AN EXPERIMENTAL STUDY ON PRODUCTION OF BRICK BY USING A MIXTURE OF WASTE PLASTIC AND SAND IN ETHIOPIA

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Abstract: *Plastics are the most multipurpose man made materials in the world and generally used as medicine package, liquid container, water bottles, pipes and roof cladding etc. Plastic has a disastrous impact on our environment because of its non-degradable rather very slow nature of degradation. It is a well-known fact that plastic takes almost 400 years of time to decompose completely. Improper disposal of plastic has a negative effect on the marine life, ground water and on our environment. In Ethiopia out of total 83 plastic bottled water factories only 4 factories recycle the plastic bottle and remaining plastic bottles does not get recycled and disposed safely which is a cause of concern from environment perspective. So the present research work has been conducted to use waste plastic in the construction activities in form of producing bricks which would help minimizing the negative effects of waste plastics in our environment along with producing cost effective alternative engineering masonry plastic bricks. Experimental tests were conducted by casting several test specimens of bricks of size 25 cm x 12 cm x 6 cm with different plastic to sand ratios such as 20:80, 25:75, 30:70, 35:65, 40:60 and 45:55. The brick specimens were tested for their physical properties according to ASTM specifications. The test results showed that the specimen with 20:80 percentage ratios has fewer bonds between plastic and sand because of which it does not give a proper rectangular shape of plastic bricks while 50:50 plastic to sand ratio has not been mixed well. The compressive strength and water absorption test results indicated that bricks made with 35% of plastic and 65% sand gives higher compressive strength and lower water absorption.*

IndexTerms Waste plastic, brick, sand.

I. INTRODUCTION

Brick is commonly produced as a rectangular block composed of inorganic, nonmetallic substances of mineral origin and hardened by heat or chemical action [1]. The conspicuous importance of plastics pollution is due to its inexpensive and durable nature. In addition to these plastics is extensively used due to ever their characteristics like versatility, lightness, hardness, chemical resistance etc. In Ethiopia the consumption as well as disposal of waste plastics is rapidly increasing day to day which affected living organism. Now days in Ethiopia raw materials required by the local plastic products manufacturing sub sector plastic resins are entirely imported. During the period 2009–2011, the local plastic manufacturing sub sector has imported on average 67,235 tons of various type plastic polymers of which the largest share (40.58%) is accounted by polyethylene, profile on production of recycled plastic waste.Today it is unattainable for any vital sector to work powerfully without usage of plastic starting from agriculture to industries. Thus we cannot exclude the use of plastic. So recycling of plastic should be the better option. [2]. Presently waste plastics are effectively converted into useful permanent structural and non-structural materials [3]. [4]The aim of this study was to examine the production of bricks from waste plastic by using it as a binding material which is used to solve waste plastic problem emphasized in developing countries this time by polluting environment because urbanization. Knowing engineering properties of this waste plastic material as alternative binding material to make brick and improve the strength and durability of the investigated. In addition to that this experimental work used to reduce environmental pollution comes from waste plastic and compare the new plastic brick with that of convenient one based on strength and durability. Generally This experimental investigation inspect the effects of 20:80, 25:75, 30:70, 35:65, 40:60 and 45:55 of worn waste plastics and sand ratios on bricks. Finally this work tries to produce purposeful plastic bricks which is better in terms of compressive strength and temperature resistant along with lower water absorption which may replace the standard clay bricks

II. Materials and method

2.1 Materials

Waste plastic bottles (PET (Polyethylene terephthalate) or rHDPE (Recycled High Density Polyethylene)) (HDPE which, now day's useful and valuable polyethylene plastic as civil engineering materials. HDPE is relatively stress-free to recycle and is also the most recycled type of plastic. HDPE has slight branching, giving it tougher intermolecular forces and tensile strength than LDPE (low density polyethylene)), River sand (It is a naturally occurring granular material which is composed of mineral particles and the most abundant widely used in concrete structural work as a raw material. For this experimental work the properties of Yirgalem sand properties were studied and have specific gravity of 2.3 absorption of sand were 1.04%.), Plastic bottle (Plastic bottles are used as an important element, so we have gone through every property of the PETE (Polyethylene terephthalate Ethylene) bottles so as to ensure a stable structure. Polyethylene Terephthalate Ethylene (PETE) bottles is thermoplastic materials. This type of plastic are polymers

and with or without cross linking and branching, and they soften on the application of heat, with or without pressure and require cooling to be set to a shape)

