Utilization of Styrene-Butadiene Rubber (SBR) Polymer Replacement of Fine Aggregate in Concrete

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Abstract. This paper aims to examine the effect of styrene-butadiene rubber (SBR) polymer incorporation on the performance of no-fine aggregates produced from lightweight concrete. This type of concrete usually utilized for partitions and external walls and infilling panels in framed structures. Three concrete mixtures with varying aggregate/cement ratios (4:1, 6:1, and 8:1) were used by volume. Each of these mixtures consists of five sub-mixes with different proportions of polymer/cement (0, 5, 10, 15, and 20%) by mass. For using a (300×50) cylinder specimen, a tensile strength test was carried out on all concrete mixes after curing on 28 days in water. The test results demonstrated that no-fine aggregate concrete's strength increased with the increase in the polymer/cement ratio for all mixes. Whereas the rate of development in a group ratio (4:1) for water curing when increasing the polymer (0-10) %, was (192) % more than the strength in the control mix and the mix (M4-15) for water curing the strength was (130) % more than control mix. That indicates that the polymer is more effective in poor mixtures due to its containing high voids.

Keywords: Styrene-butadiene rubber; splitting tensile strength; lightweight concrete; ANOVA.

1. Introduction
This research's main object was to examine the representation of no-fine concrete produced with lightweight aggregate (porcelainize) and modify with (SBR) polymer and recommend potential applications of this kind of concrete. The commodity method categorizes Lightweight Concrete (LWC) broadly into three significant groups: aerated concrete, lightweight aggregate concrete, and no-fine concrete [1] as shown in Figure 1. Aerated concrete is accomplished by adding foam bubbles into the cement matrix or the grout of sand-cements. Lightweight aggregates used in lightweight concrete include a wide variety of products that can be raw materials, raw manufactured materials, or synthetic materials from recycled by-products or agricultural waste [2]. As the name suggests, no-fine concrete is concrete without any fine aggregate: just cement, water, and coarse aggregate. Consequently, no-fine concrete is an agglomeration of coarse aggregate particles, each becoming covered by a cement paste coating up to 1.3 mm thick [3-5].
No-fine concrete's interests include lower density, lower thermal conductivity, comparatively low drying shrinkage, no segregation and capillary water flow, more insulating properties than conventional concrete due to the absence of large voids [6]. This research's primary purpose was to study the efficiency of no-fine concrete manufactured modifications with lightweight aggregate (porcelainize) and with Styrene Butadiene Rubber (SBR) proposes possible concrete solutions of this kind. Many researchers and investigators are lately reusing the admixtures in economically sustainable ways [7-9].

![Aerated concrete](image1)
![No-fines concrete](image2)
![Lightweight aggregate concrete](image3)

**Figure 1.** Main shapes of lightweight concrete.

### 2. Methodology

All concrete samples were cast in steel molds in layers of around 100 mm depth. Every layer was compacted by simplistic rodding. The specimens were stored in their molds at room temperature with a plastic sheet covering to decrease water losses during 24 hrs. Then, it was demolded and soaked in a water tank up to the age of 7 days at a temperature of the laboratory about (23±2°C). The splitting tensile test was performed as maintained by ASTM C496. (d = 150 mm, h = 300 mm) cylinders’ concrete specimens were utilized. Figure 2 shows the specimens of cylinders’ concrete. The specimens were examined employing an electrical testing device with a capability of 2000 kN.

![Specimens of cylinders’ concrete](image4)

**Figure 2.** Specimens of cylinders’ concrete.

The materials utilized in this research were cement, coarse aggregate, and Styrene-Butadiene Rubber (SBR). The cement used in the study was brought from a cement factory – Sulaymaniyyah/Iraq. The cement’s percentage oxide composition and physical properties indicate that the adopted cement according to CEM I 42.5 R used in general construction confirmed by EN 197-1. Local natural lightweight porcelain stone aggregate was utilized as a coarse aggregate with a particular 19 mm size. The aggregate was washed by water then spread within the laboratory to produce the aggregate particles. The coarse porcelainizing aggregate specifications are described in Table 1. A white latex-based on modified styrene-butadiene copolymer emulsion, which is identified commercially as Cempatch SBR 100, was utilized during this study. Table 2 shows the description of the aqueous solution of SBR adopted in this investigation which is complied with ASTM C 1059. Figure 3 demonstrated the color of SBR.
Table 1. Specifications of porcelainize lightweight aggregate

| Property                        | Value | Property                        | Value |
|---------------------------------|-------|---------------------------------|-------|
| Absorption, %                   | 33    | Dry loose unit weight, kg/m³    | 711   |
| Specific gravity                | 1.64  | Sulfate content (as SO₃), %     | 0.32  |
| Aggregate crushing value, %     | 17    | Dry rodded unit weight, kg/m³   | 755   |

