# Properties of Concrete Containing Tire Rubber Particles

Prepared By

**Nawroz Mustafa Amin**

# Abstract

The volume of tire rubber wastes is growing at a very quick rate. An Investigation estimated that millions of tires reach the end of their useful lives every year and millions more are predicted to be discarded on a systematic basis by the year 2030. Till present, a few of rubber waste recycled and millions of tires are just stored, landfilled or buried. The aim of this study is to inspect the properties of concrete inclosing tire rubber particles. The study shows the effect of waste materials, such as rubber particles substituted by volume on the fresh and hardened properties of concrete, When cement and aggregate (fine and coarse) are replace by rubber particle with different content, a significant change in the properties of concrete will develop according to the percent of the rubber particle, shape, and size. In this study based on the literature review, some properties of concrete mix that affected by rubber particle are illustrated, including (compressive strength, tensile strength, flexural strength, density, workability, and toughness). Generally by adding the rubber content to the concrete mix, the mechanical properties of concrete decrease, except the toughness of concrete that growth by increasing the rubber content.

# Table of Contents



# List of Figures



# List of Table

## 1- Introduction

It is estimated that in the United Kingdom about 40 million tires per year (i.e. more than one hundred thousand tires in a day) have been ending up as waste. This amount is predicted to rise by a further 63% by 2021, and this increase is due to the predicted evolution of road traffic. This quick growth rate for using rubber as a general in the UK becomes a series problem because of elimination of tire wastes in the not easy process as a waste rubber is not easily biodegradable. Stored rubber waste also make much health, environmental and economic problem through the air, water, and soil pollution, littering the landscape, and providing a breeding habitat for various pests [2]. In the producing of concrete mix, 55% to 80% take natural aggregates like crushed stone and river sand, and it is important to think about another alternative material for the sand and gravel to be used in the producing concrete especially in the regions that the natural resource is less for obtaining sand and gravel. Waste materials like coal fly ash, glass pieces, plastic crumbs, copper slag, bottom ash, and crushed rock dust were used in the producing concrete. Also, the waste tire crumb rubber was used as an alternative to river sand and gravel and their properties were investigated. So, waste materials as a general are used to modify and improve the mechanical properties and performance of concrete so as to make it suitable for any situation from one hand and in the other hand it is very important to eliminate the waste materials and save the natural resource. A review of recent research has shown that it is possible to use industrial by-products as well as other materials in the concrete production as a replacement for cement and aggregate. Waste tire rubber as a waste material is a very good substitute material in the construction industry because of its low specific gravity, more elasticity, very good energy and sound absorption. In this study, the result of different experiments that performed in the literature was discussed and the effect of the waste rubber tire using as an alternative for sand, gravel, and cement on the mechanical properties of fresh and hardened concrete are presented. [1].

## 2-Fresh Concrete Properties (Workability)

Replacing the cement, coarse aggregate, fine aggregate, coarse and fine aggregate together, by the rubber particle with a different amount, have a significant effect on the workability of fresh concrete (Slump Test). Below illustrated the effect of each (cement, coarse aggregate and fine aggregate.) on the fresh concrete properties (workability).

The replacement of cement by rubber particles in the concrete mix reduce the workability of the fresh concrete, the result of the slump test shows that by increasing the rubber particle as a cement replacement the workability of the fresh concrete is reduced. In general, workability of fresh concrete with rubber particles is lower compared to the concrete with no rubber particle. Figure.1 shows the effect of rubber particle percentage on the workability of fresh concrete, from (0% to 3%) there is a slight decrease in the workability, while from (3% to 9%) there is a sudden decrease in the workability of fresh concrete, and by increasing the rubber particle up to (12%) the slump value is decreased to zero. In this study, constant water/cement ratio used in all mix, therefore by modification in this ratio can improve the workability without large give adverse effect to its mechanical properties [1].

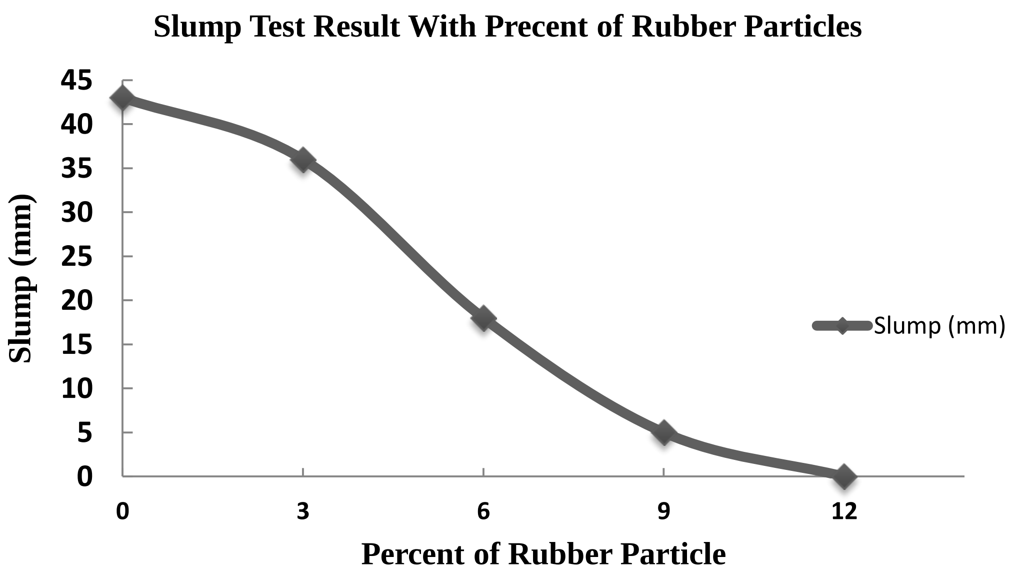


**Figure 1- Effect of the Percent of the Rubber Particles on the Workability of Fresh Concrete**

Using a rubber particle as replacement of coarse and fine aggregate have a significant effect on the fresh concrete properties especially workability of the concrete mix. Because the aggregate has a large contribution to the concrete mix. Tow different mix prepared including rubber aggregate, in the first group the coarse rubber aggregate (CRA) replaced partially with coarse mineral aggregate (CMA). In another group, the fine rubber aggregate (FRA) substituted partially with fine mineral aggregate. Four different contents of rubber particle as aggregate (by mass) were used to substitute the natural aggregate (10%, 20%, 30%, and 40%) respectively. In this test, the water-cement ratio was kept constant (W/C = 0.55) for all mixes.

Figure.2 represent the average results for rubber percentage from the slump test, it can be seen that the addition of fine aggregate rubber from (10%) up to (40%) cause a linear decrease in slump value. While in the coarse rubber aggregate is different, adding (10%) of rubber coarse cause an improvement in the workability of the mix, by increasing this percent to (20%) the sudden decrease in the workability appears. And a small decrease in a slump between (20%) and (30%) of coarse rubber aggregate can be seen, and then again a large decrease of about (33%) between (30%) and (40%) of rubber aggregate is shown [2].

