Flexural strength of beam concrete with PET plastic addition and 30% copper slag

Mochamad Firmansyah Sofianto1*, Meity Wulandari1, Muhammad Imaduddin1 and Dedy Yusuf1

1 Civil Engineering Study Program, Universitas Negeri Surabaya, Surabaya, East Java

Abstract. The development of renewable concrete materials has long been carried out by researchers about concrete to find alternative materials that allow it to be used as a substitute material for the use of concrete. Alternative materials can be obtained from waste materials or wasted materials from industrial products and how the manufacture of concrete is said to be environmentally friendly concrete. Copper slag is the result of copper processing waste in the form of sandy material and plastic with various types of PET, that can be found in household waste. Therefore, the objective of this study is to calculate the technical strength of the concrete beam with additional material in the form of 30% copper slag and variations of the addition of PET plastic. This research was conducted experimentally with compressive strength testing with cylindrical specimens 10 cm in diameter and 20 cm in height and beam testing with a size of 15 cm x 15 cm and a length of 53 cm according to bending beam testing standards without reinforcement. Variations of PET plastic used in concrete mixtures with 30% copper slag are 0.3%, 0.6%, and 0.9%. The results of this study show that the compressive strength value of concrete with copper-slag of 30% and PET plastic of 0.6% gives a maximum compressive strength value of 27.5 MPa, and the value of flexural strength obtained is 5.03 MPa. The optimum deflection after adding PET plastic occurs in a mixture of 0.6% PET plastic which is 0.45.

1 Introduction

Concrete materials development has led to environmental materials friendly or using of waste materials [1, 2]. This concrete development is a consideration to increase the durability and capacity of concrete either by using environmentally materials friendly as an addition to or as a substitute for some concrete materials [2-4]. In the experimental study, the use of copper-slag as a waste material from the copper industry which is said to be a hazardous material for the environment, is used as a substitute material in concrete mixtures [4-6]. Using PET plastic material plastic bottle waste is quite abundant, so it needs to be used as a recycled or reused material [1, 2, 7-9, 11]. The characteristics of PET plastic has a fairly elastic tensile ability and are material that is not easily decomposed, so this material can be used as reinforcement, especially to increase the flexural strength of unreinforced concrete beams [10, 12]. Therefore, the study used an experimental approach to determine changes in the

* Corresponding author: mochamadfirmansyah@unesa.ac.id

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characteristics of a predetermined concrete mix. Thus, this study aims to determine the characteristic values of normal concrete with waste material, copper-slag, on the compressive strength, flexural strength, and deflections that occur [12, 13]

2 Experimental Study

Experiment-based research on concrete materials that used substitutes from industrial waste materials, copper-slag. Based on Mauludi's research [6] the research development of concrete used copper-slag substitutes in the characteristic strength of normal concrete or K-225. It was discovered that the characteristic strength of concrete was able to reach the optimal normal strength with copper slag of 30% as a substitution material. In the future, this study will consider the copper slag as a substituted material for fine aggregate by 30%. Mix-design calculations were determined based on the results of material laboratory tests, obtained fine modulus for fine aggregate (sand) which was 3.0 and copper-slag which was 3.9, the specific gravity of sand was 2.63 gr/cm$^3$, copper-slag was 3.38 gr/cm$^3$, and coarse aggregate is 2.43 gr/cm$^3$. The cement/water factor used is 0.52. The additional material used here is PET plastic taken from drinking bottle waste with the description of the type of plastic recycle PET 1. The provisions for this added material are 50 mm in length and 2~3 mm in width with a proportional amount. So that the design proportions of the concrete mix with the addition of copper slag and PET plastic can be seen in the following table.

Table 1. Material proportion in 100% mixing

<table>
<thead>
<tr>
<th></th>
<th>Cement (%)</th>
<th>Fine Agg (%)</th>
<th>Copper-Slag (30%)</th>
<th>Coarse Agg (%)</th>
<th>PET (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% PET</td>
<td>16.67</td>
<td>33.33</td>
<td>0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>0,3% PET</td>
<td>16.67</td>
<td>23.36</td>
<td>9.97</td>
<td>50</td>
<td>0.3</td>
</tr>
<tr>
<td>0,6% PET</td>
<td>16.67</td>
<td>23.36</td>
<td>9.97</td>
<td>50</td>
<td>0.6</td>
</tr>
<tr>
<td>0,9% PET</td>
<td>16.67</td>
<td>23.36</td>
<td>9.97</td>
<td>50</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table 2. Mix-design proportion in 1 m$^3$.

