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Mechanical Properties of Polyethylene-Sand Blocks Produced from Recycled Plastic Bags

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Abstracts-Plastic polythene bags are non-biodegradable waste, generating on daily basis creating environmental pollution and adversely affecting life style of human beings. It is a common practice worldwide to use the waste plastic bags as a construction material. The basic aim of the current study is the use of molten polythene bags as binder for dry sand, to produce construction material like blocks or bricks, and to find out the mechanical properties of composite material. In this paper the compressive strength, stiffness, ductility, Young's modulus, thermal stability and impermeability has been measured and reported. It has been discovered that molten polyethylene based plastic waste may be used as a binding material. The building blocks produced were found to be 6 times ductile than typical brick masonry and 1.3 times stronger in compression compared to brick. Furthermore, the product obtained is environmentally friendly and feasible to manufacture.

Index Terms: Polyethylene Plastic Bags, Waste, Pollution, Construction material, Binding Material, Brick Masonry.

1. INTRODUCTION

IT is a natural fact that every nation wants to be develop their countries without consideration of the environmental degradation and natural environment. Globally people for their daily needs use plastic polythene bags because of its ease, cheaper and convenience but, which are hazardous to environment causing land pollution. It is said that people began the use of plastic in 1970s, and become popular in the last of 20th century [6] (Moharam & Maqtari 2014). Up till now no any accurate statistical estimate has made about 500Bn number of plastic bags used worldwide [6] (Moharam & Maqtari 2014).

Pakistan generates about 48 million tons of solid waste a year, which has been increasing more than 2 percent annually. Like other developing countries Pakistan lakes waste management infrastructure, creating serious environmental problems. Most municipal waste is either burned, dumped or buried on vacant lots, threatening the health and welfare of the general population [7] (Naseer, A. 2009)

These discarded plastic bags are found their way anywhere to Oceans, River, streams and canals thus causing a serious threat to aquatic life and effects the aquatic growth due to the hazardous and toxic chemicals. Beside it these discarded waste plastic bags cause water pollution and destroy the natural beauty of water. These waste plastic bags have major contribution in the chocking of sewer and drainage line of community which may causes flooding in the extreme cases [6] (Moharam & Maqtari 2014). Automatically the water for irrigation from water resources contain these waste polythene bags causes land pollution in the fields and retard the growth of crops directly effects the crops yields. It is a very serious alarming for countries which has an ago-based economy.

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The plastic bags are very sensitive to degradation by natural decomposition, takes up to 1000 years. The feasible solution up-till now is dumping these wastes in landfill site. Dumping site require land acquisition and require huge of amount of money, huge dumping area in hectares are required to dumped these trillion amounts of the waste plastic directly effects on the economy of a nations.

Dumping Sites in hectares are used to dump these trillion amounts of the waste plastic bags. It is a well-known fact that landfilling has land and environmental effects. Landfilling converts the nearby fertile agricultural land in to infertile land. The direct burning of waste plastic is a crime and banded to be burned in open atmosphere. The decomposition of waste plastic bags continuously emits methane gas and carbon dioxide and other constituent in low concentration such as ammonia, and other non-volatile organic compounds. These gases cause ozone depletion, acid rain acidification, global warming and other social effects on human health.

Polythene bags are used in coating of Recycled Coarse aggregates (RCA) Concrete by melting (Melting point of plastic 200-250) in solar oven up to 315-degree C [8]. (Rehman & Adil 2009)

Structurally individual bricks play key role in the resisting of vertical compressive load. Mostly if the strength of material is not sufficient than the brick may breaks locally or globally and leads to failure in crushing strength. This type of failure is more common in unreinforced brick wall and is known as rocking failure and crushing of bricks. (Naseer, A. 2009).

