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Effect of Adding Styrene Butadiene Rubber Admixture (SBR) on Concrete Properties and Bond Between Old and New Concrete

تأثير إضافة المضاف (SBR)(ستايرين –بيوتاين – مطاط) على خصائص الخرسانة والربط بين الخرسانة القديمة والحديثة الصب

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ABSTRACT:

The study involves the effect of adding cempatch SBR (Styrene- Butadiene – Rubber) emulsion to the followings:

1- Cement mortar with different dosages of SBR (10 %, 25%, 35%) by volume of water. Compressive strength of this mortar was tested at ages (7, 28, 60) days. Initial and final setting time were also recorded.

2- Concrete mix 1 : 2 : 4 with 0.45 water to cement ratio by weight, and SBR in dosages of (10 %, 2 5%, 35 %)by volume of water . Compressive strength in ages (7, 28, 60) days was tested, also absorption, slump loss with time and flexural strength were also measured.

3- SBR was also used as bonding mortar layer between old and new concrete layers, the compressive strength and flexural strength of bonded samples were tested.

Adding SBR emulsion to cement mortar affects compressive strength negatively at all ages. Initial and final setting time decrease with increasing the dosage of SBR.

The using of SBR emulsion as admixture for concrete mix affects compressive strength with decreasing at early ages (7 days) and increased at later ages. It also reduces; the absorption of concrete and slump loss with time and increase the flexural strength.

The use of SBR as bonding layer showed increasing in compressive and flexural strength of the bonded samples compared with samples having old and new concrete without bond layer.

الخلاصة :

تم دراسة تأثير إضافة مستحلب (Cempatch SBR) (ستارين , بيوتا دين , مطاط) إلى ما يلي:

أولا: مونة الإسمنت بنسب مختلفة من مستحلب (SBR) (10%, 25 %, 35 %)من ماء الخلطة ودراسة بعض الخواص مثل زمن التجمد الابتدائي والنهائي ومقاومة الانضغاط بأعمار مختلفة (7, 28, 60) يوم.

ثانيا: الخلطة الكونكريتية (1 :2 : 4) مع نسبة ماء إلى الإسمنت (0.45) حيث تم إضافة مستحلب (SBR) بثلاث نسب هي (10%, 25%, 35%) من ماء الخلطة, وتم دراسة تأثير هذا المضاف على بعض الخواص الخرسانية مثل الهطول, الامتصاص, مقاومة الانضغاط , مقاومة الانثناء.

ثالثا: وتم استخدام المستحلب (SBR) كطبقة رابطة بين الخرسانة القديمة والخرسانة الجديدة وتم فحص مقاومة الانضغاط ومقاومة الانثناء للنماذج الخرسانية الملصقة بواسطة المستحلب.

أن استخدام المستحلب مع المونة الإسمنتية يقلل مقاومة الانضغاط في الأعمار المبكرة (7 يوم) ويزيدها في الأعمار المتأخرة وأيضا يقلل من زمن التجمد الابتدائي والنهائي مقارنة مع الخلطة المرجعية. أما نتائج استخدام المستحلب كمضاف إلى الخرسانة فوجد أنة يؤثر سلبيا على مقاومة الانضغاط في الأعمار المبكرة (7 يوم) وايجابيا في الأعمار المتأخرة, كما ويقلل بشكل كبير من الامتصاص للخرسانة كما ويؤدي الى فقدان كبير في الهطول مع الزمن ويزيد من مقاومة الانثناء بزيادة نسب الإضافة مقارنة مع الخلطة المرجعية. وكانت نتائج استخدام المستحلب كطبقة رابطة بين الخرسانة القديمة والخرسانة الجديدة ظهور زيادة في مقاومة الانضغاط لجميع الأعمار (7, 28, 60) يوم وكذلك زيادة في مقاومة الانثناء مقارنة مع النماذج المتكونة من خرسانة قديمة وخرسانة جديدة بدون إضافة المستحلب كطبقة رابطة.

INTRODUCTION

Admixtures are not essential components of the concrete mix. They are important and increasingly wide spread components in many countries. The mix which contains no

admixture is now a days an exception. The use of admixtures are growing because they are capable of imparting considerable physical and economic benefits with respect to concrete.

