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Improvement of Mechanical Properties of Waste Glass Coarse Aggregates Concrete Using Polymer and Silica Fume Admixtures

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Abstract— This study includes the effect of using styrene butadiene rubber (SBR) latex as an admixture material with specified mixes of of concrete with mix proportions of (1:1.5:3) and also using silica fume with constant percentage of 5% from weight of cement to improve the mechanical properties. The coarse aggregate used in this study is a glass aggregate which has been obtained from the glass waste. Then, the glass aggregate has been broken and sieved to be satisfied with Iraqi Specifications. The reasons behind using glass aggregate are: firstly, to get sustainability and secondly, to reduce the cost of producing concrete using local materials. Different percentages of SBR as percentage of cement weight and studying the effects of compressive strength, splitting tensile strength and flexural strength. The study includes testing concrete beams for flexural strength using beams of dimensions of 150x150x750mm. It has been found that high increment in compressive, flexural and tensile strengths at 15% SBR and reduction in these strengths after 15% SBR.

Index Terms— Recycled glass, coarse aggregate, polymers, styrene butadiene rubber.

1. Introduction

Sustainable constructing materials through definition are materials which are locally generated and provenance which may decreases the costs of conveyance and releasing of co_2, they may involve materials which are recycled, they have a lesser influence on the environment, they are effective thermally, they need minimal energy than most new or traditional materials, they make utilize of renewable resources, they are lesser in poisonous emissions and they are financially applicable [1].

The use of polymer concrete has been widely used in the world since 1970 and replacement of coarse aggregate becomes necessary to reduce the cost of production of concrete. One of these different alternatives of aggregate is the use of recycled glass (waste glass) as coarse aggregates which improve the strength due to high bond and relatively high strength. However, it is brittle material. The use of polymer improves the mechanical properties of concrete such as flexural, compressive and tensile strengths. This makes the concrete less permeability and its ability not to fail under impact load and more durability. This type of concrete has been widely used in the bridge foundation and roads. This includes using polymer in order to produce high performance concrete for roads. It also used as alternatives for coarse aggregates due to high cost of this aggregate. The glass aggregate used in this study is more durability due to its impermeability for water, high strength and angular tapered edges. These characteristics give high bond [1].

In addition to what mention above, the using recycled glass as aggregate can also greatly improve the aesthetic of the concrete. There is a unique inert material existed in glass which could be recycled several times without any change in its chemical properties. Moreover, it can help in reducing waste glass material in the environment produced by community [2]. It was used by researches in concrete construction in terms of glass beads, crushed glass, glass powder etc. Generally, it is partially utilized with cement, coarse and fine aggregates and occasionally used instead of fine aggregate. Commercially, waste glass is already being utilized in decorative concrete or architectural concrete. For the widely used implementations of glass in decorative concrete are (1) seeding and (2) mixing integrally [1].

Serniabat et al., [1] used recycled glass as a coarse aggregate with different ratios. Compressive strength test was implemented on concrete samples at various ages. The results show that glass has a good compressive strength.The chemical resistance of polymer concrete mainly depends on the ratio of polymer to cement and chemical components [3].

2. Waste glass

Glass is widely used for thousands of years in dif-

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ferent products such as bottles flat glass from which windows are made, specialized glass used in TV and computer screens, insulation made from fiberglass and other applications. The main components of glass are sand, calcium carbonate and limestone [4].

The use of waste glass in concrete tends to decrease the compressive strength of a mixture. As the amount of waste glass increases, the compressive strength decreases, too. Topcu and Canbaz studied the utilize of waste glass in concrete that had a size between 4 and 16mm. The mixtures studied contained two sizes of coarse aggregates as well as fine aggregate or sand. The waste glass was used to replace a portion of the smaller sized coarse aggregate. The authors investigated that mixtures with 15%, 30%, 45% and 60% waste glass replacement rates reduced the compressive strength of the mixture by 8%, 15%, 31% and 49% respectively when tested after 28 days [5]. A study by Park et al., [6] replaced fine aggregate with waste glass showed a similar pattern but less of a decrease in strength. In the study waste glass with a size less than 5 mm was used. Mixtures with 30%, 50% and 70% indicated a reduction in compressive strength of 0.6%, 9.8% and 13.6% respectively when tested after 28 days. In order to offset the reduction in strength, a polymer was added to some mixtures including waste glass and was found to increase strength [6].

