

## Influence of Polymer Waste (Polyethylene Terephthalate) in Composites Structure Materials.

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### Abstract

*Nowadays the use of insulation wall in building construction faces some problems such as having high weight, very reflective sound, heat transfer (the effectiveness of heat conductivity) incompetent and mechanical properties (strength) limited. The sounds which impinge the wall cannot be absorbed efficiently but instead gives high reflection. This causes some noise on high echo in a room. So a good acoustic insulation must be efficient in absorbing the sound. This project proposes lightweight concrete as a replacement for insulation wall. This lightweight concrete will be developed using thermoplastic polymer waste which is recycle plastic bottles, sand, water, and cement. This research was used thermoplastic polymer waste which is PET (Polyethylene Terephthalate) material as the reinforcement material to replace small gravel in lightweight concrete. All its composition percentage of raw materials was divided into different samples composition. Its composition determines the performances of the samples in thermal conductivity coefficient, density, porosity and mechanical properties (strength and bending performance).*

**Keywords:** Composites, Polyethylene Terephthalate, porosity, density, thermal conductivity

### 1. Introduction

Lightweight aggregates were used for lightweight concrete construction. Forming agent such as aluminum powder also can be used which generates gas while the concrete is still plastic. Natural lightweight aggregates include pumice, scoria, volcanic cinders, tuff, and diatomite. Lightweight aggregate can also be produced by heating clay, shale, slate, diatomaceous shale, perlite, obsidian, and

vermiculite. Industrial cinders and blast furnace slag that has been specially cooled can also be used (Neville 1996, ACI Committee 1994).

The most widely used for natural lightweight aggregates were pumice and scoria. They can be found in Western United State which comes in various colors, porous and froth-like volcanic glass. A strong concrete as an ordinary concrete was made with expanded shale and clay, but its insulation value is about four times better. A concrete of intermediate strength, but with even more impressive value as insulation was produced by pumice, scoria, and some expanded slag. For the very low strength of concrete, but with superior insulation properties was made from perlite, vermiculite, and diatomite. However it is producing more shrinkage (Kohno et al., 1999).

Concrete is a construction material cement based adhesive, and the aggregate of: sand and stone (gravel). This product will be modify the use of materials that have been commonly used in the manufacture of the concrete so as to produce concrete material better than the existing concrete and used for this. Modification of this product still refers to the standards design requirements that already exist. The product will include the replacements of modified binder (cement) with a thermoplastic material and replace the gravel the whisker of PET (Polyethylene Terephthalate). Until now, there has growing interest in studies on effect of polymer to composite structure (Rossignolo et al., 2002, Blanco et al., 2000, Choi et al., 2002). They found that the resulting product were lighter and have a low of the wet ability by water.

The objective of the study is to develop a polymer binder product with additives and the application of short (aggregate) PET (Polyethylene Terephthalate) polymer waste instead of gravel aggregate in the concrete matrix.

## **2. Experiment Procedure**

The research is a laboratory scale to determine the optimum composition of the manufacture of lightweight concrete by replace the gravel with thermoplastic waste material which is PET (Polyethylene Terephthalate). Specimen made with different percentage composition of sand, cement, PET (Polyethylene Terephthalate), water, and additives. This research having compression test, density and porosity test, and thermal conductivity test. The research study will follow the flowchart steps as shown in Fig. 1. All concrete samples had undergone physical and mechanical properties testing after reach room temperature that consist of ASTM C39 Test Press (Compressive) and Test ASTM C373-88 Density and Porosity. In addition, the sample best result which was the highest value of load and compressive strength that they can stand had undergone Thermal Properties Test to

determine the value of thermal conductivity. The Apparent porosity and density of a specimens measuring diameter 57 mm by 60 mm high was estimated by the Archimedes method using kerosene (ASTM C 380-79). Subsequently their specific gravities were determined by dividing the unit weight of the sample by the unit volume.

$$\text{Density, } \rho = \frac{m}{V} \quad (1)$$

Where  $m$  is the weight dry sample ( $kg$ ),  $V$  is the volume cylinder ( $m$ ), and  $\rho$  is density of the concrete sample ( $kg/m^3$ ).