Admixture can be defined as a chemical product which, except in special cases is added to the concrete mix, it may be organic or inorganic for the purpose of achieving a specific modification, or modifications, to the normal properties of concrete**. [Neville , 1995]**

Admixtures also can be used as bonding agents :

Bonding layers are generally used to establish unity between fresh concrete or mortar and the parent concrete. Bonding agents may also used for additional insurance. Epoxy, Latexes (SBR) and Polyvinyl acetates are types from bonding agents These materials develop about having greater tensile and shear strength than concrete. They are resistant to most chemicals and some for mulations are highly water - resistant, good crack resistance. **[ACI 201.2R- 92]**

AIM OF STUDY

The aim of this research is to study the effect of using SBR emulsion as admixture in different dosages on properties of cement mortar , concrete mix and using SBR as bonding layer between old and new concrete by conducting the following tests: initial and final setting time, slump, compressive strength, flexural strength, and absorption.

LITERATURE REVIEW

There are limited researches which studied the effect of using SBR emulsion in different dosages and different purposes on concrete properties and the efficiency of this admixture to increase durability of hardened concrete. **Ohama 1981** reported that the chemical resistance of latex -modified concrete is dependent on the polymer -cement ratio and the nature of chemicals. Most latex –modified concretes are attacked by inorganic or organic acids and sulfates as they contain hydrated cement that is non – resistant to these chemical agents, but resist alkalis and salts except the sulfates. **Sujjavanich and Lundy 1998** examined the properties of the latex modified concrete (LMC) which contained styrene butadiene polymer. Strength and the properties of this concrete at ages ranging from (5) hours to (28) days were investigated. The mix proportions of the materials used throughout this study the concrete mix ratio were 1 : 2.45 : 2 .1 , the cement content was 391.5 kg /m ^{3}, w/c =0.32 and polymer /cement ratio was (0.15). This study provides information on early age characteristics of latex modified concrete (LMC). Standard cylinders, 152 × 305 mm were tested for compressive strength and splitting tensile strength at ages o.5, 1, 2, 3, 7, and 28 days, flexural strength and dynamic modulus of elasticity tests were conducted on beams at ages 0.5, 1, 3, 7 and 28 days.

Results of tests show that the compressive strength, modulus of elasticity, tensile and flexural strengths increase with the increase of curing time. But ratio of compressive strength to splitting tensile strength (fc / f t) decreases from about 12.5 to 6.8 and increase and again after about 12 hours. Similar Trends are reported for conventional concrete.

Folic and Radonjanin 1998 studied the properties of latex -modified concrete containing (SBR) and they tested concretes modified with 2.5, 5 and 7.5 percent of polymer admixture to the cement.

The test results showed that the water absorption decrease with the increase of polymer - cement ratio. Although it was the case of capillary water absorption, such a positive change is important as it influences the increase of concrete durability.

Ohama 1981 reported that the pore structure of latex - modified hydraulic cement system is influenced by the polymer –cement ratio. The total porosity or pore volume tends to decrease with an increase in the polymer - cement ratio. This may be improved in the impermeability and durability of the latex -modified concrete. Generally, the water absorption and permeation of latex- modified concretes are considerably reduced with an increase in polymer - cement ratio. This is because they have a structure in which the larger pores can be filled with polymer or sealed with the continuous polymers films. The freeze –thaw durability of the latex -modified concretes is improved at a polymer - cement ratio of (5) percent or more due to composite effects of water impermeability and air entrainment. Increasing the polymer -cement ratio does not necessarily cause an improvement in the freeze -thaw durability.

Abdul Amir, 2008 investigate the effect of using sodium benzoate, potassium dichromate as corrosion inhibitors in three concentrations (1%, 2%, and 3% by weightof cement) and SBR (Styrene- Butadiene- Rubber) emulsion in three concentrations (10%, 15% and 25% by volume of water) is studied on concrete properties; compressive strength, splitting tensile strength, flexural strength and absorption. The test results of SBR emulsion in concrete 25% by volume of water leads to a considerable improvement in all mechanical properties of concrete mixes with an increase in; compressive strength about 8%, 11% and7% at ages 28, 60 and 90 days respectively, splitting tensile strength and flexural strength about 37%, and cased amaximum reduction in absorption about 77%.

Al –Bderriy, 2001 investigated the ability of produce high performance polymer concrete by using SBR emulsion, high range water reducing agent (HRWRA) +SBR emulsion and high range water – reducing agent (HRWRA) only.