Physical Properties of PET and Sand Materials

Table 1: Physical properties of PET

Melting point	260◦C
Long Term Service Temperature	115◦C-170◦C
Specific Gravity	1.3- 1.4
Absorption Of Water	0.07-0.1%

Table 2**:** Physical properties of Sand

yirgalem river sand were used for this experimental work	
moisture content	2.04%
specific gravity	2.34
absorption of water	1.04%

2.2 Method

For this experimental research, river sand and waste plastics have been used to prepare the bricks and six trial composition plastic bricks have been developed. The mechanical properties of plastic bricks have been examined and compared with that of burned clay bricks. The mixtures done with trial mix and the compressive strength value and durability test of plastic brick compared with the standard Alemgena clay brick factory production. The mortar mix from the mixture bowl was then placed into a 252 × 122 × 602 mm metal sheet mould in five equal layers. Each layer was then manually compacted using a steel plate. The mold was then slightly overfilled with the mixtures. Again, the mixtures in the mold were placed and compaction made manually. The specimens were finally removed from the mold. Once the bricks were made, they were wrapped with plastic and kept in the lab for 24 hours before starting to test.

The following are steps followed during the experiment time.

1. Collect the raw PET waste plastic bottles from the disposed environment.
2. Remove dust from collected plastic bottles and rag to make it fine.
3. Prepare required amount of, river sand, and water.
4. Sieve the sand to remove dust particles as well as large particles from the sand.
5. Shredded plastic melt the plastic up to become liquid may become liquid form.
6. Mix properly sand with melted plastic.
7. Mold the mixture uses the extruder to give shape of brick.
8. Provide for mechanical test

III.Results and discussion

In this study, recycled plastic bottle have been introduced in crushed and as molten liquid form. The result in this study suggests the opportunity for converting plastic waste into an economically feasible product in the form of production bricks. The test was begin with 50:50 percent ratio of plastic and sand or using equal proportion of sand and plastic make a segregation between them due to plastic was less denser than sand and it is departs from it. While 20% of plastics and 80% of sand have no workable bondage between sand and plastics since binding materials waste plastics less than sand.

3.1 Absorption Test Result

Absorption test results according to ASTM C67 section 8.3.2.1 absorption test result calculation is done as follows.

$$\%\mathrm{A} = \frac{W2 - W1}{\mathrm{W1}} \times 100$$

Absorption test results according to ASTM C67 section 8.3.2.1 absorption test result calculation is done as follows.

(E 1,2,3,4,5=specimen symbol for absorption test)

$$\%A = \frac{\mathrm{E1} + \mathrm{E2} + \mathrm{E3} + \mathrm{E4} + \mathrm{E5}}{5}$$

$$\%\mathrm{A} = \frac{13.59\% + 15.14\% + 15.38\% + 14.59\% + 13.97\%}{5} = 14.564\%$$

In this test, bricks are measured in dry condition and let them wrapped up in fresh water for 24 hours. After 24 hours of soak, those are taken out from water and clean out with cloth. Then, brick is measured in saturated condition. The difference between mass is the water absorbed by brick. The percentage of water absorption is then determined. The smaller amount of water absorbed by brick the greater its quality. Quality brick doesn't absorb more than 20% water of its own weight. So the result showed that average of five bricks water absorption is 14.564% which is less than 20% of absorption of water of weight of bricks according to ASTM standard. According to British standard the absorption of good quality of bricks should have less than 7% of dry weight of bricks so this result shows has less quality [5]

