Effects of various reinforcement on mechanical properties of plastic block: A review

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Abstract: Solid waste management is one of the major problems of any developing country due to the rapid growth in urbanization and industrialization. In solid waste one of the main components is plastics. Some of the plastics used in household and industrial applications are polypropylene (PP), polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET) and this kind of plastics can be recyclable but these plastics are simply dumped in landfills and water bodies and then plays a vital role in the causes for environmental pollution and other threats. Degradation rate of plastics also very slow, hence disposal of these plastic wastes without any cautions are not only affecting our surroundings but also affecting humans and other living beings. In addition to plastic waste another one main element is construction waste. Most of these waste plastics and construction wastes such as ceramic waste, metal scraps and quarry dust can be recycled by proper processes and can be reused. These waste plastics can be used to manufacture plastic blocks that may be used in construction works. This paper mainly focuses on the review of researches done on Improving mechanical properties of paver blocks using various waste materials as reinforcement. These plastic paver blocks with reinforcement can be used in nontraffic roads such as walkways, footpaths, pedestrian plazas, landscapes, monument premises and in waterlog areas due to their low water absorption property.

1. Introduction
Every year billions of tons of solid waste formed globally due to the urbanization and industrialisation of developing countries. These solid wastes are simply accumulated at the surroundings and plays a vital role in the causes for environmental pollution, production of toxic gases and new diseases. Approximately 56 lakhs ton of waste are produced in India per year [1]. In these most of them are food and green waste but these are bio-degradable hence it may degrade in some days or months. The main consideration in solid waste are plastic and other non-bio-degradable materials due to their low degrading rate. Plastic waste production are expected to 2.2 billion tons per year by 2025 [2]. Another main component is construction waste such as ceramic wastes and metallic wastes. Constructional wastes are dumped in landfills and river banks causes many problems for humans and other living beings [3]. These plastic wastes are causing many issues like blocking drainage pipes and providing a way for formation of new water borne diseases. Plastics thrown away on the ground may destroy the soil fertility and also get into the oceans through water bodies. Plastic waste dumped in the rivers, streams are reach oceans and causes many health issues for marine and aquatic animals. There is a possibility that, aquatic animals may consume these plastic wastes and it may damage their health. Approximately one lakh sea mammals are die every year after consumption of plastic wastes [4]. Plastic waste consists of packaging bags, used bottles, wrappers, use and throw products, toys, shopping bags, garbage bags etc. Main cause...
for the rapid generation of solid waste is population growth. In China due to high population growth, solid waste generation is increased from 31.3 million tons in 1980 to 212 million tons in 2006 [5].

In Construction materials, ceramics are a main component used for walls, floors, countertops and pools[6]. Ceramic tiles are manufactured from raw materials by various processes such as grinding, mixing followed by firing, polishing. In these processes ceramic waste is formed may weigh up to 2% of the final product but it cannot be used due to the impurities in it. Hence it is normally left as a waste in landfills[7]. These ceramic wastes are mainly divided into two categories. One is before the actual manufacturing of ceramic tile and the another one is after the manufacturing process. Wastes produced before the manufacturing processes includes the excess clay wastage and wastes produced after manufacturing process includes polishing waste and excess material trimmed out from the manufactured ceramic tiles to get uniform shape [6]. Another one constructional waste that can be reused is quarry dust. In quarries rocks and granites are crushed and powdered based on the requirement, during this process dust is produced. This dust is disposed as a waste and forms as a constituent in solid waste. But in recent years quarry dust is reused as a component in many of the constructional processes such as cement mortar, paver blocks, concrete etc [8]. Fly ash is another reusable component in solid wastes that is disposed in most of the scenarios. In India, power generation is mainly depending on coal-based power plants in these coal-based power plants produce tons of fly ash per day. Nearly 200 million tons of fly ash produced in India every year but only 56% of this fly ash is used. These fly ash wastes are not disposed safely it may cause many hazardous results [9].

Recycling of wastes may reduce solid waste generation and it also reduce environmental pollution and other hazards. For instance, manufacturers can use fly ash as a constituent in paver blocks by using recycled materials are promised around the performance of paver blocks that contains no recycled materials [10]. This paper mainly reviews about the ways of recycling plastic as a composite in paver blocks and also discusses the effects of various reinforcement on the mechanical properties of paver block.

