Journal of Engineering and Development, Vol. 16, No.3, Sep. 2012 ISSN 1813- 7822

Improvement the Properties of Cement Mortar by Using Styrene Butadiene Rubber Polymer

Dr. Ahmed S. Ali
Lecturer at College of Engineering / Al-Nahrain University
Ahmed_sltn2007@yahoo.com

Hawraa Saeed Jawad
Assistant lecturer at College of Engineering / Al-Nahrain University
eng.hawraa@yahoo.com

Inas Sami Majeed
Assistant lecturer at College of Engineering / Al-Nahrain University
En_Sami@yahoo.com

Abstract

The use of polymers in mortar and concrete as admixture can improve the physical and mechanical properties like higher strength and lower permeability than the conventional concrete. Rheomix 141 is styrene-butadiene co–polymer latex (SBR), specifically designed for use with cement composites. It is used in mortar and concrete as an admixture to increase resistance to water penetration, improve abrasion resistance and durability. The objective of the present investigation is to examine the ability of improve cement mortar by using SBR (Rheomix 141). Polymer-modified cement mortars were prepared by varying polymer/cement ratio (P/C). The effects of styrene–Butadiene rubber (SBR) emulsion on the physical properties like bulk density and setting time, and mechanical properties like compressive strength and flexural strength of cement mortars is studied. The results explained the improvement in compressive in flexural strengths in cement mortar with added 8% polymer content. The rates of increase in compressive strength at 3,7, and 28 days were in the range of 13.5%, 8.35% and 9.12% respectively compared with conventional mortar (0% polymer), while the maximum increase in flexural strength (at 8% polymer content) was 11%. Also that, as the polymer content increase up to 8%, setting time of modified mortars decrease.

تحسين خواص مونة الاسمنت باستخدام الستايرين بيوتايدين ربر

الخلاصة:

ان استخدام البوليمرات في مونة الاسمنت او الخرسانة يحسن من خصائصها الفيزيائية والميكانيكية و يعطي مقاومة أعلى ونفاذية أقل من الخرسانة الاعتيادية. ان الـ(Rheomix 141) هو عبارة عن ستايرين بيوتايدين بوليمر (SBR)، وهو مصمم خصيصاً للاستخدام مع مركبات الاسمنت، فهو يستخدم مع مونة السمنت و الخرسانة كمضاف لزيادة مقاومتها ضد النفاذية، و تحسين مقاومتها ضد التآكل ، والديمومة.

إن الهدف من هذا البحث هو دراسة إمكانية تحسين خواص مونة الاسمنت باستخدام الـ(SBR). لذا فقد تم تحضير نماذج من المونة البوليمرية بنسب مختلفة من البوليمر الى السمنت (P\C)، و قد تم دراسة تأثيرات مستحلب الـ(SBR) على الخصائص الفيزيائية كالكثافة الكلية وزمن التصلب، و الخصائص الميكانيكية مثل مقاومة الانضغاط ومقاومة الانثناء لمونة السمنت. وقد اوضحت النتائج تحسن في مقاومتي الانضغاط والانثناء لمونة السمنت عند نسبة مضاف 8%. و كانت نسبة الزيادة لمقاومة الانضغاط بأعمار 3، 7، و 28 يوم هي 13,5%، 8,35%، و 9,12% على التوالي مقارنة بالمونة الاعتيادية (0% بوليمر). بينما كانت أعلى نسبة زيادة لمقاومة الانثناء هي 11% عند استخدام بوليمر بنسبة 8%. كما قل زمن التصلب للخرسانة البوليمرية عند هذه النسبة.

1. Introduction

Mortar and concrete made with Portland cement has been a popular construction material in the world for the past 170 years or more. However, cement mortar and concrete have some disadvantages such as delayed hardening, low tensile strength, large drying shrinkage and low chemical resistance. Several approaches have been taken to improve mortar or concrete properties, resulting in quite different materials, one of them is polymer mortar or concrete.