The compressive, splitting tensile and flexural strengths, dynamic modulus of elasticity, initial surface absorption, total absorption, porosity, permeabiliy and penetraion of sulfate ion tests were investigated for Reference, HRWRA, SBR and HRWRA- SBR concrete. The tests results indicate that using 7% (SBR) emulsion by weight of cement leads to considerable improvement in all mechanical and physical properties of concrete mixes.The conpressive strength in 28 days reached 64.4 Mpa. While the percentage of reduction in drying shrinkage after drying age of 90 days was 47.2% compared with reference concrete. Also this concrete has high resistance to penetration of sulfate ions and excellent improvement in durability properties.

EXPERIMENTAL WORK

1- Materials

1- 1 Cement

Ordinary Portland cement type 1 manufactured in Saudia Arabia was used in this research. This cement is conforming to The Iraqi specification IQS No. 5/ 1984.
The chemical composition and physical properties of this cement are given in Table (1).

Table (1): Chemical composition and physical analysis of cement used

Oxide	Test Result	Limits According to IQS No.5 1984	Conformed to IQS No.5 1984
CaO %	62.23	-	-
SiO2 %	20.8	-	-
Al2O3 %	5.14	-	-
Fe2O3 %	3.40	-	-
MgO %	1.52	<=5 %	OK
K2O %	-	-	-
Na2 O %	-	-	-
SO3 %	2.41	<= 2.5% if C3A <5 % <=2.8 % if C3A >5%	OK
Free Lime %	1.51	-	-
Loss on Lgniton%	4.0	<=4 %	OK
InsolubleResdu %	1.27	<=1.5 %	OK
Lime Saturated Facter	0.88	0.66 – 1.02	OK
C3S %	42.8	-	-
C2S %	27.34	-	-
C3A %	7.87	-	-
C4AF %	10.35	-	-

Setting Time, min, Initial, Final	130 240	>= 4 min <= 600min	OK OK
Fineness (Blaine), in m2 /kg	345	>= 230	OK
Compressive Strength, MN/ m2 3 days 7days	 17 25	 >=15 >=23	 OK OK
Soundness (Auto Clave), %	0.45	<= 0.8	-

1- 2 Fine Aggregate

Graded sand was used in this research, It was brought from AI –Akhaidhur – Karbalaa, Table (2) shows the sieve analysis, and chemical composition according to IQS NO. 45 - 1984 specification.

Table (2) : Sieve analysis and chemical composition of fine aggregate

Sieve (mm)	% Passing	Limits of Iraqi specification, No 45/ 1984 Zone 2
10	100	100
4.75	95	90-100
2.36	80	75 -100
1.18	67	55- 90
0.6	51	35 -59
0.3	21	8 - 30
0.15	4	0 - 10
0.075	0	<=5%

Fineness modulus	2.8

Property	Result	Limit of Iraqi specification No. 45 -1984
Sulfate content as SO3%	0.135	<= 0.5 %
Materials finer than (76)µm sieve%	1	<= 5 %

1 – 3 Coarse Aggregate

Graded gravel used in this research was brought from AL –Nibaee. Table (3) shows the sieve analysis, and chemical composition according to IQS NO .45- 1984.

Table(3) : Sieve analysis and chemical composition of coarse aggregate

Sieve (mm)	%Passing	Limit of Iraqi specification, No 45/ 1984 (5 -40)mm
63	100	100
37.5	100	95 -100
20	66	35 - 70
10	14	10 - 40
5	0.4	0 - 5

Property	Result	Limits of Iraqi specification No. 45 -1984
Sulfate content as SO3%	0.03	<= 0.1%
aterials finer Than 75 µm- Sieve %	1	<= 3 %

1 – 4 Cempatch SBR

Styrene –

Butadiene – Rubber, Latex, cempatch SBR is added to improve the physical properties of cement mixes and slurries

SBR is ideally designed for use in the following applications.

- Bonding of new to old concrete when used as a slurry coat.
- To produce a repair mortar for patching of honey – combed concrete. Internally and externally.
- To produce water – proof renders. **[Billmeyer .F ,1971]**
- Bonding of thin polymer modified screeds and/or toppings to old substrates . **[Paco System , 1997]**
- To provide a mechanical key prior to rendering of various plaster mixes on concrete brick and block surfaces.
- To produce polymer modified screed and floor toppings.