Topcu and Canbaz investigated that the tensile strength of concrete reduced as the quantity of waste glass increased in a mixture. The tensile strength reduced 37 % for a coarse aggregate replacement of 60% waste glass [5]. In the light of above, the rate of waste glass used as a replacement rate for the smaller coarse aggregate only not from the total coarse aggregate used in the mixture. Park et al., (2004) found that waste glass led to a reduction of 5% in tensile strength for replacing of 30% fine aggregate. The results obtained from Topcu and Canbaz study indicated that the flexural strength were inconsistent results, but mainly the flexural strength decreased as the value of added waste glass increased [5]. The flexural strength reduced by 3.2% with a replacement rate of 30% and 11.3% reduction for a replacement rate of 50% [6].

3. SBR

Sujjavanich and Lundy conducted experimental work to test the strengths at agesfrom 5 hours to 28 days of concrete in order to investigate the properties of the SBR [7]. The authors used 15% of polymer to cement ratio with mix ratio of (1:2.45:2.1), w/c=0.32 using standard cylinders to test compressive strength and splitting tensile strength. In addition, flexural strength and dynamic modulus of elasticity tests were carried out on prisms at the same ages. They concluded from their work as the curing period increases the compressive strength, modulus of elasticity, tensile and flexural strengths increases, too.

The use of the SBR with the concrete in the percentage of 2.5, 5 and 7.5 as admixture decreases the rate of water absorption with the increment of polymer [8].

The polymer has an effect on total porosity and the increase in its ratio leads to reduce the porosity [3]. In addition, the absorption and permeability of the concrete treated by polymer is reduced with the increment of the ratio of polymer-cement. This behavior may be attributed to the filling of large pores with the polymer or sealing the continuous polymer films.

Essa et al., [9] concluded according to their experimental works of adding SBR on concrete properties that the following points:

- There is a high reduction in the absorption with the increment of SBR as indicated in Figure 1.
- Figure 2 demonstrates that as the percentage of dosage for SBR increases the flexural strength increases, too.
- It was noticed that the increment in compressive strength at all ages for 25% and 35% of SBR. Whereas, at 10% of SBR there was a reduction in compressive strength as indicated in Figure 3. The authors indicated that behavior was because of low percentage of SBR.

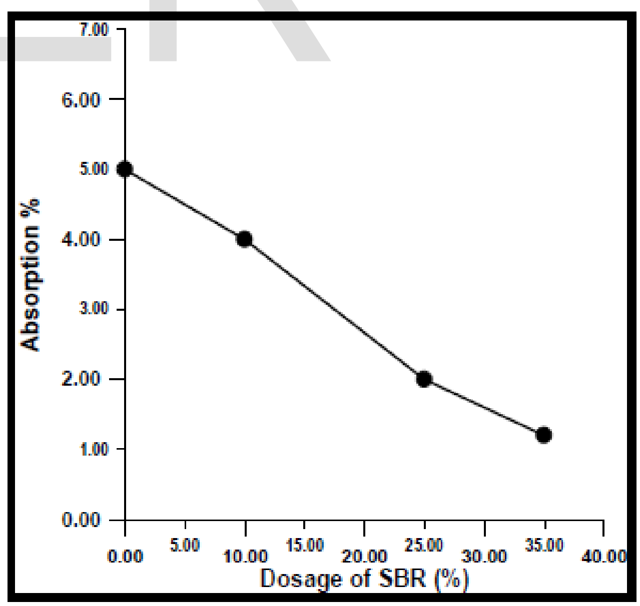

Figure 1: Influence of SBR on absorption of concrete samples [9].