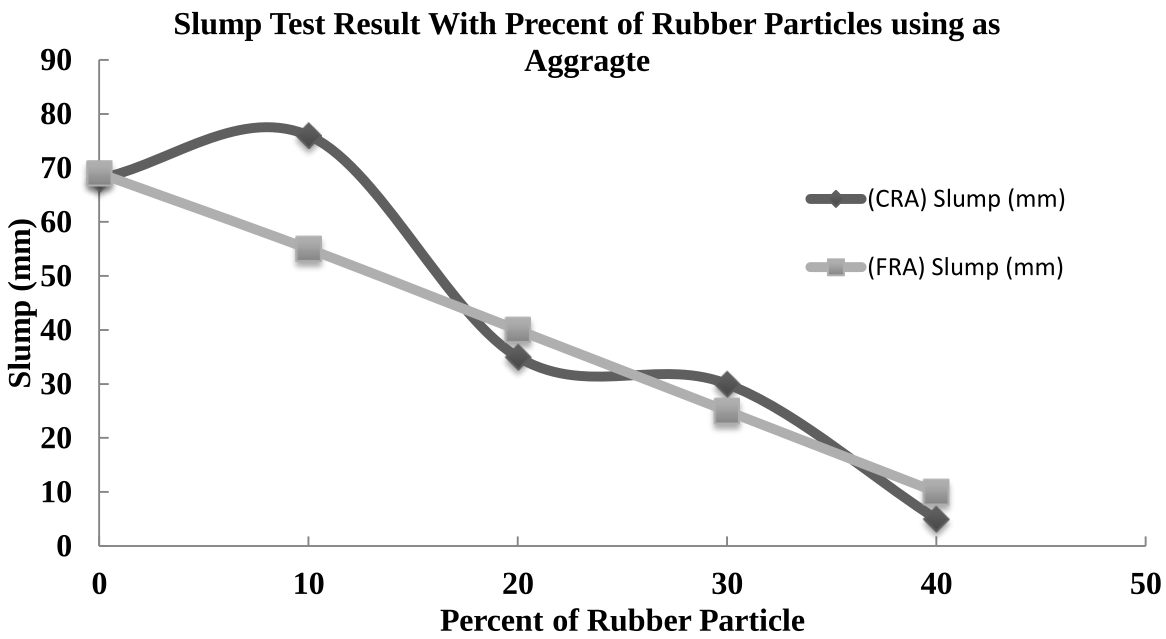


**Figure 2- Effect of the rubber particle on the workability of concrete, replacing natural aggregate by rubber aggregate**

Another test was executed to assess the effect of rubber particles derived from discarded tires substituting natural aggregates, on the workability of fresh rubberized concrete, slump tests were performed for all mixes and the composition of the mixes are summarized in Table.1

**Table 1-Concrete Mix Design (1 m$^3$ concrete)**

| Mix ID | Cement | Fly ash | Sand | Crushed stone | Water | Fine rubber particle | | Coarse rubber particle | | Superplasticizer |
|---|---|---|---|---|---|---|---|---|---|---|
| | Weight (kg) | Weight (kg) | Weight (kg) | Weight (kg) | Weight (kg) | Weight (kg) | % by volume | Weight (kg) | % by volume | Weight (kg) |
| M0 | 332 | 58.5 | 680 | 1200 | 155 | 0 | 0% | 0 | 0% | 2.73 |
| M1 | 332 | 58.5 | 612 | 1200 | 155 | 30.18 | 10% | 0 | 0% | 2.73 |
| M2 | 332 | 58.5 | 544 | 1200 | 155 | 60.35 | 20% | 0 | 0% | 2.73 |
| M3 | 332 | 58.5 | 476 | 1200 | 155 | 90.53 | 30% | 0 | 0% | 2.73 |
| M4 | 332 | 58.5 | 408 | 1200 | 155 | 120.71 | 40% | 0 | 0% | 2.73 |
| M5 | 332 | 58.5 | 340 | 1200 | 155 | 150.88 | 50% | 0 | 0% | 2.73 |
| M6 | 332 | 58.5 | 680 | 1080 | 155 | 0 | 0% | 52.27 | 10% | 2.73 |
| M7 | 332 | 58.5 | 680 | 960 | 155 | 0 | 0% | 104.53 | 20% | 2.73 |
| M8 | 332 | 58.5 | 680 | 840 | 155 | 0 | 0% | 156.80 | 30% | 2.73 |
| M9 | 332 | 58.5 | 680 | 720 | 155 | 0 | 0% | 209.07 | 40% | 2.73 |
| M10 | 332 | 58.5 | 680 | 600 | 155 | 0 | 0% | 261.33 | 50% | 2.73 |

The results of slump tests are shown in Figure.3 When natural sand was substituted by fine rubber particle at the low amounts (10% and 20% by volume), it can be observed that the slumps or workability of fresh rubberized concrete were not changed too much compared to that of the control mix (M0). At the large substituting amounts such as (30%, 40% and 50% by volume), the slumps comparatively increased.

Once gravel was partly substituted by coarse rubber particle at the low and medium sizes such as (10%, 20%, and 30% by volume), it was observed that the slumps somewhat increased in comparing to that of the control mix. However, while the substituting proportion increased to 40%, the slump is slightly decreased. Especially, at the replacing proportion of 50%, the slump was observed to be decreased significantly. This can be explained that when coarse rubber particles were used at high proportion, the contacts around coarse rubber particles and among rubber particles with other aggregates increased leading to the increase in the inter-particle friction between rubber particles and other aggregates, therefore it reduce the workability of rubberized concrete [3].

The difference between this study and the previous study is in the first study using particle rubber cause decreasing the workability of the fresh concrete, while in the second the study using rubber particle as a replacement of aggregate increase workability of a fresh concrete as a general, this is due to using superplasticizer in the second study for improving the workability of fresh mix.

