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# Experimental Investigation on Concrete with Tire Rubber and Fly Ash

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**Abstract:** The increasing downside of tire waste disposal in Iraq is often alleviated, if new ways of working for excess tires are found. One of the most important ways in construction. However, the use of waste tires in engineering is very low at present. The increasingly negative trend of tire waste disposal in the Republic of Iraq is often reduced if modern working methods are created for excess tires. The use of recycled tire rubber as a partial replacement from Coarse Aggregate (CA) can be very positive to have an influence on the mechanical properties of concrete. The most popular building materials is concrete technology. For that reason, construction modification often seeks to exaggerate its uses and applications, increase its properties and reduce cost. The purpose of the pilot school education is to ascertain the recycled concrete properties of the vehicle tires in the past and to act as a partial replacement of the aggregates. The tests were conducted on concrete samples containing 0, 10, 15 and 20% of the rubber as a total. The replacement of aggregate by rubber in concrete has resulted in reduced compressive strength and density. Decrease in strength depend on the amount of rubber. The loss of mechanical strength and relatively high change in durability prevent the widespread use of scrap tires in concrete. Additional construction materials were examined during this study to reduce the loss of mechanical specifications in rubber-coated concrete. Therefore, some mixtures on fly ash include cement swap of 15% by volume. The results reveal that apart from a slight improvement in the strength of coated rubber, the synergistic result of the pre-coated vats and fly ash as an alternative to cement significantly increased the mechanical properties of the mixtures.

**Key words:** Compressive strength, split tensile strength, junk rubber, Republic of Iraq, coarse aggregate, specifications

## INTRODUCTION

Disposal of tire waste causes environmental and health problems. The management of damaged tires can be a source of serious international tension. Waste tires are established, usually in a non-dominant manner, leading to great environmental degradation. Because tires are sturdy and naturally non-perishable they remain in waste burial sites with little degradation of work, posing environmental hazards. The state of Iraq has taken a great initiative to improve infrastructure such as rapid methods, electrical projects, industrial structures and others to meet up the needs of modern globalization. Under the makeup of alternative buildings and structures, concrete plays an appropriate part because almost projects use concrete. aggregate, so, it is one of the components used in the assembly of the standard concrete where it become expensive and scarcity. Therefore, the use of waste materials plays an important role in concrete. Concrete is one of the best standard construction materials where tire rubber was partially swapped in a coarse mix. The use of recycled chipper rubber tire as partial mixtures in concrete technology can be highly interested to have an impact on concrete properties over a wide range. For that pilot study was carried out to study the specifications of rubber concrete behavior and specifications. The target of experimental program was intended to verify the specifications of the recycled concrete once a vehicle tire and was used as a partial of aggregate. The exchange of rubber decreases the density and compressive strength for concrete samples containing 10, 15% tire rubber as an aggregate. Results shown decrease in the strength and the density depend on the rubber added (Reddy *et al*., 2013). Over the years, researchers have investigated the use of recycled rubber tire waste as an alternative to a concrete mix and its effectiveness. The "Rubcrete-Mix" that may result from such a replacement has been found to have many engineering applications and carry promise in the future. Rubcrete has built-in mechanical properties and is considered one of the simplest and most

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economical ways to use used tires. The tire rubber used in the study was obtained when the mechanical adjustment method was for tires that were subsequently consumed from trucks. The results, obtained when replacing thin and coarse aggregates, combine in concrete with tire rubber. The objective of the pilot study was to reach the optimum amount of substrates for aggregates in concrete mixtures for various engineering applications. To achieve true bonding with a comprehensive concrete paste, the recycled aggregates are designed with their size, shape and gradient fit. With a quantitative relationship of water cement with a constant fine non continuous the coarse mixture was replaced with rubber powder in the tire and broken rubber and the composite cement was replaced with silicon dioxide fumes. When preparing the concrete, slag cement was used in conjunction with the superconductor but I weighed the concrete weight to achieve the required workability of the concrete that followed (Kumar *et al*., 2014).

