Study the Ability of Styrene Butadiene Rubber on Improving the Properties of Cement Mortar

Zainab M. I. Kammouna
Assistant Lecturer, Civil Engineering
Department, Nahrain University

Abstract

Polymers are considered one of the admixture kinds which they are used to improve the performance of mortar and concrete. In this study Styrene Butadiene Rubber (SBR) was used to evaluate the ability of this polymer to improve the properties of mortar. Four cement mortar mixes were made in this study. The first one was considered as a reference mix which is free of (SBR), while the other mixes were included (SBR) in different percentages of the cement weight. The percentages of (SBR) were 5% for the second mix, 7.5% for the third mix, and 10% for the fourth mix. The added water was decreased to be replaced by the proposed amounts of (SBR). For each mixture two prisms were prepared to carry out the drying shrinkage test, three cubes to carry out the compressive strength, and three cubes to carry out the total water absorption tests. The results show that (SBR) is a useful agent used for improving the properties of mortar under study. When the percentage of (SBR) was 10%, the drying *shrinkage was decreased by 7.6%, comparing with* the reference mix. When the percentage of (SBR) was 7.5% the compressive strength was increased by 19% and the total water absorption was decreased by 15% comparing with that of the reference mix.

Keywords: *cement mortar, SBR, drying shrinkage, compressive strength, and total water absorption.*

1. Introduction

As the development in building complex structures and complex architectural requirements have been increased, the demand for improving the concrete and mortar mixtures becomes very necessary. In addition, the need for greater resistance to cracking and greater stability under hot climate (like in Iraq) leads to use additives to concrete and mortar mixes to improve their abilities. This work was carried out to detect the efficiency of (SBR) to improve cement mortar this because the cement mortar is used in finishing works. So, it becomes very necessary to improve its properties for decreasing deformations and cracks arising.

As Styrene Butadiene Rubber Latex is one of the most important polymer kinds, because of its adhesiveness property, it was adopted in this work to study its effect in improving the quality and the performance of cement mortar. It is the copolymerized product of two monomers Styrene and Butadiene. The chemical structure of this polymer is shown in Figure (1) [1, 2].

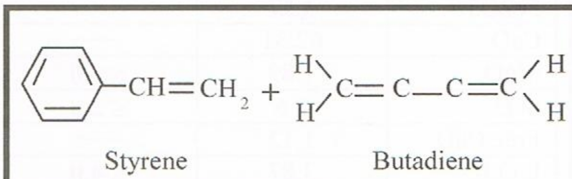

Figure (1) Chemical Structures of SBR

Latex is typically included in concrete or mortar in the form of colloidal suspension polymer in water. *This polymer latex, usually a milky-white fluid,* contains small, spherical, copolymer particles that vary in size from about 0.05μm to 0.5μm in diameter [3].

In the polymer latex - modified mortars and concretes, both cement hydration and polymer-phase formation by the coalescence of polymer particles proceed well to yield a monolithic matrix phase with a network structure in which the hydrated cement phase and polymer phase interpenetrate into each other, and aggregates are bound by such a comatrix phase[4].

The work of this study is composed from four series. As this study was carried out to verify the effect of (SBR) on the cement mortar, the first series was considered to be the reference one, where no (SBR) was added, while the other series the (SBR) was added in deferent percentages of the cement weight.

2. Specimens and Materials

The Ordinary Portland Cement (Type I), which was manufactured in Lebanon, was conforming to Iraqi Standard No. 5 [5]. The physical characteristics and chemical analysis of this cement are listed in Table(1).

The fine aggregate used in making the mortar was; natural sand from Al-Ekhaidher quarry and it was conforming to Iraqi Standard No.45- Zone (4) [(6)]. Table (2) shows the grading of it after sieving on sieve No. 16. That was done to remove particles of size greater than (1.18mm) to resemble the grading of sand that is used in actual works of cement mortar. The used sand was in saturated dry surface state and its specific gravity was 2.48, the percentage of water absorption was 1.52%, and SO_3 content was 0.34%.

Styrene Butadiene Rubber (SBR) is a milky-white fluid and it is a copolymerized product of two monomers, styrene and butadiene. The polymer which was used in this work is manufactured in Egypt and its specific gravity was 1.04.