Many kinds of polyethylene can be made from ethylene. Plastic bags typically are made from one of three basic types: high-density polyethylene (HDPE), low-density polyethylene (LDPE), or linear low-density polyethylene (LLDPE). Those thick, glossy shopping bags from the mall are LLDPE, while grocery bags are HDPE, and garment bags from the dry cleaner are LDPE. The major difference between these three materials is the degree of branching of the polymer chain. HDPE and LLDPE are composed of linear, unbranched chains, while LDPE chains are branched. Branching can influence a number of physical properties including tensile strength and crystallinity. The more branched a molecule is, the lower is its tensile strength and crystallinity. That's why garment bags from the dry cleaner are so weak and flimsy. They are made from highly branched LDPE.[1] (Saadat Ali 2019)

Ghernouti and Bahia incorporate plastic bag waste as a fine aggregate in Mortar and study the mechanical properties and durability of mortar in comparison to control mortar. They concluded that incorporating plastic bag wastes in mortar reduce the compressive strength of the mortar by 18-20% of the reference mortar. The replacement of sand by plastic bag wastes improve mortar behavior in acidic medium and its sensitivity to cracking [3]. (Ghernouti & Rabehi, 2012)

Glaoui, B. (2015) used plastic bags (PVC) as a construction material as an aggregate in concrete and concluded that the use of these materials in concrete reduces its compressive strength and increase its tensile capacity up to ambient limit [4]. (Da Silva et.al 2014.) Studied the behavior of mortar by use of PVC as an aggregate in three different percentages and concluded that using PVC aggregate leads to worse performance in some properties. However, the modified mortars show a significant improvement in comparison to control mortar [2].

2. EXPERIMENTAL PROGRAM

2.1. MATERIALS

The material used for this research are Polythene bags (Plastic waste), Brick, and Mortar. Their properties and their sources are discussed in detail below.

2.2. PLASTIC

The source of plastic used in the case study is collected waste polythene plastic bags. These plastics are separated on the basis of its color and type and washed off to remove other impurities. Waste plastic are shredded in to small pieces through a mechanical shredder. Waste plastic used are in the form of small pieces in order to have a maximum contact area and effective melting. The process of extraction of Plastic to be used as construction material is shown in Fig.1 below.

Figure 1 Process of Plastic bags conversion to usable Plastic material

2.1.1. CHEMICAL NATURE OF PLASTIC

Plastics are composed of polymers-large molecules consisting of repeating units (monomers). In the case of plastic bags, the repeating units are ethylene or ethane. When ethylene molecules are polymerized to form polyethylene, they form long chains of carbon atoms in which each carbon also is bonded to two hydrogen atoms.

2.1.2. SAND

Sand is basic constituent's material for the current study i.e. bricks, tiles and blocks. The source of Sand used in the study is Local River located at Peshawar. Sand is dry and non-clayey sand. The gradation test of the sand is performed and shows that the sand is a coarse sand with F.M = 3.1

2.1.2.1. SAND GRADATION ASTM- C136

The apparatus consist of six different types of sieves i.e. #4, #8. #16, #30, #50 and #100 seive. The smallest sieve nmuber is at the top and the others are arranged in ascending order. The sample weight is 500gm. The whole appratus is shaked for 15 minutes with sieve shaker.

2.1.2.2. SPECIMENS AND TESTING

The waste plastic is collected from various locally collected informal waste collection sector. The plastic bags are then washed up to remove impurities. The plastic bags are dried and shredded in to small grains like particles (Size 3mm to 4mm) by using shredder machine which is available in industrial state Hayatabad Pakistan,

The shredded plastic pieces are then melted in the closed chamber (pressure cooker) with required amount of thermal heating for the 30minutes. Coarse dry sand is taken and warmed with sun drying heating before mixing with plastic paste. After the complete melting of plastic, warm sand is manually mixed with plastic paste residue for 2 minutes. After proper mixing 5cm x 5cm x 5cm cube molds are filled with plastic paste in three equal layers and tamped with tamping road. Once molds are filled after cooling of cube through in water tank the specimens are de-molded and keep for 24 hours at room temperature for further cooling and hardening. The cube has smooth surface finish surface with straight edges. Compressive strength test is performed using universal testing machine.

The following plastic to sand ratios is selected ant tested for the compressive strength in order to confirm an optimum ratio and maximum compressive strength and to further evaluate the desire engineering parameters based on optimum ratio.