2. Solid Waste Management

Solid waste management system consists of various steps like generation of waste, collection of waste generated, final disposal of waste. It starts with the collection of solid waste and ends with disposal or beneficial use. It is one such service to recycle those waste or disposal into safe manner. The urban population grew at a rate of 31.8% up to last decade study. The improper solid waste management deteriorates to public health issue, impact on environment pollution, causes natural resource degradation and cause climatic change. Improper disposal of solid waste management [11] shown in figure 2. The world produced 2.01 billion tons of municipal solid waste annually. It comes under the problem of urban areas. The below figure distinguish relationship between population and generation of waste rural areas. Production of waste generation and population in some countries [12] is shown in figure 1.
Figure 1. Shown the production of waste generation [12].

There are so many solid wastes are available in our world. In this the massive amount of producing wastes are municipal, industrial and domestic waste in our day-to-day life. It is the important required construction materials in the field of civil engineering. The widely spread solid waste materials were used in recycled concrete aggregate, fly ash, bottom ash, asphalt, waste rubber and waste plastic. Other than these are sent for recycling process to utilize them. It has been recycled and sent for direct usage to make pavement blocks. The investigation reveals that it has both environment and economic benefits [13].

2.1 Solid waste treatment
To dispose the solid waste in a systematic manner there are different methods available. They are incineration, compaction, pyrolysis, gasification and composting [14].

2.2 Municipal solid waste
The material used for this waste is useless after usage and it’s not represent any economic value for a manufacturer. Indian cities were lagging to collect the MSW. Metro and many other economic cities in India collected between 70-90% of MSW. It will be collected and disposed in open land or unsanitary landfills. It has been categorized into different ways based on physical appearance solid, liquid and gaseous state. Its will be recycle by planning, collection, transportation etc. MSW dumped in landfills to generate the greenhouse gases like methane and it had 21 times more potential global warming than carbon dioxide. Unsanitary landfills pollute the land and ground water [11].

2.2.1 Types of municipal solid waste and their sources
These were the waste produced by household, commercial and industrial. MSW usually contains food wastes, plastic, paper, glass, metals etc. Various types of municipal solid waste are tabulated in table 1.

2.2.2 Problems on solid waste management
It consists of organic as well as inorganic matter. There is no organized system for segregating the biodegradable and non-biodegradable solid waste. By research the smaller cities have generate biodegradable waste higher than the non-biodegradable waste. In India the systematic storage facility is not available in practice. So, the generating wastes were thrown into land, lakes etc. Some of the traditional methods are followed by Indian like incineration, pyrolysis etc. The municipal will not provide protective clothing for rag pickers. The children's and aged peoples are involved in waste segregation process [15].
Table 1. The various types of municipal solid waste [11].

| Sources          | Typical waste generators                               | Components of solid waste                                                                 |
|------------------|--------------------------------------------------------|------------------------------------------------------------------------------------------|
| Residential      | Single and multifamily dwellings                       | Food wastes, paper, cardboard, plastics, textiles, glass, metals, ashes, special wastes (bulky items, consumer electronics, batteries, oil, tires) and household hazardous wastes. |
| Commercial       | Stores, hotels, restaurants, markets, office buildings | Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes. |
| Institutional    | Schools, government centre, hospitals, prisons         | Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes. |
| Municipal services | Street cleaning, landscaping, parks, beaches, recreational areas | Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas. |

Figure 2. Improper disposal of solid waste management [11].

2.2.3 Existing methods of recycling plastic waste
The plastic normally consists of polymer. It gives the elastic properties to plastic. The polymers are recycled or converted into product. Every plastic has been made from different materials. It has been categorized into polymer as well as non-polymer. The plastic waste has been recycled into mechanical or by chemical. The recycled wastes are separate into two categories open loop and closed loop recycling to send for manufacture. Open loop is recycled and produce same product. Closed loop is recycled and produced different product [16].

2.2.3.1 Mechanical recycling steps
To convert the waste into new raw materials by mechanical recycling method requires some following steps. Processes in mechanical recycling is shown in figure 3.
2.2.3.2 Chemical recycling
It will be used or interrelated with output of mechanical recycling. It is defined as the process of converting waste or polymers into monomer by chemical recycling. After this monomer will be undergone polymerization process to make new product. Some of the chemical reactions were used for converting polymer to monomers are hydrogenation, glycolysis, metanalysis, thermal cracking, ultrasound degradation etc. This method is not fully developed due to high cost and need [12].

