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# Mechanical Properties of Sustainable Concrete Utilizing Rubber Wastes as Fine Aggregate Replacement

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***Abstract:*** *Among industrial wastes, tyre rubber waste is one of the hazardous wastes which are being generated and accumulated on a very large scale worldwide every year. In this research, an experimental investigation was carried out to study the effect of using waste tyre rubber as fine aggregate on concrete which was evaluated through mechanical properties. A total of 12 different concrete castings were conducted in this study by replacing fine aggregate of sand particles with fine rubbers with different ratios of 0%, 10%, 20%, 30%,40%, and 50%. Dolomite was used as coarse aggregate and silica fume with a constant content equal to (12.5%) of the weight of cement. Also, waste crumb rubber (CR) particles were pretreated using NaOH for 24 hr., and steel fiber (SF) was added with constant content equal to 1% of concrete volume. Slump, density, compressive strength, splitting tensile, and flexural strength tests were performed. In addition, scanning electron microscopy (SEM) was studied to determine the microstructure properties of concrete. The results showed a decrease in workability, and a decrease in dry density was 24% less than the control mix when we used 50% rubber replacement of fine aggregate. The mechanical properties of compressive strength, splitting tensile and flexural strength decreased as rubber waste content increased especially tyre rubber without treatment. It was also observed that tyre rubber treatment with NaOH and adding steel fiber caused a decrease in losses of mechanical strength compared to using without treatment and steel fiber. The microscope shows the characteristic of rubberized concrete is poorer than traditional concrete, the reductions are related to the poor bonding characteristic between rubbers and cement paste around the ITZ of rubberized concrete.*

***Key Word****: Aggregate Replacement; Compressive Strength; Flexural Strength; Rubberized Concrete; Splitting Tensile; Tyres.*

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## I. Introduction

Waste is divided into solid waste, liquid waste, and gaseous waste. Solid waste has become a serious problem on a global scale due to the massive accumulation of human activity field [1-2]. By 2050, the World Bank predicts that 3.4 billion tons of municipal solid waste would have been produced [3-5]. There are lots of disposal ways for liquid and gaseous waste materials. The amount of waste has been steadily increasing due to the increasing human population and urbanization [6]. Over the last two decades, using recycled materials and sustainable design has gotten much attention [7]. Recently, more Concern has been given to recycling waste materials and reusing them again in sustainable design [8]. One of the main ecological objectives is the recycling of solid wastes. According to reports, the burning of solid trash around the world contributes an additional 5% of the world's carbon emissions. The amount of CO2 emitted globally might be reduced by up to 15% with better waste [9].

Tyres rubber is considered one of the important solid wastes caused by cars tyres disposed of in landfills have turned into an environmental issue over the past few decades as globalization and the industry that makes vehicles have grown [10]. Waste tyre disposal has been a significant problem for countries all over the world. Burning used tyres is typically the simplest and least expensive approach to decomposing them. However, this approach is illegal in many countries due to the pollution it causes from the massive amount of smoke [11]. Tire rubber contains styrene, a strongly toxic component that is highly damaging to people's health [12]. Every year, 981 million tyres are disposed of away globally. Nevertheless, just 7% of them are recycled, 11% are used as fuel, and 5% are exported. The remaining 77% are thrown illegally or in landfills [13-14]. Recycling end-of-life tyres is one of the main issues that both the scientific community and environmental organizations have. End-of-life tyres are produced in around one billion tons annually, according to estimates [15-16].

Numerous research has been done on concrete that replaces fine and/or coarse natural aggregate with scrap rubber from old tyres in varying percentages [17-18]. The angular crumb rubber (CR) particles have a smooth surface texture, a specific gravity of 1.10± 0.05, and an angular form [19]. By lowering the need for natural aggregates, the addition of flexible rubber to rigid concrete affects the overall performance and qualities of the material and may assist create low self-weight structures with economic sustainability. By substituting CR for 10–30% of the sand in concrete, it is possible to reduce the unit weight by 14–28% [20]. It reduces the risk of high-strength concrete (HSC) spalling with fire. On the other hand, it reduces concrete stiffness without a high strength loss, because the volume fraction of rubber needed is only 2% [21]. Due to the lower strength and elastic modulus of rubber particles, the compressive strength and elastic modulus were often lower than those of natural concrete. As a result of the air inclusion during mixing, the Interfacial Transition Zone (ITZ) between the hydrophobic rubber particle surface and the cement paste was weaker and had a larger porosity [22]. Crumb rubber is mainly used in a concrete mix to replace natural sand; hence their crack bridging effects are minor [23]. According to certain studies, utilizing 20%, 30%, 40%, and 50% CR, respectively, reduced tensile strength by 40.1%, 44.1%, 48.9%, and 58.5%. The interfacial transition zone (ITZ) between the CR and the matrix is where tensile cracks in CRC begin, and the ITZ has been identified as the weak link in CRC because of the subpar CR-paste bond [24].

Research has been done on two main methods of modification, physical and chemical treatments, to improve the surface conditions of rubber. Physical techniques include washing with clean water and preparing with cement, silica fume, or limestone powder. Cleaning the surface of the raw material with water could remove particles and other additives, enhancing the adhesion of the rubber to the paste [25-26]. The mechanical properties of CRC are greatly enhanced by the treatment of CR. After being exposed to NaOH for 24 hours, CR particles were manually roughened with sandpaper [27], which increased the compressive strength by 40%. The surface texture of CR has also been altered using chemicals like KOH, KMnO4, H2SO4, HCl, acetone, methanol, and ethanol [28]. The treatment methods have improved the durability of CRC. However, the quantity of CR should be limited to 16% while using NaOH [29]. Sand is a limited resource in many regions of the world, hence the increase in CRC's durability increases the usage of CR. Additionally, the use of CR in concrete supports the global circular economy [37] by utilizing waste products, especially used tyres from cars.