Table (1) Physical Characteristics and Chemical Analysis of OPC

Oxide composition	Oxide content %	Limits of IQS (5-1984)
SiO2	20.44	----
Al2O3	5.12	----
Fe2O3	3.57	----
CaO	62.31	----
MgO	1.89	≤ 5.0
SO3	2.6	≤ 2.8
Free CaO	1.12	----
L.O.I.	3.87	≤ 4.0
I.R.	0.65	≤ 1.5
L.S.F.	0.92	0.66-1.02
main components (using Bogue's formulas)		
C3S	46.75	----
C2S	23.58	----
C3A	7.85	----
C4AF	10.85	----
The physical properties		
e Fineness (Blai /kg) (m	32	≥ 230
Initial setting time (Vicat) (min)	2:05	≥ 45
Final setting time(Vicat) (Hrs:min)	3:50	≤ 10
Compressive Strength (MPa)		
3 days	16.9	≥15
7 days	24.8	≥23

Table (2) Grading of Sand

Sieve No.	Sieve Size	Percentage Passing %	Limits of IQS (45-1984) Zone (1)
16	1.18mm	100	90 - 100
30	600 μm	89	80 - 100
50	300 μm	42	15 - 50
100	150 μm	3	0.0 - 15

The mix proportions were 1: 2.75 (cement: sand) by weight of cement for all the mixtures. Series 1 considered as a reference mixture the water /cement ratio was decided to be 0.48. For this series no polymer (SBR) was added while for other series this polymer was used as a ratio by weight of cement. As the specification of (SBR) product confined it between 5% and 10% of cement weight, the ratios used were 5%, 7.5% and 10% for series 2, 3 and 4 respectively.

The weight of mixing water was decreased by the same amount of the added (SBR). So, the percentages of water to cement were 43%, 40.5% and 38% for series 2, 3 and 4 respectively.

The specimens that were used for compressive strength test[(7)] and absorption test[(8)] were cast in cubic steel moulds of 50 mm, while the specimens that were used for shrinkage test[(9)] were molded in prism shapes (25×25×280)mm.

3. Mixing, Casting and Compaction

For the reference mixture, the mixing procedure was carried out according to ASTM C 305-99 [(10)]. First, all the mixing water was placed in the bowel of the mixer then the cement was added to the water and the mixture was turned on at slow speed. After 30 sec. of mixing, the entire quantity of sand was added slowly over 30 second period. Then the mixer was stopped to be changed to medium speed and let it mix for 30 sec. . After that, the mixer was stopped for 1.5 min. and restarted at medium speed for 1 min. For the other mixtures that include polymer, the same procedure was adopted with the following changes which were recommended by ASTM C 1439-99 [(11)]. All the quantities of (SBR) and mixing water were placed in the bowel then the cement was added to them and the mixer was started to mix at slow speed. After that, the mortar was cast in the moulds in two layers for cubes and prisms. Mortar compaction was performed by a vibrating table and followed by trawling the surface to level it.

4. Curing Conditions

All the specimens of the four series were exposed to the same curing conditions. According to Ohama[(4)], the optimum strength in most latex-modified concretes is obtained by achieving a reasonable degree of cement hydration under wet conditions at early ages, followed by dry condition to promote a polymer film formation. So, all the specimens under study were stored in moist conditions for three days then the specimens were stored in dry conditions until the time of testing.

After casting and compacting the mortar specimens were cured in the laboratory temperature (23°C) while covered by polyethylene sheets. After 24 hrs., the specimens were removed from the molds carefully and stored in a particular moist cabinet. The moist cabinet was conforming to the requirements of ASTM C 511-98 [12] where the atmosphere inside have a temperature of 23°C and a relative humidity of 95%. At age of three days (from the time of casting), the specimens were translated to be stored in the laboratory for all the time of testing. The temperature inside the library was 23°C while the relative humidity was 55%.

For determining the compressive strength the cube specimens were tested at age of 28 days taken from the time of casting. The total water absorption test was carried out on the cube specimens at age 28 days taken from the time of casting.

5. Test Measurement

1) Drying Shrinkage: The term drying shrinkage is defined by ASTM C 596-01 [9] as decreasing in length of the testing specimen, where the decrease is caused by any factor other than externally applied forces under stated conditions of temperature, relative humidity and evaporation rate in the environment. For each patch two mortar prisms of (25×25×280) mm ware prepared with stainless steel studs inserted at their ends. The prisms were measured by means of a length change comparator, using a standard invariable length to calibrate the instrument at each reading. The accuracy of the dial gage used in this test was (0.002) mm. After removal from the moist cabinet (at age of 3 days) the first reading was taken and recorded as the initial comparator reading. According to ASTM C 596-01 [9], the comparator readings for all the specimens were taken after 4, 11, 18 and 25 days of air storage. Also, an additional reading was taken at 7 days of air storage.