3. Plastic Waste Constituents
Plastic wastes mainly consists of low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS) [10]. Major composition of plastic waste consists of HDPE, LDPE, PET, PP accounting a total of around 80% and the other plastic such as PS, PVC and other plastics are coming around 10 to 20% but these plastics are disposed as a waste in landfills, rivers and streams [16]. Main constituents of plastic waste are shown in figure 4.

![Figure 3. Steps involved in mechanical recycling [17].](image1)

![Figure 4. Composition of plastic waste [16].](image2)
3.1 **Polyethylene**

Polyethylene is one of the widely produced plastics in the world due to their various usage in the household and industrial applications. Polyethylene is a lightweight thermoplastic made from the polymerization of ethene monomer.

Some of the most common types of polyethylene are given below:

- Linear low-density polyethylene
- Ultra-high molecular weight polyethylene
- Low density polyethylene
- Cross linked polyethylene
- High density polyethylene

### 3.1.1 Low density polyethylene

Low density polyethylene is a semi rigid polymer. It is produced at a pressure of 1000 to 3000 bar and at a temperature of 80 to 300°C by free radical polymerization process. It is composed of many short branches when compared to high-density polyethylene. Properties of LDPE are tabulated in table 2. In many countries LDPE bags, sheets and water sachets are a major problem due to poor waste collection and recycling systems [18].

**Table 2: Properties of low-density polyethylene [3, 10].**

| PARTICULARS                     | VALUES                                      |
|--------------------------------|---------------------------------------------|
| Melting point                  | 150°C                                       |
| Thermal coefficient of Expansion| $100 \times 10^{-6}$ to $200 \times 10^{-6}$ K$^{-1}$ |
| Density                        | 0.910 to 0.940 g/Cm$^3$                     |
| Tensile strength               | 0.20 to 0.40 N/mm$^2$                       |
| Percentage Elongation          | 100 to 650%                                 |
| Thermal Conductivity           | 0.33 W/m K                                  |
| Softening point                | 85°C                                        |
| Meting index                   | 0.8 g/min at 190°C                          |

#### 3.1.1.1 Applications of low-density polyethylene

- LDPE is used in food containers and bottles shown in figure 5 such as milk cartons, soft drinks due to their resistance against alcohol and acids.
- Another main usage of LDPE is plastic bags that can be used in household applications. This usage also causes a major role in accumulation of plastic waste around the world.
- LDPE is used in packaging foam to ensure that the fragile items are safe when transporting and handling [10].

![Figure 5. Water sachets [18].](image-url)
3.1.2 High density polyethylene

High density polyethylene is a linear structure thermoplastic with no or less degree of branching. In HDPE molecules are fit close together, results in stronger and rigid bonding than low-density polyethylene [10]. HDPE are odourless, non-toxic and have great chemical resistance. Some of the properties of HDPE are tabulated in table 3. HDPE is a tough and durable material with many performance properties that can be used in a range of applications. HDPE is mainly produced by two techniques
  
  - Slurry polymerization.
  - Gas phase polymerization.

| PARTICULARS               | VALUES                      |
|--------------------------|-----------------------------|
| Melting point            | 131 °C                      |
| Thermal coefficient of Expansion | 106 to 198 x 10^{-6} °C^{-1} |
| Density                  | 0.959 g/cm³                 |
| Tensile strength         | 22.1 to 31.0 MPa            |
| Percentage Elongation    | 10 to 1200%                 |
| Thermal Conductivity     | 0.48 W/m K                  |
| Opacity                  | Non transparent             |
| Melt flow rate           | 6.12 g/10 min               |

3.1.2.1 Applications of high-density polyethylene

- HDPE are used in food packaging and making bottles because it won’t leach into the content inside the package or bottles. Another main usage is blow moulding process applications.
- Due to the UV resistance it can be used in toys to resist discolouring effects.
- HDPE is used in chemical containers such as oil containers, cleaning products shown in figure 6, laundry products due to their resistance to chemicals [10].