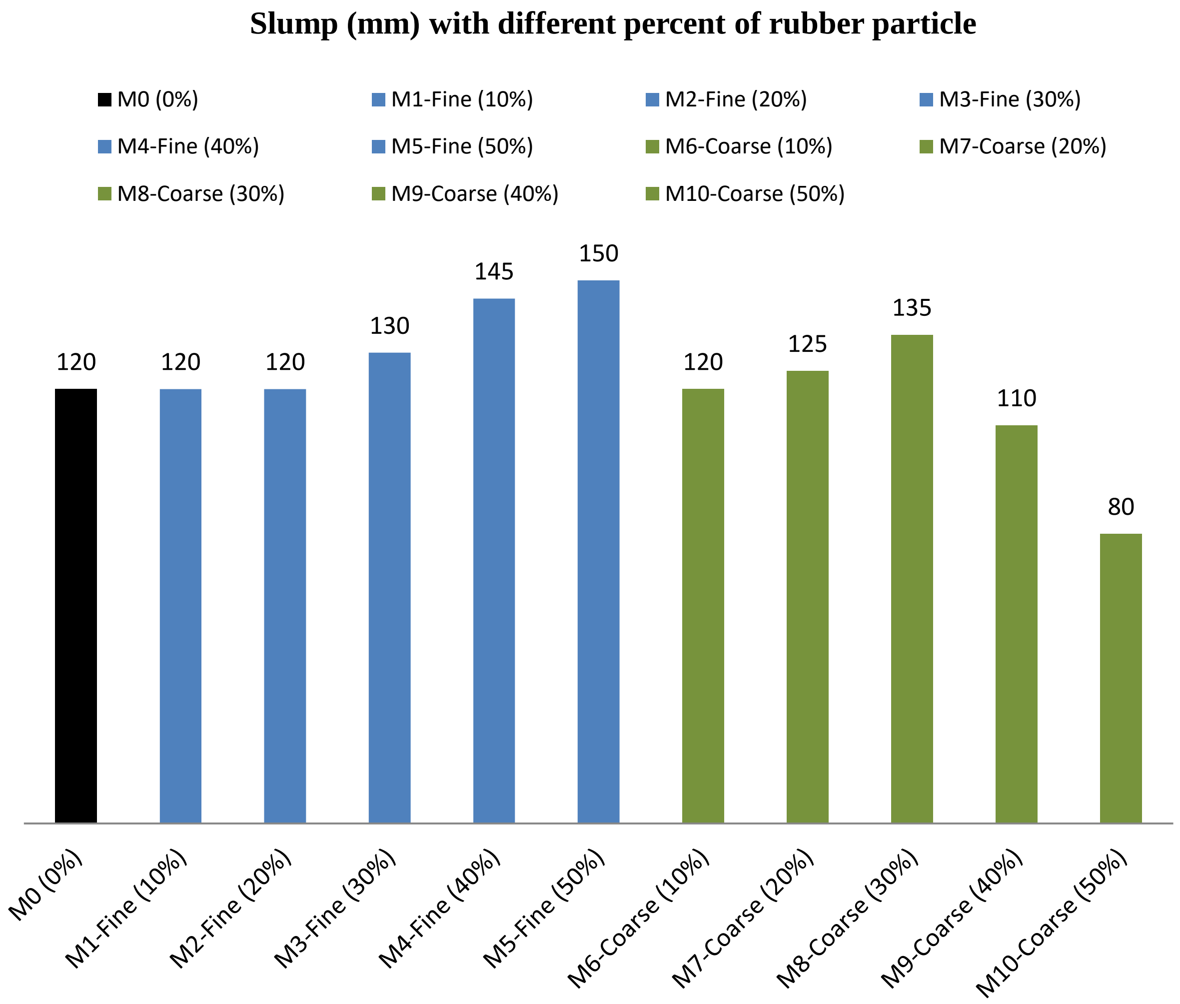


**Figure 3- Effect of Coarse and fine aggregate replaced by coarse rubber and fine rubber aggregate**

## 3-Hardened Concrete Properties

### 3-1 Compressive Strength

Replacing coarse and fine aggregate with the rubber particle in different size and proportion have a great effect on the compressive strength of concrete. Guneyisi et al. [4] "mentioned that the strength of concretes containing silica fume, crumb rubber, and tire chips decreases with rubber content." These authors recommended that it is probable to produce a concrete with compressive strength (40 MPa) substituting a volume of 15% of aggregates by rubber waste. Ghaly & Cahill [5] studied the use of different percentage of rubber in concrete (5%, 10%, and 15%) by volume also observing that as rubber content increases the compressive strength of concrete decrease. Aiello & Leuzzi [6] used tire shreds to replace fine and coarse aggregates concluding that the size of the rubber particles has a major influence on the compressive strength. When gravels are changed by the tire particles the reduction in compressive strength is much more significant when compared to the compressive strength loss of concretes in which sand was substituted by rubber particles [7].

The 7-day and 28-day compressive strengths as a dependent on different percent contents of waste rubber particles with different sizes are shown in Figure 4. As predicted, the compressive strength increased with curing time for all the specimen at all replacing proportions. The compressive strength of the control sample was assessed as 34.5 MPa and 49.5 MPa at 7 and 28 days, respectively. The test results show that there was a significant reduction in the compressive strength of rubberized concrete as the rubber content increased in comparison to that of the control specimen at both 7 and 28 days. It was observed that depending on the quantity and size of substituting waste rubber particles, the degree of drop in the compressive strength was different as summarized in Table.2 When the amount of substituting 10%, the decrease in the compressive strength of the sample containing fine rubber particles at 7 and 28 days were 8.7 and 9.7%, respectively; while the counterpart for the sample having coarse rubber particles at 7 and 28 days were 16.2 and 30.3%, respectively. From this result, it can be observed that substituting coarse rubber particles reduce the compressive strength of rubberized concrete more than in the case of substituting fine rubber particles. When the substituting sizes increased to 20, 30, and 40% by volume, the compressive strengths also drop accordingly, The replacing proportion of 50% caused the largest reductions in the compressive strength of samples containing fine and coarse rubber particles at both 7 and 28 days. The test results show that using fine rubber particles, instead of fine natural aggregate, at the low amount (up to 10%) might not cause the significant effect on the compressive strength of rubberized concrete. [3]

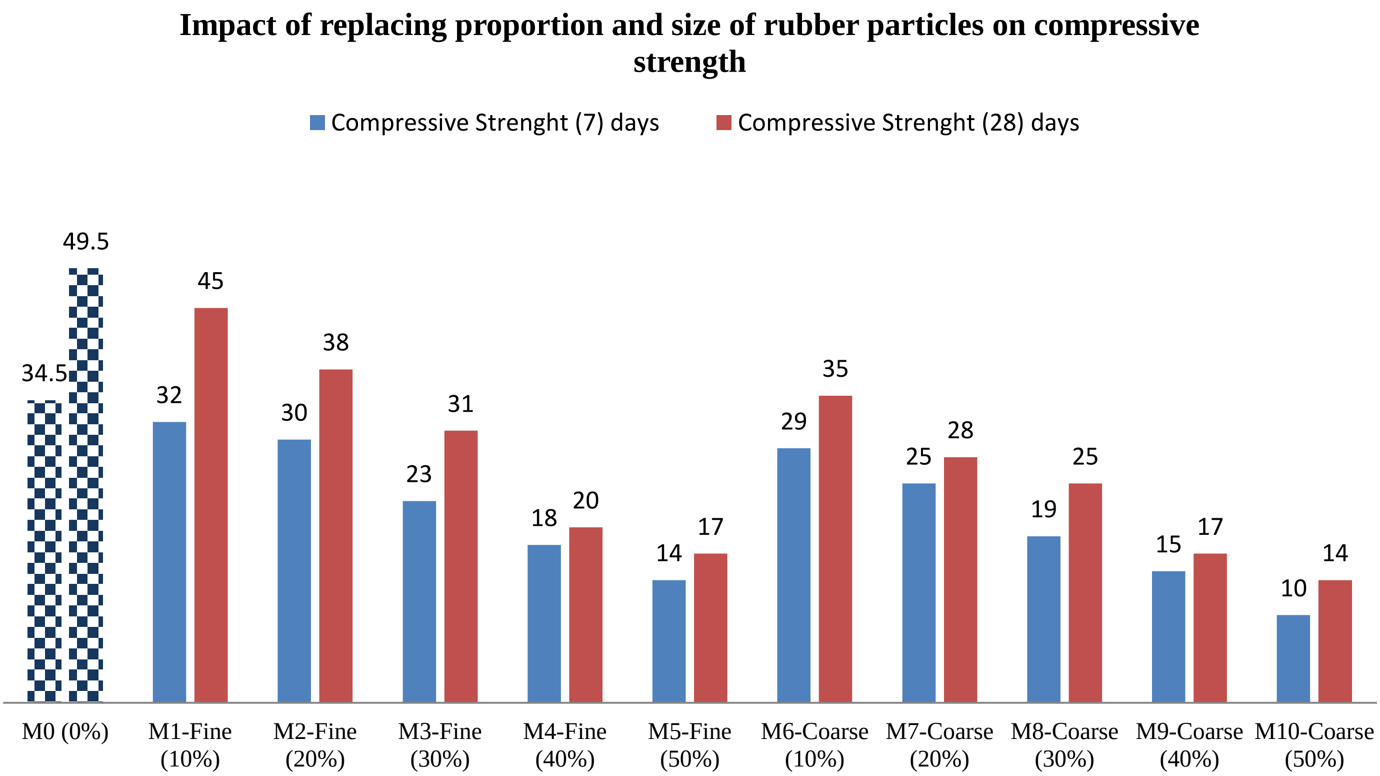


**Figure 4- Impact of replacing proportion and size of rubber particles on compressive strength**

### Table 2-Reduction (%) in Compressive Strength of Rubberized Concrete Compare to Plain Concrete.

| | Cured time (day) | Specimen (Proportion of natural aggregates replaced with rubber particles, % by volume) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **M0 (0%)** | **M1 (10%)** | **M2 (20%)** | **M3 (30%)** | **M4 (40%)** | **M5 (50%)** |
| Reduction (%) in compressive the strength of rubberized concrete using fine rubber particle to replace fine aggregate | 7 | 0 | 8.7 | 14.2 | 36.5 | 48.4 | 57.7 |
| | 28 | 0 | 9.7 | 24.8 | 38.2 | 58.4 | 65.5 |
| | | M0 (0%) | M6 (10%) | M7 (20%) | M8 (30%) | M9 (40%) | M10 (50%) |
| Reduction (%) in compressive strength of rubberized concrete using coarse rubber particle to replace coarse aggregate | 7 | 0 | 16.2 | 34.2 | 45.8 | 58.0 | 71.0 |
| | 28 | 0 | 30.3 | 41.4 | 47.5 | 65.7 | 72.7 |

There are many reason for the drop in the compressive strength of rubberized concrete which mainly influenced by the physical and mechanical properties of constituent aggregates [8, 3].