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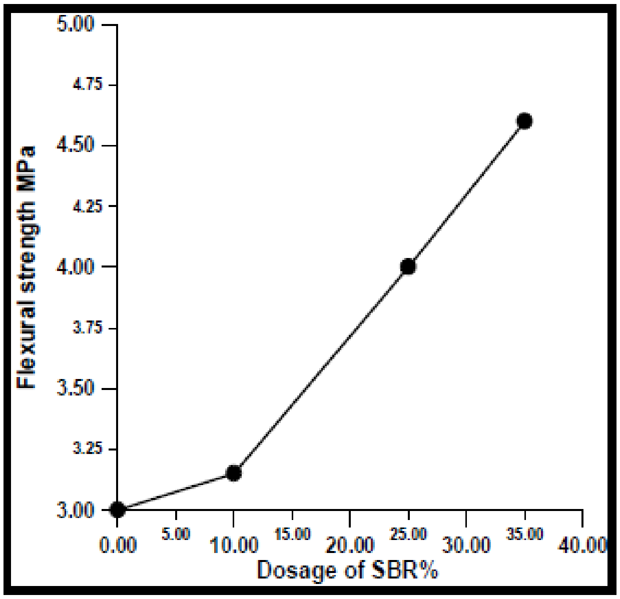

Figure 2: Increment of flexural strength with SBR in concrete samples[9].

4 Experimental work

This work has been implemented on five mixes with mixes proportions (1:1.5:3). These mixes were made with different percentage of SBR and a constant of 5% silica foam as a replacement of cement weight. Whereas, water/cement (W/C) was 0.45 and waste glass were used instead of coarse aggregate.

The mixes have been just made to study the hardened properties of concrete such as compressive strength; splitting tensile strength and flexural strength with different percentages (0%, 5%, 10%, 15%, and 20%) of SBR were used in current study.

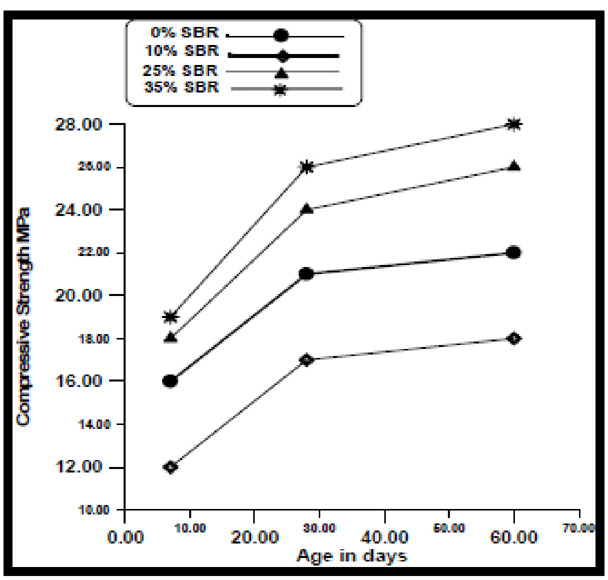

Figure 3: Increment of compressive strength with age for SBR in concrete samples[9].

5. The used materials

5.1 Cement

Sluphate Portland cement (Type V) manufactured by AL-Kufa factory was used throughout in this project conforming to Iraqi specification (IQS 5) [10]. To avoid any differences between different batches, the whole quantity of cement was brought to the laboratory and stored in a dry place.

5.2 Fine Aggregate

Normal natural sand was usedas a fine aggregate in this work. Before its incorporation into the concrete mix, sand was sieved on 10mm sieve. The grading of the sand is given in Table 1. Results indicated that the grading of fine aggregate lies within the requirements of the Iraqi specification number (45/1984).

5.3 Coarse Aggregate

Waste glass has been used as a coarse aggregate. This material has been sieved as indicated in Table 2. The grading of glass coarse aggregate has been found within the requirements of the Iraqi specification number (45/1984).

5.4 Specimens preparation

5.4.1 Mixing and pouring of concrete

The mixing of materials in the laboratorywas a manual mixing according to the specific mix ratios in this work. The flipping of the components of a dry for about two minutes until it was to get a homogeneous mixture. Mixing time should not exceed five minutes to avoid separation particleboard.