The porosity was determining using equation as below:

$$\% \text{ Porosity} = \frac{W_{final} - W_{initial}}{W_{final}} \times 100\% \quad (2)$$

Where  $W_{final}$  the weight after dipping or weight is wet sample ( $g$ ) and  $W_{initial}$  is the weight before dipping or weight dry sample ( $g$ ).

### 3. Result and Discussion

#### 3.1 Physical Properties: Density and Porosity

Table 1 shows the density, porosity and compressive strength result for PET composite with various compositions. The density range is between  $1538 \text{ kg/m}^3$  to  $1647 \text{ kg/m}^3$  and the porosity range from 9.3% to 12.6%. The value range record were fulfilled the lightweight requirement. The compressive strength range from 2.33 MPa to 5.29 MPa were fulfilled for lightweight concrete compressive strength (Kohno et al., 1999).

Fig. 2 shows the comparison and relationship between the density and porosity with percentage of additive for sample A which consumed of 500 gram of sand. When the percentage of additive is increased, the density value also increased, while the porosity value became decreased. These show that the additives were reacted as binder between the PET waste and the other raw materials in concrete. The more percentage of additive were used, the more strong bonding were produced in concrete structure which then produced less porosity and higher density. But for the porosity value at 5% additive, it became increased. This is due to percentage of PET waste for 5% of additive sample which is 24% was higher than sample with 1% and 3% additive which are 20% and 22%. This make the materials were not completely mixed each other and produce more porosity. This situation can affect the compressive strength value during the compression test.

Fig. 3 shows the density values for each samples from group A, B and C. the percentage of PET waste for sample A are between 20%-24% where they are the highest amount compared to sample B and C where the PET waste amount between 15%-19% and 10%-14% respectively. The density values obtained show the sample A were low density. This means the lightweight concrete produced were light in weight. This is because of the properties or characteristic of PET waste is light in weight. Group B and C have less percentage of PET waste but have more amount of sand. This make the density values were higher compared to sample A.

Fig. 4 shows the result data of compressive strength from compression testing for all samples from group A, B and C that marked as 500 g, 550 g and 600 g respectively. Based on the graph, sample A with 500 g sand, the compressive strength were increased as the percentage of additive increased. This show that the additives were reacts as binder between the raw materials when they mixing together. The more additives were applied to these samples the stronger bonds were existed between them. Thus it produced less porosity in the structure. The main purpose additive usage was to make the PET waste material make bonding with the other materials. The same results go to sample B and C with 550 g and 600 g sand respectively. But, at the 5% of additive the compressive strength were decreased. The amount of sand and PET waste may affected the strength values. This is because for sample with 5% additives the amounts of PET waste are more higher compared to sample with 1% and 3% additive. Couple with the amount of sand is more than sample A, all the materials were not fully mixed during concrete preparation processes. In addition the amount of additive may not enough to make the strong bonding between PET waste and the others material. Thus it was produced low strength.

Fig. 5 shows the compression testing data for sample that obtained the highest value of compressive load and compressive strength for each group sample A, B and C. According to this graph, line A1 which is the red color was the sample with the highest result from group A, whereas for group B and C, sample B2 and C2 were the highest which are the green and purple lines respectively. For the blue line data marked as A01 is the additional sample with composition of raw material same with A1 which is the highest result among the entire group samples A, B and C but used small gravel as the reinforcement material. From Table 2 the compressive load and strength for A1 with PET waste as the reinforcement material are 13.89 kN and 5.295 MPa. Compared to A01 the values are 14.35 kN and 5.412 MPa. The difference result between A1 and A01 are slightly different.