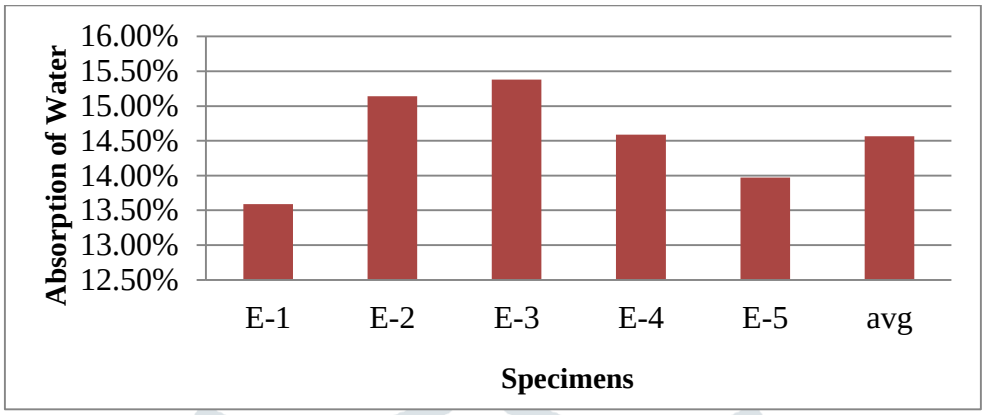

Figure 1: Clay brick absorption in percent

The absorption test averages of five specimens are as follows %A of each five specimens

Absorption Test Results

$$\%A = \frac{W1 - W2}{W1} \times 100$$

Average of five bricks are summations of absorptions of water in percent those five individual bricks divided by five. (TPB=Trial Plastic Brick)

$$\%A = \frac{TPB21 + TPB22 + TPB23 + TPB24 + TPB25}{5}$$

$$\%A = \frac{7.63\% + 3.42\% + 7.77\% + 4.68\% + 4\%}{5} = 5.327\%$$

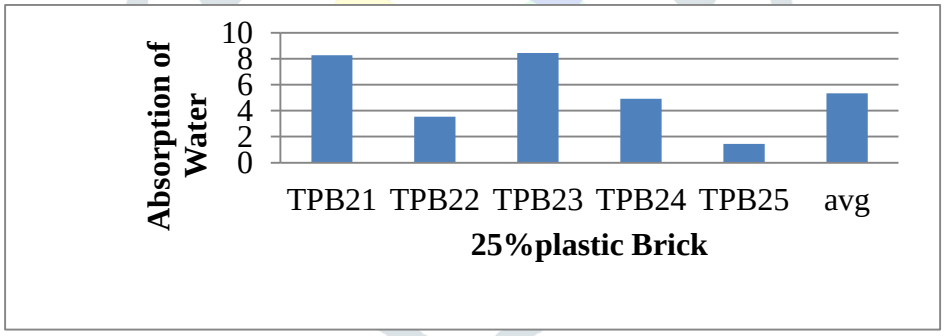

Figure 2:.Absorption of Water 25% of PETE Plastics

$$\%A = \frac{W1 - W}{W1} \times 100$$

$$\%A = \frac{TPB31 + TPB32 + TPB33 + TPB34 + TPB35}{5}$$

$$\%A = \frac{7.168459\% + 8.098592\% + 6.15942\% + 0.940439\% + 0.877193\%}{5} = 4.6488\%$$

$$\%A = \frac{W1 - W2}{W1} \times 100$$

$$\%A = \frac{TPB41 + TPB42 + TPB43 + TPB544 + TPB45}{5}$$

$$\%A = \frac{1.572327\% + 1.298701\%\% + 1.497006\% + 1.19403\% + 1.470588\%}{5} = 1.351805\%$$

Absorptions of water for this test also attain ASTM C936 recommended based 5% of dry weight of specimens [6].

