Influence of Waste Rubbers Particle Size as Partial Substitution with Coarse Aggregate on Compressive property and water absorption ratio of Concrete

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Abstract. The enormous development on production of vehicles resulted in growing amount of waste tires rubber. Consequently, waste rubber is considered as one of the most waste materials that might cause environmental problems. Incorporating tires rubbers in concrete pavement has been widely studied as one of the promising and sustainable solutions to these current environmental problems. This paper explored the effect of replacing coarse aggregate with waste tires rubber according to their sieve sizes. Three replacement ratios were suggested to substitute the coarse aggregate in concrete of 5 wt. %, 10% and 15%. Two replacement techniques were chosen in order to investigate the rubber particle size. The results illustrated that the compressive strength reduced by 8.5, 51% for 5 to 15 % replacing from all particle sizes. While it shows lower percentage of 0.3 to 11%, 12 to 19% and 7 to 17% for replacing 5 to 15% from sieve #20 to #4.75, respectively. The dry density for all samples decreased slightly with increasing rubber percentage. Furthermore, water absorption ratios of the tested samples were comparable with the reference sample by replacing from each sieve separately. In contrast, it shows higher increase by replacing from all sieves.

1. Introduction
The high development in economic activities was resulted in increasing waste materials which have a detrimental effect on the environment. As a result, utilizing technological wastes, such as furnace slag, wood chippings, crushed glass and tire rubber, in some applications is very important as it considered as a major environmental problems. While the process of discarding waste tires in landfill increase, major environmental concerns stand behind that since the waste (tires) rubber is not biodegradable even with a long-time landfill treatment. Therefore, recycling of rubber tires might be a possible technique to reduce their environmental impacts. A number of studies have been conducted to use recycled (waste) tires in various applications e.g., asphalt pavement, waterproofing systems, and membrane liners[1, 2]. Other studies have experimentally conducted the effect of using waste (tires) rubber on the properties of concrete. Giedrius and Dziigita [3] investigated the impact of crushed waste rubber on the compressive strength of concrete. They concluded that the compressive strength is reduced by 68% and 61.3% at 20-wt % replacing coarse and fine aggregate, respectively. Similarly, Khatip and Bayomy [4] found the effect of using different rubber contents to replace aggregate in the concrete mix on its compressive
strength. Sakdirat et al. [5] investigated the effect of crumb rubber particles size on the electrical resistivity of concrete. Their results showed that a microscale particle illustrates lower electrical conduction capacity compared with nanoscale particles. Their results indicated that rubberized concrete shows enhanced behavior to resist freeze and thaw environment compared with plain concrete. Bompa et. Al [6] studied the uniaxial behavior of rubberized concrete that replaced the mineral aggregates. They stated that the quantity and type of mineral aggregates have noticeable effect on the mechanical properties of concrete. In the current study, the impact of using different sizes of waste rubber (tires) as partial replacing coarse aggregates of concrete on its compressive strength and the water absorption ratio was experimentally conducted. The coarse aggregate was replaced by 5%, 10% and 15% from sieves #4.75, #10 and #20, respectively. In addition, similar percentages were replaced from all sieves.

2. Experimental work

2.1. Materials
Cement, sand, gravel and tire rubber were the main component used to produce the concrete mixes. Ordinary Portland cement produced according to the Iraqi Standard No. 45 [7] with specific gravity and specific surface area of 2.9 and 3220 cm², respectively. Natural sand of 4 mm maximum particle size and fineness coefficient of 2.69 according to Iraqi Standard No. 45 [7] used as fine aggregate whereas the crushed stone of 20 mm (larger size) used as coarse aggregate. The specific gravity of fine aggregate is 2.63 and coarse aggregate is 2.68 kg/m³. Scrap truck tires rubber were cut into different size and sieved to act in accordance with the particle size of coarse aggregate Fig.1.

