in electronics and automotive products. Thermoset plastics contain alkyd, epoxy, ester, melamine formaldehyde, phenolic formaldehyde, silicon, urea formaldehyde, polyurethane, metalised and multilayer plastics etc.

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

## 5. 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 (Na2CO3), acetic acid, hydrochloric acid (HCl), acetone, nitric acid (HNO3), benzene, and sodium chloride (NaCl) are needed to evaluate composite tiles' chemical resistance.

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

## 6. Result and Discussion

Water absorption

PEK 4 tile achieved the highest value (0.011407%) while PEK 1 presented the lowest values. This means that the water absorption of the polymer tiles is directly a function of the polyethylene content but inversely related to the kaolin content.

Density

The density of the tiles were determined, and the PEK 1 had the lowest density (426.8692 kg/m3) while PEK 5 had the highest density (1431.267 kg/m3). Therefore, increases in the polyethylene content decreased the density of the composite polymer tile.

Compressive strength

Polymer composite that contains 100% polyethylene (PEK 1) exhibited the lowest compressive strength value (0.783368 N/mm2) while PEK 3 had the highest compressive strength value (16.51100 N/mm2). The results show that increasing the polyethylene waste content reduces the compressive strength of the composite.

Resistance to Chemical Reagents

Chemical resistance tests were performed on the samples in accordance with ASTM D543-14 guidelines. The samples were prepared with length = 20 mm, width = 20 mm, and thickness = 10 mm, then weighed and immersed in various chemicals: hydrochloric acid (HCl), sodium chloride (NaCl), sodium carbonate ($Na_2CO_3$), acetone, benzene, acetic acid, and carbon tetrachloride ($CCl_4$). The experiment was carried out at room temperature for 168 hours. Following the soaking time, the samples were removed, rinsed with distilled water, and air-dried before measuring the weight and dimensions of the soaked samples and comparing them to the weight and size of the non-soaked samples. Comparative findings revealed no significant changes in sample weights or measurements after seven days of soaking in different chemicals; this finding is consistent with Dhawan et al., 2019.

## 7. Conclusion

Based on the experimental results, the following conclusions were reached:

• A higher polyethylene content in the tile reduces water absorption. The percentage of water absorption decreased with increased polyethylene.

• Samples with 100% polyethylene content had the lowest average density hence density increased steadily with increasing kaolin content but decreased with an increasing percentage of polymer waste.

• The compressive of the polymer tiles decreased as the polyethylene content increased.

• Polyethylene polymer tile tolerance in different chemical solutions has been demonstrated, with no significant changes in weight or dimensions found after seven days of soaking in different chemicals.

These results from this study indicate that polyethylene wastes can be used to produce long-lasting, good strength, minimal water absorption, and eco-friendly tiles for both residential and commercial applications. This prospect of tile production using polyethylene (PE) waste and kaolin would not only minimize the cost of building products but will also act as a waste diversion to mitigate environmental emissions caused by plastic waste disposal.

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