### 3.2 Thermal Conductivity

The purpose of this testing is to determine the thermal conductivity value of one sample code that has the best result among the nine sample. From Table 5.3 sample A1 with percentage raw materials (50%

sand, 25% cement, 20% PET, 5% Additive and 40% water) is the best sample code that have been fulfilled the lightweight concrete requirement and has the highest value of compressive strength. For the density testing requirement, from the previous research CIP36 made by National Ready Mixed Concrete Association, the density value for lightweight concrete is in range 1440-1840  $kg/m^3$  (CIP36, 2012). The less density value means the concrete more light in weight. For the porosity testing, the range of porosity value for good lightweight concrete is between 5 to 20%. Lastly is compressive strength, the higher value of compressive strength, it shows the stronger the concrete and can accept more load applied. The value of thermal conductivity was 0.124 W/m.K and determined by apparatus named KD2 Pro.

#### 4. Conclusion

Based on the result and analysis had been done for this research, the product sample that created were gave positive and good result based on several testing. The physical properties such as density and porosity of lightweight concrete were determined. All of the nine sample result values recorded in the result table were fulfilled the lightweight concrete requirement. The requirement value for density is in range 1440-1840  $kg/m^3$  and for porosity is between 5-20%. The highest and the lowest value of density and porosity among the nine samples of lightweight concrete are 1647.47  $kg/m^3$  and 9.33%. The sample that has the highest value of compressive strength is the best sample among the others. The highest compressive strength and maximum load are 5.295 MPa and 13.89 kN. The optimal percentage composition of raw material to produce the optimal result was determined which is sample A1 with 50% sand, 25% cement, 20% PET Waste, 5% Additive and 40% water.

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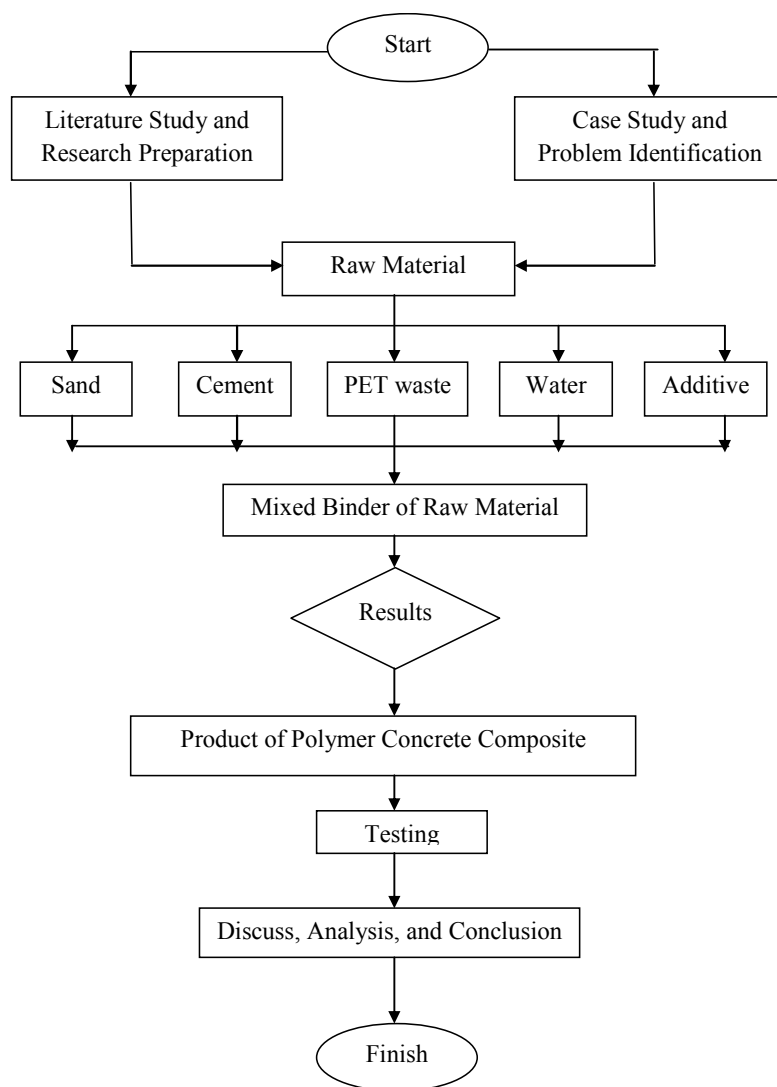
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<http://www.countymaterials.com/literature/item/cip-36-structural-lightweightconcrete>.