![Figure 6. Laundry product containers from HDPE plastic [19].](image-url)
3.2 Polypropylene

Polypropylene is the second most widely used plastic in the world after polyethylene. Polypropylene is a tough and rigid type of thermoplastic and it is used in a variety of applications like polyethylene and having similar properties like polyethylene but hardness and heat resistance is much better when compared to polyethylene. Some of the properties of polypropylene are tabulated in Table 4. It is produced by chain-growth polymerization. Polypropylene retains its mechanical and chemical properties at elevated temperature. Some of the demerits are flammability, it has high flammability and poor UV resistance. Mechanical properties of recycled polypropylene based on its melt flow index and contaminants in it but these properties can be altered by adding additives to it when recycling [10]. Some of the common types of polypropylene are given below:

- Polypropylene homopolymer
- Polypropylene copolymer
- Expanded Polypropylene
- Polypropylene terpolymer

### Table 4: Properties of polypropylene [10].

| PARTICULARS                     | VALUES            |
|---------------------------------|-------------------|
| Melting point                   | 175°C             |
| Thermal coefficient of Expansion| 146 to 180 x 10⁻⁶ C⁻¹ |
| Density                         | 0.905 g/cm³       |
| Tensile strength                | 31.0 to 41.4 MPa  |
| Percentage Elongation           | 100% to 600%      |
| Thermal Conductivity            | 0.12 W/m K        |
| Melt flow index                 | 12 g/min          |

3.2.1 Applications of polypropylene:

- High strength and good surface finish enable to use for packaging applications. Some of the applications are straws, wrappers, bottle caps, bottles.
- Polypropylene is widely used in automobile parts such as battery cases, interiors, bumpers, doors etc. Some of the applications in automobile is shown figure 7.
- Polypropylene is used to make medicine bottles. Also PP is used in ropes and tapes due to their high strength [10].

![Figure 7. Applications of polypropylene in automobiles [20].](image)
3.3 Polystyrene
Polystyrene is a synthetic aromatic hydrocarbon polymer used in variety of applications. Polystyrene is transparent polymer hence it is mainly used in transparent containers like food containers and packaging that require to showcase the items inside. Polystyrene is also used as a foam material called as expanded polystyrene which is used for cushioning and safe handling of products [21]. Expanded polystyrene consists of 95% of air and it is also used in household applications. Some of the Properties of polystyrene are tabulated in table 5. Polystyrene is used in packaging materials for electronic devices, food items such as coffee cups, bowls, plates commonly referred as Styrofoam [22]. Nciri et.al [22] study the usage of waste expanded polystyrene as a modifier in road pavements. Author states that modified asphalt with waste expanded polystyrene is an alternative for conventional concrete asphalt in roadways.

Table 5: Properties of expanded polystyrene [22].

| PHYSICAL PROPERTIES       |               |
|---------------------------|---------------|
| Molecular weight          | 300,00 g/mol  |
| Density                   | 17 kg/m³      |
| Thermal conductivity      | 0.040 W/mK    |
| Flexural strength         | 24 N/cm³      |
| Compressive strength      | 10 N/cm³      |

| CHEMICAL COMPOSITION      |           |
|---------------------------|-----------|
| Carbon                    | 92.34%    |
| Hydrogen                  | 6.93%     |
| Nitrogen                  | 0.51%     |
| Oxygen                    | 0.22%     |

3.3.1 Applications of polystyrene
- Polystyrene is used in housing and parts for computers, television, electric panels, compact disc cases etc [10].
- Polystyrene is used for packaging of medicines due to their transparency. It can be used to showcase the medicines inside it.
- Polystyrene in the form of foam material used to prevent breaking of fragile materials in packaging [21].

3.4 Polyethylene Terephthalate
Polyethylene terephthalate is one of the thermoplastics that belongs to polyester type of polymers [10]. PET is one of the most recycled plastics among other polymers. It is also fourth most produced plastic after polyethylene, polypropylene, polyvinyl chloride. Properties of polyethylene terephthalate are tabulated in table 6. It is highly flexible and colourless and it may be rigid to semi rigid based on the process. PET is similar to polystyrene in transparency so it can also be used in transparent containers and packaging. Another main usage is that, PET can be used as a replacement of glass due to their shatter resistance. PET have low resistance to alkalis and strong bases but having high resistance to alcohols. PET bottles are filled with sand and clay and it can be used as an alternative for bricks to build walls and small buildings [18].
Table 6: Properties of polyethylene terephthalate [10].

| PARTICULARS               | VALUES                  |
|---------------------------|-------------------------|
| Melting point             | 265°C                   |
| Thermal coefficient of Expansion | 117 x 10^{-6} C^{-1} |
| Density                   | 1.35 g/cm³              |
| Tensile strength          | 0.8 N/mm²               |
| Percentage Elongation     | 30% to 300%             |
| Thermal Conductivity      | 0.15 W/m K              |

3.4.1 Applications of polyethylene Terephthalate
- Like most of the plastic PET also used in food packaging and bottles.
- PET has wide range of applications in textile industries due to its flexibility, light weight.
- Due to its electrical insulation properties PET is used in many household appliances such as electric panels, solar panels, automotive interiors.