- First, it could be related to the physical properties of rubber particles which are less stiff than cement paste. This could lead to the deformability of rubber particles compared with surrounding cement paste that resulted in the rapid development of cracks around rubber particles.
- The second reason for the decrease in the compressive strength is the poor bond between rubber particles and cement paste in comparing to the bond between natural aggregates and cement paste. A weak boundary could initially cause micro-cracks which finally grow to macro-cracks, and result in the failure of the rubberized concrete sample under compression.
- The third cause for the drop in the compressive strength of rubberized concrete might be related with the low specific gravity of rubber, coupled with the weak bond of rubber particles with other aggregates, which might make rubber particles going up during shaking in the casting process and

concentrating at the top layer of the sample. This could result in a non-homogeneous distribution of rubber particles and other aggregates, and therefore reduce the strength of the specimen.

- The other reason for the decreased compressive strength could be the increased matrix porosity or weak points in a rubberized concrete matrix which largely depends on the size, density, and hardness of aggregates.
- Rubber is weaker and less rigid than the mineral aggregate that they replace, which reduce the compressive strength.
- Increasing rubber particle amount has been observed to increase the air content, which also decreases the compressive strength of concrete.
- The bond characteristics between the cement past and the rubber may also reduce compressive strength.
- In general, the water to cement ratio, density, workmanship, and curing affect the compressive strength.
- The purpose for the strength decrease of rubber mixed concrete is primarily due to absence of adhesion between crumb rubber particles to other concrete materials. Normally the rubber particles softer than cement paste for that when the load applied to the specimen the crack generation are very quick around the rubber particles [9].

## 3-2 Flexural Strength

In general, investigated that flexure strength of concrete having rubber particle decreases by increasing the waste rubber amount in concrete [10]. The effects of different substiuting amount and different sizes of rubber particles on the 28-day flexural strengths of rubberized concrete are shown in Figure 5. The flexural strength at 28 days of the control sample was 7.2 MPa. The test results show that there were significant decrease in the flexural strength of rubberized concrete sample compared to the control sample when replacing proportions increased.

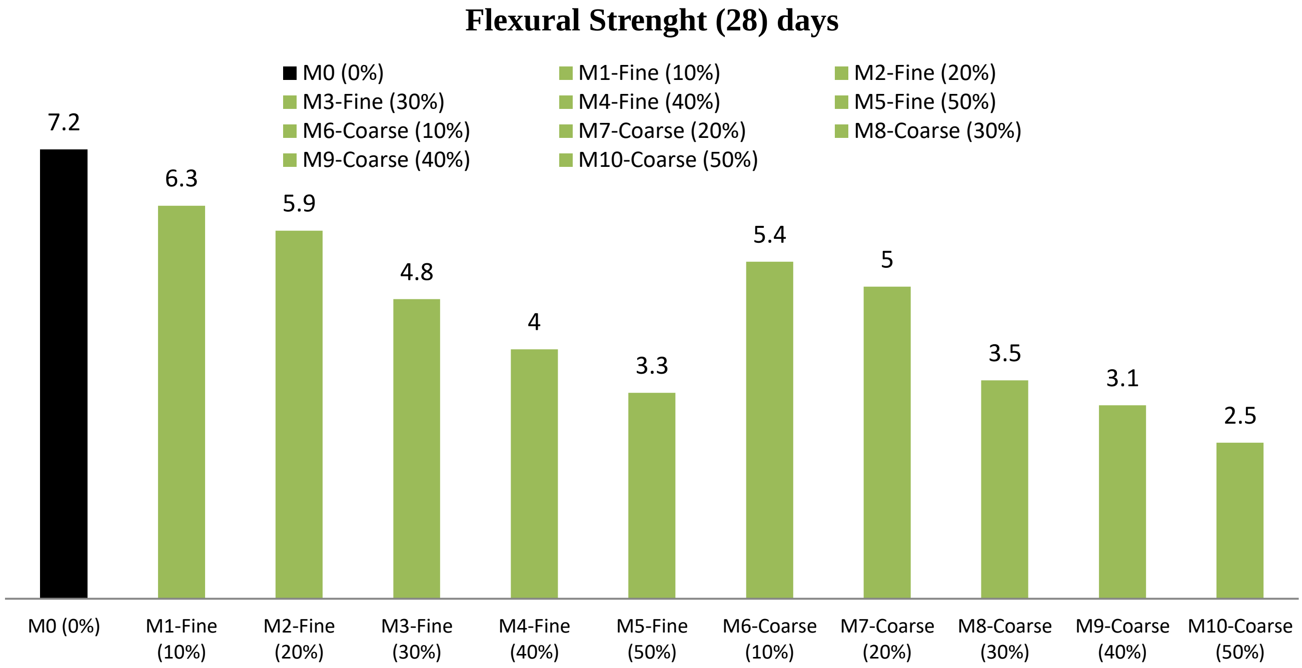


**Figure 5- Impact of replacing proportion and size of rubber particles on flexural strength at (28) days of rubberized concrete**

The degree of reduction in the flexural strength was also largely influenced by the size of replacing rubber particles as shown in Table 3. As expected, a smaller reduction of the flexural strength was observed when fine aggregate was replaced by fine rubber particle, compared to the case of coarse rubber particle, for all replacing proportions. This could be related to the substantial effect of fine rubber particles that rise the compactness of rubberized concrete sample, The test results suggest that using fine rubber particles for substituting naural sand at the low replacing proportion (up to 10%) might not cause the significant effect on the flexural strength of rubberized concrete which similar to the case of the compressive strength. [3]

**Table 3-Reduction (%) in Flexural Strength at 28 Days of Rubberized Concrete Compared to Plain Concrete.**

| | Specimen (Proportion of natural aggregates replaced with rubber particles, % by volume) | | | | | |
|---|---|---|---|---|---|---|
| | M0 (0%) | M1 (10%) | M2 (20%) | M3 (30%) | M4 (40%) | M5 (50%) |
| **Reduction (%) in flexural strength of rubberized concrete using fine rubber particle to replace fine aggregate** | 0 | 12.5 | 19.4 | 34.7 | 45.8 | 56.9 |
| | M0 (0%) | M6 (10%) | M7 (20%) | M8 (30%) | M9 (40%) | M10 (50%) |
| **Reduction (%) in flexural strength of rubberized concrete using coarse rubber particle to replace coarse aggregate** | 0 | 27.8 | 37.5 | 52.8 | 61.1 | 68.1 |

Another study was performed in literature to find the effect of rubber particle as a replacement of cement and coarse aggregate, on the flexural strength of concrete. The mix proportion is summarized in Table 4.