The change in length at any age was determined by taking the percentage of the difference between the reading at that age and the initial reading divided by the gauge length (clear length between the studs) which is taken to be equals to 250 mm. The average of two prisms results at each age were given in the presentation of test results.

2) Compressive strength: It may be defined as the measured maximum resistance of concrete or mortar specimen to axial loading. The compressive strength test was carried out at age of 28 days (taken from the time of casting).

For each batch three cubes of 50 mm were prepared. The compressive strength test was carried out according to ASTM C 109-02 [7]. The bearing plates of the compression machine were cleaned then the specimen was placed on opposite sides, as cast, on the center of the plates. The failure load was recorded and the compressive strength calculated by divided this load by the cross-sectional area of the cube. The final compressive strength recorded was the average of the results obtained from three cubes.

3) Total Water Absorption: It may be defined as the percentage of water absorbed by hardened mortar or concrete to its dry weight. For each batch three cubes of 50mm were prepared made of mortar. The conditions of this test were carried out according to the ASTM C 642-97 [8]. At age of 28 days, taken from the time of casting, each cubic specimen was immersed in water for 24 hrs. then its weight was taken after drying the excess water. After that, the specimen was dried in an oven of temperature 100°C for 24 hrs., then its weight was taken after cooling it for another 24 hrs. keeping it in a desiccator. Water absorption was computed from the difference between the two weights (wet and dry) divided by dry weight and multiplied by 100. The total water absorption was recorded as an average of results obtained from three cubes.

6. Results

The average drying shrinkage of two prisms for each time of testing was taken at periods of air storage (after removing from the moist cabinet) of 4, 7, 11, 18 and 25 days for each series. The results are shown in figure (2).

It could be seen that the value of shrinkage, for each time of testing, is decreasing with increasing the percentage of (SBR).

The average compressive strength at age of 28 days for the four series is as shown in table (3).

It could be seen that the compressive strength is increasing when the percentage of (SBR) is increased except for series 4.

The average total water absorption of three cubes for each series at age of 28 days was as shown in table (4).

It could be seen that the percentage of the total water absorption is decreasing when the percentage of (SBR) is increased except for series 4.

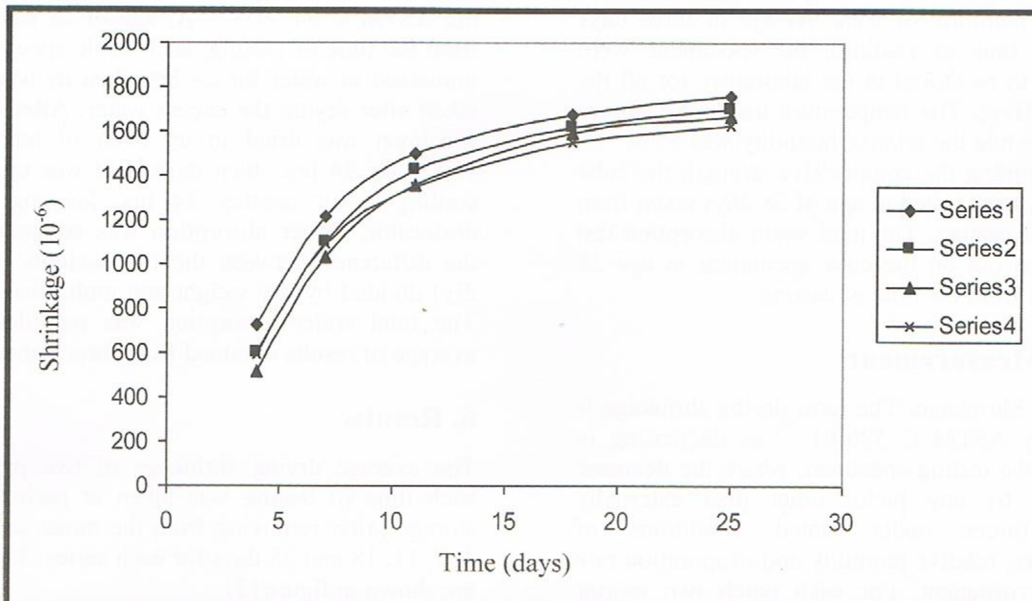

Figure (2) Shrinkage versus Time of Air Storage

Table (3) Compressive Strength Results

Series No.	Percentage of (SBR) %	Compressive Strength (MPa)
1	0	29.2
2	5	32.4
3	7.5	34.8
4	10	28

