Adding Polymer to Mortar Mixture According to the Procedure Recommended by ASTM C 1439

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Abstract

Polymers are considered one of the admixture kinds which they are used to improve the quality and the performance of mortar and concrete. In this study the Styrene Butadiene Rubber (SBR) was used as a polymer to see its effects on the mortar. The (SBR) is considered as a water resistance polymer and bonding agent.
Four cement mortar mixes were made in this study, the first one was considered as a reference mix which is not include (SBR) while the other mixes were included (SBR) in deferent percentages. The (SBR) was added as a percentage of cement weight. The amount of mixing water was varied to achieve the same flow which was accomplished in the reference mix throughout carrying out flow table test. Flow table test was adopted according to ASTM C 1439-99 [1] recommendations.
For each mix, two prisms were prepared to carry out the drying shrinkage test, nine cubes for the compressive strength test and three cubes for the total water absorption test.
It was found that when the quantity of (SBR) increases, the physical properties of mortar under study (drying shrinkage, compressive strength and total water absorption) deteriorate which is adverse to the proposal of advantages due to adding (SBR). This result leads to that the recommendation of ASTM C 1439-99 [1] that adopt the flow table as criteria of adjusting the amount of adding water accompanying with deferent percentages of (SBR) is not adequate.

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

1. Introduction

The climate in our country (Iraq) is so hot which is representing in elevated temperature and low relative humidity. These conditions are leading to the deterioration of concrete as well as cement mortar. The need for greater resistance to cracking and greater stability under severe environmental conditions has led to use additives to concrete and mortar. The polymers are one of the most important additives for their properties to improve strength, stiffness and durability[2]. A polymer (from the Greek poly, meaning many, and meros, meaning part) is a long molecule consisting of many small units (monomers) joined end to end [3].
Styrene Butadiene Rubber Latex is one of the most important polymer kinds which are used in concrete. It is the copolymerized product of two monomers Styrene and Butadiene. Latex is typically included in concrete or mortar in the form of colloidal suspension polymer in water. The chemical structure of this polymer is shown in Figure (1) [4,5].

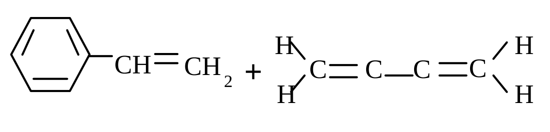

Figure (1) Chemical Structures of SBR

The emulsion polymerization of latex modifies the concrete structure system through two processes; cement hydration and film formation. The polymer particles form a continuous film on the surface of the cement gel-unhydrated cement particle mixture. This film will retain internal mixture and enhance curing. The continuous matrix also bridges some capillary pores and microcracks[5] .

Recently in Iraq, several experimental works have been made for studying the effect of (SBR) on the concrete properties. But most of these works are focuses on one property of concrete that is the compressive strength. Also, these works are very little, consequently the information obtained from are limited. In addition, there is a lack in work of studying the effect of (SBR) on the cement mortar.

Because the cement mortar is used in the finishing works, it becomes very necessary to improve its properties for decreasing the arising of cracks. As the Styrene butadiene Rubber has an adhesiveness property, this work was carried out to study its effect on some of physical properties of cement mortar in order to improve them.

The experimental work was divided into four series and deferent percentages of (SBR) were added for each of them except the first one were no (SBR) was added.

2. Specimens and Materials

The Ordinary Portland Cement (OPC) manufactured in Lebanon was used. It was conforming to Iraqi Standard No. 5 [6]. 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 Alakhaidher quarry and it was conforming to Iraqi Standard No. 45 [7]. 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 plaster. The used sand was in saturated dry surface state and its specific gravity was 2.54 and the percentage of water absorption was 1.6 %.

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

The mix proportions were 1: 2.75 (cement: sand) for all the mixtures. The polymer (SBR) was used as a ratio by weight of cement and the product specification restricted it between 5% and 10%. The ratios used were 5%, 7.5% and 10% for the series 2, 3 and 4 respectively.