Polymer-modified cementetious material has been available for over more than 70 years. Polymers are made from simple organic molecules (monomers) that combine to form more complex structures through a process called polymerization. The polymers are dispersed in water or redispersible powders. These are added to hydraulic cement, with or without aggregate, depending on the desired results. The addition of a minor amount of a polymer to a cement mix can significantly enhance the properties of it, which is known as polymer–modified cement based material. These additives known as admixtures can be in the form of polymer particles or liquids.

SBR Polymer is the most widely used for modify cement mortar. *Fig.(1)*, shows the chemical structure of Styrene butadiene Rubber latexes. Co-polymers of butidine with styrene (styrene-butadine rubber (SBR)), are a group of large-volume synthetic rubbers [1]. High adhesion occurs between the polymer films that form and cement hydrates. This action gives less strain compared to ordinary concrete and improves the properties of concrete such as flexural and compressive strengths with higher durability [2].

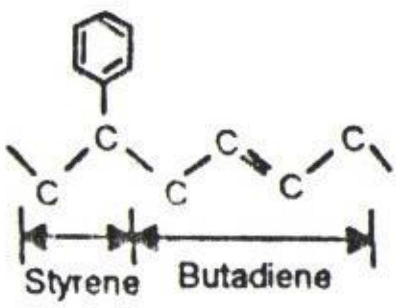

Fig.(1) Chemical structures of SBR polymer latexes [1]

When the polymer latexes are mixed with fresh cement mortar or concrete, the polymer particles are uniformly dispersed in the cement paste phase. In the polymer- cement paste, cement gel is gradually formed by the cement hydration and the water phase is saturated with calcium hydroxide $Ca(OH)_2$ during the hydration, whereas the polymer particles deposit partially on the surface of the cement gel-unhydrated cement particle mixtures. It is likely that the calcium hydroxide in the water phase reacts with a silica surface of the aggregate to form a calcium [3].

Fig(2)[4] shows the SEM microphotos of the fracture surface of the 28-days wet-cured polymer- modified mortars.(a) is the SEM of the control mix, (b) to (g) are the SEM of the modified mix at the P/C ratio of 1%, 5%, 10%, 15% and 20% respectively. The SEM analysis exhibits that the constitute of the control mortar are loosely joined with each other in (a). By contrast, the structure of the mortar is compactly joined with each other than 1% polymer is added, although no polymer film is formed in (b). Some scattered polymer films are found in the surface in the fracture surface of the modified mortar at a P/C ratio of 5% in (c). Coherent polymer film forms in the modified mortar at P/C ratio of 8% , and the lost inorganic phase is also coherent, so the interpenetrating structure between the polymer and cement hydrates form in (d). and the structure fully develops when P/C ratio reaches 10% in (e). When the P/C ratio above 10%, the formed polymer film in the modified mortars becomes thicker and the structure of the modified mortars is still interpenetrating (f and g).

SBR emulsion could reduce Water/cement ratio, effectively enhance both flexural and tensile strengths, substantially decrease the ratio of compressive strength to flexural strength and improve the ratio of flexural strength to elastic modulus. At the same time, it was found that the porosity of the hardened mortar had relation with the bulk density of the fresh mortar to a certain extent; the compressive strength, flexural strength and elastic modulus had some relations with the porosity and bulk density [4].

The use of styrene butadiene rubbers (SBR) as an emulation polymer is of vital importance in reducing water cement ratio of the mix, hence, increasing its strengths with a significant reduction in permeability.

The objective of present wok is to study the effect of SBR polymer (Rhomix 141) on the physical and mechanical properties of cement mortars with different polymer / cement ratios.