Table (4) Total Water Absorption

Series No.	Percentage of (SBR) %	Total Water Absorption (%)
1	0	10.30
2	5	9.60
3	7.5	8.77
4	10	9.82

7. Discussions and Conclusions

From the previous results it could be seen that increasing the quantity of (SBR) in the mixture improves the properties of mortar. The drying shrinkage was decreasing with increasing the percentage of the added (SBR) for all the series. Drying shrinkage at age of 28 days decreased for series 2 by 3.4%, for series 3 by 5.5% and for series 4 by 7.6% comparing with series 1.

This effect of (SBR) on decreasing the value of shrinkage could be related to the sticky behavior of (SBR) which may act as an obstacle to the movement of a specimen, i.e. restraining the shrinkage.

The polymer film bridges the microcracks and improves the bond between aggregate and cement paste. Also, the high adhesion which occurs between the polymer films that form and cement hydrates gives less strain compared to ordinary concrete and improves the properties of mortar[3,13].

At a polymer/cement ratio lower than 5%, the continuity of the polymer film is only present through small tiny bridges on a limited number of spots. At higher polymer/cement ratios, the film is denser [14]. So, that could explain why the shrinkage of the second series decreased in a small percentage.

The contrary results of series 4 at early ages (4 days and 7 days) where the values of drying shrinkage are reaching to the values of series 2 (600×10^{-6} and 1100×10^{-6}) could be related to that polymers are achieving their activity in progressing the dying of specimens which are used in, and as the specimens of series 4 (where the greatest percentage of (SBR) was added) at the first ages are still damp, so the polymer doesn't acquire the proposed activity yet.

The compressive strength at age 28 days was affected directly with increasing the amount of the added (SBR) except the result of series 4 which decreased by 4% comparing with series 1.

The compressive strength at age of 28 days increased for series 2 by 11% and for series 3 by 19% comparing with series 1. According to Ohama[3], the wide size variation of polymer particles (from about 0.05µm to 0.5µm in diameter) results in an effective void-fill-in and a closely-packed system of film formation. The form of this film is continuous on the surface of the cement gel-unhydrated cement particle mixture, this film will retain internal moisture and enhance curing [3, 13]. So, that could lead to an increasing in compressive strength of the latex-modified mortar.

The contrary result of series 4 may be related to that the amount of added water is not sufficient for completing the reactions of cements components. The water/cement ratio used in series 4 was 0.38 which is accepted theoretically for completing the reaction but practically the complete reaction could not be achieved especially that the moisture curing period (produced for the specimens) was achieved only for three days.

The total water absorption was decreasing with increasing the percentage of the added (SBR). The total water absorption at age 28 days decreased for series 2 by 6.8%, for series 3 by 14.9% and for series 4 by 4.7% comparing with series 1. In latex-modified mortars the total porosity or pore volume tends to decrease with an increase in the polymer-cement ratio. This may contribute to improvements in the impermeability and durability of the latex-modified mortars. That is because latex-modified mortars have a structure in which the larger pores can be filled by polymers or sealed by continuous polymer film[4].

Instead of that, it could be seen that the percentage of decreasing of series 4 is less than the other series. That could be related to; as it was discussed previously, the amount of added water was not sufficient for completing the reactions of cements components. So, the reaction products were not sufficient to fill all the available volume of pores. Subsequently, these cubes of series 4 absorbed more water than the cubes of any other series which have adequate water/ cement ratio.