2.2. Concrete mixtures
To determine the effect of various sizes of tire rubber on the concrete properties, the water–cement ratio is determined of 0.5 in the concrete mix. The percentages of concrete mix were 1:2:2.35 by weight for cement, sand and gravel, respectively. Cement content of 400 kg/m³ was used to achieve a target compressive strength of 33 MPa for concrete. Gravel particles were replaced by 5%, 10% and 20% of tire rubber. In this study, the waste rubber particle was replaced in such way to achieve the main objective of the research. The replacement percentages were chosen from all sieves and from each sieve separately. Table 1 shows the quantities coarse aggregate and the replaced tire rubbers. Three cubes of 150 mm size were cast for each mix. All mixtures were prepared and cast at room temperature about 25 °C. Plastic sheets were used to cover the moulds for 24 hr and cured for 28 days in water tank, with controlled temperature of 25–27 °C.
Table 1. Quantities of coarse aggregate and tire rubbers for each mix.

| Sample  | #20 | #10 | #4.75 | #20 | #10 | #4.75 |
|---------|-----|-----|-------|-----|-----|-------|
| CR0     | 464 | 8815| 6186  |     |     |       |
| CR5A    | 441 | 8374| 5877  | 23  | 441 | 309   |
| CR10A   | 418 | 7933| 5567  | 46  | 882 | 619   |
| CR15A   | 394 | 7493| 5258  | 70  | 1322| 928   |
| CR5S20  | 441 | 8815| 6186  | 23  |     |       |
| CR10S20 | 418 | 8815| 6186  | 46  |     |       |
| CR15S20 | 394 | 8815| 6186  | 70  |     |       |
| CR5S10  | 464 | 8374| 6186  |     | 441 |       |
| CR10S10 | 464 | 7933| 6186  |     | 882 |       |
| CR15S10 | 464 | 7493| 6186  |     | 1322|       |
| CR5S4.75| 464 | 8815| 5877  |     |     | 309   |
| CR10S4.75| 464 | 8815| 5567  |     |     | 619   |
| CR15S4.75| 464 | 8815| 5258  |     |     | 928   |

3. Experimental results

Fig. 2 presented the compressive strength of concrete mix incorporating different percentage of tire rubber. The test results show that the compressive strength of concrete samples containing 15% of rubbers is significantly decrease compared to the control mix. The test compressive strength of the control sample was calculated as 34.4 MPa at 28 days. High reductions in compressive strength at 28 days were observed by replacing gravel by tire rubber from all sieves. The compressive strength decreases by 8.5%, 27.9% and 51% for 5%, 10% and 15% fractions, respectively. This trend is similar to previous research conducted by Jing lv. et al. [8]. On the other hand, replacing coarse aggregate by similar percentage of rubber from each sieve separately shows less reduction in compressive strength. This behavior might result from the variation of particles quantity for each size. Comparisons between three rubber replacement rations according to particle size of rubber indicate that replacing particles from higher sieve number resulted in slight reduction of compressive strength. However, replacing aggregate particles from sieve #4.75 showed slight improvement in compressive strength compared with sieve #10. This behavior confirm the previous studies conclusion which indicated that size of rubber particles, its proportions and surface textures caused in a reduction of the compressive strength of the rubberized concrete [9].

The average density of the control specimen is 2406 kg/m3. Fig. 3 shows the average density of the tested specimens. The lowest average density of 2199 kg/m3 was observed for specimen with replacement ratio of 15% from all sieves where the highest quantity of rubber was used. Fig. 3 also shows that the increase of rubber content in the concrete mix caused the reduction in the density of the tested specimens. On the other hand, replacing waste rubber from higher sieve size produce denser mix compared to the lower size sieves.

Fig. 4 demonstrates the average water absorption percentages for the tested samples. The control specimen shows average water absorption of 4.63%. The highest average water absorption 6.2% was calculated for replacement ratio of 15% from all sieves. The results showed that the water absorption rises with the increase of rubber proportion in the concrete mix. The results also showed that replacing
rubbers from lower sieve size resulted in increase of water absorption. This behavior might result from the granular shape of rubber particles which increase the porosity of the sample.

Figure 2. Compressive strength versus rubber replacement ration

Figure 3. Density versus rubber replacement ration

Figure 4. Water absorption versus rubber replacement ration
4. Conclusions

- The compressive strength of concrete partially replaced its coarse aggregates with waste tires (rubber) from all sieves is considerably reduced. The test results showed that the compressive strength dropped from 8.5 to 51% for substitution of 5 to 15% of coarse aggregate.
- Lower reduction of compressive strength occurred by replacing coarse aggregate from each sieve separately. The strength reduced from 0.3 to 11%, 12 to 19% and 7 to 17% for replacing 5 to 15% from sieve #20 to #4.75, respectively.
- The dry density of the concrete mixes reduces with the increase in rubber (tires) waste content. This is due to the low specific gravity of tire (waste) rubber particles compared to coarse aggregate.
- Specimens containing high rubber content exhibit high water absorption. However, replacing coarse aggregate from lower sieves result in slight increase in water absorption ratio than other sieve.

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