The chemical and physical properties of cempatch SBR used are given in Table (4). **[Cempatch SBR, DCP]**

Table (4) : Chemical and physical properties of cempatch SBR used [Fosroc company for building chemicals, Ltd]

Colour	White
Shape and appearance	Emulsion
Solid in aqueous solution	45%
Mixing with water	Mix with water at any percent
Specific gravity	1.081 kg/lit
Storage condition	Free from soft, No high temp, and/or high humidity
Shelf life	1year when closed
Butadiene	40 (by weight)
Styrene	60 (by weight)
Sodium alkyl sulfate	0
Sodium phosphate	0
(PH) value	9.5
Packaging	5litre, 25litre,200litre
Fire	Non - flammable

2 - Test Procedures

2 – 1 Compressive Strength Test

The compressive strength of concrete was determined according to BS.1881 – part 116 – 1989. (100mm) cubes were tested using standard testing machine with a capacity of 2000kN, at loading rate of 15N/mm² per minute for the concrete samples. As for cement mortar samples the compressive strength was determined according to BS. 1881 – part 4. (70.7mm) cubes were tested. The average of three cubes was adopted at each test. The test was conducted at ages of 7, 28, 60 days for both specimens. The cubes were moist cured until the age of testing.

2 - 2 Flexural Strength Test

Flexural strength of concrete was carried out on 100× 100×400 mm simply supported prisms with a clear span of 300mm.The prisms were tested by two – point load. The test was performed according to BS. 1881 – part 118 – 1989. The test was conducted at ages of (28 days) for all specimens. Flexural strength can be calculated from the following equation:

$$f_t = \frac{P\,L}{bd^2} \qquad \ldots (2 - 1)$$

Where

f_t : flexural strength (N / mm2)
P : maximum applied load (N)
L : effective length (mm)
b : width of prism (mm)
d : depth of prism (mm)

2 – 3 Slump Test

This is a test used extensively in field all over the word. The slump test does not measure accurately the workability of concrete, it is ameasure of consistency, but the test is

very useful in detecting variations in the uniformity of a mix of given nominal proportions. **[Neville, 1995]**

The slump test is prescribed by ASTM C 143 -90 a.

2 - 4 Absorption Test

. Cube specimens with 100mm were used for the concrete absorption test. This test was conducted according to BS. 1881 part 122 -1989 after (28 days) of moist curing. These specimens were dried in an oven at (105 ± 5C°)for (72 hours), then the specimens were immersed in water for (24 hours).

The percentage of absorption can be calculated from the following equation:

$$\text{Absorption } (\%) = \frac{[W2 - W1] \times 100}{W1} \quad \ldots(2-2)$$

Where:

W1 : the average weight of three dry specimens (g).

W2 : the average weight of three wet specimens (g).

2 - 5 Initial And Final Setting Time

For cement mortar Vicat apparatus was used to record initial and final setting time. This test was carried out according to BS. 12 :1971 specifications.

PREPARING MIXES AND TESTS :

SBR was used in the present work in three ways:

1 - SBR was used as admixture to cement mortar (1 : 3) (cement : sand) in dosage of (10% , 25% , 35%) by volume of mixing water . For the specimens the initial and final sitting time with (vicat apparatus), and compressive strength in ages (7, 28, 60 day) were tested. Each value in the compressive strength results represents the average of three samples.

2 - SBR was used as admixture to concrete mix (1 : 2 : 4) (cement : sand : gravel) with (w/ c) ratio (0.45) in dosage of (10%, 25%, 35%) by volume of mixing water. For this concrete mix slump was recorded, the absorption, compressive strength in ages (7, 28, 60 days) and flexural strength were measured.

3 - SBR was used as bonding mortar layer between old and new concrete, with ratio (1: 1: 3), (SBR : Water : OPC (Ordinary Portland cement)) by weight.