4. Constructional wastes

4.1 Ceramic wastes
Ceramic products such as ceramic tiles, sanitary are most widely used products all around the world. Manufacturing or production of these products results in tons of waste that are simply accumulated in the surroundings. It is assessed that nearly 30% of daily production in the ceramic industry throw out the wastes. Ceramics are heat resistance, corrosion resistance, non-metallic, inorganic solids. It can also be used as a good insulation material in most of the applications.

There are two main categories of ceramics, they are
- Traditional ceramics
- Advanced ceramics

4.1.1 Traditional ceramics
- Traditional ceramics are mainly produced from clay and cement that may be heated at high temperature to form different shapes and sizes due to the requirement.
- Some of the examples are dishes, flowerpots, roof and tiles.

4.1.2 Advanced ceramics
- Advanced ceramics consists of carbides and oxides such as silicon carbide and aluminium oxide and many other materials.
- These ceramics are used to reach extreme temperature, to handle high stresses.
- Advanced ceramics enables more modern engineering applications for instance insulation rings in brakes, valve plate in common rail injection system, semiconductors.

4.1.3 Properties of ceramic
Some of the properties of ceramic are
- Hardness: Hardness of ceramics are mainly based on the components included. Typical hardness may reach 2000HV.
- Thermal conductivity: Ceramics can be used as an insulator against heat and electric current based on the composition of ceramics.
- High working temperature: Ceramics can be used at very high temperature from 1000°C to 1600°C.
- Melting point: Melting point of ceramics is around 2000°C.
- Weather resistance: ceramics are highly resistance to any kind of weather they can sustain high temperature as well as low temperature.
• Wear resistance: ceramics are extremely hard hence wear of ceramics are very low when compared to other materials.

Zhao et al. [13] conducted a research on using solid waste materials (SWM) in pavement engineering. SWM had good affinity with conventional pavement block materials. Recycled based aggregates contain concrete as well as a mix of concrete aggregates, bricks, gypsiums, glass, ceramics, these were produced from structure or building and destructive process. RCAs are mostly obtained from four sources. Reclaimed asphalt pavement- is recycled aged pavement milled or ripped from an available pavement during highway restructure or restoring. It must crush and cullender the Reclaimed asphalt pavement to receive target binder content as well as target gradation.

4.2 Quarry Dust
In quarries, granites are crushed into different sizes based on requirement. When crushing these granites and rocks into smaller sizes dust is generated as a by-product [3]. This quarry dust is not used in any processes involved in quarry activities hence it is formed as a waste and dumped at the surroundings of quarry.

4.2.1 Usage of Quarry Dust
Quarry dust can be used as a substitute of cement or sand in many construction materials. Using quarry dust as an alternative for cement in bricks, paver blocks and tiles leads to a cost-effective approach in constructions. Quarry dust also having required mechanical properties that are suitable for construction materials. Some of the properties of quarry dust are tabulated in table 7.

Table 7: Properties of quarry dust [8].

| PHYSICAL PROPERTIES | PARTICULARS     | VALUE        |
|---------------------|----------------|--------------|
| SPECIFIC GRAVITY    | 2.69           |              |
| PHYSICAL FORM       | Powder Form    |              |
| DENSITY             | 1630 kg/m3     |              |

| CHEMICAL PROPERTIES | COMPOSITION       | PERCENTAGE   |
|---------------------|-------------------|--------------|
| Silicon Dioxide (SiO₂) | 69.94%            |              |
| Aluminium Oxide (Al₂O₃) | 14.60%            |              |
| Ferric Oxide (Fe₂O₃)    | 2.16%             |              |
| Calcium Oxide (CaO)     | 2.23%             |              |
| Magnesium Oxide (MgO)   | 0.38%             |              |
| Manganese oxide (MnO)   | 0.07%             |              |