$$\%A = \frac{W1 - W2}{W1} \times 100$$

$$\%A = \frac{TPB51 + TPB52 + TPB53 + TPB54 + TPB55}{5}$$

$$\%A = \frac{0.917\% + 0.633\%\% + 0.935\% + 0.929\% + 0.585\%}{5}$$
$$=0.860799\%$$

$$\%A = \frac{TPB61 + TPB62 + TPB63 + TPB64 + TPB65}{5}$$
$$\%A = \frac{1.95\% + 3.215\%\% + 1.558\% + 0.923077\% + 0.90909\%}{5} = 1.7102$$

The results calculated above are summarized as shown in the table below.

Table 3: Average of Five Bricks Absorption Test

Specimens	TPB2	TPB3	TPB4	TPB5	TPB6
Average absorption of water	5.33%	4.65%	1.35%	0.86%	1.71%

3.2 Compressive Strength (CS) Result for Clay Bricks as Well as for Different Plastic Brick Ratios

Compressive Strength Test Result for Burned Clay Bricks (BC)

$$CS = \frac{BC - 1 + BC - 2 + BC - 3 + BC - 4 + BC - 5}{5}$$
$$CS = \frac{20.5\% + 22.32\%\% + 5.5\% + 18.656\% + 18.55\%}{5} = 17.1MPa$$
$$CS = \frac{TPB21 + TPB22 + TPB23 + TPB24 + TPB25}{5}$$
$$CS = \frac{3.269\% + 2.424\%\% + 2.71\% + 2.104\% + 3.457\%}{5} = 2.793mpa$$

Compressive strength of 25% of volume of plastic have less strength than other mix proportions of plastic with sand its strength almost similar strength with minimum requirements of unburned clay bricks 2.06MPa.

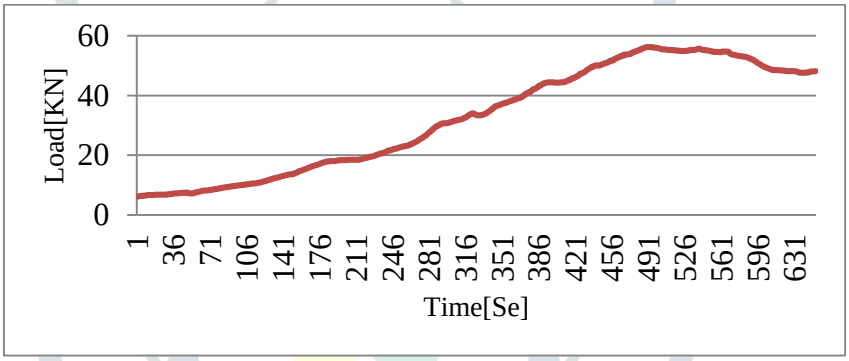

Figure 3: Load vs. Time Graph of 25% of PETE Plastic Bricks

This figure shows failure graph of compressive strength test the result clarifying that as plastic amount is more less than optimum value of the experiment have minimum failure load of 56.179KN as well as less compressive strength than other tests relatively but the failure shows ductile failure due to plastic ductile nature.

Compressive Strength Result for Plastic Bricks For 30% Plastics

$$CS = \frac{TPB61 + TPB62 + TPB63 + TPB64 + TPB65}{5}$$

$$CS = \frac{7.439\% + 7.849\% + 6.179\% + 6.202 + 6.213}{5} = 6.776MPA$$

This result shows that average compressive strength of 30% use of waste plastics is increasing in strength about 59% more than 25% use of plastic mixing ratio. So as binding material plastic content increase the void between sand and binding material plastics are decreases and bonding of the later plastic brick is higher than the former 25% use of plastic content.