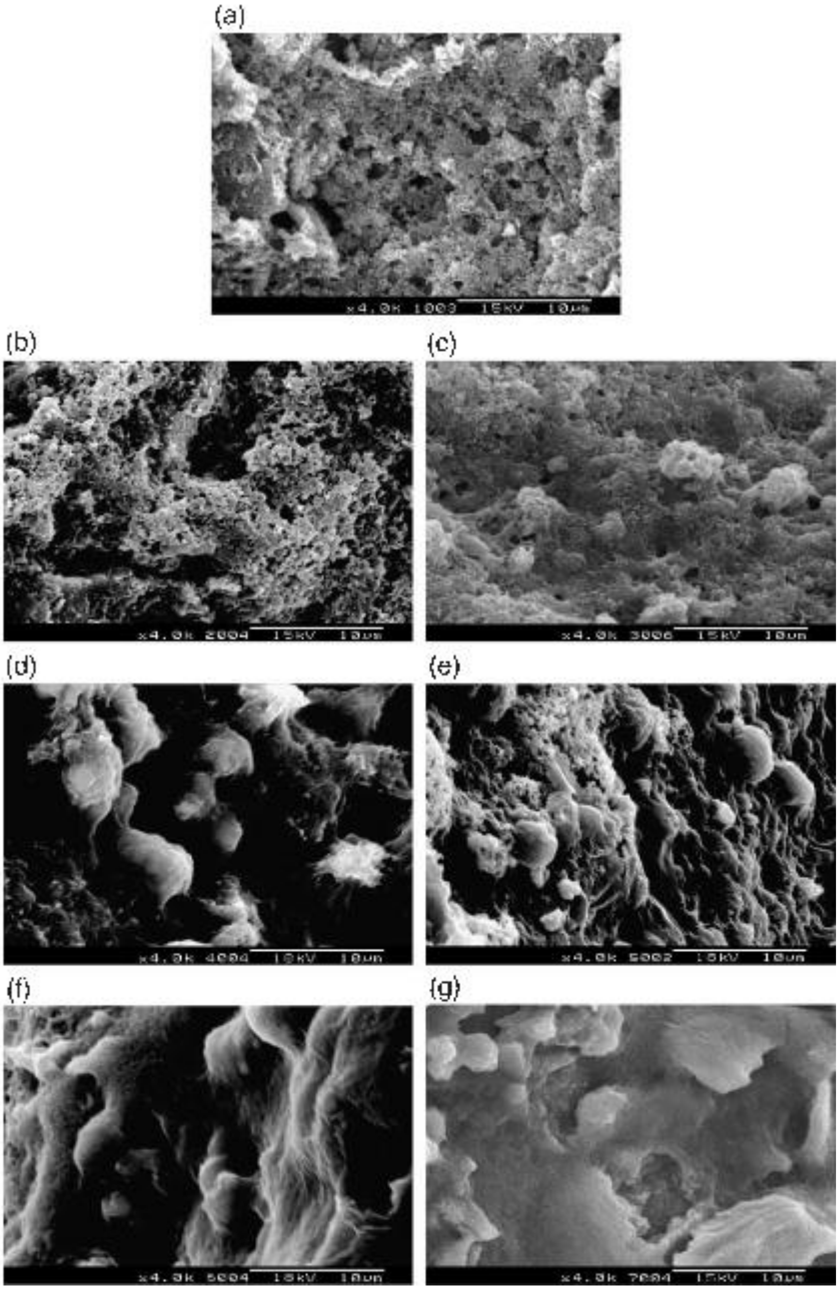

Fig. (2) Fracture Surface of 28-day wet cured polymer- modified mortars at (P/c) of (a) 0%, (b) 1%, (c)5%, (d) 8%, (e) 10%, (f) 15% and (g) 20%.[4]

1. Experimental Work

2.1. Materials

Ordinary Portland cement type I was used in all mixes in this work. The chemical composition and physical properties of the cement used are listed in Table (1). The cement conforms to the Iraqi specification No.5/1984 [5].