- 10% Plastic-90% Sand
- 20% Plastic-80% Sand
- 30% Palstic-70% Sand
- 40% Plastic-60% Sand
- 50% Plastic-50% Sand

2.1.2.3. COMPRESSIVE TEST:

The compression test is conducted on specimens of 5cm x 5cm x 5cm cube of using different plastic to sand ratio. For each Mix ratio three cubes are prepared and tested to get an acceptable average result. Compressive strength test is performed using universal testing machine

2.1.2.4. WATER ABSORPTION TEST:

ASTM C20-00 (2015) test used to measure specimen internal porosity, to evaluate quality and comparison of material. Test are conducted on three cubes (5cm x 5cm x 5cm) Specimens are weighed in dry condition and put it immersed in fresh water for 24 hours. After 24 hours specimens are taken out from water and wipe out with dry cloth. Cubes are then weighed in wet condition. The difference between weights of cubes in wet and dry condition is the water absorbed by the specimens. The moisture absorption is then expressed in percentage of water absorption. The less water absorbed by block the greater is its quality. Good quality block doesn't absorb more than 20% water of its own weight. The moisture absorption value for the plastic sand blocks are found to be 0.66% using the moisture content equation.

2.1.3. BRICK & CEMENT SAND MORTAR:

Brick &Sand cement cube (5cm x 5cm x 5cm) are tested by UTM machine according to standard method of testing. Steel plates are placed on the top surface of the specimen, transducer is connected to the steel plate. The deformation as a result of downward compression through UTM is measured by transducer. Load and deformation data are recorded by digital data logger. The following stress strain graph is obtaining by plotting the experimental data. Ultimate strength, ductility factor and modulus of elasticity presented in the following table. These graphs show the behavior of bricks and Sand cubes under axial compression. In Graphs strain is taken on x-axis while stress is taken along y-axis. The engineering parameter are calculated from the Fig. 2 & 3 and presented in the Table 1 & 2 Shown Below. Bricks graphical behavior under loading are presented with the recorded data.

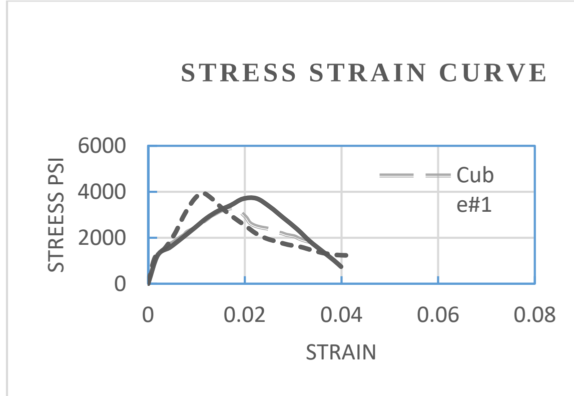

Figure 2 Stress Strain Curve for Cement Sand Block

TABLE 1 PARAMETERS FOR CEMENT SAND BLOCK

Sample	Strength (Psi)	Mod of Elasticity (KSI)	Ductility
Cube 1	3416	1000	16
Cube 2	3940	4000	11.5
Cube 3	3710	1000	22
Average	**3689**	**2000**	**17**

Bricks graphical behavior under loading are presented with the recorded data.

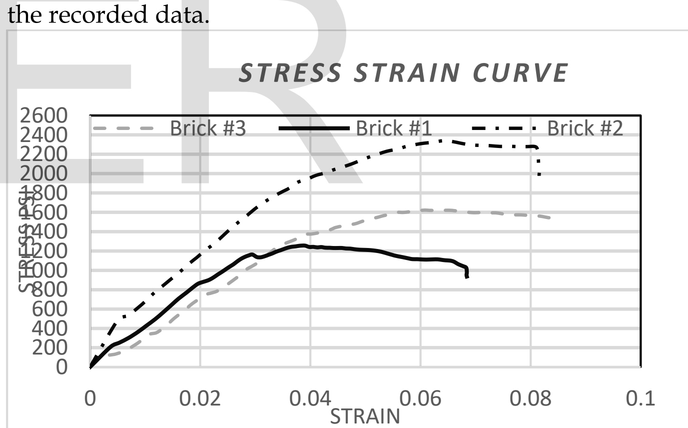

Figure 3 Stress Strain Curve for Brick Behavior

TABLE 2 PARAMETERS FOR BRICK BEHAVIOR

Sample	Strength (Psi)	Mod of Elasticity (MPA)	Ductility
Brick 1	1254	384	10
Brick 2	2340	327	13
Brick 3	1620	338	19
Average	**1738**	**350**	**14**

3. RESULTS AND DISCUSSION

Table 3 and Fig. 4 show the results for compression test of different plastic to sand composite blocks.