**Objective of the study:** The main targets of this study as: research effect of rubber added to concrete mixes in ratios of 10, 15 and 20% of the weight of coarse aggregate with dimensions of (width 10, thickness 7 and length 15 mm) on compression strength, split strength and flexural strength. Using consumer tire material in construction materials to provide light-weight concrete having appropriate properties. Investigation the strength using silica fume to enhanced the interfacial bonding zone.

## MATERIALS AND METHODS

**Experimental work:** This analysis describes materials used with regard properties, mix proportions, combination procedure, casting, action condition and testing procedures adopted throughout this study. In this research, an attempt is made to produce concrete using different ratios of granular rubber tire as a percentage of the weight of the coarse aggregate as pieces which have dimensions of (width 10, thickness 7 and length 15 mm), natural sand as fine aggregate with ordinary Portland cement. The tests are administered within the Laboratory of Fabric and Construction of Al-Esra'a University.

**Properties of construction materials**

**Ordinary Portland cement:** Created at Northern manufactory (Arbil) Ordinary Portland Cement (OPC) (Type-I) is employed throughout this study. Table 1 show the chemical structure and Table 2 show the physical composition of the cement used throughout this study.

Table 1: Chemical structure of OPC

| Composition | Weights (%) | Local specification No. 5 |
|---|---|---|
| LOI | 3.1 | 4.0* |
| $SiO_2$ | 20.1 | - |
| MgO | 2.4 | 5* |
| $Fe_2O_3$ | 4.6 | - |
| $Al_2O_3$ | 4.35 | - |
| $SO_3$ | 2 | 2.8* |
| CaO | 62.25 | - |
| I.R | 0.47 | 1.5* |
| C2S | 13.30 | - |
| C4AF | 13.60 | - |
| C3A | 3.2 | 5* |
| L.S.F | 47/50 | (33/50)-(51/50) |
| C3S | 61.8 | - |

*Maximum limit

Table 2: Physical composition of OPC

| Physical properties | Results | Local specification No. 5 |
|---|---|---|
| Fineness ($m^2$/kg) | 285 | (460/2)** |
| Soundness | (3/25%) | (4/5%)* |
| Setting time | 193 | (180/4) ** |
| Initial (min) | 4.7 | (50/5)* |
| Final (h) | | |
| Compressive strength | | |
| Cube (707/10 mm) at: | | |
| 3 days (MPa) | 19.40 | 5** |
| 7 days (MPa) | 28.23 | 23** |
| 28 days (MPa) | 41.5 | |
| 56 days (MPa) | 60.5 | |

*Maximum value **Minimum values

OPC had been hold on plastic containers to keep away from region conditions. Results show that the adopted cement conforms to the Iraqi specification No. 5/1984 (Elchalakani, 2015). Examine at the National Center for Construction laboratories and Research (NCCER) for the chemical and physical properties.

**Fine aggregate:** Fine Aggregate (FA) transported from Al-Nabai Region was examined results show that FA grading and also the salt concentration was going with the Iraqi specification No. 45/1984 (Anonymous, 1984a, b). FA has (4.75 mm) most size with rounded particle form and sleek texture with fineness modulus of (2.84). The grading of FA is shown in Table 3 and 4 shown physical composition of F.

**Coarse aggregate:** The grading of Coarse Aggregate (CA) is shown in Table 5. The gained results indicated that CA grading was going with the local specification No. 45/1984 (Anonymous, 1984a, b). The particular gravity and absorption were (2.66) and (0.66%) severally. The crushed stream CA was washed then keep in air to dry the surface and so, keep during a filled dry surface case before using. CA with most size of (14 mm) was used throughout the tests.