The fine aggregate used for making the all mixes was standard sand and conform to ASTM Specification C 778-06[6].

The SBR Polymer used in the present investigation was RHEOMIX141 commercially marketed by BASF. Its composition, specific gravity, mean particle size, PH value and butadiene content are given in Table (2).

2.2. Specimen Preparation

The mortar specimens were prepared with 1:2.75 (cement : sand) by weight for all mixtures. The polymer (SBR) to cement and the ratios used were 0%, 4%, 8%, 10%, 12% and 15%. The amount of mixing water was decreased by the same amount of (SBR) added. So, the percentages of water cement ratios (W/C) were 48% for reference mix and 44%, 40 %, 38%, 36% and 33% respectively for the other mixes. The polymer emulation was added to water firstly, and then used for all prepared specimens used in this work.

2.3. Tests measurement

2.3.1 Compressive Strength: The compressive strength was determined by using 50mm cube According to ASTM C109-02 [7]. The specimens were demolded after 1day, then cured according to ASTM C 511-03 [8]. The compressive strength test was carried out at age of 3, 7 and 28 days. Nine cubes were prepared from each mix. The final compressive strength recorded was the average of the results obtained from three cubes.

2.3.2 Flexural Strength*:* The prisms with a dimension of 40×40×160mm were prepared According to ASTM 348-02 [9]. The specimens were demolded after 1day, then cured according to ASTM C 511-03 [8]. The flexural strength test was carried out at age of 7 days. The final flexural strength recorded was the average of the result obtained from three prisms.

2.3.3 Density*:* is the density of the cured specimens prepared for compressive strength with surface dried by moist soft towel by weighing them accurately.

2.3.4 Setting time*:* the time of setting of cement paste can be determined by using Vicat needle according to ASTM C191-08[10].

Table (1) The chemical composition and physical properties of the ordinary Portland cement#

Oxides Composition	Oxide content%	Limits of Iraqi Specification No.5/1984
SiO_2	20.11	-
Al_2O_3	5.53	-
Fe_2O_3	3.40	-
CaO	63.22	-
MgO	3.74	< 5.00
SO_3	1.61	< 2.8
Free CaO	1.12	-
Lose on Ignition	0.74	< 4.00
Insoluble Residue	1.23	< 1.50
Lime Saturation Factor	0.86	0.66-1.02
Main Compounds (Bogues Equations)		
C_3S	57.73	
C_2S	14.21	
C_3A	8.91	> 5.00
C_4AF	10.33	
Physical Properties		
Fineness (Blaine)(m^2/kg)	321	≥230
Initial setting, h:min	2:40	≥45 min
Final setting, h:min	4:07	< 10hr
Compressive strength (MPa) **3 days** **7 days** **28 days**	 17.30 23.60 26.36	 ≥ 15.00 ≥ 23.00 -
Soundness Le Chatelier method, mm	1	≤ 10

this test was made in Consultative Engineering Bureau at Baghdad University

Table (2) Properties of SBR used*

Properties	Description
Composition	A milky, white styrene butadiene copolymer latex, specifically made for use with Portland cement
Mean part size	0.17 micronicle
Specific gravity	1.00-1.03
PH value	10.50
Chloride content	Nill
Butadiene	40% by wt. of RHEOMIX 141 polymer
Compatibility	Can be used with all types of Portland cement

* Properties obtained from product catalogue

2. Results and Discussion

3.1 Compressive Strength of Polymer –Modified Mortars

The compressive strength of polymer – modified mortars with different polymer/cement ratios (P/C) is illustrated in *Fig.3*. It is seen that at the rate of SBR increase from 0% to 8% the compressive strength of mortar increase to for all testing age, reaching to 13.5 %, 8.35% and 9.12% for 3, 7 and 28days respectively. From 8% to 15% SBR content the compressive strength was sharply decrease.

Ohama[3] sited, 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]. So, that could lead to an increasing in compressive strength of the latex- modified mortar.