Rubberized concrete has lately been suggested to be reinforced with steel fibers to increase strength while retaining its exceptional flexibility and toughness due to the significant drop in strength [30-33]. Compressive strength and elastic modulus only slightly increased with the addition of 0.9 percent steel fibers, but flexural strength increased dramatically. Concrete's ability to bend has a modest effect on rubber particles. [34].

Researchers have investigated the possibility of using rubber from waste tires in different civil engineering projects. Such as road pavement, buildings, reducing sound barriers, and geotechnical operations applications where tires can be utilized. [35]. According to studies, rubber concrete might be used to create sound barriers and seismic shock absorbers for buildings [36].

According to the previous literature research, the ductility improvement and lightweight properties of rubberized concrete mix are inversely related to the amount of rubber in the concrete mix. The recycled rubber from waste tyres may need to be treated with a NaOH solution prior to use in the concrete mix to remove any possible zinc stearate coatings that may have formed during the tyre manufacturing process. Mechanically created rubber particles can be utilized without treatment. As a result of this process, the surface of the rubber becomes rough and porous, which can improve the cohesiveness between the rubber and cement [38].

## II. Material And Methods

### 2.1 Materials

#### 2.1.1 Cement

This investigation employed Portland cement type (CEM I 42.5 N). The specific gravity of cement is 3.15 and the specific surface area of cement equals 2900 cm2/gm. It is produced according to the Egyptian standards ES 4756/1-2013 and Table 1,2 contain the chemical composition of OPC as shown in Fig. 1 and its physical properties

**Table no 1:** Cement's Physical Properties (CEM I 42.5 N)

| Property | Test Results | Limits* |
|---|---|---|
| Specific gravity | 3.15 | -------- |
| Unit weight (Kg/m$^3$) | 1440 | -------- |
| Initial setting time (min) | 120 | >60 min |
| Final setting time (min) | 380 | -------- |

**Table no 2:** Cement's Mechanical Properties

| Constituent | % |
|---|---|
| Lime (Cao) | 63.90 |
| Silica ($SiO_2$) | 20.10 |
| Alumina ($Al_2O_3$) | 4.08 |
| Iron Oxide ($Fe_2O_3$) | 5.10 |
| Magnesia (MgO) | 1.48 |
| Sulphur Trioxide ($SO_3$) | 2.20 |
| $N_2O$ | 0.05 |
| Loss of Ignition | 3.41 |
| Lime saturation factor | 0.92 |

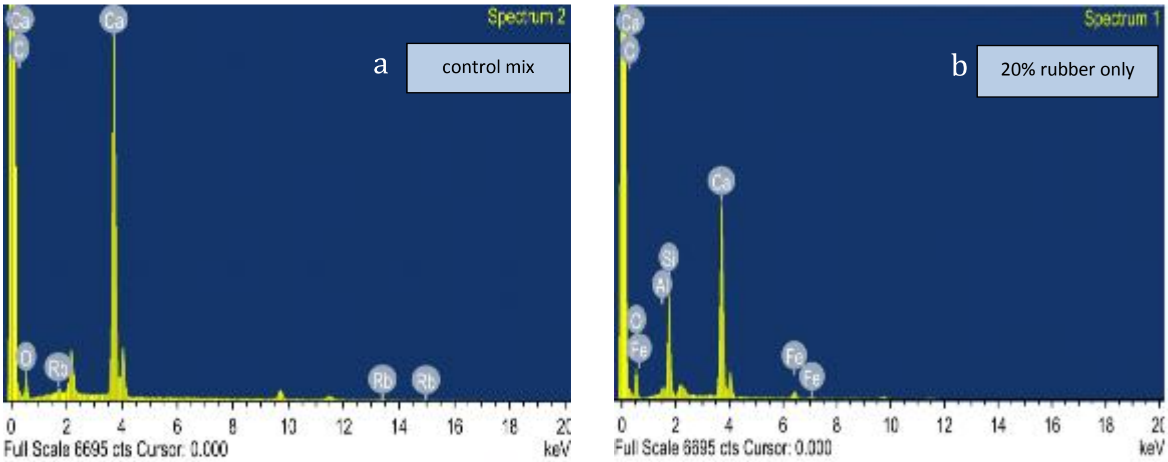


**Fig. 1.** Chemical analysis of cement and tyre rubber using EDX: (a) control mix, (b) rubber tire 20%

## 2.1.2 Aggregates

### 2.1.2.1 Coarse aggregate

Crushed dolomite was used as a coarse aggregate in all mixtures. Natural crushed type 4/19.5, The specific gravity was 2.65. The physical and mechanical properties of the coarse aggregate are shown in Table no 3.