Table 2. Description of the SBR Latex

| Property             | Value       | Property             | Value       |
|----------------------|-------------|----------------------|-------------|
| Specific gravity     | 1.02        | pH                   | 10.7        |
| Particle size        | 0.18 micron | Color                | White emulsion |
| Solid particles content | 57 %     |                      | -           |

Figure 3. Milky White SBR Latex.

Fifteen concrete mixes with various aggregate/cement ratios (4:1, 6:1, and 8:1) by volume were used. These mixes covered five mixes that differed in polymer/cement ratios P/C (0%, 5%, 10%, 15%, and 20%) by mass to obtain the optimum P/C ratio. A water/cement ratio w/c, higher than the optimum, would get the cement paste flows to the bottom of the concrete and makes that portion dense, whereas, with additionally low a water/cement ratio, the cement paste will be so dry that aggregates do not get characteristic covered with a paste which occurs in insufficient adhesion between the particles. The specifications of all concrete mixes used throughout this research are shown in Table 3.

Table 3. The mixes portion of this study (*NP Non-Polymer).

| Type of mix | Agg./Cement ratio by volume | P/C ratio by weight (%) | w/c ratio by weight of cement |
|-------------|----------------------------|-------------------------|-----------------------------|
| M1-NP*      | 4:1                        | 0%                      | 0.33                        |
| M2-5        | 4:1                        | 5%                      | 0.31                        |
| M3-10       | 4:1                        | 10%                     | 0.28                        |
| M4-15       | 4:1                        | 15%                     | 0.26                        |
| M5-20       | 4:1                        | 20%                     | 0.25                        |
| M6-NP*      | 6:1                        | 0%                      | 0.38                        |
| M7-5        | 6:1                        | 5%                      | 0.35                        |
| M8-10       | 6:1                        | 10%                     | 0.33                        |
| M9-15       | 6:1                        | 15%                     | 0.31                        |
| M10-20      | 6:1                        | 20%                     | 0.30                        |
| M11-NP*     | 8:1                        | 0%                      | 0.43                        |
| M12-5       | 8:1                        | 5%                      | 0.41                        |
| M13-10      | 8:1                        | 10%                     | 0.38                        |
| M14-15      | 8:1                        | 15%                     | 0.36                        |
| M15-20      | 8:1                        | 20%                     | 0.34                        |
3. Results and Discussion

The test results of the tensile splitting strength of different characters of no-fine concrete mixes are described in Table 4 and graphically displayed in Figures 4 and 5. It is observed that the highest splitting tensile strength was at an aggregate/cement ratio of 4:1 and decreased as the aggregate/cement ratio was increased. Furthermore, the splitting tensile strength has been increased with the increase of the polymer/cement ratio for all mixes with different Agg./cement ratio, Figure 5. The results indicated that the splitting tensile strength increased corresponded with adding the polymer/cement ratio from 5 to 20%. This can be described in terms of the influence of high tensile strength by the polymer itself and comprehensive development in the bond between cement-aggregate, the results are acceptable with other researchers such as [4, 10-12].

Table 4. The splitting tensile strength test results for all no-fine concrete mixes.

| Type of mix | Agg./cement ratio by volume | P/C ratio by weight (%) | w/c ratio by weight of cement | Splitting tensile strength MPa |
|-------------|-----------------------------|-------------------------|-------------------------------|-------------------------------|
| M1-NP       | 4:1                         | 0%                      | 0.33                          | 0.56                          |
| M2-5        | 4:1                         | 5%                      | 0.31                          | 0.46                          |
| M3-10       | 4:1                         | 10%                     | 0.28                          | 0.33                          |
| M4-15       | 4:1                         | 15%                     | 0.26                          | 0.72                          |
| M5-20       | 4:1                         | 20%                     | 0.25                          | 0.62                          |
| M6-NP       | 6:1                         | 0%                      | 0.38                          | 0.43                          |
| M7-5        | 6:1                         | 5%                      | 0.35                          | 0.83                          |
| M8-10       | 6:1                         | 10%                     | 0.33                          | 0.66                          |
| M9-15       | 6:1                         | 15%                     | 0.31                          | 0.47                          |
| M10-20      | 6:1                         | 20%                     | 0.30                          | 0.88                          |
| M11-NP      | 8:1                         | 0%                      | 0.43                          | 0.81                          |
| M12-5       | 8:1                         | 5%                      | 0.41                          | 0.56                          |
| M13-10      | 8:1                         | 10%                     | 0.38                          | 0.96                          |
| M14-15      | 8:1                         | 15%                     | 0.36                          | 0.9                           |
| M15-20      | 8:1                         | 20%                     | 0.34                          | 0.63                          |