The contrary result of the specimens with P/C ratio greater than 8% may be related to that the amount of added water is not sufficient for completing the reactions of cement components. The water/ cement ratio used was 0.38, 0.36 and 0.33 for 10%, 12% and 15% SBR content respectively.

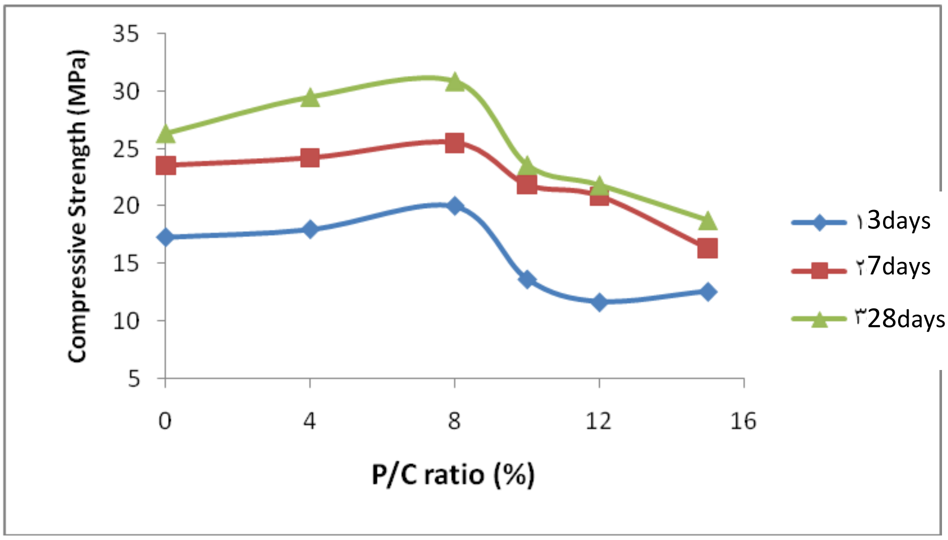

Fig. (3) Compressive Strength of polymer – modified mortars with different (P/C) ratio

3.2 Flexural Strength of Polymer –Modified Mortars

The flexural strength of polymer –modified mortars increase with the increase polymer/cement ratio (P/C) up to 8%. The rate of increase was 11%, after this percentage the flexural strength decrease as shown in *Fig.4*.

This behavior the considerable in the flexural strength is attributed to the influence of polymer modification on the flexural strength in short term is limited. From the moment a dry curing period is introduced, a polymer film start to build the binder phase and an increase in the flexural strength is measured with increasing P/C ratio.

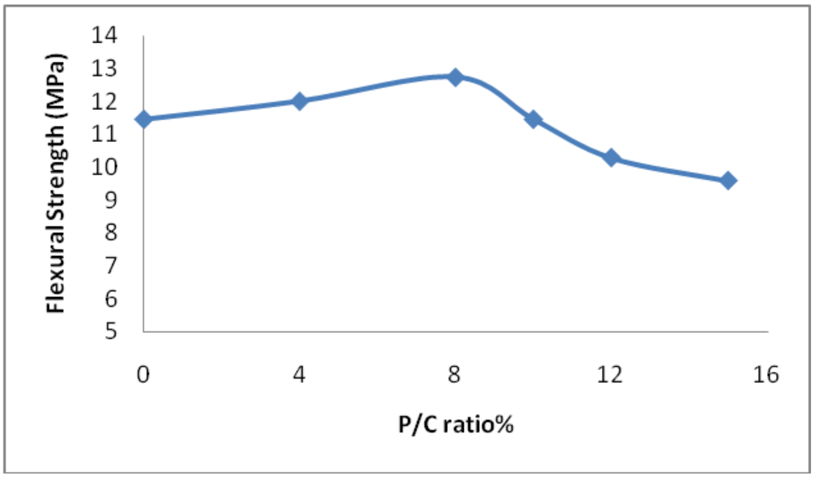

Fig. (4) Flexural Strength of polymer – modified mortars with different (P/C) ratio

The influence on the flexural strength by the retardation of the cement hydration is compensated by the presence of the polymer film.

