Tensile strength of pervious concrete with different mix proportions

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Abstract. No-fines concrete is a distinctive kind of concrete that has an amount of porosity that lets the water and any liquid sources pass immediately through it. Often, many mechanical properties of concrete refer to its strength through the testing of the compressive strength, flexural strength, and splitting tensile. Thus, this research mainly focused on the splitting tensile strength with different mix ingredients. Two series of penetrable concrete were prepared to study the effect of two parameters on such concrete. In the first group, the sand was eliminated for one sample and the styrene butadiene rubber (SBR) was added to the mix with a percentage of 5% and 8% by cement weight. The second group was to study the effect of a partial replacement of coarse aggregate with sand in three varied proportions of 15%, 30%, and 45% of the total volume of aggregate. The water/cement ratio (w/c) was chosen to be 0.38 and 0.42. The results showed that the sand content has a higher positive effect than SBR on the tensile strength of pervious concrete.

Keywords: pervious concrete, splitting tensile strength, styrene butadiene rubber (SBR), sand content, mix proportions.

1. Introduction
Previous concrete or (No-fines concrete) is the term that represents a near zero-slump, having a high void content and high porous product because of the elimination of the fine aggregate in the components of the concrete mix. These voids led the concrete to behave as a lightweight structure[1]. The ratio of the porosity of No-fines concrete ranges from 15% to 30% [2]. Thus, the characteristic of porosity plays the main role in designing the mixture of this type of concrete [3]. The most important function of this kind of concrete is its suitability for using it in pavement work when there is a need to drain the water because of its ability to reducing storm water run-off or any other sources to pass directly through it. Therefore, it can enhance skid resistance of the paved road and thus promoting road safety[4].

The pervious concrete is a composite from a binder material (cement), a filling material (coarse aggregate), a low quantity of fine aggregate (which can be omitted), water for the hydration reaction, and optionally, admixtures[5]. However, it has different properties from the other conventional concrete (normal weight concrete). The most important difference between them is concentrated in the resisting strength for the deflection in the building structure[6]. Due to the lack of fine Aggregate, the pervious concrete suffers from the reduction in strength because of the weak bonding between the matrix (cement paste) and the filler (the aggregates)[7]. Based on this concept, many researchers have made attempts to improve the strength of the cement paste by replacing the coarse aggregate with proportions of fine aggregate but there was a significant reduction in the permeability[8].

Therefore, many studies focused on improving the porosity to achieve the required strength and permeability properties[9].

Huang et al.[10] Present an illustrative study about the incorporation of sand as well as latex in a previous concrete. Three types of graded limestone aggregates (4.5 mm, 9.5 mm, and 12.5 mm) and Styrene Butadiene Rubber (SBR) latex were used to make the mixture of pervious concrete. Through the study, many pervious concrete properties were evaluated such as; splitting tensile strength, compressive strength, permeability, and air void content. The laboratory experiments revealed there were a significant improvement in pervious concrete properties and the possibility to produce this type of concrete with acceptable strength and permeability by the combination of latex and sand.
Mahesh and Lavanya [11] focused on making a balance between permeability and the strength of such concrete. The mixtures used in their study consist of 1: 0.3: 5.5 (cement: sand: coarse aggregate), 0.40 w/c, the SBR and plasticizer dosages were 0.2% and 0.6% by weight of cement respectively. The results indicated that it is possible to produce a pervious concrete mixture suitable for parking lots, sidewalks, and many other applications.

Borhan and Al Karawi [12] investigated the impact of Styrene Butadiene Rubber (SBR) on the mechanical and physical properties of Pervious concrete. The proportions of SBR were 0, 5, 8 % by wt. of cement with two water/cement ratios (0.30 and 0.35). Several properties were tested through the study such as density, water discharge, compressive strength, and modulus of rupture. The outcomes of the experiment work showed a positive effect for using SBR on the properties of the Pervious concrete compared with the reference mixture that has no SBR. This result was due to increasing the hydration products with the existence of the polymer.