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TABLE 3 COMPRESSIVE STRENGTH OF PLASTIC- SAND COMPOSITE BLOCKS

Items	***Percentage Proportions***	***Compression***
	Plastic- Sand	*(Psi)*
1	10% -90%	946
2	20% -80%	1983
3	30% -70%	2315
4	40% -60%	2516
5	50% -50%	1835

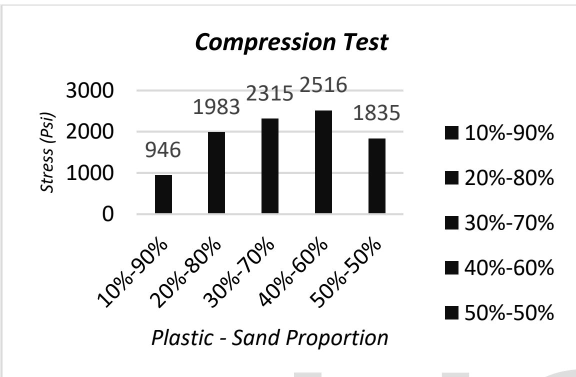

Figure 4 Compressive strength relation with plastic-sand percentage

The results show that with the increasing the amount of plastic percentage the compressive strength is also increasing up to 40% of plastic by weight. For 50% plastic – Sand Specimen the compressive strength is decreased due to the too much plastic makes the specimen a spongy type material. It compresses with the application of load and don't resist it as it is for the lower plastic percentages. A1 class brick has an average compressive strength of 1800 Psi. The 20% plastic to 80% sand by weight have same results as A1 Class Brick. Hence for a strength more than A1 class bricks and a good quality blocks 30% plastic to 70% Sand have tremendous output.

3.1. ENGINEERING PARAMETERS:

Some of the mechanical parameters are under our observation that are Compressive strength, Young modulus and ductility are experimentally determined using UTM machine and data logger attached with strain gauges and the following results were achieved presented in table below. Tale shows comparison between typical bricks used in construction with the Composite blocks (Waste polythene bags with sand blocks). Table data is obtain based on the plotting of sample recorded data. Comparison of different properties of Brick, Mortar and Plastic-sand Cube samples under external load are shown in Table 4, 5 & 6. Moreover, stress strain curve for various percentages of plastic-sand composition in cubes are shown in Fig. 5 & 6 below.

TABLE 4 COMPRESSIVE STRENGTH COMPARISON OF BRICK, MORTAR CUBES AND COMPOSITE PLASTIC-SAND CUBES

Item	**Comp Sth (Psi)**	**Comp Sth (Psi)**	**Comp Sth (Psi)**	**Avg. Comp.Sth (Psi)**
Bricks				
Sample	B1	B2	B3	
	1254	2340	1620	1738
Mortar Cubes				
Sample	C1	C2	C3	
	3416	3940	3710	3689
Composite Plastics-Sand Cubes				
Sample	PS1	PS2	PS3	
	1983	2315	2516	2271

TABLE 5 ELASTIC MODULUS COMPARISON OF BRICK, MORTAR CUBES AND COMPOSITE PLASTIC-SAND CUBES

Item	**Elasticity (Psi)**	**Elasticity (Psi)**	**Elasticity (Psi)**	**Avg Elasticity (Psi)**
Bricks				
Sample	B1	B2	B3	
	55680	47415	49010	50701
Motor Cubes				
Sample	C1	C2	C3	
	1000	2000	1000	2000
Composite Plastics-Sand Cubes				
Sample	PS1	PS2	PS3	
	108746	80320	90415	93160