For the reference mixture (series 1), where no polymer was added, the water /cement ratio was decided to be 0.48.

The flow table test which was carried out according to the ASTM C 230-98 [8], was found, for the reference mixture, to achieve a flow of 40%. The percentage of water /cement ratio was varied for the other three series to be (0.46, 0.45, 0.44) for the series 2, 3 and 4 respectively, that to accomplish the same flow table of the reference mixture. The flow table is the criterion that is recommended by ASTM C 1439-99 [1] to control the amount of mixing water with polymer.

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		
Fineness (Blaine) (m2/kg)	321	≥ 230
Initial setting time (Vicat) (min)	2:05	≥ 45
Final setting time(Vicat) (Hrs:min)	3:50	≤ 10
Compressive Strength (MPa) 3 days 7 days	 16.9 24.8	 ≥15 ≥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	83	80 - 100
50	300 μm	18	15 - 50
100	150 μm	2	0.0 - 15

The specimens that were used for compressive strength test and absorption test were cast in cubic steel moulds of 50 mm while the specimens that were used for shrinkage test were molded in prism shape (50×50×280) mm.

3. Mixing, Casting and Compaction

For the reference mixture, the mixing procedure was carried out according to ASTM C 305-99 [9]. 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 (140 ± 5 rpm). After 30 sec. of mixing, the entire quantity of sand was added slowly over 30 sec. period. Then the mixer was stopped to be changed to medium speed (285 ± 10 rpm), and let it mix for 30 sec. . After that, the mixer was stopped for 1.5 min. and restarted at medium speed (285 ± 10 rpm) 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 [1]. All the quantity of (SBR) and the mixing water was placed in the bowel then the cement was added to the bowel 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. Compaction was effected by a vibration table and followed by trawling the surface to level it.

4. Curing Conditions

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 [10]. 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.

All the specimens (of the reference mixture and those include (SBR)) exposed to the same curing conditions. After casting and compaction the mortar specimens were cured at laboratory temperature while covered by polyethylene sheets. After 24 hr, 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 [11] which 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 replaced in the laboratory (where the temperature was 23?C and the relative humidity was 55%) till the time of testing.

For determining shrinkage, the specimens were tested after removal from the moist cabinet to take the initial comparator reading. Also, others comparator readings for each specimen were taken after periods of air storage of 4 days, 7 days, 14 days, 21 days and 28 days.

The specimens for compressive strength were tested at age 7 days, 14 days and 28 days (from the time of casting). The total water absorption test was carried out at age 28 days (from the time of casting).

5. Test Measurement

1) Drying Shrinkage: The term drying shrinkage is defined by ASTM C 596-01 [13] as the decrease in length of the test 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. From each mix two prisms of (25×25×280) mm ware prepared made of mortar with stainless steel studs inserted at their ends. The prisms were measured by means of a length change comparator, utilizing a standard invar 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. The others comparator readings for each specimen was taken after 4 days, 7 days, 14 days, 21 days and 28 days of air storage.

The length change 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 (length between the studs) which is taken, as it is recommended by the specification, to be equal 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 7 days, 14 days and 28 days (taken from the time of casting). From each mix nine mortar cubes of 50 mm (three for each age) were prepared. The compressive strength test was carried out according to ASTM C 109-02 [12]. 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 dividing 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. From each mix three mortar cubes of 50 mm were prepared. The test was carried out at age of 28 days from the time of casting. Each cubic specimen was immersed in water for 24 hr then its weight was taken after its surface was dried of excess water. After that the specimen was dried for 24 hr then its weight was taken after cooling it for another 24 hr keeping it in the scatter. 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 and Discussions

The average drying shrinkage of two prisms of air storage for each time of testing was taken at periods (after removing from the moist cabinet) of 4 days, 7 days, 14 days, 21 days and 28 days for each series. The results are as shown in Figure (2).

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

The average compressive strength was taken of three cubes at age of 7 days, 14 days and 28 days for each series and the results are as shown in Figure (3).

Also, the average compressive strength at age of 28 days for the four series was as shown in Table (3).