**Table no 3:** Dolomite's Physical Properties.

| property | Test Results | Limits* |
|---|---|---|
| Specific gravity | 2.65 | 2.5-2.75 |
| Unit weight (kg/$m^3$) | 1600 | -------- |

### 2.1.2.2 Fine aggregate

Sand and rubber were used as fine aggregates. A typical sample of sand is illustrated in Fig.2, natural sand type 0/4 and its properties are shown in Table no 4. The rubber was used as a fine aggregate replacement, one size was used illustrated in Fig.2 with different ratios (0-10-20-30-40-50) %. Rubber created from recycled tyres was produced through shredding tyres obtained from a local company (Ismailia, Egypt). To separate the steel fibers from the rubber, the used tyres were shredded and minced. Rubber's maximum size was 5mm. The approximate specific gravity of both sizes of rubber particles is 1.15 as shown in Table no 5. The absorption value is negligible.

**Table no 4:** Sand's Physical Properties.

| property | Test Results | Limits* |
|---|---|---|
| Specific gravity | 2.60 | 2.5-2.75 |

| | | |
|---|---|---|
| Unit weight (kg/$m^3$) | 1650 | --------- |

**Table no 5:** Rubber's Physical Properties.

| property | Test Results | Limits* |
|---|---|---|
| Specific gravity | 1.15 | ------- |
| Unit weight (kg/$m^3$) | 1250 | ------- |

### 2.1.3 Superplasticizer

Sika (Viscocrete-5920) is considered a third-generation superplasticizer for concrete and mortar. It meets the requirements for superplasticizers according to ASTM-C- 49/4 Types G and F and BS EN 934 part 2: 2001 with a density of 1.09 ± 0.01 kg/It.

### 2.1.4 Silica-fume

Sika Fume as shown in Fig.2 is a concrete additive of a new generation in powder form, Sika silica fume technology contains extremely latently reactive silicon dioxide. The presence of this substance imparts greatly improved internal cohesion and water retention. The concrete becomes extremely soft and pumping properties are substantially improved. In the set concrete, the latently reactive silica fume forms a chemical bond with the free lime with a surface area of 20,000$cm^2/kg$, and specific weight equal 2.15.

### 2.1.5 Fiber

End-hooked type steel fibers illustrated in Fig.2 with a circular cross-section were used with a length of 20 mm. The steel fibers were made from ordinary steel with a melting temperature of 1538 °C and a density of 7.8 g/cm$^3$, their properties are illustrated in Table no 6.

**Table no 6** Fiber's properties.

| Property | |
|---|---|
| Length of fiber | 20 mm |
| Thickness (diameter) | 0.25 mm |
| Aspect ratio | 80 |
| Specific gravity | 7.8 |
| Tensile strength | 2000 MPa |
| Modulus of elasticity | 200 GPa |

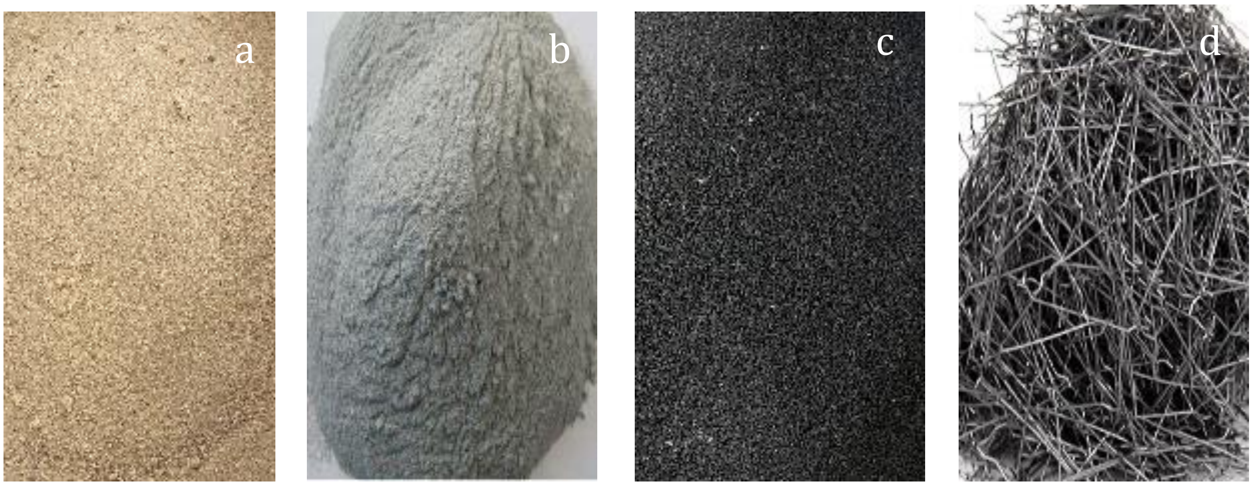


**Fig. 2.** (a) Sand, (b) Silica fume, (c) Fine rubber, and (d) Steel fiber.

## 2.2 Mix proportions

Table no 7 shows the components of the rubberized concrete mixtures used in this study. The lab produced a total of 12 different mixture types. The cement, dolomite, sand, water, silica fume, and superplasticizer-based mixture served as the control. Fine rubber aggregate (5 mm) was used in place of sand in percentages of 0, 10%, 20%, 30%, 40%, and 50% by volume to create the rubberized concrete. Fig. 4 illustrates the sieving analysis for dolomite, sand, and fine rubber particles. We added steel fibers for four mixes of 10% & 20% rubber once re-treated by NaOH solution and others without treatment.