TABLE 6 DUCTILITY COMPARISON OF BRICK, MORTAR CUBES AND COMPOSITE PLASTIC-SAND CUBES

Item	**Elasticit y (Psi)**	**Elasticity (Psi)**	**Elasticity (Psi)**	**Avg. Elasticity (Psi)**
Bricks				
Sample	B1	B2	B3	
	10	13	19	14
Motor Cubes				
Sample	C1	C2	C3	
	16	11	22	19
Composite Plastics-Sand Cubes				
Sample	PS1	PS2	PS3	
	89.8	90	90.1	90

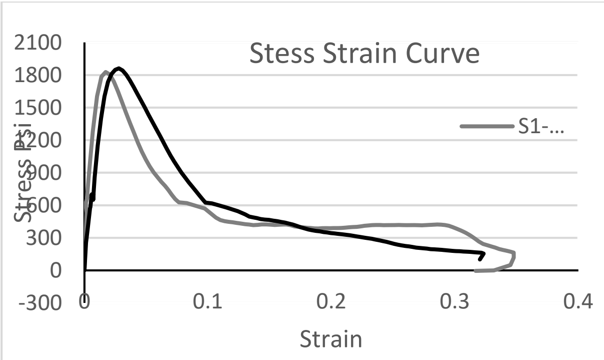

Figure 5 Stress Stain Curve for 20%-80% of Plastic-sand Cubes

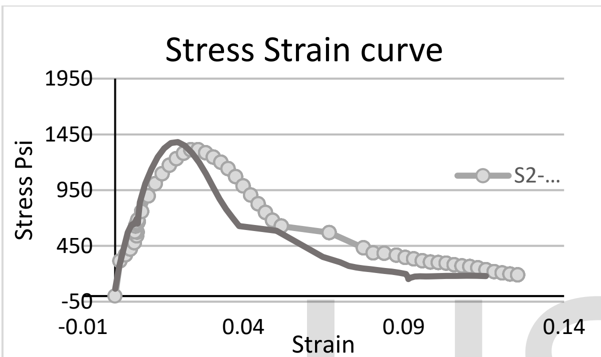

Figure 6 Stress Stain Curve for 30%-70% of Plastic-sand cubes

Plastic sand blocks are loaded with Uni-axial compression machine (UTM). Transducers are attached to measure vertical deformation. Specimens sample are of 2”x2”2” cube with 30% -70% plastic to sand by weight. Test results are displayed in Fig 4. The graph shows stress to strain relationship. Slope of the graphs shows Young modulus. The ultimate strength is 1700 Psi which is higher than A1 Class brick.

Moisture absorption value is determining according to standard test method. The absorption value of sand plastic composites blocks is 0.66%. The less water absorbed by block the greater its quality and have high resilience to the moisture induced problem to the buildings. Good quality block doesn’t absorb more than 20% water of its own weight.

4. CONCLUSIONS

The study concluded that bricks, tiles can be replaced with use of waste low hydro carbon polythene (plastic bags) with sand as a binding material.it will reduce the current plastic waste amount in community and describe an appropriate way of plastic recycling to construction industry. Experimentally it is proved that the ultimate strength and ductility is higher than the typical bricks and tike. The composite material has high water repellent property. The composite materials bricks have an alternate for bricks in term of the waste production to the atmosphere during manufacturing. In Case of converting the composite material in to Wall Panel it would provide an ease in the construction and increase the rate of construction by introducing a mechanical bond among blocks.

The individual mechanical strength & Ductility are experimentally checked and graphs are plotted. By the combination of bricks with motor form the masonry panels. The wall is in integral in nature but the introduction of bond makes the masonry panels overall a weaker than its individual strength and properties.

5. RECOMMENDATION:

Form the current Study it is recommended to determine that conversion of melting of shredded plastic bags by sun melting oven instead of thermal melting. During the melting process of plastic bags low hydrocarbon gases are produced. Determination of techniques to collect the evaporated hydrocarbon gases during the melting of plastics. Composite bricks walls are useful with the evaluation of interlocking strength of bricks walls. The cost comparison analysis of typical brick with the composite sand block units on industrial scale.

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