It could be seen that the compressive strength decreases when the percentage of (SBR) is increased for each time of testing.

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 total water absorption increases when the percentage of (SBR) is increased.

From the previous results it could be concluded that increasing the percentage of (SBR) in the mixture deteriorates the properties of mortar which is contrary to the expectation which suppose that polymer improves the properties of mortar. Referring to the procedure of ASTM C 1439-99 [1] which specifies the quantity of the mixing water when polymer is decided to be used, the following could be concluded:

1- As the specification made the flow table test as criteria of determining the amount of the mixing water with a specified quantity of polymer, the quantity of the mixing water which achieves the same flow of the reference mixture is considered to be ideal. That requires to decrease the amount of the mixing water till the required flow is achieved (here in this test was 40%). The trial mixes reveals that the water was decreased in a very little amount and the require flow was achieved.

2- When the total quantity of the added liquid (water + polymer) is computed, it could be seen that liquid/cement ratio becomes very high (see Table (5)). For example; for series 2 to achieve the same flow of that for series 1, the water / cement ratio was decreased by 0.02 (2%) while polymer / cement ratio was increased by 0.05 (5%). So, the liquid (water + polymer) / cement increased by 0.03 (3%) comparing with that of series 1.

3- The increasing in the percentage of (water + polymer) / cement ratio, i.e. liquid / cement ratio will lead to increase the volume of pores in the prepared mortar. Increasing the pores volume within the cement paste will increase the water absorption. Also, increase the pores volume will cause the mortar to become weaker and that will cause in decreasing the strength of mortar. As well as, lower strength lead to lower modulus of elasticity and hence the cement paste has a greater tendency to shrinkage [14]. So, increase the (water + polymer) / cement ratio will deteriorate the physical properties of mortar, in spite of the bonding advantage of (SBR).

4- It could be concluded that choosing the flow table test, by the ASTM C 1439-99 [1], as a criterion to specify the amount of mixing water with a specify percentage of polymer is not accurate. So, instead of the flow table test other criteria must be taken to specify the amount of mixing water when polymer is decided to be added

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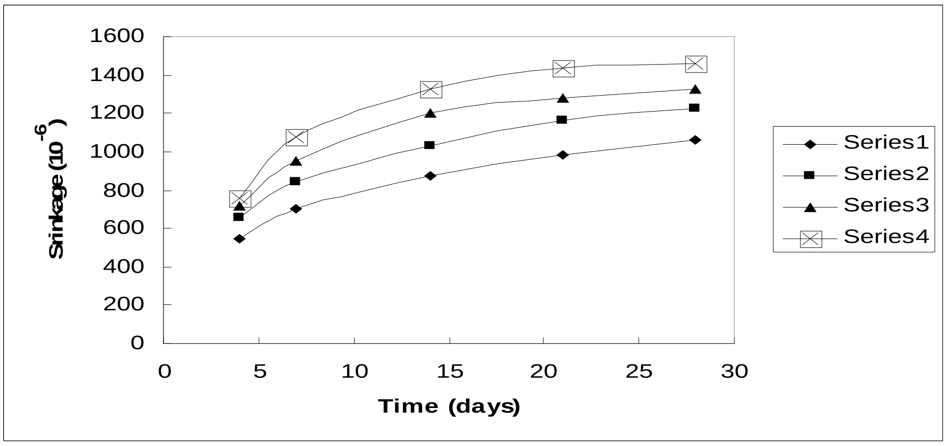