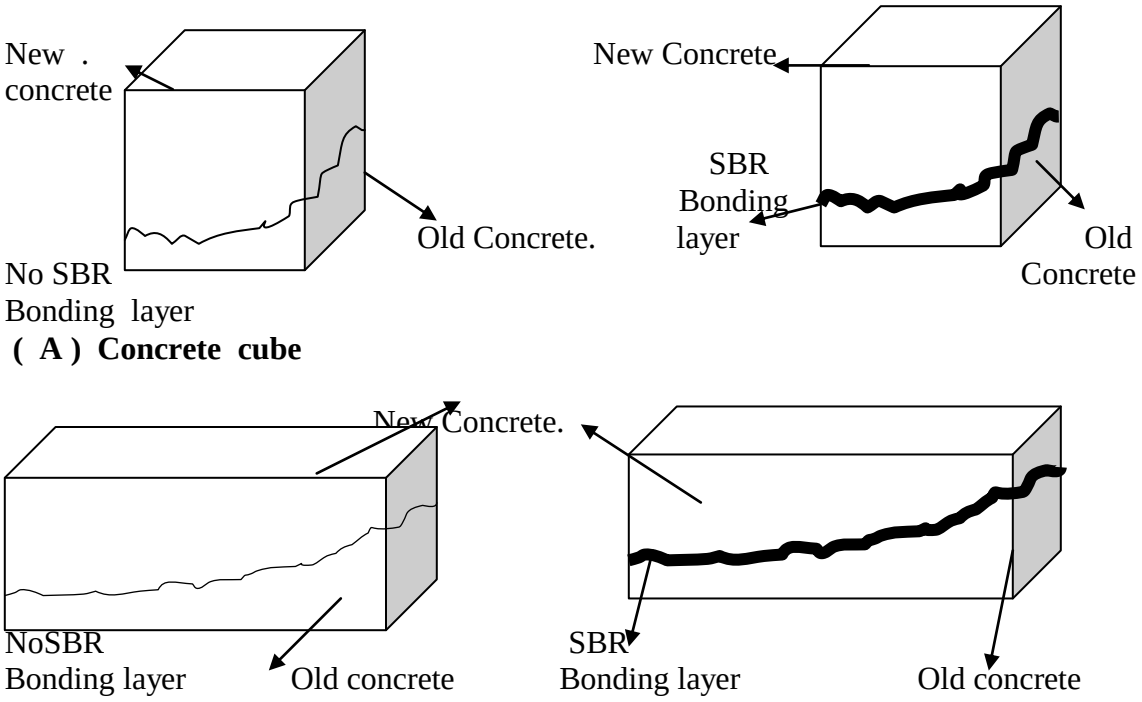
To investigate this bonding action of SBR mortar. Two types of tests were conducted:

The first is casting the compressive strength cubes (100 mm) in two layers. The bottom (1: 2 : 4) concrete layer, with (w/ c) ratio (0.45) was cast with the upper surface been highly irregular. After (7) days a layer of SBR mortar (1 : 1 : 3) (SBR : Water : OPC) by weight was applied on the top irregular surface of the stiffened concrete, then after (10) minutes, the cube mould was filled with newly mixed same (1 : 2 : 4) concrete. Figure (1 - A) shows the cubes.

The cubes were moist cured until the age of testing (7 , 28 ,60) days, and the results were compared with the compressive strength of identically cast concrete cubes but without bond layer.

The second is casing the flexural prisms (100* 100 * 400 mm) in two inclined layers between which a bonding SBR mortar layer was applied in the same procedure mentioned above. These prisms were tested by two point load method for the flexural strength. The

results were also compared with the flexural strength of identically cast concrete prisms but without bond layer. Figure (1 - B) shows the prisms.
The compressive strength was measured at (7, 28, 60) days, and flexural strength at (28) days.



(A) Concrete cube

(B) Concrete prism

Figure (1) : Samples with and without SBR as a bonding mortar layer

RESULTS AND DISCUSSION:

The results of using cempatch SBR as admixture to cement mortar in dosages of 10%, 25%, and 35% affects adversely compressive strength. Figure (2) shows that in all these dosages there was a reduction in compressive strength with increasing of SBR dosage in ages (7, 28, 60 days). This may be due to partially increasing the total liquid (water +SBR) to cement ratio.

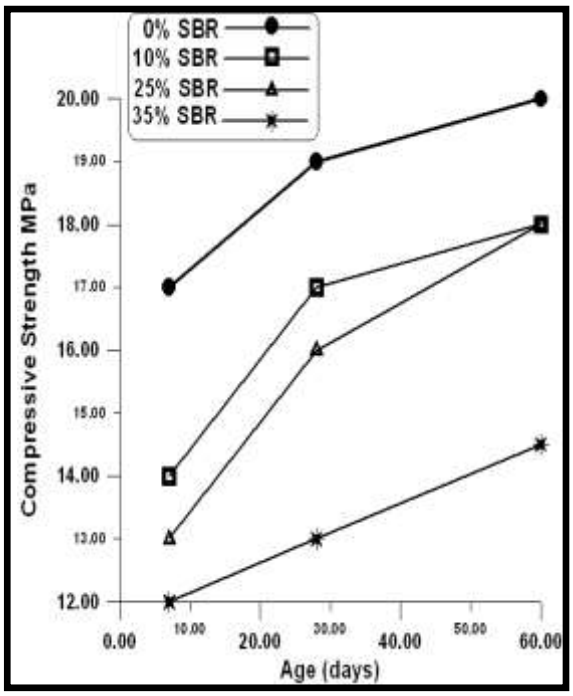
Figure (3) shows the reduction in initial and final setting time with increasing the dosage of SBR and that gives may be accelerating action to the process of setting. That has harmful property when preparing and using SBR with cement mortar.