**Table 4-Mix Proportion, Cement, and Sand Replaced by Rubber Particle.**

| Mixture | Description | Cement (kg/m$^3$) | Weight of the used materials (kg/m$^3$) Tire rubber | | Fine aggregates (kg/m$^3$) | Coarse aggregates (kg/m$^3$) |
|---|---|---|---|---|---|---|
| | | | Chipped | Powder | | |
| C | Control | 380 | 0.0 | 0.0 | 858 | 927 |
| RA5 | Substituting 5% by weight rubber particles for aggregates | 380 | 46.4 | 0.0 | 858 | 884 |
| RA7.5 | Substituting 7.5% by weight rubber particles for aggregates | 380 | 69.5 | 0.0 | 858 | 861 |
| RA10 | Substituting 10% by weight rubber particles for aggregates | 380 | 93 | 0.0 | 858 | 839 |
| RC5 | Substituting 5% by weight rubber powder for cement | 361 | 0.0 | 19.0 | 858 | 927 |
| RC7.5 | Substituting 7.5% by weight rubber powder for cement | 352 | 0.0 | 28.0 | 858 | 927 |
| RC10 | Substituting 10% by weight rubber powder for cement | 342 | 0.0 | 38.0 | 858 | 927 |

The results of flexural strength tests are shown in Figure.6 replacement of rubber decrease flexural strength as estimated. The reduction in flexural strength happened in both mixtures and only the rate was different. A decrease of 37% compared to the control mix was found in the first mixture. This value extended to 29% for the second mixture. As a result, the most important reason that decreases flexural strength, as well as the compressive strength is the lack of good bonding between rubber particles and cement paste. This fact was obtained because after breaking the concrete specimens for flexural strength test, it was found that chipped rubber could be easily removed from concrete. Weak bonding in the first mixture, which contained chipped rubber, was more obvious and weaker than the second mixture, which contained powdered rubber [11].

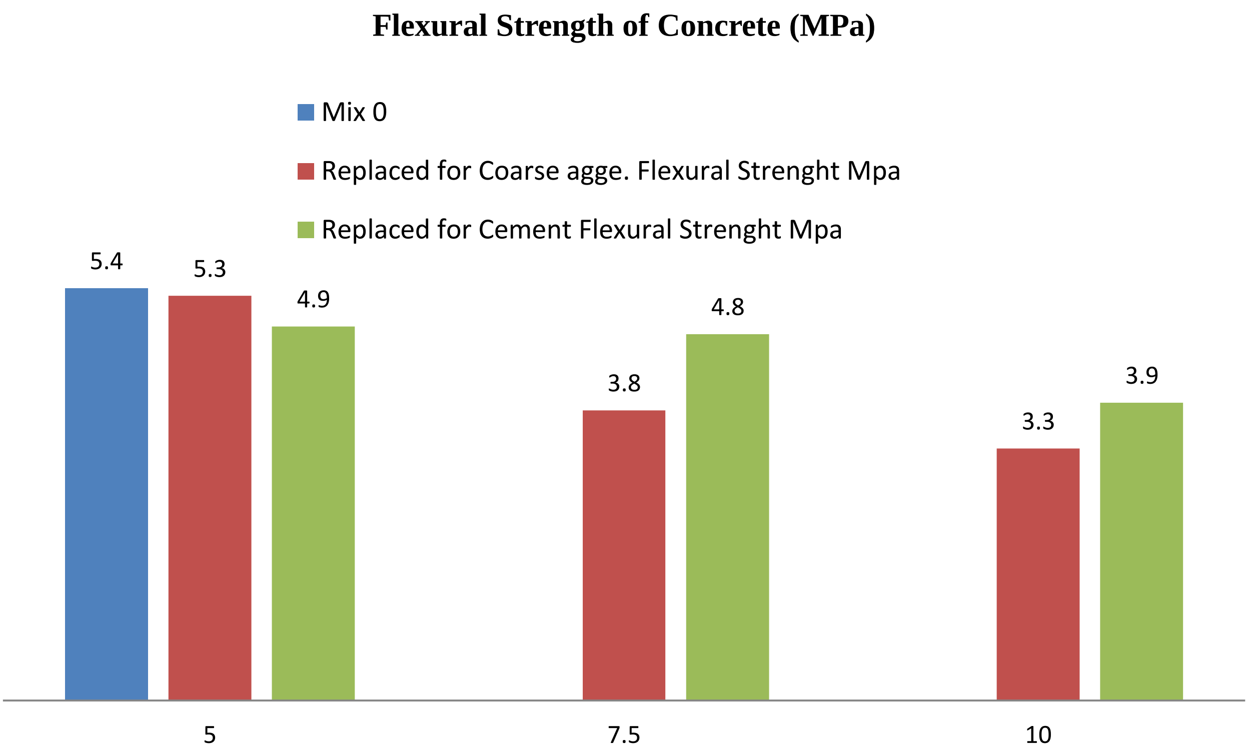


**Figure 6- Flexural Strength Test Result, Cement and coarse aggregate replaced by rubber particle**

## 3-3 Modulus of Elasticity

From the previous experiments shows that the concrete contains waste rubber particle as a replacement of cement or aggregate, has a low compressive strength, and there is a strong relationship between compressive strength and modulus of elasticity of concrete, it is estimated that the rubber particles reason for decreasing modulus of elasticity. The clarification for this reduction in modulus of elasticity is associated to the low modulus of elasticity of rubber particle [7]. In general modulus of elasticity decreased with increasing rubber content as a replacement of cement and aggregate, it is the same condition that found in the compressive strength. Increasing the amount of rubber contents by 5%, 10%, 15%, 20% and 25% as a replacement of fine aggregate cause decrease, to the static modulus of elasticity to 4.67%, 10.98%, 21.40%, 32.41% and 45.60% respectively [9,11]. A study was performed to find the modulus elasticity of different mix in term of different (water/cement ratio, and different rubber particle content) were tested at the ages of 28 days. The test results are represented in Figure.7 There was a drop nearly about 30% in modulus elasticity value when crumb rubber content increased from 0% to 30%. The presence of crumb rubber cause weaknesses in the internal structure of the composite material, producing a reduction of compressive strength and a decrease in stiffness. The observation showed that there were a large displacement and deformation due to the fact that crumb rubber has an ability to withstand large deformation. This can be described by the performance of the crumb rubber particles inside the mix; these particles appear to act as spring and caused a delay in widening the cracks and avoiding the catastrophic failure which is usually experienced in normal concrete specimens [12].

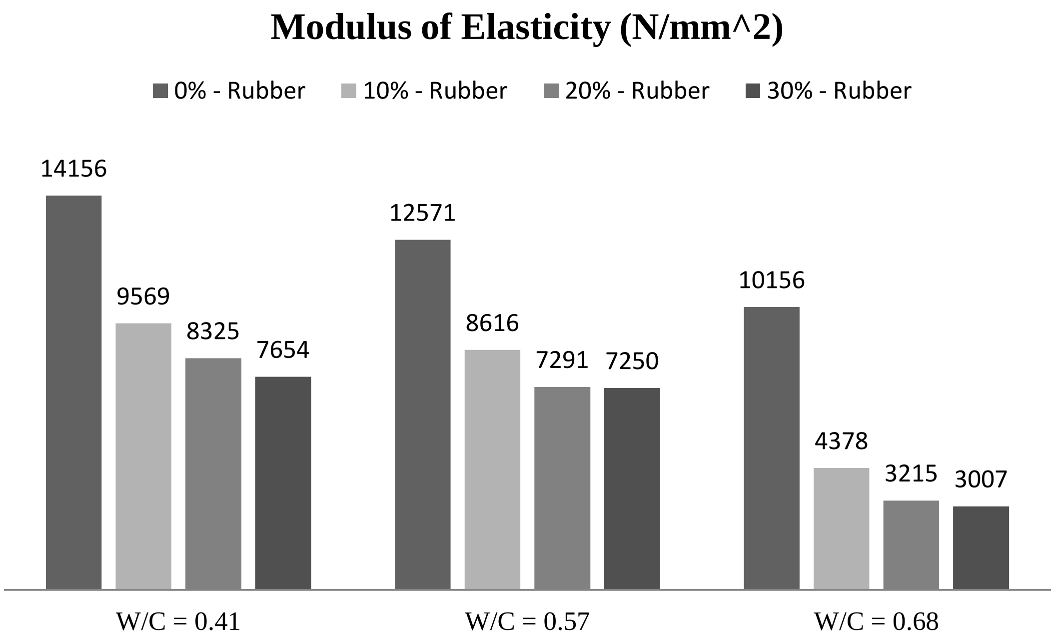


**Figure 7- Modulus of Elasticity of Concrete with Different Percent of Rubber Particle Content and Different W/C at (28) days age**

### 3-4 Split Tensile Strength

Observed that the tensile strength of rubberized concrete is frequently affected by the size, shape, and textures of the aggregate and the strength of concretes decreases as the volume of rubber aggregate increases [10]. The tensile strength of rubberized concrete drops but the strain at failure growths correspondingly. High tensile strain at failure is indicative of more energy absorbent mixes [10]. Tests performed on the performance of rubberized concrete containing tire chips and crumb rubber as a substituting of aggregates having sizes 38, 24 and 19 mm showed a fall in tensile strength by almost 50% but also presented maximum energy absorption during tensile loading [10].