Table 3: Grading of FA

| Sieves | Passing (%) FA (%) | Local specification No. 45 for zone (2) |
|---|---|---|
| 4.75 (mm) | 90.54 | 90-100 |
| 2.36 (mm) | 74.69 | 75-100 |
| 1.18 (mm) | 60.46 | 55-90 |
| 600 (μm) | 43.47 | 35-59 |
| 300 (μm) | 13.72 | 8-30 |
| 150 (μm) | 1.98 | 0-(50/5) |
| Pan | 0.00 | - |

Table 4: Physical composition of FA○

| Physical composition | Test | Iraqi specification No. 45 (Zone (2) |
|---|---|---|
| Specific Gravity (SG) | 2.75 | - |
| Sulfate (%) | 0.08 | • 0.5% |
| Absorption (%) | 0.70 | _- |

○ Whole examined were created within the National Center for Construction Laboratories

Table 5: Grading of CA

| Sieve | Passing (%) CA (%) | Local specification No. 45 |
|---|---|---|
| 14 (mm) | 97.13 | 90-100 |
| 10 (mm) | 57.57 | 50-85 |
| 5 (mm) | 1.6 | 0-10 |
| Pan | 0 | |

Table 6: Chemical structure and physical composition of TRF

| Chemical composition of TRF (Al-Khamisi, 1999) | | Physical properties of TRF | |
|---|---|---|---|
| Rubber hydrocarbon | Cumulative passing (%) | Specific gravity | 1.106 |
| Carbon black | 31 | Density | 1.16(g/cm³) |
| Acetone extract | 15 | Ultimate tensile strength | 9 (MPa) |
| Ash | 2 | Elongation at break | 150% |
| Residue chemical balance | 4 | Hardness shore A | 64 |

*The physical properties of TRF tests are made in the National Center of Construction Laboratory and Research (NCCLR)

Fig. 1: Tire rubber fibers (length = 15 mm)

**Chipper rubber:** Consumed Tire Rubber Fibers (TRF) for small vehicles cut by hand to small pieces which have dimension of (width 10, thickness 7 and length 15 mm) as shown in Fig. 1. Three percentages of TRF were used, 5, 15, 20% as percent of the weight of CA. Table 6 shown, chemical structure and physical composition of TRF (Table 6).

Table 7: Chemical structure of fly ash (Powal1 and Dwivedi, 2013)

| Chemical compositions | Formula | Content (%) |
|---|---|---|
| Silicon dioxide | $SiO_2$ | 56.26 |
| Aluminium trioxide | $Al_2O_3$ | 28.54 |
| Iron oxide | $Fe_2O_3$ | 5.42 |
| Lime | CaO | 4.54 |
| Magnesium oxide | MgO | 1.37 |
| Potassium oxide | $K_2O$ | 1.74 |
| Loss of ignition | LOI | 1.35 |

Table 8: Properties of concrete mixes

| Parameters | Normal strength concretes |
|---|---|
| W/C | 0.5 |
| Water (w) | 200 ($L^3$) |
| Cement (C) | 400 (kg/m³) |
| FA | 692 (kg/m³) |
| CA | 1058 (kg/m³) |
| Density | 2336 (kg/m³) |

**Fly ash:** Fly ash is incredibly economical as its cost compare with cement. Although, fly ash can not be used as substitute of cement and it doesn't gain strength once mixed with water. However, it's compliments cement is such some way that it uses by product of cement. Thus, fly ash is accustomed mix to with cement to realize a lot of cost effective cement solution. The partial replacement of OPC with fly ash. It can have the same properties as cement used in concrete as per IS: 3812:1999. The optimum replacement of fly ash is (0.1-0.3) (Al-Khamisi, 1999). Table 7 shown the chemical structure of fly ash.

## Experimental program

**Mix proportion:** Table 8 shown mixture details. Mixture produces fine workability and uniform combination of concrete without segregation when strength of concrete is designed in in conformity with Neville (1973) mix design at 28 days cube compressive strength of (25 MPa). In order to create concrete strength and alternative mechanical properties for traditional concrete there were 72 cubes, cylinders and prisms were ready. Mixing ratios were classified into different percentages of substitution mixtures and quantities obtained for mixtures as follows in Table 9 shows percentage ratios for the replacement of CA with rubber and Table 10 shows the replacement of OPC by fly ash with 20% and a different ratio of rubber.