## Figures



**Fig. 1:** Flowchart for this research

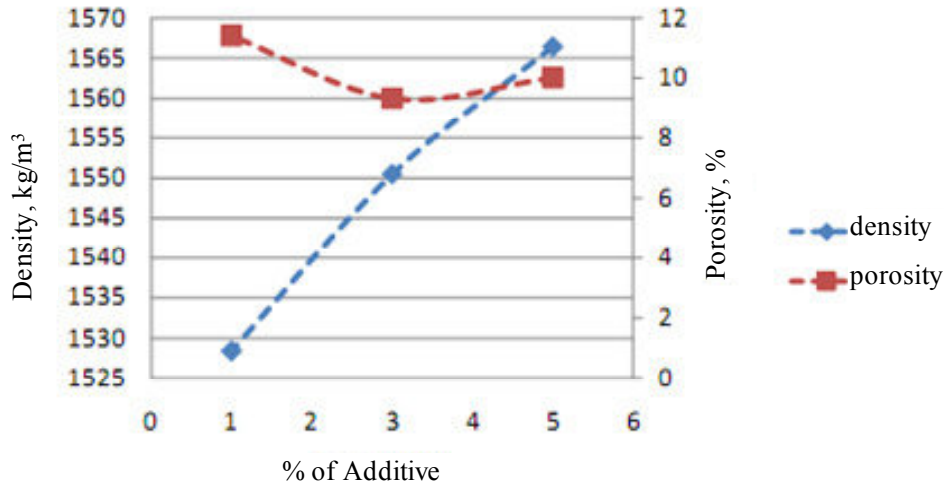


Fig. 2: Comparison of Density, Porosity vs %Additive for 500 g of sand.