Figure 4. Polymer/cement ratio effect on splitting tensile strength value.
Figure 5. Splitting tensile strength, P/C and Agg/cement ratio for no-fine concrete.

4. Statistical analysis
All data obtained from the experimental study are processed and entered into the Minitab program (Version 18). In the (ANOVA) Analysis of variance at 95% confidence level has been implemented to find the statistical factors' significance. In this investigation, the design factors are P/C, and Agg./cement is considered the main parameters, and the splitting strength is defined as design response. Also, ANOVA is presented to understand the level of effectiveness of the independent variables on the design responses. P-values for the statistical analysis results demonstrated in Tables 5 and 6, which is higher than 0.05, the parameter rejected as an insignificant factor on the response at 95% confidence level, such as 10% in P/C. Moreover, the highly effective outcomes obtained in P/C and Agg./cement, as shown in Tables 5, 6, and Figure 6.

Figure 6. Normalization of parameters.
### Table 5. Analysis of variance.

| Source      | Degree of Freedom | Adj Sum of Squares | Adj Mean Square | F-Value | P-Value |
|-------------|-------------------|--------------------|-----------------|---------|---------|
| P/C         | 4                 | 0.257707           | 0.064427        | 52.52   | 0.000   |
| Agg./cement | 2                 | 0.243453           | 0.121727        | 99.23   | 0.000   |
| Error       | 8                 | 0.009813           | 0.001227        |         |         |
| Total       | 14                | 0.510973           |                 |         |         |

### Table 6. Coefficients of statistics analysis.

| Term      | Coefficient | SE Coef | T-Value | P-Value | VIF |
|-----------|-------------|---------|---------|---------|-----|
| Constant  | 0.65467     | 0.00904 | 72.39   | 0.000   |     |
| P/C       |             |         |         |         |     |
| 0         | -0.2047     | 0.0181  | -11.32  | 0.000   | 1.60|
| 5         | -0.0647     | 0.0181  | -3.58   | 0.007   | 1.60|
| 10        | -0.0013     | 0.0181  | -0.07   | 0.943   | 1.60|
| 15        | 0.0953      | 0.0181  | 5.27    | 0.001   | 1.60|
| Agg./cement |          |         |         |         |     |
| 4         | 0.1353      | 0.0128  | 10.58   | 0.000   | 1.33|
| 6         | 0.0353      | 0.0128  | 2.76    | 0.025   | 1.33|
| 8         | 0.0285      | 0.0128  | 1.58    | 0.015   | 1.33|

To predict the value of splitting strength according the ratios of P/C and Agg./cement by using regression equation as Eq. 1.

\[
\text{Splitting Strength} = 0.65467 - 0.2047P/C_0 - 0.0647P/C_5 - 0.0013P/C_{10} + 0.0953P/C_{15} + 0.1753P/C_{20} + 0.1353\text{Agg./cement}_4 + 0.0353\text{Agg./cement}_6 + 0.0285\text{Agg./cement}_8
\]  

(1)

### 5. Conclusions

Using SBR in no-fine concrete has some important conclusions that can be described in the following points:

- The mix proportions 4:1 gives higher tensile strength than the other two proportions.
- While the polymer/cement ratio was increased in all mixtures containing different aggregate/cement ratios, the splitting tensile strength was increased.
- The value of amelioration in splitting tensile strength compared with the control mixture increased approximately 30-50%, increasing the polymer/cement rate from 5 to 20%.
- When aggregate/cement increased, the tensile strength decreased due to adding SBR.
- The results showed that no-fine concrete's enhancement strength properties improve it and are utilized in engineering projects.
- Finally, using SBR materials in construction buildings improves the quality of concrete for sustainability and durability of the structures; therefore, no-fines concrete differs from other types. It does not contain fine aggregate, resulting in no segregation of ingredients.

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