## 2.3 Treatment of fine rubber

When recycled rubber tyres are used in replacement for natural aggregate, concrete loses strength. The lack of significant adhesion between rubber and cement paste is the cause of this degradation. Before using rubber tyre surfaces in concrete, several techniques were created to treat them. As illustrated in Fig.3, one of these efficient procedures involved soaking rubber tyres in 15% of NaOH solution for 24 hr. to enhance their surface and get rid of the weakness between the rubber tyre and the cement paste, then we leave it to dry. Additionally, the gaps created by the NaOH solution on the rubber's surface rendered it rough, which improved the bond between rubber tyres and the cement paste.


**Fig. 3.** Treatment of rubber tyre: (a), (b) Rubber tyre soaked in NaOH solution, and (c) Rubber tyre air dry

## 2.4 Mixing procedure and curing

Following the addition of all aggregates to the concrete mixer, tyre fine rubber, and cement, once the dry mix seems visually uniform, half of the water is added to the rotating concrete mixer. The remaining half of the water is then completely incorporated with the chemical additive superplasticizer before being added to the mixture. All the components in the mixer must be mixed for an additional 2 to 3 minutes before casting. After that, the concrete was removed from the mixer as Fig.5, and the concrete was then taken out of the mixer and put into the steel moulds for the different types of specimens needed for each test. Before adding concrete mix, these steel moulds were oiled to make it easier to remove the specimens. The mixture was put into moulds and subjected to vibration. Steel moulds were stored in the laboratory at room temperature. After 24 hrs., specimens were removed from moulds and stored in laboratory water for 7 and 28 days in the temperature range of 22°

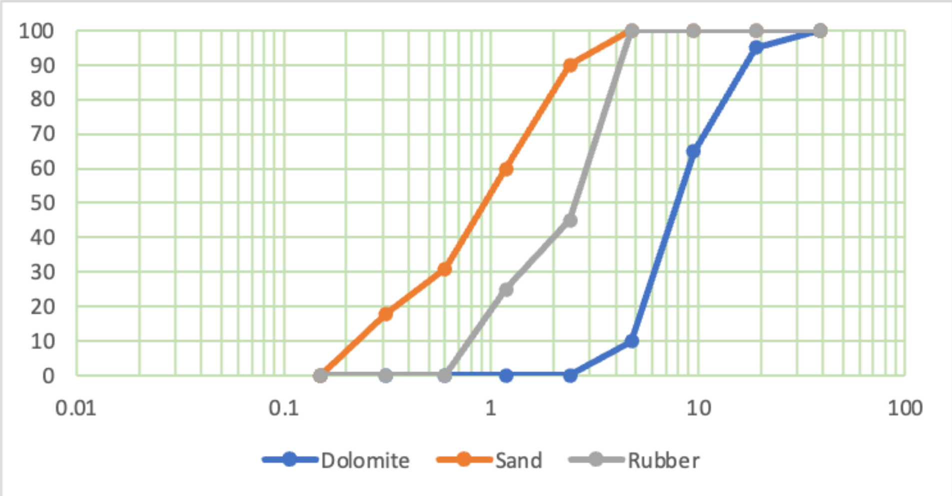


**Fig. 5**. Sieve Analysis of dolomite, sand, and fine rubber aggregate

**Table no 7:** Proportions of Rubberized Concrete Mixtures (kg/m$^3$)

| Mixture ID | CEM I | Coarse Aggregate | Fine Aggregate | | Fiber | Silica Fume | SP | water |
|---|---|---|---|---|---|---|---|---|
| | | Dolomite | Sand | Rubber | | | | |
| **M1-R0% (REF. CONCRETE)** | 400 | 1130 | 750 | 0 | 0 | 50 | 9 | 140 |
| **M2- R10%** | 400 | 1130 | 597 | 66 | 0 | 50 | 9 | 140 |
| **M3-R20%** | 400 | 1130 | 476 | 119 | 0 | 50 | 9 | 140 |
| **M4-R30%** | 400 | 1130 | 378 | 162 | 0 | 50 | 9 | 140 |
| **M5-R40%** | 400 | 1130 | 296 | 198 | 0 | 50 | 9 | 140 |
| **M6-R50%** | 400 | 1130 | 227 | 227 | 0 | 50 | 9 | 140 |
| **M7-R10%-FCR1%** | 400 | 1130 | 597 | 66 | 78 | 50 | 9 | 140 |
| **M8-R20%-FCR1%** | 400 | 1130 | 476 | 119 | 78 | 50 | 9 | 140 |
| **M9-R10%-T15%** | 400 | 1130 | 597 | 66 | 0 | 50 | 9 | 140 |
| **M10-R20%-T15%** | 400 | 1130 | 476 | 119 | 0 | 50 | 9 | 140 |
| **M11-R10%-FCR1%-T15%** | 400 | 1130 | 597 | 66 | 78 | 50 | 9 | 140 |
| **M12-R20%-FCR1%-T15%** | 400 | 1130 | 476 | 119 | 78 | 50 | 9 | 140 |

## 2.5 Testing procedures

### 2.5.1 Fresh properties

In this research, the fresh concrete properties were measured to assess the quality of rubberized concrete. Workability of Concrete is a broad and subjective term describing how easily freshly mixed concrete can be mixed, placed, consolidated, and finished with minimal loss of homogeneity. Workability gives the concrete mix the ability to be poured in any shape. To evaluate the influence of waste tyre rubber particles, replacing mineral aggregate, on the workability of fresh rubberized concrete, slump tests were performed according to BS EN 12350-2. First rubberized concretes were prepared by adding rubber particles with a maximum size of (5) mm, replacing fine aggregate. Mix proportions and materials characteristics are reported in Table no 3. Rubber particles were added by hand during the mixing procedure as shown in Fig.5.