Compressive Strength Result for Plastic Bricks for 35% Plastics

Compressive strength tests for trial plastic brick four passes ASTM requirements for average of five bricks 10.3MPa as well as individual bricks minimum requirements are 8.6 MPa negligible weathering conditions but, for this TPB4 the result shows that 15MPa of strength also attained so in Ethiopia since there is medium temperature or has no freezing area in most parts of the regions. However, ASTM C129 standard specifications for non-load bearing wall minimum of 4.14 MPa [7].

$$CS = \frac{\text{TPB31} + \text{TPB32} + \text{TPB33} + \text{TPB34} + \text{TPB35}}{5}$$

$$CS = \frac{9.213\% + 15.894\%\% + 10.577\% + 9.66\% + 9.211\%}{5} = 10.911mpa$$

The graph has high failure load than 25%, 30%, 40% and 45% of the graph since the result of 35% use of plastics gives optimum value of the experiments.

Compressive Strength Result for Plastic Bricks for 40% Plastics

$$Avg = \frac{\text{TPB51} + \text{TPB52} + \text{TPB53} + \text{TPB54} + \text{TPB55}}{5}$$

$$Avg = \frac{7.218\% + 7.871\%\% + 6.764\% + 8.684\% + 8.5\%}{5} = 7.807mpa$$

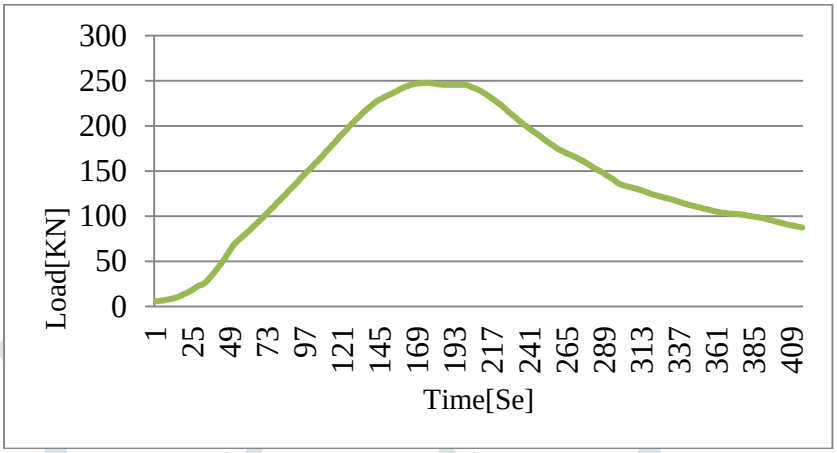

Figure 4: Load vs. Time Graph of 40% Plastic Bricks

Compressive strength result for plastic bricks for 45% plastics

$$CS = \frac{TPB61 + TPB62 + TPB63 + TPB64 + TPB65}{5}$$

$$CS = \frac{8.18\% + 7.576\%\% + 6.179\% + 7.7\% + 7.71\%}{5} = 7.469MPa$$

Average compressive strength of 45% use of plastics also gives higher strength than 25% and 30% but has a compressive strength less than 35% and 40% of plastic bricks.

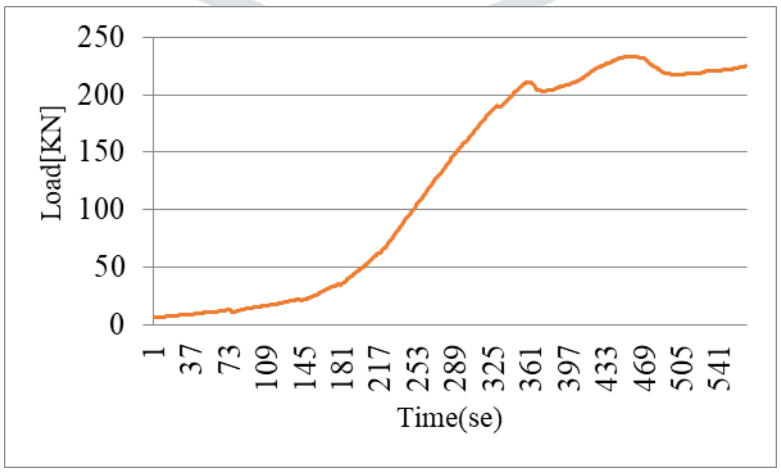

Figure 5: 45% of Load vs. Time Graph

Load vs. time graph of this figure has failure load than 25% and 30% of plastic bricks but lower result of 35% and 40% use of plastics.