The results of using cempatch SBR as admixture for concrete mixes show a better action. Figure (4)`shows a high reduction in percentage absorption with increasing the dosage of SBR. This agrees with what stated by (Folic and Radonjanin, 1998) . Figure (5) shows the development of flexural strength with increasing the dosage of SBR. This agrees with the instructions for use of SBR with the published production references (Cempetch SBR, DCP and Paco system,1997).

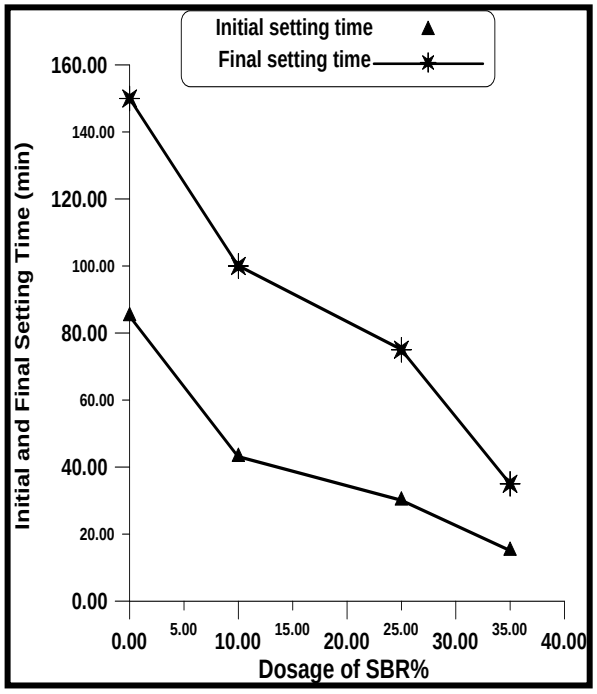
In figure (6) the results show also decreasing in slump values with increasing the dosage of SBR, which means that it affects negatively the concrete workability. In figure (7) the results of concrete compressive strength show increasing with the dosage of SBR (25 %, 35%) at ages of (7, 28, 60) days. But the concrete mix with a dosage of (10 %) SBR by volume of water shows a decreasing in compressive strength. This may be due to

the low concentration of SBR. That agrees with what was found by (Abdul Amir, 2008)

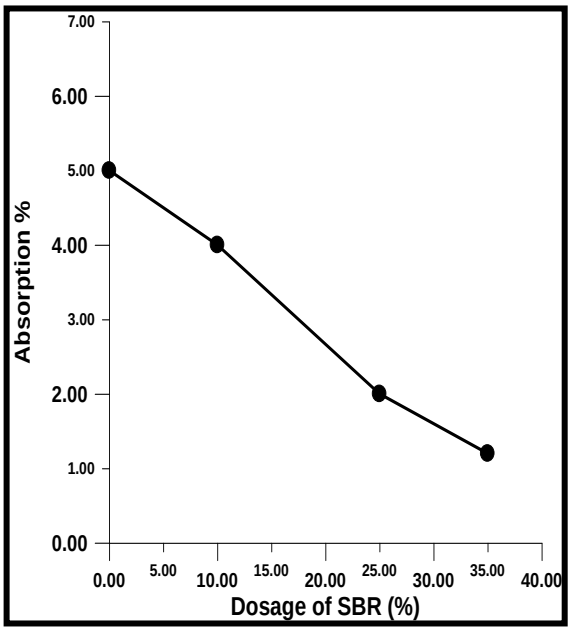
From figures (8)and (9) it was found that using SBR as a bonding mortar layer with ratio (1: 1: 3) (SBR : water : OPC) gives increasing in flexural strength and compressive strength as compared with samples of old and new concrete but without bond layer.