### 2.5.2 Mechanical properties

Each mix's dry density was estimated in accordance with BS EN 12390-7. each mixture was tested on three cubic samples (100x100x100) mm, and the findings were averaged. compressive strength was evaluated for all mixes in accordance with BS EN 12390-3. At 7 and 28 days, three cubic samples (100x100x100) mm of each mixture were analyzed and take the average of the results excluding the outlier above or lower than 25%. likewise, tensile strength was evaluated in accordance with BS EN 12390-3 at 7 and 28 days, three-cylinder samples (100) mm diameter x (200) mm height of each mixture was analyzed, and the findings were averaged finally flexural strength was evaluated in accordance with BS EN 12390-3 at 28 days, two rectangular prism samples (100x100x500) mm of each mixture was analyzed, and the findings were averaged at 28 days.

### 2.5.3 Microstructural tests

Scanning electron microscopy was used to examine the microstructure of rubberized concrete and the interfacial transition zone (ITZ) between rubber and cement paste (SEM). Images were taken from each sample. A total of four samples taken from the center and core of the concrete, which was chopped into pieces of 2 mm x 2 mm, were subjected to SEM analysis. The bond strength between the tyre particles and the cement paste is strengthened by these indentations.

## III. Results and discussion

### 3.1 Properties of fresh concrete

The workability of rubberized concrete was evaluated by a slump. The workability of rubberized concrete decreased when rubber content increased due to the irregular surface texture of the rubber, which caused higher inter-particle friction.

### 3.2 Dry density

The specific weight of concrete modified with waste rubber is reduced as the level of substitution of aggregates with tyre particles increases as shown in Fig.6. This reduction can be attributed to the specific weight of tyre rubber being lower than that of traditional aggregates 1.15 g/cm$^3$ for tyre rubber and 2.60-2.65 g/cm$^3$ for aggregates. In most cases, the density of rubberized concrete reduces from 10% to as high as 30% [1] when compared to a plain control concrete mix while finer rubber aggregates (0.5 mm size). Results showed a slightly higher level of reduction as the increase of rubber the percentage which showed a reduction of 24% in the density of the final concrete when crumb rubber replaced fine aggregates by 50% for concrete, The EN 206-1 code defines lightweight concrete mixtures as having a density less than 2000 kg/m$^3$ and a cubic compression strength greater than 9 MPa. The mixtures that this study considers to be lightweight concrete as mix M5-R40% & M6-R50%.

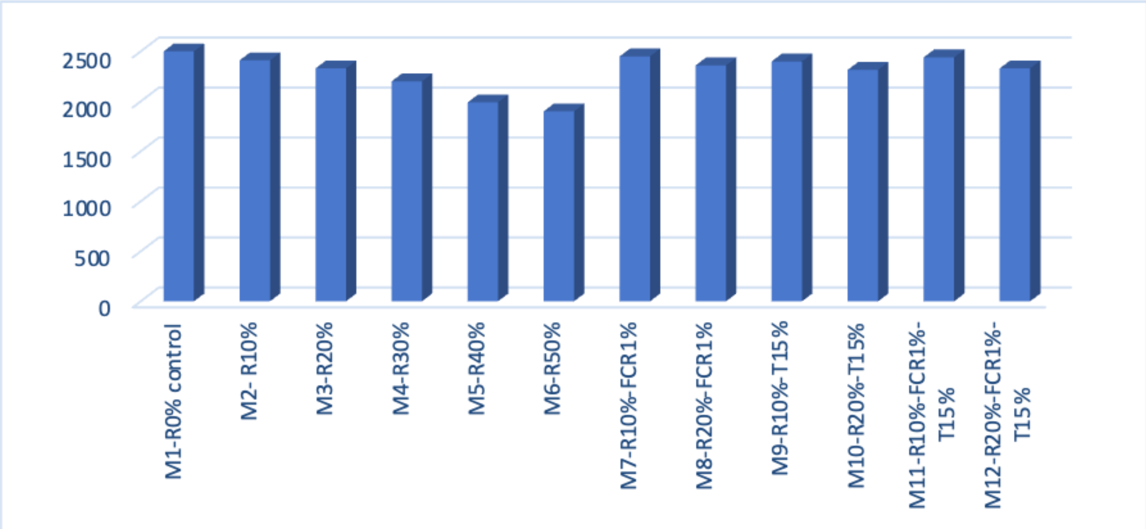


**Fig. 6.** Dry density test.

## 3.3 Mechanical properties

### 3.3.1 Compressive strength

The results of the compressive strength of concrete are illustrated in Fig.7. Each mixture represents the average result for three cubes at the age of 7 and 28 days as shown in Fig. 8. The results of Compressive strength decreased when increasing the replacement rubber ratio, it reduced by an average of 74% to the control mix when fine rubber replaced the sand with percentages of 10, 20, 30, 40, and 50 % by volume, while it decreased by 25, 39, 55, 62 and 74 %. After 7 days, the maximum compressive strength (40 MPa) was obtained for the control mix with 0% crumb rubber and the minimum value (8.8 MPa) for the mix with 50% crumb rubber. The same trend was observed for the compressive strength at 28 days, a strength above (51 MPa) was obtained for all the mixes in which the amount of rubber was 0% and the minimum value (13 MPa) for the mix with 50%. Treating rubber with NaOH solution is so useful it reduced the losses in compressive strength. Re-treated rubber increased by 8% compressive strength than without treatment in 10% replacement with fine rubber and 16% in 20% replacement with fine rubber. Compressive strength was slightly increased when using steel fibers because it hasn't had a high effect on compression. It was reported the result increased by 2% in 10% replacement with fine rubber and 3% in 20% replacement with fine rubber. finally, when we used both re-treated rubber and steel fiber the resulting enhancement of 10% in the 10% replacement and 18% in the 20% replacement