According to Ohama[3] , when long term behavior is considered, a maximum of flexural strength is established around 8% P/C ratio.

3.3 Toughness of Polymer –Modified Mortars

The ratio of compressive strength to flexural strength of mortar is an important factor to judge its toughness. *Fig.5* shows the ratio of the compressive strength to flexural strength of the modified mortars with different P/C. as can seen from this figure there is no significant decrease in this ratio with increasing P/C until 8%, at the P/C ratio increase from 8% to 15% the compressive strength to flexural strength ratio decline very slightly.

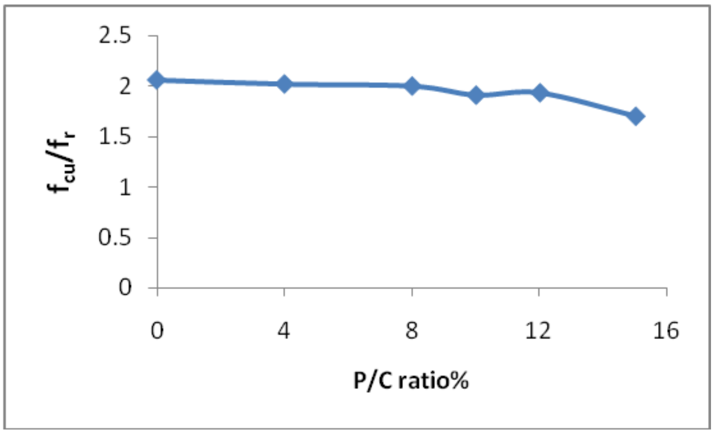

Fig. (5) Ratio of the compressive strength to flexural strength (f_{cu}/f_r) of the modified mortars with different P/C ratio

3.4 Bulk density of Polymer –Modified Mortars

The bulk density of mortars is closely related to its properties. The relationship between the apparent bulk density of the modified mortars and P/C ratio is shown in *Fig.6*. It is found that apparent bulk density of modified mortars increase at 4% polymer content, then decline with increasing P/C. The porosity of the hardened mortar had relation with the bulk density of the fresh mortar to a certain extent [4]; a reduction in composite density due to an increase of air trapped during the mixing process and hence heightened porosity was also occur .

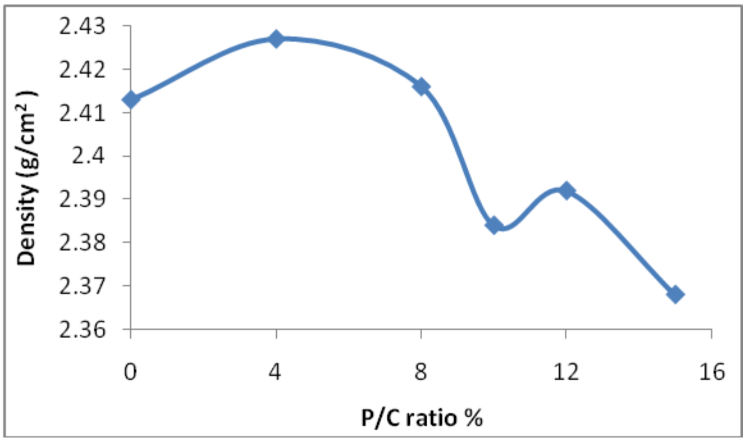

Fig.(6) Bulk density of Polymer –Modified Mortars versus P/C

3.5 Setting time of Polymer –Modified Mortars

The setting time of polymer –modified mortars versus P/C is shown in *Fig.7*. this figure show that as the P/C ratio increase the setting time decrease reaching 1hr and 50min at the 15% of P/C ratio but still within the standard limits . This behavior is due to the accelerator effect of SBR.