**Casting and curing of samples:** The eight mixes were ready during this study and forty eight cubes were ready (150 mm cube) for conducting the compressive strength. Also, forty eight samples of prisms (100×100×500 mm) for flexural strength and 48 of cylinders (150×300 mm) diameter and height, respectively, for split strength were prepared. Samples of six cubes, six cylinders and six prisms were tested at 2 ages (7 and 28 days) and for every variety of proportion replacement mixes of CA with rubber in varied proportion of 10, 15 and 20% as shown in Fig. 2.

Table 9: Percentage of CA replaced with rubber

| W/C | 0.5 | 0.5 | 0.5 | 0.5 |
|---|---|---|---|---|
| W (kg/m$^3$) | 200 | 200 | 200 | 200 |
| C (kg/m$^3$) | 400 | 400 | 400 | 400 |
| FA (kg/m$^3$) | 692 | 692 | 692 | 692 |
| CA. (kg/m$^3$) | 1058 | 1005.1 | 899.3 | 846.4 |
| Rubber chipped/Replace (%) | 0 | 5 | 15 | 20 |
| (kg/m$^3$) | 0 | 22 | 66 | 88 |

Table 10: Fly ash percentage of OPC and percentage of CA replaced with rubber

| W/C | 0.5 | 0.5 | 0.5 | 0.5 |
|---|---|---|---|---|
| W (kg/m$^3$) | 200 | 200 | 200 | 200 |
| C (kg/m$^3$) | 320 | 320 | 320 | 320 |
| Fly ash replaced (20%) | 80 | 80 | 80 | 80 |
| FA (kg/m$^3$) | 692 | 692 | 692 | 692 |
| CA (kg/m$^3$) | 1058 | 1005.1 | 952.2 | 899.3 |
| Rubber chipped/Replace (%) | 0 | 5 | 10 | 15 |
| (kg/m$^3$) | 0 | 23.07 | 46.14 | 69.21 |

Fig. 2: Specimens during curing

Finally, OPC was replaced by Fly ash in optimum proportion of 20%. Cast of the sample and placed in curing tank for 7 and 28 days and when they were tested for compressive strength, split strength and flexural strength.

## RESULTS AND DISCUSSION

**Compression strength:** Results were presented in Fig. 4. Which indicates the strength pattern when CA was replaced with rubber and OPC by fly ash. It was showed that 40% of compressive strength was decrease with replacement of CA with rubber by 20 and 28% decrease of compressive strength was show up when OPC was replaced by fly ash 20% and CA was replaced with rubber by 20%. All cubes were cast and tested after 28 days of curing period as shown in Fig. 3. This is due to the impairments of interaction between the OPC matrix and tire rubber when liken with the CA.

**Split tensile strength:** Results are shown in Fig. 6. The results show the strength pattern when CA was replaced with rubber it was show up that 44% of the split tensile strength was reduced by increasing the percentage replacement of CA with tire rubber up to 20%. Finally, 32% decrease of strength was show up when replacing 20% of OPC with fly ash and replacing 20% of the CA with rubber. All cylinder was cast and tested after 28 days as shown in Fig. 5. This can be explained by the poor bond between OPC paste and tire rubber. Interface zone is probably going to cut back the bond between OPC paste and tire rubber.

Fig. 3: Compression strength test

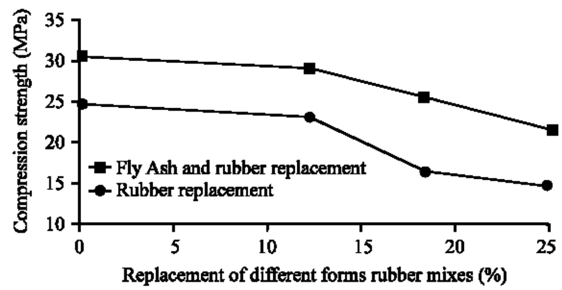


Fig. 4: Compression strength tested at age of 28 days

Fig. 5: Splitting tensile test

**Flexural strength:** The flexural strength decrease by 42% due to replacement of tire rubber by 20% in place of CA. In addition to this, 22% of flexural strength reduction was observed when both OPC was replaced by fly ash and CA