Table 1: Grading of the fine aggregate (sand).

Sieve Size(mm)	Percentage of Passing(%)	% Passing limits 45/1984 (Zone 2)
10	98.12	100
4.75	93.20	90-100
2.36	76.45	75-100
1.15	60.85	55-90
0.6	47.35	35-59
0.3	22.12	8-30
0.15	7.77	0-10

Table 2: Grading of the coarse aggregate (crushed glass).

Sieve Size(mm)	Percentage of Passing(%)	% Passing limits of I.O.S 45/1984
37.5	100	100
20	96.56	95-100
10	42.65	30-60
5	3.75	0-10

5.5 Tests of mechanical properties

5.5.1 Compressive strength test

This test was carried out to get the necessary information about the voids formed within the concrete as they have direct effect on its compressive strength. This test was done on three concrete cubes with dimensions (150mm) for the five mixes according to British standard specification (BS1881: part 116) [11]. The specimens were tested at age of 7, and 28 days by using (ELE Digital Testing Machine) with maximum capacity (2000 KN). The rate of concrete cubes has been calculated after excluding outliers. Then, a total number of tested cubes were 30 for both ages (7 and 28 days).

5.5.2 Splitting tensile strength test

This test was executed on two cylinders with dimensions (300mm height, 150mm diameter) according to American specification (ASTM- C496) [12]. The samples were tested for both 7 and 28 days and using the same machine for compressive strength.

5.5.3 Flexural strength test

This test was executed on prisms with dimensions (150*150*750) according to American specification (ASTM C293-83). Just two prisms have been tested for 28 days only. In this work the rate of strength of two prisms has been adopted as a flexural strength. So the total number of sample for this test was 10 only.

6.1 Compressive Strength Test Results

The results of the compressive strength until an age of 28 days are offered in Figure 4. This figure shows that the presence of SBR as an admixture in concrete leads to an increment in the compressive strength and this increment increases with the increase of SBR ratio up to 15% of SBR. The maximum increment has been achieved for 15% ratio of SBR at 28 days. The increment for compressive strength at this level is approximately 55.7%. Whereas; the increment at 7days was observed to be less than that for 28 days which was around 43%. This figure also demonstrates that the increment continues to increase at 20% but this increment is still less than of 15% of SBR.

As mentioned by Serniabat et al., [1], the recycled glass has increased from the compressive strength to be about 40 MPa at 28 days. This could be attributed to providing high bond with other components of concrete.

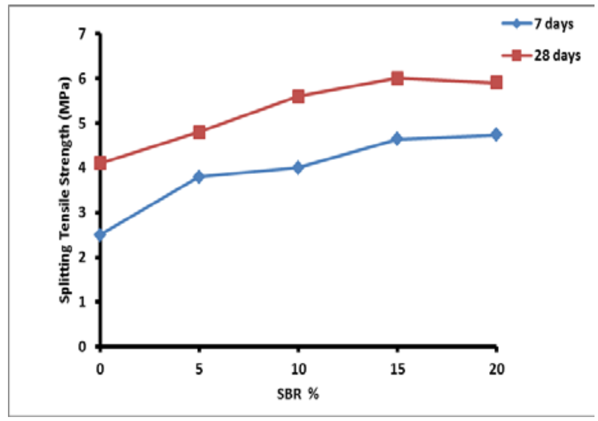

Figure 4: Effect of SBR on the compressive strength of concrete.

6.2 Splitting Tensile Strength Test Results

The influence of SBR on the splitting tensile strength is appeared in Figure 5. The influence of SBR on the splitting strength is observed comparatively similar to that of compressive strength. The extremely increasing has been spotted for 15% of SBR. The splitting strength at this level is approximately85.6% at 7 days. Whereas, at 28 days, the increasing percentage 46.34% comparing with the reference mix. This reduction in splitting tensile strength can be relatively attributed to the same reasons mentioned in the compressive strength.