The tensile strength has a considerable weight in finding the reliability of the rigid structure and pavement. Therefore, the cementitious material and ingredients of concrete should be designed based on the demand of the tensile strength[13]. Hence, the aim of the laboratory experiment conducted in this study is to investigate the influence of incorporating SBR and using sand as a partial replacement of coarse aggregate, in different verities, on the tensile strength of pervious concrete.

2. Experimental Work
This study included two groups of specimens, the first group involved adding SBR as a percentage of the cement weight and in the second group specimens, the fine aggregate was used as a partial replacement of coarse aggregate.

2.1. Preparation of concrete mixes, samples, and testing
The mixtures of concrete were prepared by casting the specimens with Ordinary Portland cement (Type I) as a binder material. It is within the requirement of Iraqi Standard Specifications No.5. To study the influence of SBR on the characteristics of this kind of concrete, two various ratios (5,8) % were used as a % of cement weight. The Styrene butadiene rubber (SBR) used is a whit colour liquid with a 1 % air entrainment and a specific gravity of 1.16. Natural sand (filling material) was used as a fractional substitution of gravel (coarse aggregate). The properties of the sand and coarse aggregate are complying with the instructions of Iraqi Standard Specifications No.45. The Table 1 shows the grading and physical properties of sand.

| Sieve (mm) | % passing | Limits of IQS (5-1984) | ASTM limits C33-86 |
|-----------|-----------|------------------------|--------------------|
| 10        | 100       | 100                    | 100                |
| 4.75      | 99        | 90 – 100               | 95 – 100           |
| 2.36      | 85.6      | 60 – 95                | 80 – 100           |
| 1.18      | 40.1      | 30 – 70                | 50 – 85            |
| 0.60      | 17        | 15 – 34                | 25 – 60            |
| 0.30      | 5         | 5 – 20                 | 10 – 30            |
| 0.15      | 0.3       | 0 – 10                 | 2 – 10             |

Properties | Value | IQS limits |
-----------|-------|------------|
SO3 %      | 0.2   | ≤ 0.5      |
Material finer than (75μ) % | 0.8 | ≤ 5          |
The gradation of coarse aggregate used in the study was with extreme granular size from (5 to 10) mm. The properties of the reference mix were 1:5 (Ce: Gr) volume ratio where no fines particles (sand) and SBR (latex) were added.

To investigate the impact of partial substitute coarse aggregate with the sand, three varies the proportion of (Ce: Sa: Gr) volume ratios (1:0.75:4.25, 1:1.5:3.5, 1:2.25:2.75) (15%, 30%, and 45% from the total aggregate content) were used.

Two water/cement ratios (0.38 and 0.45) were used in this study to investigate the influence of this ratio on pervious concrete tensile strength. The Table 2 shows Proportions of the material used for each mix.

| Code of the mix (CM) | Ratio of Sand (%) | Ratio of SBR (%) | w/c = 0.38 Tensile strength (MPa) | w/c = 0.42 Tensile strength (MPa) | Ce: Sa: Gr |
|---------------------|-------------------|-----------------|-----------------------------------|-----------------------------------|------------|
| CM0.0               | 0                 | 0               | 7.67                              | 5.09                              | 1:0:5      |
| CM0.5               | 0                 | 5               | 8.83                              | 10.2                              | 1:0:5      |
| CM0.8               | 0                 | 8               | 9.3                               | 12.59                             | 1:0:5      |
| CM15.0              | 15                | 0               | 15.29                             | 12.96                             | 1:0.75:4.25|
| CM30.0              | 30                | 0               | 31.81                             | 12.69                             | 1:1.5:3.5  |
| CM45.0              | 45                | 0               | 28.18                             | 24.34                             | 1:2.25:2.75|

2.2. Testing method
The splitting tensile strength was conducted according to the requirement of specification ASTM C496-90. To perform this test, three-cylinder molds with dimensions of 10 cm length and 20 cm diameter were cast. The concrete samples were slipped off the molds after 24 hours to be cured in a water tank until the day of testing all specimens which is 28 days.