4.3 Fly ash
Fly ash is a pozzolanic material, can be used as an alternative for cement in paver blocks and tiles [9]. Form thermal power plants, huge amount of fly ash is disposed into landfills and surroundings of power plants every year. Fly ash mainly categorized into two types as per the standard ASTM C 618 one is ‘F’ fly ash and another one is ‘C’ fly ash. Some of the properties of fly ash are tabulated in table 8. Major differences between these two types are the percentages of silica, alumina, iron and calcium content in the composition [9].
Table 8: Properties of fly ash [8].

| PHYSICAL PROPERTIES          |                               |
|-------------------------------|-------------------------------|
| SPECIFIC GRAVITY              | 2.00 to 2.05                  |
| PHYSICAL FORM                 | Powder From                   |
| DENSITY                       | 1155 kg/m³                    |

| CHEMICAL PROPERTIES           |                               |
|-------------------------------|-------------------------------|
| Silicon Dioxide (SiO₂)        | 54.92%                        |
| Aluminium Oxide (Al₂O₃)       | 23.04%                        |
| Ferric Oxide (Fe₂O₃)          | 4.5 to 4.8%                   |
| Calcium Oxide (CaO)           | 3.84%                         |
| Magnesium Oxide (MgO)         | 2.82%                         |

5. Effect of various reinforcement on properties of paver block

Globally many researchers discuss the effects of reinforcements on mechanical and chemical properties of paver block and tiles. Alexander et al. [18] discusses the recycling of plastic waste in sand blocks. LDPE waste bonded sand blocks shows a compressive strength of 27 MPa and the results shows density and compressive strength increases with decrease of sand particle size [18]. The process of fabrication is shown in figure 8.

Effects of sand particle size on density of paver block shows that if the sand particle size is decreased by using sieved sand it helps to increase compressive strength of paver block and the below figure 9 shows that the compressive strength decreases with increases in sand particle size [18].

Ghuge et al. [21] study the effects of waste plastic in paver blocks and compares the effects of ordinary paver block and plastic reinforcement paver block. Author fabricate two different batches with different constituents and conduct compression test at an interval of 7 days and 28 days and results tabulated in table 9 shows that the compressive strength of both blocks is similar after a curing time of 28 days.
Figure 8. Fabrication of LDPE reinforced paver blocks [18].
Figure 9. (a) density vs sand particle size  (b) Compressive strength vs particle size [18].

Table 9: Compressive strength of plastic reinforced block [21].

| Block              | Cement (kg) | Quarry dust (kg) | 10mm coarse aggregate (kg) | Water (gm) | Waste plastic (gm) | Compressive strength after 7 days (N/mm²) | Compressive strength after 28 days (N/mm²) |
|--------------------|-------------|------------------|---------------------------|-------------|-------------------|------------------------------------------|------------------------------------------|
| Ordinary block     | 1.14        | 1.60             | 2.08                      | 440         | -                 | 11.96                                    | 19.54                                    |
| Plastic reinforced block | 1.14    | 1.60             | 2.08                      | 440         | 600               | 10.93                                    | 16.05                                    |

Agyeman et al. [2] investigates the effects of using waste plastic as a binder in paver blocks production. In this study authors discuss about the waste generation in Ghana which is a country in west Africa and how to recycle the plastic waste as a binder in paver blocks. Recycled plastic wastes from water sachets, polythene bags and wrappers are casted and moulded in a 200˟100˟100mm mould with cement and coarse aggregate and curing for 7 to 21 days is done as per ASTM C192/C192M - 16a standard [2]. The compressive strength of the plastic blocks is improved by aging for some days and blocks which having less amount of plastic and high amount of plastic shows similar compressive strength after 21 days. However, the concrete paver blocks show higher strength than plastic blocks having same mix ratio.

Bijivemula et al. [23] study the effects of used PET flakes and fly ash as a reinforcement in paver blocks. For a mixture of 1% NaOH, 38% water and 10% Ca (OH)₂, the outcomes were observed to be fulfilling the ASTM C 62/2013 55% reduction of CO₂ emissions. Any other way research was also be done in using the PET waste in different structural elements. The sodium silicate or sodium hydroxide solution mass ratio was fixed to be 2.5, mass ratio of foaming paste is 1:2 and sodium hydroxide solution exist 12 Molar concentration is used. Quarry dust were utilized as a replacement for making Alkali operated bricks and pavement blocks. Distinguish that the manufacturing of geopolymer bricks yields the same compressive strength of fired bricks. manufactured geopolymer Fly ash bricks by using cement as additive. As much increase in cement content, the flexure strength and compressive strength increased. The blocks density of construction blocks was established to be reduced with the increase in PET content. Water absorption of alkali activated blocks were within permissible limit for few mixes. However, increase in water absorption was found in the study by replacement by PET flake [23].
According to Santos et.al [6] ceramic tile polishing waste can be reused as partial replacement of sand and cement in concrete paver blocks. Author prepare the standard concrete blocks in the ratio of 1: 3: 0.6 of cement, sand and water and another batch with 35% cement or sand replaced with ceramic tile polishing waste. It’s productive in a 60% average reduction in slump of the concrete as reconciled to the control concrete, while the exchanging of cement by porcelain tile waste, finally in an outcome the slump reduction of up to 40% in relation to the control concrete.