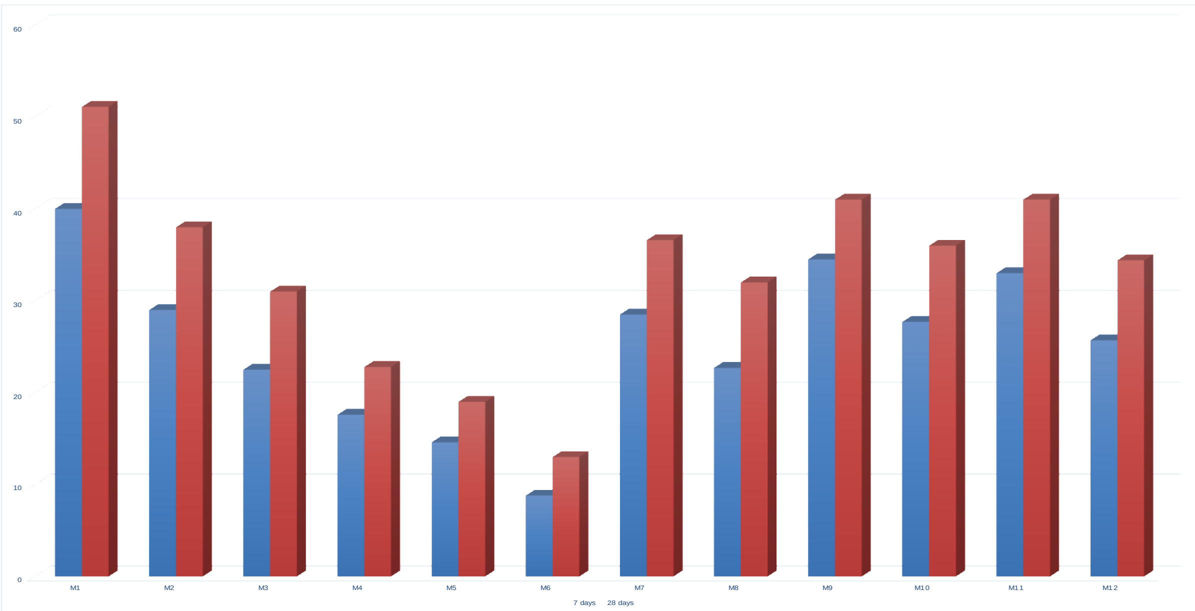


**Fig. 7.** Compressive strength test result.


**Fig. 8.** Compressive strength machine: (a) M3 after the compressive strength test, (b) Cubic during the test, and (c) M7 after the compressive strength test.

### 3.3.2 Splitting tensile strength

The results of the splitting tensile strength of concrete are illustrated in Fig.9. Each mixture represents the average result for three cylinders at the age of 7 and 28 days as shown in Fig.10. The results of splitting tensile decreased when increasing the replacement rubber ratio, it reduced by an average of 65% to the control mix. When fine rubber replaced the sand with percentages of 10, 20, 30, 40, and 50 % by volume, while it decreased by 18, 25, 55, 40, 53, and 65 %. After 7 days, the maximum splitting tensile (10.5 MPa) was obtained for the M11 mix with 10% rubber-retreated 15% and 1% steel fiber and the minimum value (3.3 MPa) for the mix with 50% crumb rubber. The same trend was observed for the splitting tensile at 28 days, a maximum strength (13.5 MPa) was obtained in the mix which the amount of rubber was 10% retreated by NaOH 15% and 1% steel fiber, and the minimum value (4.2 MPa) for the mix with 50%. Treating rubber with NaOH solution is slightly reduced the losses in tensile strength. Re-treated rubber increased by 4% splitting tensile than without treatment in 10% replacement with fine rubber and 3% in 20% replacement with fine rubber. Splitting tensile was increased when using steel fibers because it had a high effect on tension. It was reported the result increased by 26% in 10% replacement with fine rubber and 24% in 20% replacement with fine rubber. finally, when we used both re-treated rubbers. finally, when we used both re-treated rubber and steel fiber the resulting enhancement of 28% in the 10% replacement and 26% in the 20% replacement.