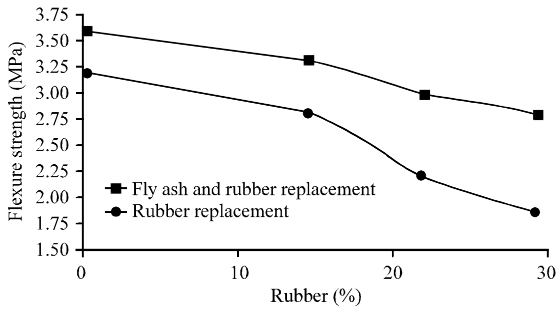


Fig. 6: Split tensile strength of cylinders at age of 28 days

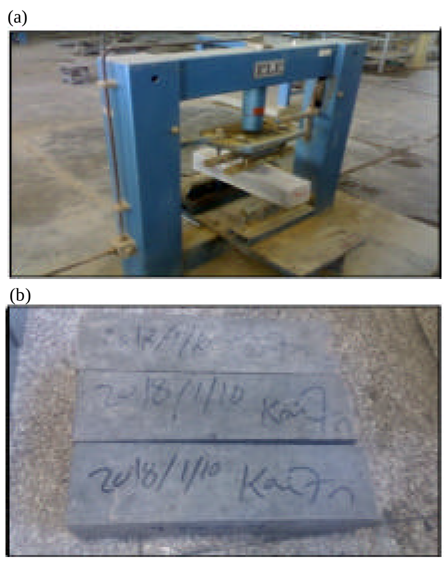


Fig. 7: a and b) Modulus of rupture test

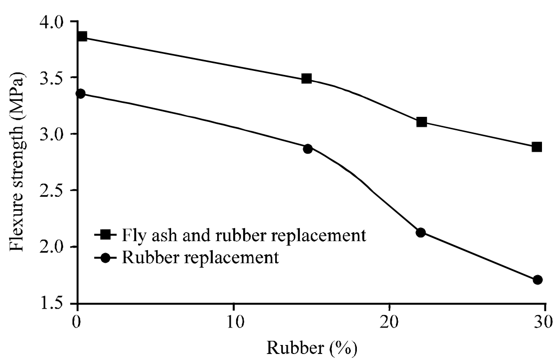


Fig. 8: Flexure strength of prism at age of 28 days

was replaced with rubber. All the prisms were tested after 28 days as shown in Fig. 7. The seemingly reason for this reduction of strength is that there'll be an awfully weak bond between OPC paste and also the tire rubber. The results are shown in Fig. 8.

## CONCLUSION

Depend on the experimental results of cubes, cylinders and prisms with and without the addition silica fume with dimensions of fibers (width 10, thickness 7 and length 20 mm) for three different percentages (5, 10 and 15%) by weight of coarse aggregate. The major conclusions can be drawn as follows: the addition of (TRF) decreases the compressive strength of cubes specimens in the range between 6 and 33% and decreases the compressive strength for concrete when replacement of OPC with fly ash in the range between 6 and 22% compared with the compressive strength of the reference concrete without (TRF). Part of the reduction of strength, the existing air and which swells with the rubber content. The increase of (TRF) causes a decrease in density within the range between 3 and 13% compared with that of normal concrete.

The increase of (TRF) causes a decreasing in the tensile strength ranging between 12 and 24% and decreases the tensile strength for a concrete with silica fume in the range between 7 and 20% when compared with the normal concrete. The increase of (TRF) causes decrease in flexure strength ranging between 13 and 25% and decreases the flexure strength of concrete with silica fume in the range between 7 and 15% when compared with that of normal concrete. Used tires were used in the study method to reduce tire waste and economic and environmental management. Fly ash is used as a replacement for cement to enhance mechanical properties and durability of concrete containing scrap tire rubber. Based on the experimental results granted, a significant improvement was observed in the strength of pressure, tensile strength and flexural strength in mixtures containing rubber and fly ash.

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