A study in the literature was performed to find the effect of rubber particle on the splitting tensile strength of crumb rubber concrete cured at 28 days, in this study the rubber particle used as a replacement of fine aggregate and the mixture at different proportion the mix proportion of the sample summarized in the Table.5

**Table 5-Mixture Proportion of Crumb Rubber Concrete.**

| Mix | Rubber Content (%) | Weight per Cubic Meter (kg/m$^3$) | | | | |
|---|---|---|---|---|---|---|
| | | Water | Cement | Fine Aggregate | Coarse Aggregate | Crumb Rubber |
| RC | 0 | 180 | 430 | 593 | 1197 | 0 |
| Fine aggregate is replaced by crumb rubber | | | | | | |
| CF1 | 5 | 180 | 430 | 563.4 | 1197 | 13.4 |
| CF2 | 10 | 180 | 430 | 533.7 | 1197 | 26.8 |
| CF3 | 15 | 180 | 430 | 504.1 | 1197 | 40.2 |
| CF4 | 20 | 180 | 430 | 474.4 | 1197 | 56.3 |
| Mixture is replaced by crumb rubber | | | | | | |
| CM1 | 1 | 178.2 | 425.7 | 587.1 | 1185.0 | 12 |
| CM2 | 3 | 174.6 | 417.1 | 575.2 | 1161.1 | 36 |
| CM3 | 5 | 171.0 | 408.5 | 563.4 | 1137.2 | 60 |
| CM4 | 10 | 162.0 | 387.0 | 533.7 | 1077.3 | 120 |

Note: RC represents the reference concrete; CF and CM represent the concretes produced by replacing fine aggregate and mixture with crumb rubber, respectively.

And the test result as shown in Figure.8 and Figure.9 it was founded that the value of splitting tensile strength reduced with the increase in the volume percentage of crumb rubber. Similar to compressive strength, the decrease in the splitting tensile strength of (fine aggregate replaced) is smaller compared to the (crumb rubber replacing mixture). This was because substituting mixture with crumb rubber particle decrease the quantity of the cement. The splitting tensile strength was low because of loss of binding material. Moreover, the ratio of the reduction in the splitting tensile strength was lower than the compressive strength, When 20% fine aggregate was replaced by crumb rubber, the splitting tensile strength reduces by 2.5%, while compressive strength decreased by 3.9% [13].

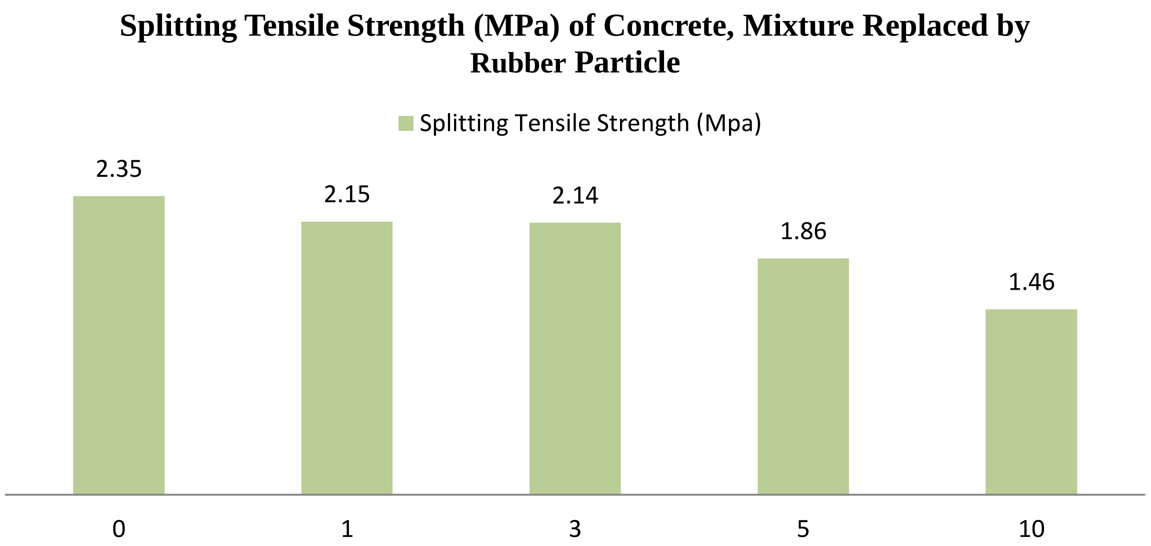


Figure 8- Splitting Tensile Strength (MPa), Mixture Replaced by Rubber Particle

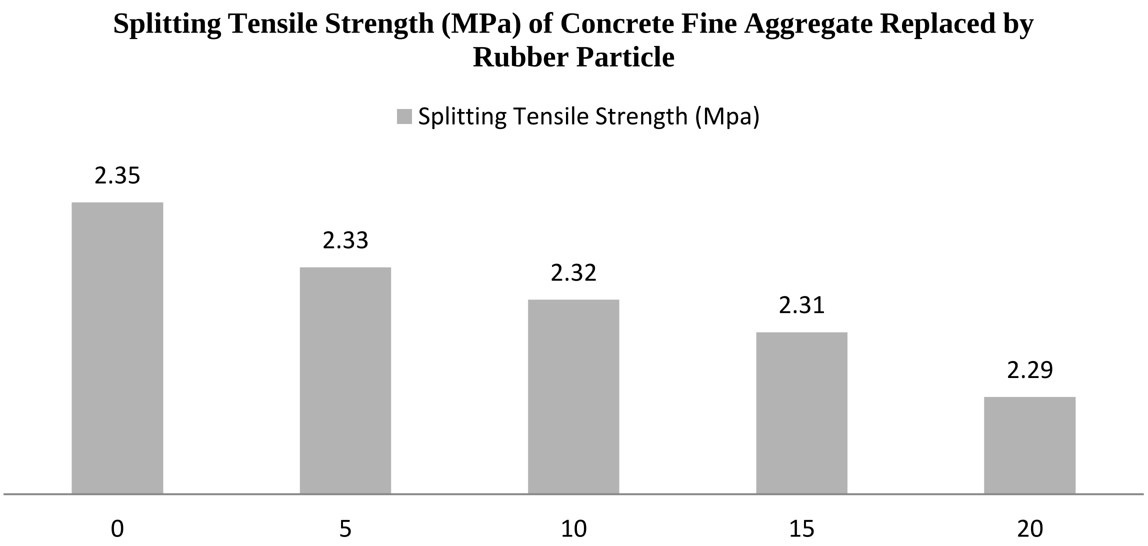


Figure 9-Splitting Tensile Strength (MPa), Fine Aggregate Replaced by Rubber Particle

