Compressive Strength of Concrete Utilizing Waste Tire Rubber

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Abstract

Waste-Tire rubber is one of the significant environmental problems worldwide. With the increase in the automobile production, huge amounts of waste tire need to be disposed. Due to the rapid depletion of available sites for waste disposal, many countries banned the disposal of waste tire rubber in landfills. Research had been in progress for long time to find alternatives to the waste tire disposal. Among these alternatives is the recycling of waste-tire rubber. Recycled waste tire rubber is a promising material in the construction industry due to its light weight, elasticity, energy absorption, sound and heat insulating properties. In this paper the density and compressive strength of concrete utilizing waste tire rubber has been investigated. Recycled waste tire rubber has been used in this study to replace the fine and coarse aggregate by weight using different percentages. The results of this paper shows that although, there was a significant reduction in the compressive strength of concrete utilizing waste tire rubber than normal concrete, concrete utilizing waste tire rubber demonstrated a ductile, plastic failure rather than brittle failure.

Keywords: waste-tire rubber, concrete, compression, coarse aggregate, fine aggregate

INTRODUCTION

Management of waste-tire rubber is very difficult for municipalities to handle because the waste tire rubber is not easily biodegradable even after long-period of landfill treatment (Guneyisi et al. 2004). However, recycling of waste tire rubber is an alternative.

Recycled waste-tire rubber have been used in different application. It has been used as a fuel for cement kiln, as feedstock for making carbon black, and as artificial reefs in marine environment (Siddique and Naik, 2004). It has also been used as a playground matt, erosion control, highway crash barriers, guard rail posts, noise barriers, and in asphalt pavement mixtures (Toutanji, 1996). Over the past two decades, research had been performed to study the availability of using waste tire rubber in concrete mixes (Eldin and Senouci, 1993, Toutanji, 1996, Khatib and Bayomy, 1999, Siddique and Naik, 2004, Batayneh et al, 2008, Aiello and Leuzzi, 2010, and Najim and Hall, 2010).

Recycled waste tire rubber is a promising material in the construction industry due to its lightweight, elasticity, energy absorption, sound and heat insulating properties. In this paper the compressive strength of concrete utilizing waste tire rubber has been investigated. Recycled waste tire rubber has been used in this study to replace the fine and coarse aggregate by weight using different percentages.

MATERIAL AND METHOD

Materials

The material used to develop the concrete mixtures in this study were cement, fine aggregate (sand), coarse aggregate (gravel), water, chipped and crumb tire rubber. The cement used was Ordinary Portland Cement EN 197-1-CEM152.5N as per certificate of conformity CE – 0770 – CPD – C02/23. Natural sand having a fineness modulus of 2.31 was used as fine aggregate, and natural gravel of a maximum size of 19 mm was used as coarse aggregate. Two types of recycled waste tire rubber was used; chipped and crumb rubber. Chipped rubber is used to replace the coarse aggregate. To produce this rubber, it is needed to shred the tire in two stages. By the end of stage one, the rubber has length of 300 – 430 mm long and width of 100 – 230 mm width. In the second stage its dimension changes to 100 – 150 mm by cutting (Ganjian et al., 2009). Crumb rubber that replaces for sand (Figure 1), is manufactured by special mills in which big rubbers change into smaller torn particles. In this procedure, different sizes of rubber particles may be produced depending on the kind of mills used and the temperature generated (Ganjian et al., 2009).

Sieve analysis for the sand and the crumb rubber was performed according to the ECP 203-2003 to determine the gradation of these materials. Figure 2 shows the sieve analysis results of the sand and crumb rubber.
Preparation of Test Specimens
Mixing was done in a small rotary drum mixer as shown in Figure 3. Coarse aggregate, sand, rubber aggregate, cement, and water was added to the mixer respectively. After the addition of each material, the mixer continue to mix until the mixture became homogenous. Oiled steel molds of dimensions 150x150x150 mm, shown in Figure 4, were filled in approximately three equal layers and compacted manually. After 24 hours of casting, the specimens were cured by soaking in to water until the age of testing. It was noticed that the compaction of the chipped rubber group was very difficult due to the rubber property.

RESULTS AND DISCUSSION

The results of the average densities and compressive strength for control and rubber tire concrete specimens are shown in Table 2. Each of these results represents the average of three specimens, except for the chipped rubber specimens, the results represents the average of two specimens.