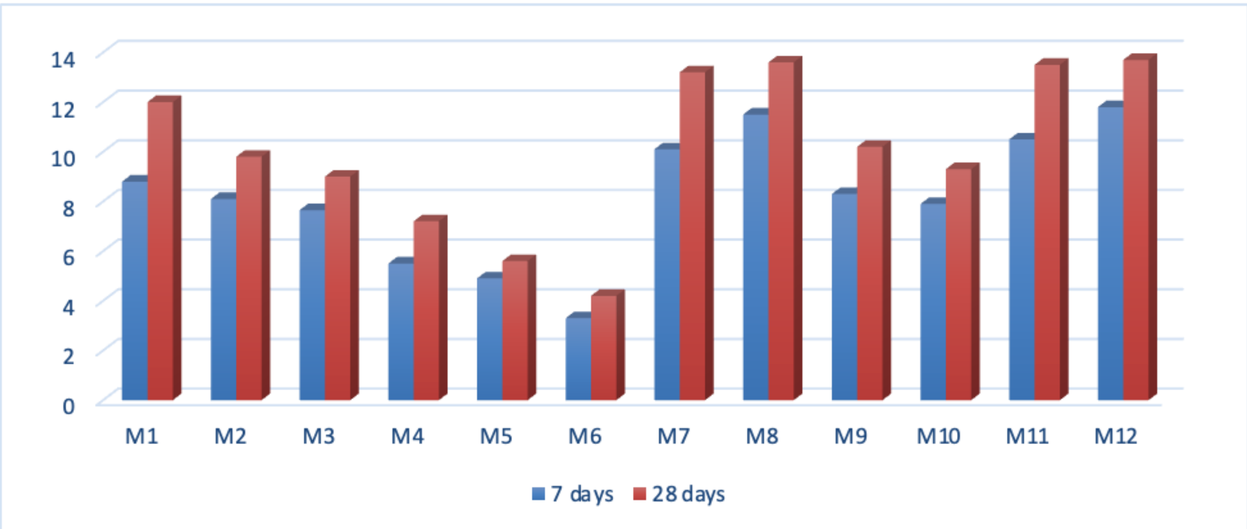


**Fig. 9.** Splitting tensile strength results.

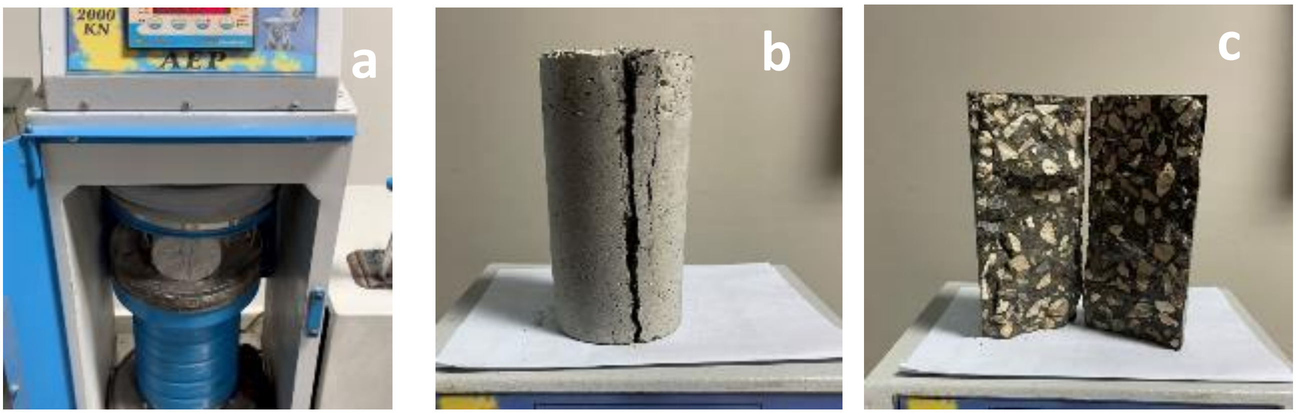


**Fig. 10.** Splitting tensile machine: (a) Cylinder during the test, (b) and (c) Cylinder after failure

### 3.3.3 Flexural strength

The results of the flexural strength of concrete are illustrated in Fig.11. Each mixture represents the average result for two beams at the age of 28 days as shown in Fig.12. The results of flexural decreased when increasing the replacement rubber ratio, reduced by an average of 45% to the control mix. When fine rubber replaced the sand with percentages of 10, 20, 30, 40, and 50 %, while it decreased by 3, 13, 23, 37, and 45%. After 28 days, the maximum flexural (5.25 MPa) was obtained for the M11 mix with 10% rubber-retreated 15% and 1% steel fiber, and the minimum value (2.68 MPa) for the mix with 50% crumb rubber Treating rubber with NaOH solution is slightly reduced the losses in flexural strength. Re-treated rubber increased by 2% splitting tensile than without treatment in 10% replacement with fine rubber and 2% in 20% replacement with fine rubber. Splitting tensile was increased when using steel fibers because it had a high effect on flexural. It was reported the result increased by 9% in 10% replacement with fine rubber and 13% in 20% replacement with fine rubber. finally, when we used both re-treated rubber and steel fiber the resulting enhancement of 11% in the 10% replacement and 14% in the 20% replacement.