Shanmugavalli et.al [3] conducted an experiment study on of plastic waste, quarry dust, coarse aggregate and ceramic waste for production of paver blocks. Author state that these materials are easily available and cost effective. Various batches with different ratios are made by varying the ratio of plastic waste, quarry dust and aggregates. The ratios of different batches and their results are tabulated in table 10 shows that the batch having gravel in it shows high compressive strength compared to others that doesn’t have gravel.

**Table 10: Mix ratio of different batches for paver block [3].**

| Batch | Plastic waste | Quarry dust | Aggregate | Gravel | Compressive Strength N/MM² |
|-------|---------------|-------------|-----------|--------|---------------------------|
| Batch 1 | 1             | 0.75        | 0.75      | 0      | 9.33                      |
| Batch 2 | 1             | 1.5         | 0.75      | 0      | 10.40                     |
| Batch 3 | 1             | 1.5         | 0.75      | 2      | 13.30                     |

Sahu et.al [9] discuss about the utilization of fly ash in paver block instead of using cement and sand. Manufacture of fly ash paver blocks and fly ash is done by IS 15658 specifications where the fly ash amount varies from 0% to 40% instead of sand in one batch and cement in another batch. Paver blocks are manufactured in different shapes and thicknesses and followed by curing. Compression test, flexural strength test and moisture absorption test of these paver blocks are done at 7 and 28 days. Results shows that paver blocks and tiles having 30% of fly ash possess required compressive strength and flexural strength and may be used in medium traffic roads. Water absorption of these paver blocks and tiles are increases with increase of fly ash. Blocks with 20 to 30% of fly ash having a water absorption capacity within the limit.

Nivetha et.al [24] study the effects of quarry dust, fly ash and PET plastic in paver blocks. Quarry dust with properties tabulated in table 11 is sieved before mixture preparation by IS: 4.75 sieve.

**Table 11: Properties of quarry dust [24].**

| Property    | Value       |
|-------------|-------------|
| Specific gravity | 2.57        |
| Fineness modulus   | 2.41        |
| Density        | 1.85 gm/cc  |
| Void ratio    | 0.42        |

According to standard IS: 516: 1964, paver blocks of size 70.6 x 70.6 x 70.6 mm are casted with different ratios of quarry dust, fly ash and PET plastic [24]. Various proportions fabricated are tabulated in table 12. Compression test is conducted on these three batches results are graphed in figure 10 and found out that the batch PPB-2 shows higher strength than other batches. PPB-2 have a compressive strength above 50N/mm².
Table 12: Proportion of different batches [24].

| Proportion Name | PET  | Fly Ash | Quarry dust |
|-----------------|------|---------|-------------|
| PPB-1           | 25%  | 25%     | 50%         |
| PPB-2           | 30%  | 25%     | 45%         |
| PPB-3           | 35%  | 25%     | 40%         |

Figure 10. Compression test on paver blocks with different ratios of quarry dust, fly ash, PET [24].

Subramani et al. [25] investigates the properties of fly ash based bricks. Bricks are casted using mould of size 190mm x 90mm x 90mm with different ratios of fly ash, sand of 1: 1.6, 1: 1.8, 1: 2. Solution of water and NaOH is used as a binder in that mixture. Properties and chemical composition of fly ash is given in table 13.