More study was performed to find the effect of rubber particle when used in the concrete mix as a replacement, another study was performed using rubber particle instead of cement and coarse aggregate, and the results of tensile strength test are represented in Figure.10 from the test result observed that the tensile strength of concrete is decreased by replacing the rubber particle in both mixes. The amount of reduction of tensile strength in the first mixture was about twice that of the second mixture. The reduction in tensile strength with 7.5% replacement was 44% for the first mixture and 24% for the second mixture as compared to the control sample. Tire rubber particle as a soft substance can act as an obstruction against crack development in concrete. Therefore, the tensile strength of concrete containing rubber particle should be larger than the control mixture. However, the results showed the opposite of this hypothesis. The aim of this performance may be due to the following points:

- The boundary zone between rubber and cement may act as a micro-crack because of weak bonding between the two materials; the weak border zone accelerates the concrete to collapse.
- Assessments of the broken concrete samples showed that the chipped rubbers were observed after breaking the concrete sample in the first mixture. The reason for this performance is that during crack expansion and when it comes into contact with rubber particle, the exerted stress causes a surface segregation between rubber and the cement paste. Therefore, it can be said that rubber acts just as a cavity and a concentration point leading to quick concrete failure.
- Another reason which may affect concrete behavior is actually the main area of segregation when tensile strength is exerted on the boundaries of the large grains and cement paste which in turn weaken the generated interface zone [11].

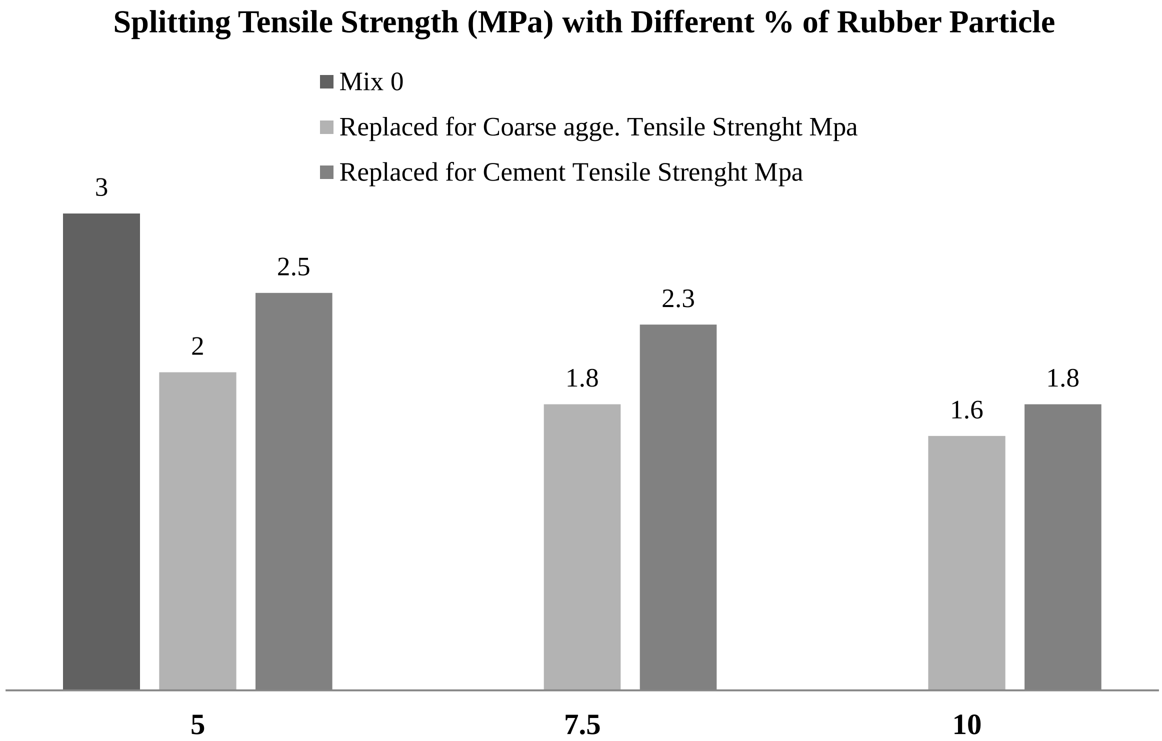


**Figure 10- Splitting Tensile Strength (MPa) of Rubberized Concrete**

## 3-5 Toughness

Concrete composites containing tire rubber waste are known for their high toughness, having a high energy absorption capacity [12].

Toughness is defined as energy absorption capability and is generally defined as the area under the stress-strain curve of a flexural sample. From the literature studies explored that the toughness of a control concrete sample and concrete contains rubber particles with 5% and 10% by volume of coarse aggregate. Found that toughness of both rubberized concrete mixtures was larger than the control concrete mixture [14].

## 3-6 Density

Because of low specific gravity of rubber particles, unit weight of concrete containing rubber particles decreases with the increase in the percentage of rubber content. Furthermore, increase in rubber content cause increases the air content, which in turn decrease the unit weight of the mixtures. The decrease in unit weight of rubberized concrete is small when rubber content is lower than 10–20% of the total aggregate volume [14].

An Experiment was conducted to find the effect of rubber particle on the concrete mix, in this study aggregate (fine and Coarse) replaced by different percent of rubber particle and the effect of rubber on the density of the mix at 7 and 28 days of curing was shown in the Figures.11 and 12 respectively the average densities for the 7 and 28 day-cured sample is decreased by the adding of rubber aggregates whether these are fine or coarse. Generally, for the similar percent of rubber particle, the fine rubber aggregate mixes had fewer densities than those containing coarse rubber aggregate. The general density decrease was to be estimated due to the low specific gravity of the rubber aggregates with respect to that of the mineral aggregates. The reduction in density can be a desirable property in a number of applications, including architectural applications such as nailing concrete, false facades, stone backing and interior construction as well as precast concrete blocks and slabs [2].