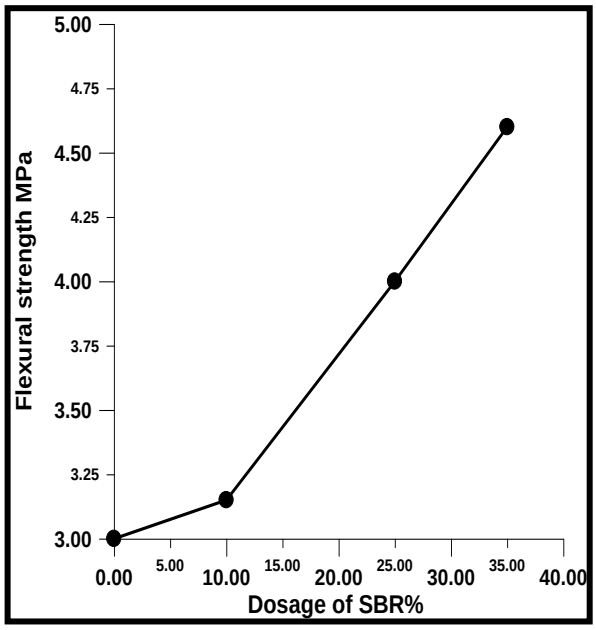


Figure(2)Development of compressive strength with age for different dosages of SBR in cement mortar

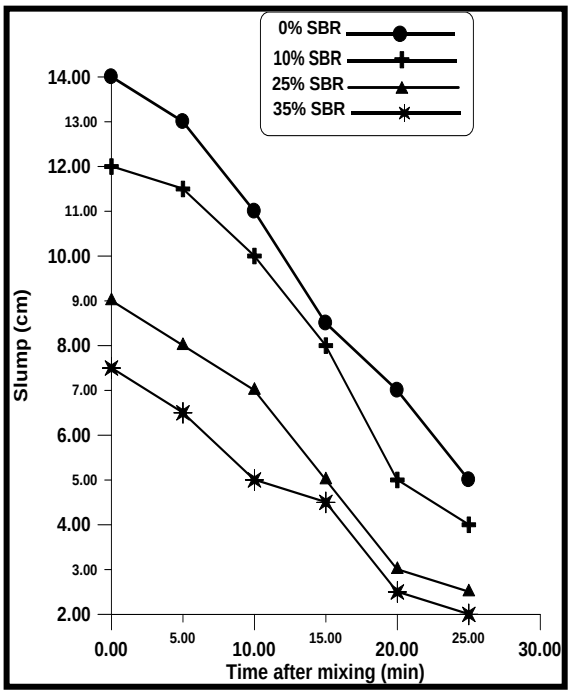


Figure(3)Decreasing of initial and final setting time with dosage of SBR in cement mortar