Table 13: Chemical composition of fly ash [25].

| COMPONENTS          | PERCENTAGE BY WEIGHT |
|---------------------|----------------------|
| Silica as (SiO₂)    | 61.65%               |
| Iron as (Fe₂O₃)     | 9.56%                |
| Alumina as (Al₂O₃)  | 25.86%               |
| Calcium as (CaO)    | 13.78%               |
| Magnesium as (MgO)  | 2.33%                |
| Titanium as (TiO₂)  | 1.09%                |
| Sodium as (Na₂O)    | 1.46%                |
| Potassium as (K₂O)  | 1.57%                |
| Sulphate as SO₃     | 0.62%                |

Various tests such as compression test, water absorption test and acid test are conducted on the manufactured bricks. Results tabulated in table 14 shows that the block with ratio 1: 2 have high compression strength and it also absorbs more water than others.
Table 14: Compression test and water absorption test [25].

| Mix Composition | Water absorption % | Compressive strength N/mm² |
|-----------------|--------------------|---------------------------|
| 1: 1.6          | 15.78              | 6.5                       |
| 1: 1.8          | 5.151              | 8.73                      |
| 1: 2            | 5.356              | 11.28                     |

Mwalimu et.al [26] discuss the effects of using rice husks shown in figure 11 as coarse aggregates in concrete paving blocks. Samples are prepared at a ratio of 1: 0.5: 1 of cement, sand, coarse aggregate.

![Rice husk](image)

**Figure 11.** Rice husk.

Author prepared seven different blocks with different percentage of rice husk replacing coarse aggregates and compare the results with standard C35 block with 0% rice husk. Seven different proportions are tabulated in table 15.

### Table 15: composition of rice husk reinforced blocks

| Description        | Cement | Rice Husks | Fine Aggregates | Coarse Aggregates |
|--------------------|--------|------------|-----------------|-------------------|
| C35                | 1      | 0          | 0.5             | 1                 |
| 5% Replacement     | 1      | 0.05       | 0.5             | 0.95              |
| 10% Replacement    | 1      | 0.10       | 0.5             | 0.90              |
| 15% Replacement    | 1      | 0.15       | 0.5             | 0.85              |
| 25% Replacement    | 1      | 0.25       | 0.5             | 0.75              |
| 50% Replacement    | 1      | 0.50       | 0.5             | 0.50              |
| 75% Replacement    | 1      | 0.75       | 0.5             | 0.25              |
| 100% Replacement   | 1      | 1.00       | 0.5             | 0.00              |
Compression test, tensile test and water absorption test are conducted on these blocks with different curing time of 7, 14, 21, 28 days and the results are shown in figure 12. Compressive strength of blocks is shown in fig at different curing times.

![Figure 12. Compressive strength tests of rice husk reinforced blocks [26].](image)

Comparison of compressive strength of these seven paver blocks shows a decline in compressive strength when increase in rice husk percentage. Result graph is shown in figure 13. Block with 5% of rice husk aggregate shows high compressive strength that other blocks and it can be used in high traffic roads [26].

![Figure 13. Comparison of compression strength and tensile strength [26].](image)
Ridwan et al. [27] uses coconut shell as an aggregate in concrete paver blocks. Author conducted compression and water absorption test on block consists of different percentages of rice husk (0%, 20%, 25%, 30%). Compression test is conducted on these blocks after a curing time of 28 days and the results are tabulated in table 16.

| Percentage of Coconut Shell and Powder | Compression Strength (MPa) | Water Absorption (%) |
|----------------------------------------|-----------------------------|----------------------|
| 0                                      | 18.5                        | 0.22                 |
| 20                                     | 11.4                        | 0.16                 |
| 25                                     | 7.6                         | 0.14                 |
| 30                                     | 6.7                         | 0.12                 |

Results shows that block with 20% of coconut shell aggregate have a compression strength of 11.4 MPa and the optimum percentage of coconut shell aggregate can be used in concrete paver blocks is 12%.

6. Conclusion
In this work, recycling of solid wastes is discussed and the reusing various wastes as a reinforcement in paver blocks and its effects on mechanical properties are investigated. The conclusion obtained are
i) Plastic waste is an innovative material that can be used in construction purposes due to the less time for manufacturing, reduction of cost and also an effective way of using resources.
ii) Paver blocks with reinforcements such as quarry dust, fly ash, plastic waste, coconut shell aggregate can be used in light traffic roads like parking lots, platforms, footpaths etc.
iii) Results shows that density and compressive strength of paver blocks shows an increase with decrease in sand particle size.
iv) Compressive strength and tensile strength of paver blocks by reinforcements shows an increase with increase of curing time. Paver blocks shows a considerable change in compressive strength between curing time of 7 days and 28 days.

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