Average Compressive Strength of those Five Trial Plastic Bricks

Table 4. Ccompressive Strength Average of Tested Specimens

Specimens	TPB2	TPB3	TPB4	TPB5	TPB6
Average Compressive Strength	2.793mpa	6.776mpa	10.91mpa	7.807mpa	7.469mpa

IV. Discussion

Bricks are used for both structural and non-structural masonry works. However from, standard methods of sampling and testing of bricks there is also specifications on compressive strength for physical tests and durability test by testing absorption test and saturation coefficient [8]. So good quality of bricks have properties of at least minimum requirement of compressive strength and the absorption of water and saturation coefficient should be less than 20% weight of dry brick and 0.8 ratio of cooling absorption of water immersed for 24 hours to immersion of bricks for 5hours in boiling water. The study showed that compressive strength of plastic bricks increases as amount of plastics mix ratio increases up to certain limit which up to optimum value of 35% of PETE wastes and 65% of sand have compressive strength of 10.91mpa which classified under good quality bricks according to ASTM negligible weathering condition and also classifications of plastics bricks according British Standard (BS) 7-14 MPa class A brick. As amount plastics increase compressive strength of concrete brick decreases since plastic in nature do not react with water unless it decrease bondage between ingredients of the concrete structure. [9] investigated plastic soil bricks the study have maximum optimum strength of 7 PMa which is classified to class C clay brick and minimum water absorption less than 1% score more durability properties than burned clay bricks class A of BS. They also assessed 60-80% range of plastic to soil ratio were used. Since they are used high amount of plastics they got less strength than plastic sand bricks as well as sand have high amount of silica content than soil naturally this also by itself loss the strength of bricks as amount of sand become less. From common tests of ASTM and BS compressive strength and absorptions of water of plastic bricks for class A bricks classifications for all bricks individually less than 8% percent. So those plastics bricks 25%, 30%, 35%, 40%and45% all is passes these requirements. But 30% 40% and45% of plastic bricks classified under class C individual result of five bricks prepared for tests of burned clay bricks 7.5mpa. . [4] Burayu brick factory Ethiopia average compressive strength of should have been classified as class C bricks average compressive strength of 10.3 MPa. While this optimum results of plastic bricks are qualified according to British Standard, ASTM and ES Standard Specifications and the plastic brick used for both non load bearing and load bearing structural wall.