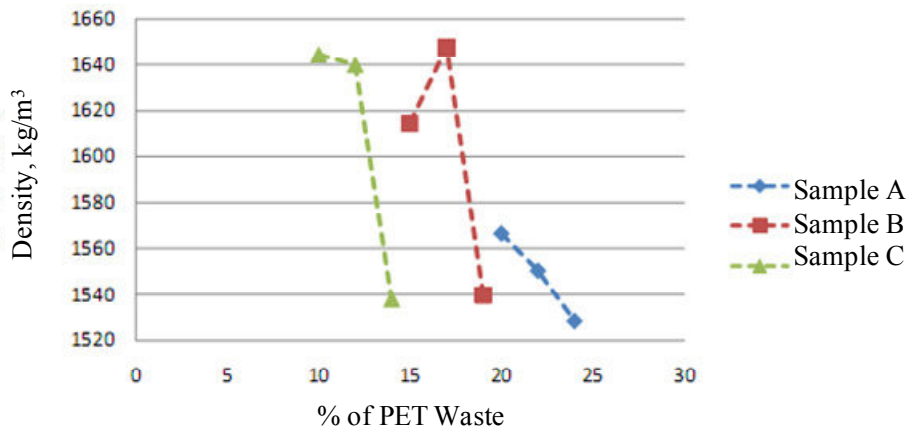


Fig. 3: Density vs % of PET waste

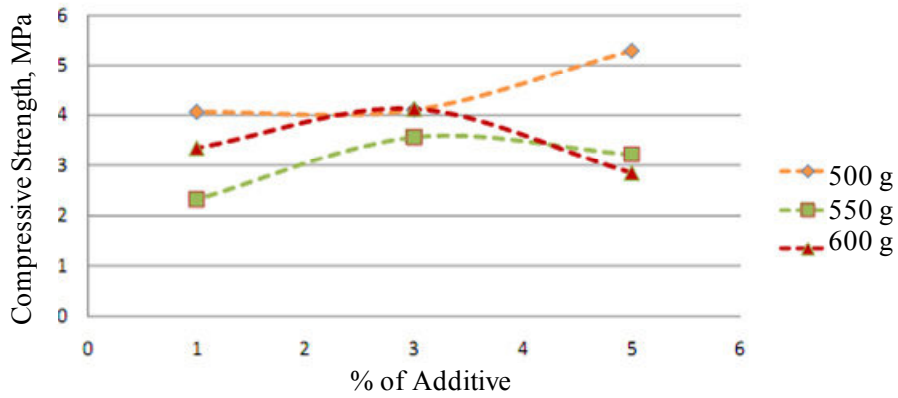
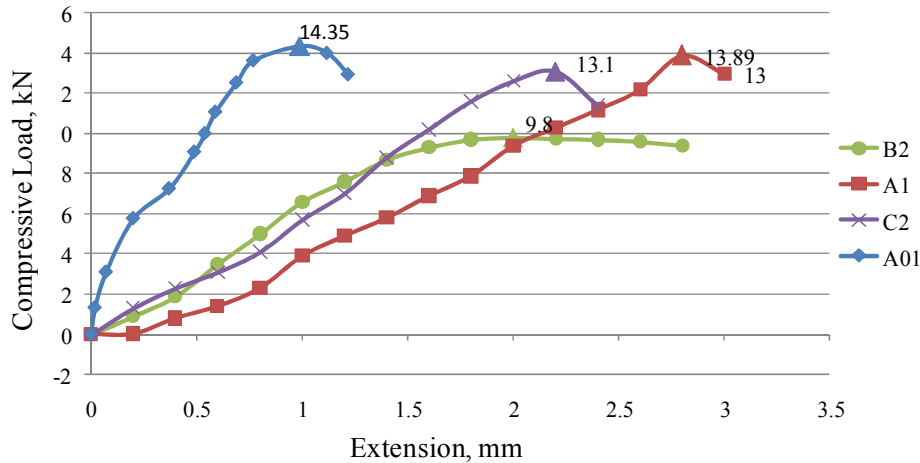


Fig. 4: Compressive Strength vs % of Additive



**Fig. 5:** Compressive Load (kN) vs Compressive Extension

### Tables

**Table 1:** Data for Density, Porosity and Compressive Strength

Specimen	Sand (%)	Additives (%)	PET(%)	Density (kg/m <sup>3</sup> )	Porosity (%)	Compressive Strength (MPa)
A1	50	5	20	1566.40	10.02	5.295
A2	50	3	22	1550.49	9.33	4.104
A3	50	1	24	1528.43	11.40	4.066
B1	55	5	15	1614.72	10.04	3.222
B2	55	3	17	1647.47	9.35	3.568
B3	55	1	19	1539.78	12.19	2.327
C1	60	5	10	1644.39	11.09	2.849
C2	60	3	12	1639.85	10.25	4.128
C3	60	1	14	1538.01	12.62	3.352

**Table 2:** Comparison between A1 and A01 samples

Sample	A1	A01
Mass (g)	299.96	319.44
Density (kg/m <sup>3</sup> )	1566.40	1836.80
Porosity (%)	10.02	6.79
Compressive Strength (MPa)	5.295	5.412
Maximum Load (kN)	13.89	14.35

**Table 3:** Result of Thermal conductivity

Sample Code	Porosity (%)	Density (kg/m <sup>3</sup> )	Compressive Strength (MPa)	Maximum Load (kN)	Thermal conductivity, k, (W/m.K)
A1	10.02	1566.40	5.295	13.89	0.124