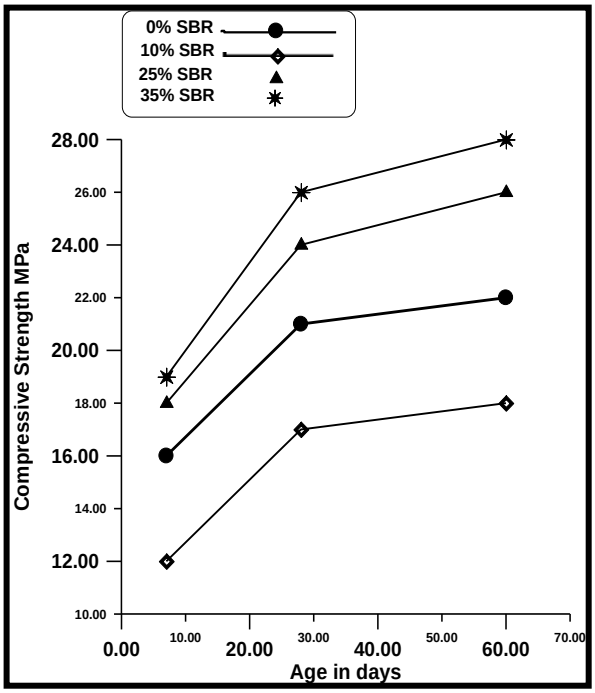




Figure(4)Effect of SBR on absorption of concrete samples

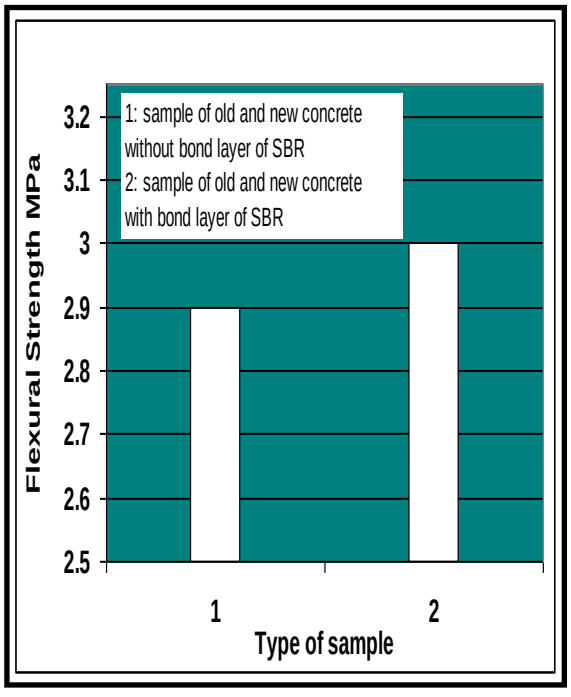


Figure(5)Development of flexural strength with dosage of SBR in concrete samples

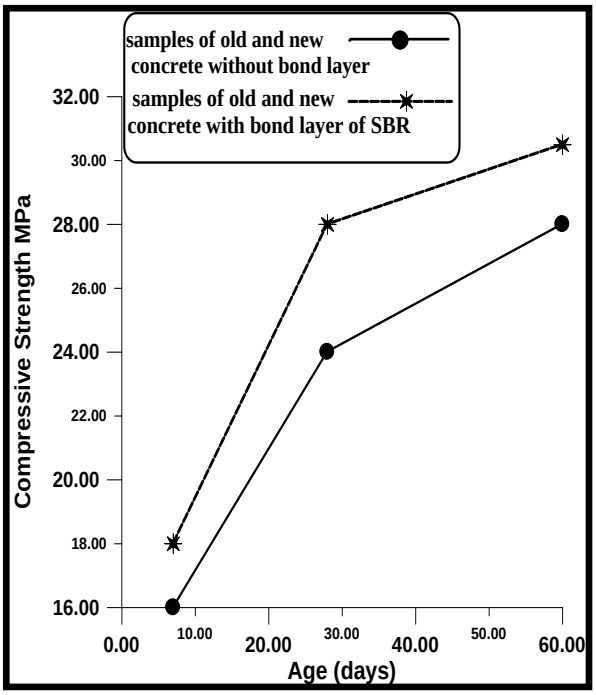


Figure(6)Slump loss with time for concrete samples

Figure(7)Development of compressive strength with age for defferent dosages of SBR for concrete samples



Figure(8)Development of flexural strength for concrete samples with and without bond layer of SBR



Figure(9)Development in comressive strength with age for concrete samples with and without bond layer of SBR

CONCLUSIONS:

1.Adding SBR to cement mortar in dosages of (10%, 25%, 35%) by volume of mixing water caused a reduction in compressive strength about (22 %, 33 % , 67 %)respectively in the age of (28) days. It acted as acceleration admixture. Also these dosages caused a reduction in initial and final setting time by 49 % and 50% for dosage 10 % SBR by volume of water, 65 % and 50 % for dosage 25 % SBR by volume of water, and a reduction of 82 % and 76 % for dosage 35 % SBR by volume of water.

2.Using SBR as admixture with concrete caused a reduction in; slump after 5 minutes from mixing reaches to 50% for dosage 35% SBR by volume of water, Absorption with 20 %, 60 %and76 % for dosage 10%, 25%, and 35% respectively It caused a considerable reduction in compressive strength at early age (7 days),Also it caused an increase in compressive strength with increase the dosage of adding. Also adding of SBR to concrete mix caused an increase in flexural strength at 28 days with increase of SBR dosage by (7%, 33%, 53%)for dosage (10%, 25% and 35%) respectively.

3.Using SBR as bond layer between old and concrete brings good results by increasing compressive strength about 12.5 %, 17 % and 9% at ages 7, 28 and 60 days as compared with samples having old and new concrete layers but without bond layer and increase the flexural strength about 3 % comparing with samples having old and new concrete layers but without bond layer.

RECOMMENDATIONS:

1.SBR emulsion can not be used for enhancing compressive strength for cement mortar at any dosage of (10 %, 25 %, 35) by volume of water.

2.SBR emulsion can be used in dosage equal to (25 %) by volume of water with concrete mixes for improving properties of concrete mix like (compressive strength , flexural strength and absorption) or with using supper plasticizer to improve the slump .

3.SBR emulsion can be used as a bonding mortar layer between old and new concrete layers in ratio (1: 1 : 3) (SBR : water : OPC) with improving the compressive and flexural strength of concrete member repaired.

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