3. Results and discussion
The results obtained from the splitting tensile strength, conducted in the experimental work, were summarized in Table 3. All the results were compared with zero percentage SBR and sand (reference mix).

| Series name | Sand % | Tensile strength (MPa) w/c=0.38 | SBR % | Tensile strength (MPa) w/c=0.38 |
|-------------|--------|-------------------------------|-------|-------------------------------|
| M0.0        | 0      | 2.5                           | 0     | 2.5                           |
| M15.0       | 15     | 3.96                          | 0     | 0                             |
| M30.0       | 30     | 4.79                          | 0     | 0                             |
| M45.0       | 45     | 4.9                           | 0     | 0                             |
| M0.5        | 0      | 0                             | 5     | 2.65                          |
| M0.8        | 0      | 0                             | 8     | 2.7                           |
3.1 Effect of adding SBR

It seems from Figure 1 and Figure 2 that adding SBR with percentages of (5% and 8%) resulted in increasing the splitting tensile strength by approximately (23.7% and 35.53%), for water/cement ratio of 0.38 while mixes of 0.42 w/c, the strength is increased by (6% and 8%), respectively. Accordingly, water/cement ratio of 0.38 increases the impact of SBR on the tensile strength (comparing with that of water/cement ratio of 0.42). This increment occurs as a result of the polymer existence that helped the formation of a continuous network of products of the polymerization process that shape a diaphragm. These results matched the results of Hao. et al [14] study indicated that (SBR) latex remarkably improved the strength of pervious concrete.

![Figure 1. Development of tensile strength versus SBR for water/cement ratio of 0.38](image1)

![Figure 2. Development of tensile strength versus SBR for water/cement ratio of 0.42](image2)
3.2 Effect of adding sand

Concerning the behavior of mixtures that containing sand, the sand appears an important effect on the tensile strength even higher than of SBR Figure 3 and Figure 4. Adding sand with three different percentages, from 15% to 45%, increases the tensile strength from 105% % to 186.5%, with water/cement ratio of 0.38, which is clear that it has a higher effect than that with water/cement of 0.42 where the development in strength is from 58.4 to 82.4 %, respectively. Increasing the percentage of w/c in the concrete to 0.42 causes a decrease in the resistance of concrete comparing with w/c of 0.83. This decrease occurs because of the non-homogeneity of mixture led to segregation phenomenon (isolation of granular) when exceed the water content which produces an imbalance in the properties of the concrete.

Borhan and Kammouna [15] claimed that the inclusion of the sand leads to an increase in the strength of concrete depends on the amount of sand used in the mixture.

![Figure 3](image1.png)

**Figure 3.** Development of the tensile strength versus % sand for water/cement ratio= 0.38

![Figure 4](image2.png)

**Figure 4.** Development of the tensile strength versus % sand for water/cement ratio= 0.42
3.3 Comparison between the effect of adding SBR and sand
The results illustrated in Figure 5 show that the SBR content has less effect than the sand content on the splitting tensile strength of concrete. This may be because the SBR does not overcome the effect of pores that are found between cement and coarse aggregate. Despite using SBR as a bonding agent between these materials. On another side, the higher effect of the partial replacement of the sand is due to reduction the voids within the mixture which leads to the growth in the tensile strength. Furthermore, the mixtures with w/c 0.38 have higher splitting tensile strength comparing to those with w/c 0.42[16].

![Figure 5](image)

**Figure 5.** Development of tensile strength versus SBR and sand content, and that for both series of different w/c ratios (0.38 and 0.42)

4. Conclusion
1- It was found using 8%, by wt. of cement, SBR content in pervious concrete improves its tensile strength due to increasing the bond between particles of the mixture (cement and aggregate) as well as increased the area of the hydration process.
2- Inclusion of the sand in pervious concrete has a good effect on the strength comparing with adding SBR due to reduction of the voids within the mixture.
3- The embodiment of the sand on the pervious concert has a higher impact than SBR content on the splitting tensile strength of concrete due to the effect of voids that still cannot be overcome when using SBR instead of sand.
4- Increasing the percentage of w/c in the concrete causes a decrease in the resistance of concrete because of the non-homogeneity of mixture.

5. References
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