Figure 1: Crumb rubber used in the concrete mix

Figure 2: Sieve analysis of aggregate and crumb rubber

Concrete Mixtures
A total of 4 main mixtures were cast. One control mixture and three rubcrete mixtures. The control mixture was designed to have a water cement ratio of 0.35 with cement content of 350 kg/m^3. To develop the rubberized concrete mixtures, tire rubber was used to replace the aggregate by weight. In the first rubberized concrete mixture, the chipped rubber totally replaced the coarse aggregate in the mixture. While, in the other two rubcrete mixtures, the tire rubber replaced the fine aggregate by 100% and 50% of fine aggregate weight. Table 1 shows the details of the concrete mixtures.

Table 1: Details of the concrete mix proportions

<table>
<thead>
<tr>
<th>Component</th>
<th>Control</th>
<th>Chipped rubber</th>
<th>100% rubber</th>
<th>50% rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (kg/m^3)</td>
<td>350</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Water/cement ratio</td>
<td>0.35</td>
<td>0.5</td>
<td>0.5</td>
<td>0.35</td>
</tr>
<tr>
<td>Water (kg/m^3)</td>
<td>122.5</td>
<td>175</td>
<td>175</td>
<td>122.5</td>
</tr>
<tr>
<td>Sand (kg/m^3)</td>
<td>588</td>
<td>588</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>Coarse Aggregate (kg/m^3)</td>
<td>980</td>
<td>0</td>
<td>980</td>
<td>980</td>
</tr>
<tr>
<td>Chipped Rubber (kg/m^3)</td>
<td>0</td>
<td>599</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Crumb Rubber (kg/m^3)</td>
<td>0</td>
<td>0</td>
<td>350</td>
<td>175</td>
</tr>
</tbody>
</table>

Figure 3: Rotary drum concrete mixer

Figure 4: Oiled steel molds for concrete casting
It could be seen from the above table that there was a significant reduction in the compressive strength of concrete when the tire rubber was used to replace the aggregate in the concrete mixtures. However, during testing of the specimens, a significant amount of compressibility was observed allowing the specimens to absorb a large amount of energy under compressive loads. This finding is consistent with what was cited in the literature.

**Concrete Density**

Figure 5 shows the effect of the tire rubber replacement on the concrete density. From this figure, it could be seen that concrete casted using chipped rubber gave the lowest density compared to the other groups, and as the amount of rubber in the mix decreases the density increase. This is because the density of rubber is much less than that of coarse aggregate and sand. It could also be seen that there was a significant reduction of about 30% in the density of concrete casted using chipped rubber replacing 100% of the coarse aggregate when compared to the control specimen. Moreover, there was no significant difference in the density of concrete casted using different percentage of crumb rubber.

It could be seen from the figure that the compressive strength was reduced significantly by 90% when using chipped rubber as a full replacement to the coarse aggregate in the concrete mix, this conforms with the result of Eldin and Senouci, 1993, and Toutanji, 1996. However, the reduction in strength was 80% when using crumb rubber as a 100% replacement to the sand in the concrete mix. It could also be seen from the figure that the compressive strength was significantly increased by 85% when using crumb rubber instead of chipped rubber, and this results conform with the results of Khatib and Bayomy, 1999 and the results cited by Siddique and Naik, 2004. Moreover, the figure shows that there was no significant increase in the compressive strength of concrete casted using crumb rubber replacing 50% of the sand compared to the compressive strength of concrete casted using crumb rubber as a 100% replacement to the sand in the concrete mix.

**Compressive Strength**

The effect of replacing tire rubber with aggregate on the concrete compressive strength is shown in Figure 6.
the control specimen. However, significant ductility was observed before failure of the specimens.
4. Concrete casted using crumb rubber as a full replacement to sand shows a significant increase in the concrete strength compared to the concrete casted using chipped rubber as a replacement to coarse aggregate.
5. There was no significant increase in the concrete compressive strength and the concrete density when different percentage of crumb rubber, as a replacement to sand, was used in the concrete mix.
6. It is recommended to test concrete with different percentage of crumb rubber ranging between (10% up to 25%) to study its effect on the concrete strength.
7. It is recommended to test concrete with different percentage of crumb rubber with silica fume additive to overcome the significant reduction in concrete strength resulting from the replacement of sand by crumb rubber.
8. It is recommended to use rubcrete in the production of curbs, roads, concrete blocks, and non bearing concrete wall.

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REFERENCES