<table>
<thead>
<tr>
<th></th>
<th>Water (in kg unit)</th>
<th>Cement</th>
<th>Fine Agg</th>
<th>Copper Slag (30%)</th>
<th>Coarse Agg</th>
<th>PET</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% PET</td>
<td>189.7</td>
<td>394</td>
<td>725.4</td>
<td>0.00</td>
<td>934.8</td>
<td>0.00</td>
</tr>
<tr>
<td>0,3% PET</td>
<td>189.7</td>
<td>394</td>
<td>453.4</td>
<td>272</td>
<td>934.8</td>
<td>1.18</td>
</tr>
<tr>
<td>0,6% PET</td>
<td>189.7</td>
<td>394</td>
<td>453.4</td>
<td>272</td>
<td>934.8</td>
<td>2.37</td>
</tr>
<tr>
<td>0,9% PET</td>
<td>189.7</td>
<td>394</td>
<td>453.4</td>
<td>272</td>
<td>934.8</td>
<td>3.55</td>
</tr>
</tbody>
</table>

The test objects prepared included 1) cylindrical concrete with a size of 10 x 20 cm and 2) concrete blocks with a size of 15 x 15 x 53 cm in accordance with SNI 4431:2011. [13] Cylindrical specimens are tested for compression using the Universal Testing Machine (UTM) for compression test, and beam specimens are tested for flexure with a symmetrical 2P load and simple supports of pins and pins. All specimens will be tested after the age reaches 28 days.
3 Result and Discussion

3.1 Compression strength and flexural strength

The difference strength value between compressive and flexural is quite different due to different testing procedures. These differences reached values sequentially according to the addition of PET plastic, including 18.04%, 13.33%, 18.29% and 20.08%. Correction factor values are obtained sequentially at 0.67, 0.48, 0.92 and 0.90. From these values, it shows that the optimum results were obtained in the mix design with the addition of 0.6% PET with a compressive strength value of 27.5 MPa and a flexural strength value of 5.03 MPa.

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The figure above shows that the pattern of compressive strength values for the addition of PET plastic has similarities with the flexural strength values. Because of the addition of excessive PET plastic which will disrupt the bonding of concrete matrix and become an imperfect bond. These imperfections cause small voids between the surface concrete matrix and the PET plastic. Thus, the value between compressive strength and flexural strength is shown in the correlation factor between the two, in order to obtain a correlation factor value of 0.92.

3.2 Maximum force and deflection

The bending testing obtained the maximum force value and each force shows the deflection value in the middle span. Bending testing in order to identify the effect of PET plastic as an additional material on concrete beams without reinforcement carries out the force value and deflection conditions.
Fig. 2. Force and deflection relation graph.

The figure illustrates that an increase in the applied force will increase deflection that occurs until the concrete beam reaches a collapse condition at the maximum moment section. From all specimens, beams with the addition of 0.6% PET plastic produced a maximum compressive strength of 3770 kg with a deflection value of 0.45 mm. When at the same load, the greatest deflection value occurs in the beam specimen without the addition of PET plastic. After that, from the results of this study, PET plastic can be considered as reinforcement in concrete, referring to research on concrete with steel fibers.

3.3 Flexural strength and deflection

Based on the results of the bending test on the beam can be obtained values of flexural strength and deflection can be obtained. The two values are related to find out how much influence the addition of PET plastic has on the flexural strength of the beam. These results can be seen in the graph below.

Fig. 3. Comparison graph between flexural strength and deflection
The graph above shows that the optimum flexural strength was obtained by 0.6% PET plastic mixture which is in accordance with the discussion from the previous sub-chapter. The smallest deflection value is also shown in the same mixture. With the result, this study concluded that the addition of 0.6% PET plastic is the optimal amount to increase the flexural capacity of unreinforced beams.

4 Conclusion

In this experimental study, the beam concrete with 30% Copper-slag as substitution material and variation of PET Plastic Addition show a significant result in compression strength and flexural strength. The optimum value on strength is reached by variation with 0.6% of plastic PET, which is 27.5 MPa of compression strength, 5.03 MPa of flexural strength, and 0.45 mm of beam deflection compared to the mix design without any additional material and the mix design with excess use of plastic PET.

Acknowledgment

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