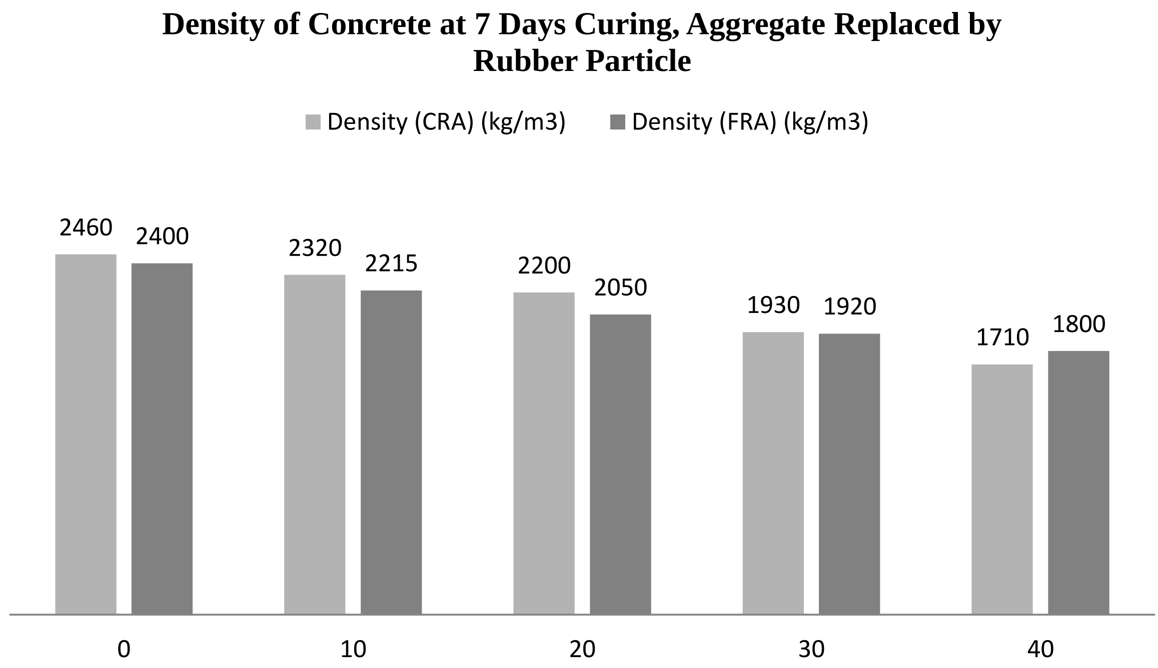


**Figure 11- Density of Concrete at (7) days of Curing, Fine and Coarse Aggregate Replaced by Rubber Particle**

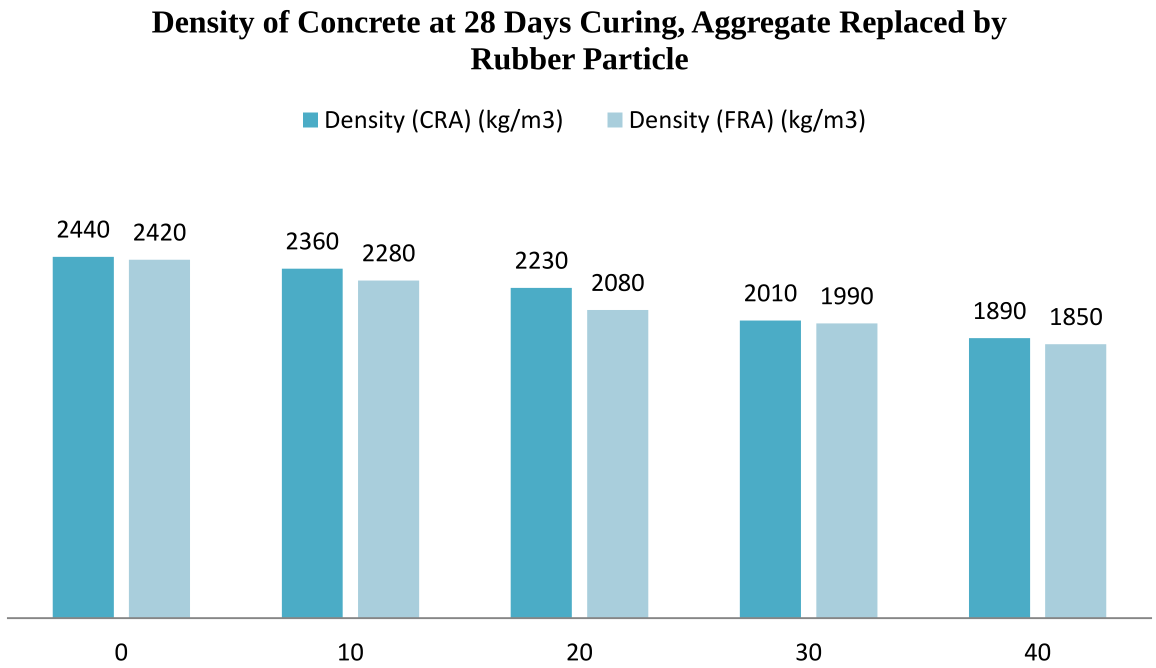


**Figure 12- Density of Concrete at (28) days of Curing, Fine and Coarse Aggregate Replaced by Rubber Particle**

## Conclusions

Using a waste rubber particle as a replacement of cement and aggregate (coarse and fine), with different content, shape, and size, together and separately had a significant effect on the mechanical properties of concrete. From this study and based on the literature data the following conclusion obtain:

1- Replacing cement, coarse and fine aggregate by the rubber particles have a significant effect on the workability of fresh concrete (Slump Test), by increasing the rubber particle into the concrete mix the workability of the fresh mix is decrease.

2- Adding waste rubber particle as replacement of cement, fine and coarse aggregate, with the different percent of content, shape, and size, decrease the compressive strength of concrete, however at the low substituting proportion (up to 10%) might not cause the significant effect on the compressive strength of rubberized concrete. By increasing the rubber content up to (20%, 30%, 40% and 50%) for both fine and coarse at 7 days and 28 days of curing cause a significant decrease in compressive strength of concrete.

3- By increasing waste rubber particle in the concrete mix, the flexural strength of concrete decrease, the replacement of coarse aggregate by rubber particle have a great effect in decreasing the flexural strength of concrete compared to the fine aggregate.

4- By decreasing the compressive strength of concrete the modulus of elasticity of concrete decrease because the good correlation exists between the compressive strength and modulus of elasticity. In general by adding the rubber particle into the concrete modulus of elasticity of concrete decrease.

5- Splitting tensile of concrete significantly affect by size, shape, and percent of rubber particle in the mix, increasing rubber particle in the concrete mix, lead to decrease the splitting tensile strength of concrete.

6- Using rubber particle as a natural aggregate (Coarse and fine) at different percent in the concrete mix, increase the toughness of the concrete, by increasing the rubber particle the toughness properties of concrete increase.

7- Density of concrete at different age of curing, decrease by increasing the rubber content in the mix.

## References


[1] Abdullah, S. R., & Shahidan, S. (2015). Strength of concrete containing rubber particle as partial cement replacement 3rd Int. In *Conf. Civ. Environ. Eng. Sustain* (Vol. 9, pp. 2-5).

[2] Mavroulidou, M., & Figueiredo, J. (2010). Discarded tyre rubber as concrete aggregate: a possible outlet for used tyres. *Global NEST Journal*, *12*(4), 359-367.

[3] Luong, N. D., Long, H. V., Tuan, N. K., & Thai, N. D. (2017). Properties of Concrete Containing Rubber Aggregate Derived From Discarded Tires. *Asian Review of Environmental and Earth Sciences*, *4*(1), 12-19.

[4] E. Guneyisi, M. Gesoglu, T. Ozturan, Properties of rubberized concretes containing silica fume, J Cem Concr Res 34 (2004) 2309–2317.

[5] A. Ghaly, J. Cahill, Correlation of strength, rubber content, and water to cement ratio in rubberized concrete, Can J Civil Eng 32 (2005) 1075–1081

[6] M. Aiello, F. Leuzzi, Waste tyre rubberized concrete: Properties at fresh and hardened state.Waste Manag 30 (2010) 1696-1704.

[7] Torgal, F. P., Shasavandi, A., & Jalali, S. (2011). Tyre rubber wastes based concrete: a review. *Wastes 2011*.

[8] Crumb Rubber Concrete California State University, Chico

[9] Murugan, R. B., & Natarajan, C. (2015). Investigation of the Behaviour of Concrete Containing Waste Tire Crumb Rubber. In *Advances in Structural Engineering* (pp. 1795-1802). Springer, New Delhi.

[10]_Alam, I., Mahmood, U. A., & Khattak, N. (2015). Use of Rubber as Aggregate in Concrete: A Review. *International Journal of Advanced Structures and Geotechnical Engineering*, *4*(02).

[11]_Ganjian, E., Khorami, M., & Maghsoudi, A. A. (2009). Scrap-tyre-rubber replacement for aggregate and filler in concrete. *Construction and Building Materials*, *23*(5), 1828-1836.

[12] Azmi, N. J., Mohammed, B. S., & Al-Mattarneh, H. M. A. (2008, June). Engineering properties of concrete containing recycled tire rubber. In *International Conference on Construction and Building Technology* (pp. 373-382).

[13] Liu, H., Wang, X., Jiao, Y., & Sha, T. (2016). Experimental investigation of the mechanical and durability properties of crumb rubber concrete. *Materials*, *9*(3), 172.

[14] Siddique, R., & Naik, T. R. (2004). Properties of concrete containing scrap-tire rubber–an overview. *Waste management*, *24*(6), 563-569.