7. References

1) Gowariker, V. R., Viswanathan, N. V. and Sreedhar, J., " Polymer Science ", Wiley Eastern Limited, 1986, p. 295.
2) Sung-Seen Choi, "Filler-Polymer Interactions in Filled Styrene-Butadiene Rubber Compounds", Korea Polymer Journal, Vol. 9, No.1, 2001, pp. 45-50.
3) Ohama, Y., "Polymer-Based Admixtures." Cement and Concrete Composites Journal., 1998, 20,pp. 189-212.
4) Ohama, Y., "Principle of Latex Modification and Some Typical Properties of Latex Modified Mortars and Concretes," ACI Materials Journal, vol. 84, No. 6, Nov-Dec. 1987, pp. 511-518.
5) المواصفات القياسية العراقية رقم (5)، " السمنت البورتلاندي" ، الجهاز المركزي للتقييس و السيطرة النوعية 1984.،
6) المواصفة القياسية العراقية رقم (45) ، "ركام المصادر الطبيعية المستعمل في الخرسانة والبناء"، الجهاز المركزي للتقييس والسيطرة النوعية ، 1984.
7) ASTM C 109-02, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)", Annual Book of ASTM Standard, Vol.04-01, 2003.
8) ASTM C 642-97, "Standard test Method for Density, Absorption, and Voids in Hardened Concrete", Annual Book of ASTM Standard, Vol.04-02, 2003.
9) ASTM C 596-01, "Standard test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement", Annual Book of ASTM Standard, Vol.04-01, 2003.
10) ASTM C 305-99, "Standard Method for Mechanical Mixing of Hydraulic Cement Paste and Mortars of Plastic Consistency", Annual Book of ASTM Standard, Vol.04-01, 2003.
11) ASTM C 1439-99, "Standard Test Method for Polymer- Modified Mortar and Concrete", Annual Book of ASTM Standard, Vol.04-02, 2003.
12) ASTM C 511-98, "Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes", Annual Book of ASTM Standard, Vol.04-01, 2003.
13) Sujjavanich, S. and Lundy, J. R., "Development of Strength and Fracture Properties of Styrene-Butadiene Copolymer Latex-Modified Concrete", ACI Material Jornal / March-April 1998, pp. 131-143.
14) A. Beeldens, D. Van Gemert, H. Schorn, Y. Ohama and L. Czamecki, " Form microstructure to microstructure: an integrated model of structure formation in polymer-modified concrete ", Materials and Structure, No. 38, 2005, pp. 601-607.

دراسة قابلية (الستايرين بيوتادين ربر) في تحسين خواص مونة السمنت

زينب محمد اسماعيل عبد الرزاق كمونه
مدرس مساعد
قسم الهندسه المدنيه/ جامعة النهرين

ألخلاصه:

تعتبر البوليمرات احد أنواع المضافات التي تستخدم لتحسين أداء المونه والخرسانه وضمن هذه الدراسه تم استخدام (الستايرن بيوتادين ربر) كبوليمر لمعرفة مدى قابليته في تحسين خواص المونه. تم عمل أربع خلطات من مونة السمنت، اعتبرت الاولى مرجعيه والتي لا تحتوي على مادة (الستايرن بيوتادين ربر) أما في الخلطات الاخرى فتم إضافة (الستايرن بيوتادين ربر) لها بنسب مختلفه، وقد أحتسبت هذه النسب كنسبه من وزن السمنت فكانت للخلطه الثانيه 5٪ وللخلطه الثالثه 7,5٪ وللخلطه الرابعه 10٪ وتم تقليل وزن الماء المضاف بنفس كمية (الستايرن بيوتادين ربر) المضافه وتم تقليل كمية الماء المضاف بنفس كمية (الستايرن بيوتادين ربر) المضافه. تم صب موشورين من كل خلطه وذلك لإجراء فحص انكماش الجفاف وثلاث مكعبات لاجراء فحص مقاومة الانضغاط وثلاث مكعبات لاجراء فحص الامتصاص الكلي. وقد أظهرت النتائج أن (الستايرن بيوتادين ربر) عامل مفيد في تحسين خواص المونه التي تضمنتها هذه الدراسه (انكماش الجفاف ومقاومة الانضغاط والامتصاص الكلي) حيث عندما كانت نسبة (الستايرن بيوتادين ربر) 10٪ قل انكماش الجفاف بمقدار 7,6 ٪ مقارنة مع انكماش الجفاف للخلطه المرجعيه وعندما كانت نسبة (الستايرن بيوتادين ربر) 7,5 ٪ زادت مقاومة الانضغاط بمقدار 19٪ وقل الامتصاص الكلي للماء بمقدار 15٪ مقارنة مع تلك الفحوصات للخلطه المرجعيه.