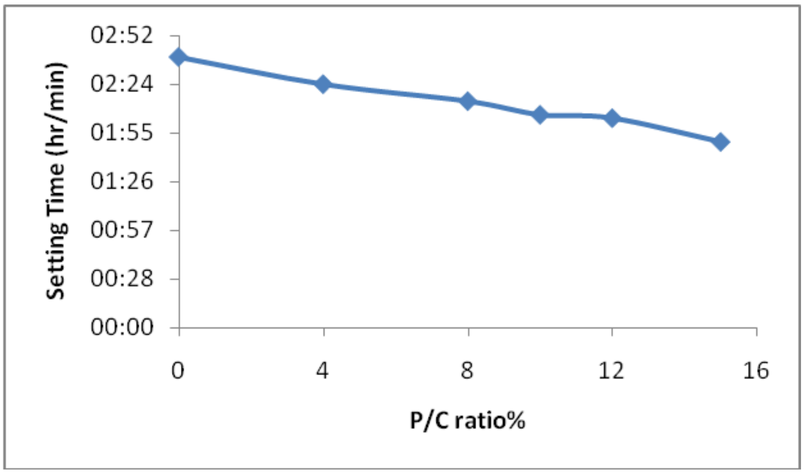

Fig. (7) Setting time of the modified cement mortar versus P/C ratio

3. Conclusion:

1- There an improvement in strength of polymer modified mortar due to the addition of polymer up to 8% polymer/cement ratio,
2- When increasing the P/C ratio greater than 8% the strength and density of polymer modified mortar decrease.
3- The increase in the compressive strength of polymer modified mortar with 8% polymer content at 3, 7 and 28 days in the range of 13.5 % , 8.35% and 9.12% respectively compared with conventional mortar (0% polymer).
4- The maximum increasing in flexural strength at 8% polymer content was 11%, after this percentage the flexural strength decrease.
5- The apparent bulk density of modified mortars increase at 4% content , then decline with increasing P/C ratio .
6- As the polymer content increase setting time of modified mortars decrease.
7- In general, it is observed that the overall performance of the cement mortar is improved with the addition of 8% polymer, by weight of cement.

4. References

[1]McCrum , N.G., Buckley .C.P. and BucknaIi.C.B.."***Principles of Polymer Engineering*** ".Oxford University Press . 2Ed. 1997.pp. 447.

[2]Ohama, Y., "***Polymer-Based Admixtures***." Cement and Concrete Composites J., 1998, 20,pp. 189-212.

[3]Ohama, Y., " ***Principle of Latex Modification and Some Typical Properties of Latex-Modified Mortars and Concretes***", ACI Materials Journal, Vol.84, No.6, November-December 1987, pp511-518.

[4] Ru Wang, Pei-Ming Wang, Xin-Gui Li, " ***Physical and Mechanical Properties of Styrene-Butadiene Rubber Emulation Modified Cement Mortars***", Cement and Concrete Research 35, 2005, 900-906. www.sciencedierect.com .

[5]المواصفات العراقية رقم (5)، "***السمنت البورتلاندي***" ، الجهاز المركزي للتقييس والسيطرة النوعية ، 1984.

[6]ASTM C 778-06, "***Specification for Standard Sand***", Annual Book of ASTM Standards, Vol. 04.01.

[7]ASTM C109-02, " ***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, 2002.

[8]ASTM C 511-03, " ***Standard Specification for Moist Cabinets, Moist Room, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concrete***", Annual Book of ASTM Standard , Vol.04-01, 2003.

[9] ASTM C 348 – 02, " ***Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars*** ", Annual Book of ASTM Standard, Vol.04-01.

[10]ASTM C C191-08, " ***Time of Setting of Hydraulic Cement by Vicat Needle***", Annual Book of ASTM Standard.