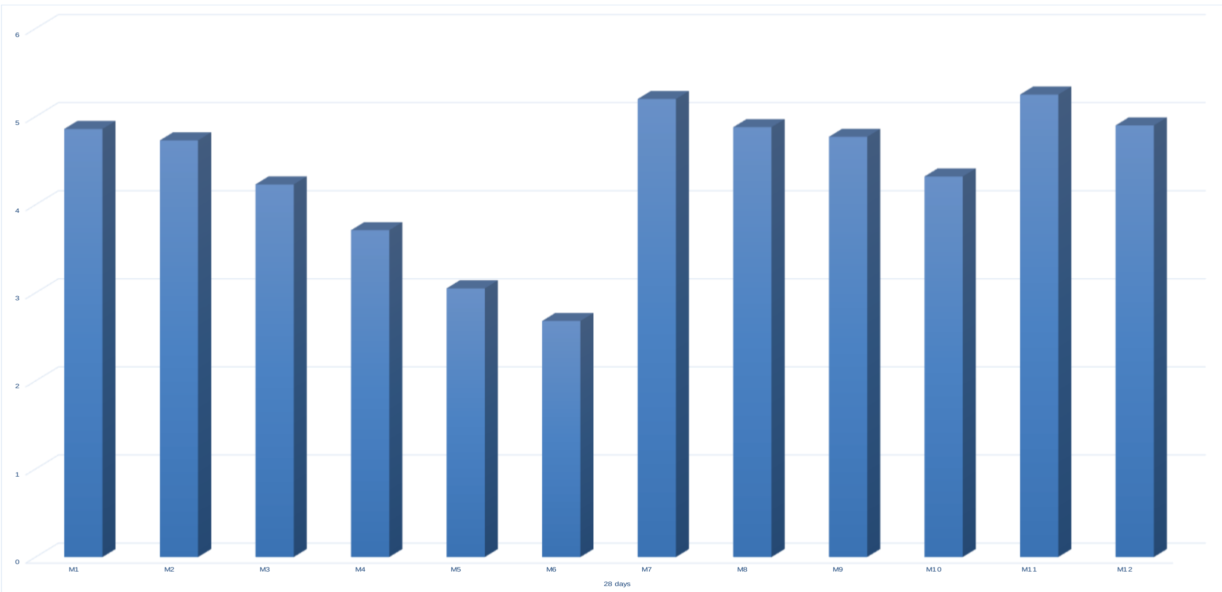


**Fig. 11.** Flexural strength test result.

**Fig. 12.** Universal machine(300KN): (a) Beam during the test, and (b) beam after failure

### 3.4 SEM analysis

The SEM images were found in Fig. 13. From the shown microscope, it is clear no interface connection between cement paste and rubber tyre has been preserved in the concrete. Fig.13. b. illustrates a case of 20% rubber replacement with retreated rubber and Fig.13. a. without treatment. On retreated rubber, the fracture surface, rubber separation, or breaking was not frequently seen as untreated. No evidence of a transition layer or even the area of tyre material that was sticking to the interface was found. This indicates a weak interfacial bonding strength. In untreated rubber, the crack formation is different from retreated rubber because the bond strength between rubber and cement paste is poorer than that of aggregate and cement paste.

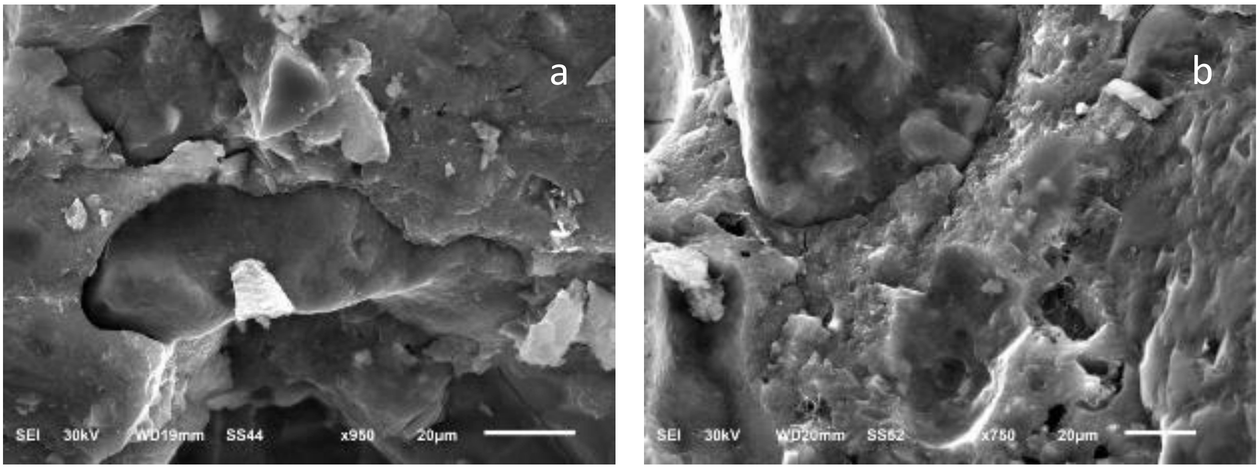


**Fig. 13.** Microscope SEM for two different mixes: (a) show the crack and weakness between cement paste and rubber untreated and (b) show the bond between cement paste and retreated rubber

## IV. Conclusion

This study investigates the effect of rubberized concrete on mechanical properties and impact resistance. Based on the obtained experimental results, the following conclusions can be summarized:

1. The increase in rubber particle content leads to a decrease in workability and dry density due to its lower specific gravity compared to natural aggregate. The maximum reduction in dry density reached 24%. As a result of reduced density, rubberized concrete can be produced in lightweight mixes to meet the requirements of several applications.

2. The compression strength, splitting tensile and flexural strength of rubberized concrete decreased when fine rubber aggregate content 50% replacement, it decreased by 74, 65, and 45% respectively compared to the reference mixture. The loss in compressive strength can be acceptable if the replacement of total aggregate content with rubber doesn't exceed 20%. Over this ratio, a severe reduction in compressive strength is noticed.

3. Adding steel fiber by 1% highly improved the splitting tensile, and flexural strength by 26, and 13% and it hasn't a high effect on compressive strength also Pre-treatment of rubber particles for 24 hr. in 15% NaOH solution improved the mechanical properties.

4. The ITZ characteristic of rubberized concrete is poor than the traditional concrete. There is a systematic reduction in strength data with the increase of the rubber content in traditional concrete. The reductions are related to the poor bonding characteristic between rubbers and cement paste around the ITZ of rubberized concrete.

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