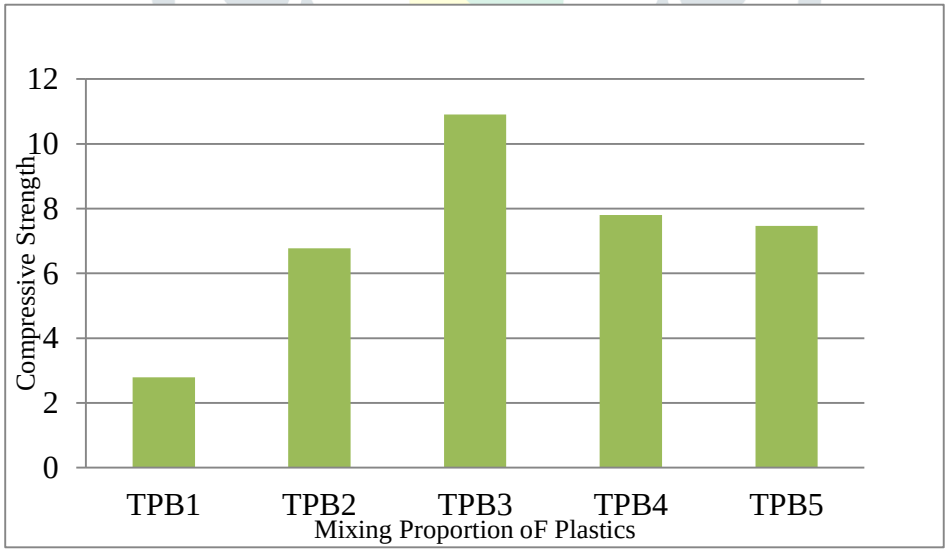

Figure 6: Averages of Five Bricks Compressive Strength for Trial Plastic Bricks

Due to PETE ductile plastic nature during the compressive tests of the plastic bricks it shows that its failure are smooth failure which sand by itself give brittle failure but compositions of both material gives ductile-brittle failure of bricks. As amount of plastics increases up to optimum trial mixing proportions, the compressive strength also increases finally its compressive strength also decreases after optimum trial plastic brick gradually. . [4] For structural engineering, one of the most essential things in design of load bearing members is understanding of material strength beside member forces. It is confirmed by laboratory test that in the case of clay brick design strength is compressive strength which in turn affects the masonry strength built using bricks, Compressive strength is significant to structural engineer calculating structural brickwork strengths in accordance with the recommendations of the Structural Masonry Codes of Practice.

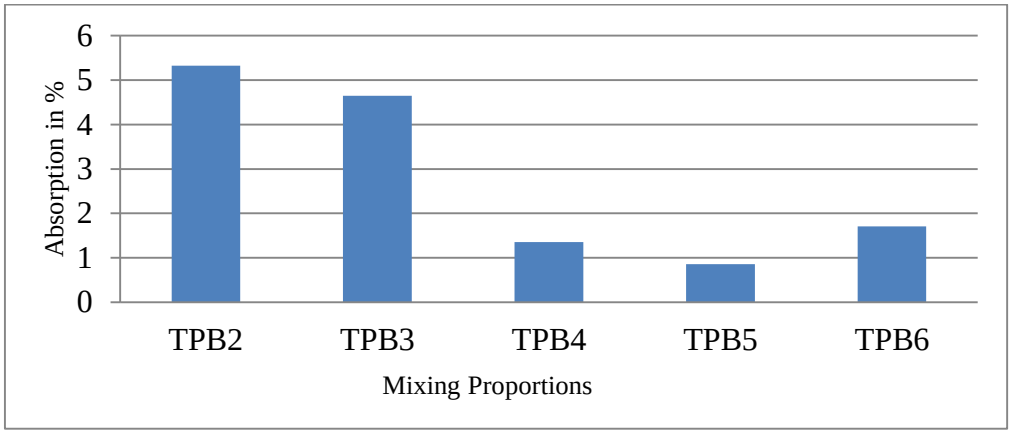

Figure 7: Absorption Test Result Graph

V. Conclusions

Plastic waste is one of the major solid wastes in our world and it also disposed to the environment. So using waste plastic bottles in construction is a way of reduction of environmental pollution and also means of minimizing cost of energy consumption during firing process of clay bricks. From the results obtained, the following conclusions were made: Considering the compressive strength test results,TPB4 has attain optimum compressive strength value of the result from all trial plastic mixing proportions has average of 5 plastic bricks compressive strength of 10.91mpa and average absorption of water from those TPB1, TPB2, TPB3, TPB4, TPB5 and TPB6 trial mixing proportions TPB5 less absorption of water than other mixing proportions so the optimum plastic bricks are classified as good bricks quality according to ASTM negligible weathering conditions. A plastic brick with optimum mix has higher strength and durability while it loses its strength smoothly after optimum limit due to bonding between pastes decreases due to segregation of sand and plastics because of the density of liquid form of plastics are less than sand and its flow above sand more than mixed properly. This result indicates also except TPB2 all plastic brick tests are compressive strength very competitive and greater to that of higher class of Hollow Concrete Block of 5.5 MPa. It is classified under load bearing according to Ethiopian standard. The temperature variation affects the compressive strength since it affects the binding properties of plastic.

VI. Acknowledgment

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