Figure (2) Shrinkage versus Time of Air Storage

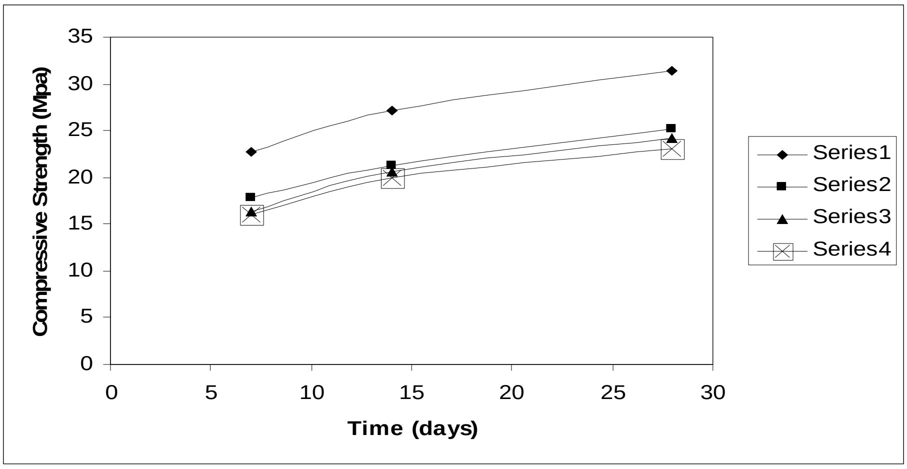

Figure (3) Compressive Strength versus Time

Table (3) Compressive Strength Results

Series No.	Percentage of (SBR) %	Compressive Strength (MPa)
1	0	31.4
2	5	25.2
3	7.5	24.2
4	10	23

Table (4) Total Water Absorption

Series No.	Percentage of (SBR) %	Total Water Absorption (%)
1	0	9.6
2	5	10.2
3	7.5	10.8
4	10	11.1

Table (5) Liquid / Cement Ratio

Sires No.	Water / Cement	Polymer / Cement	(Water + Polymer) / Cement
1	0.48	0.0	0.48
2	0.46	0.05	0.51
3	0.45	0.075	0.525
4	0.44	0.1	0.54

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إضافة البوليمر لمونه السمنت وفقا للطريقه التي توصي بها ألجمعيه ألأمريكيه للفحص والمواد ASTM C 1439

زينب محمد اسماعيل كمونه

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ألخلاصه:

تعتبر البوليمرات احد أنواع المضافات التي تستخدم لتحسين نوعية وأداء المونه أو الخرسانه. ضمن هذه الدراسه تم استخدام الستايرن بيوتادين ربر كبوليمر لمعرفة تأثيراته على المونه، ويعتبر الستايرن بيوتادين ربر ماده مقاومه للماء وعامل ربط.
لقد تم عمل أربع خلطات من مونة السمنت ضمن هذه الدراسه، تم اعتبار الاولى خلطه مرجعيه والتي لا تحتوي على مادة الستايرن بيوتادين ربر أما الخلطات الاخرى فتم إضافة الستايرن بيوتادين ربر لها بكميات مختلفه. تم اضافة الستايرن بيوتادين ربر كنسبه من وزن السمنت وكانت كمية ماء الخلط تختلف لتحقق نفس مقدار ألانتشار الذي تم تحقيقه في الخلطه المرجعيه خلال فحص طاولة ألانسياب (flow table). وقد تم اعتماد فحص طاولة ألانسياب (flow table) ليكون المسيطر والموجه خلال العمل وذلك كما توصي به الجمعيه الامريكيه للفحص والمواد (ASTM C 1439-99 [1]).
لكل خلطه تم صب موشورين لإجراء فحص انكماش الجفاف وثلاث مكعبات لاجراء فحص مقاومة الانضغاط وثلاث مكعبات لاجراء فحص الامتصاص الكلي. ولقد وجد انه كلما زادت كمية الستايرن بيوتادين ربر فان مواصفات المونه قيد هذه الدراسه (انكماش الجفاف ومقاومة الانضغاط والامتصاص الكلي) تتدهور، وهو عكس ما يفترض ان تكون الفائده المرجوه من أضافة الستايرن بيوتادين ربر. تقودنا هذه النتيجه ان فحص طاولة ألانسياب (flow table) الذي توصي به الجمعيه الامريكيه للفحص والمواد (ASTM C 1439-99 [1]) ليكون المعيار لتعديل كمية ماء الخلط الذي تتم أضافته مع نسب مختلفه من مادة الستايرن بيوتادين ربر هو فحص غير ملائم