6.3 Flexural strength test results

Figure 3 indicates the effect of using SBR on the flexural strength of concrete. When there is no SBR, the flexural strength is a round 4.5MPa. As the percentage of SBR increases up to 15%, the strength jumps to 12MPa as indicated in Figure 6. Consequently, the increment at this percentage in the flexural strength is up to 156%. The behavior of increment due to SBR addition linearly increases from zero percentage of SBR up to 15%. Then, the strength slightly decreases by about 11% at 20% of SBR which is still higher than reference mix.

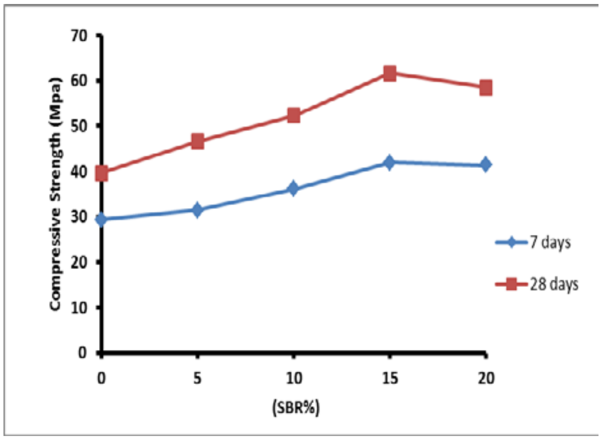

Figure 5: Effect of SBR on the splitting tensile strength of concrete

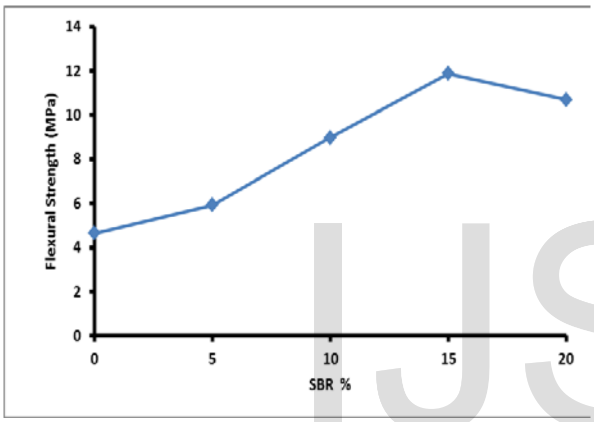

Figure 6: Effect of SBR on the flexural strength of concrete.

7.Discussion

The improvements of mechanical properties for the concrete as mentioned in the experimental works above could be attributed to the following reasons:

1. The use of SBR leads to formation of polymer films inside concrete. This polymer film can bond with Calcium ions liberated from hydration of cement and also bonds with external silica of coarse and fine aggregates [3]. These reasons affected the values of compressive strength largely and slightly affect and flexural strengths.
2. The main reasons for the increment values of flexural and tensile strengths (see Figure 5 and 6) are:
   - The high tensile strength of the polymer itself (18-19)MPa can reduce cracking and its propagations of cracks under loading, therefore, that leading to higher values of flexural and tensile strength [13].
   - The secondary reasons increment of the values of flexural and tensile strengths are the bonds between the polymer films during mixing and during hardening of concrete and calcium ions and silica of aggregates that lead to more additional strength during loading.

8. Conclusions

The research study the improvement of mechanical properties of glass coarse aggregate concrete using SBR as a polymer. The main conclusions of this study are:

1. Using SBR as an admixture in concrete tends to increase the compressive strength with increasing in the dosage of SBR up to 15% for all ages 7 and 28 days. The increment for compressive strength at this level is approximately 55.7% at 28 days.
2. Increasing in splitting strength with the increment in SBR ratio at 15% for all ages. The splitting strength at this level is approximately 85.6% at 7 days.
3. Flexural strength increases as the percentage of SBR increases as the same behavior for the compressive and splitting strengths. The optimum percentage of SBR for flexural strength is about 156% with comparison to the reference mix.

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