Effect Of SBR and Limestone Powder On Properties Of Concrete

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Abstract

This 1nvestigation is conducted to study the effect of adding (SBR + limestone powder) to concrete mix (1:1.5:3) (cement : Sand : gravel) with w/c = 0.5, and (SBR + Limestone powder) with concentration of (10% + 2%), (15% + 2%) and (20% + 2%) by volume of water and by weight of cement consequently . compressive strength at ages (7, 28, 60) days was tested, also absorption and splitting tensile strength were also measured.

Also (SBR + limestone powder) was added to cement mortar (1:2) (cement : sand) with w/c = 0.42, and (SBR + limestone powder) with concentration of (10% + 2%), (15% + 2%) and (20% + 2%) by volume of water and by weight of cement consequently. Drying shrinkage cracking of this mortar was tested . As well as SBR was used as bonding mortar layer between old and new concrete layers, the compressive strength of bonded samples was tested.

The results indicate that the use of (SBR + limestone powder) in a concentration of (10% + 2%) and (15% + 2%) by volume of water and by weight of cement consequently cause slight increase in compressive strength by about [3 % , 1.9 % and 2 %] for ages (7, 28 and 60) days respectively , and by about [6.3 % , 5.2 % and 4 %] for ages (7,28 and 60) days respectively , but the addition of (SBR + limestone powder) in concentration of (20 % +2 %) cause reduction in compressive strength by about [10.6 % , 8.6 % and 9.5 %) for ages (7 , 28 and 60) days respectively , while the use of (SBR + limestone powder) in all concentration cause slight increase in splitting tensile strength , also it reduces the absorption of concrete

Also , it was found that the addition of (SBR + limestone powder) to cement mortar retards the occurrence of shrinkage cracks .

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

الخلاصة

يتناول هذا البحث دراسة تأثير اضافة مادة [(ستايرين، بيوتادين، مطاط) + الحجر الجيري الناعم] [(SBR+ limestone powder)] للخلطة الخرسانية (1: 1.5 : 3) مع نسبة ماء الى الاسمنت = (0.5) حيث تمت الاضافة بثلاث نسب هي (2% + 10%) ، (2% + 15%) و (2% + 20%) تمت اضافة مستحلب (SBR) من حجم ماء الخلطة وتم اضافة الحجر الجيري الناعم كنسبة مئوية من وزن السمنت وكانت نسبته ثابتة في جميع الخلطات، وتم دراسة تأثيرها على بعض الخواص الخرسانية مثل مقاومة الانضغاط، و شد الانشطار والامتصاص.

وتمت اضافة [(ستايرين، بيوتادين، مطاط) + الحجر الجيري الناعم] الى مونة السمنت (1 :2) (سمنت : رمل) مع نسبة ماء الى الاسمنت = (0.42) حيث تمت الاضافة بثلاث نسب هي (2% + 10%), (2% + 15%) و (2% + 20%) وتم فحص تشققات انكماش الجفاف.كذلك تم استخدام المستحلب (Cempatch SBR) كطبقة رابطة بين الخرسانة القديمة والخرسانة الجديدة وتم فحص مقاومة الانضغاط للنماذج الخرسانية الملصقة بواسطة المستحلب.

تشير النتائج بان استخدام (SBR + limestone powder) بالنسب (2% + 10%) و (2% + 15%) من حجم الماء ومن وزن السمنت على التوالي تسبب زيادة قليلة في مقاومة الانضغاط حوالي(3%) , (1.9%) و (2%) للاعمار (60,28,7) على التوالي و(6.3%), (5.2%) و (4%) للاعمار (60,28,7) على التوالي , ولكن النسبة (2% + 20%) تسبب انخفاض في مقاومة الانضغاط حوالي (10.6%) , (8.6%) و(9.5%) للاعمار (60,28,7) على التوالي , بينما استخدام (SBR + limestone powder) بجميع النسب تسبب زيادة قليلة في مقاومة شد الانشطار وتقلل من الامتصاص في الخرسانة .

ان استخدام (SBR + limestone powder) مع المونة الاسمنتية تؤخر من حدوث تشققات انكماش الجفاف. وكانت نتائج استخدام المستحلب كطبقة رابطة بين الخرسانة القديمة والخرسانة الجديدة ظهور زيادة في مقاومة الانضغاط للاعمار (28 ، 60) يوم مقارنة مع النماذج المتكونة من خرسانة قديمة وخرسانة جديدة بدون اضافة المستحلب كطبقة رابطة .

Introduction

Admixtures are classified according to their major purpose of use. They are used to modify the properties of concrete or mortar and make them more suitable for the work at hand, economy or such other purpose as saving energy.

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 modification, to the normal properties of concrete. **[Neville 1995]**

Bonding admixtures, including addition of compounds and materials such as polyvinyl and acetates, acrylics and butadiene-styrene co-polymers, can be used to assist in bonding new/ fresh concrete with old/ set concrete . [**ACI 201. 2R. 92**] .

[**sujjavanich and Lundy 1998**] examined the properties of the latex modified concrete (LMC) which contained (styrene butadiene polymer). He investigated the strength and other properties of concrete at ages ranging from (5) hours to (28) days. The mix proportion of the materials used throughout this study were (1: 2.46: 2.1) (cement: Sand: gravel), 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 0.5, 1, 2, 3, 7 and 28 days, flexural strength and dynamic modulus of elasticity tests were conduct 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 (f c /f t)decreases from about 12.5 to 6.8 and increase again after about 12 hours . Similar trend are reported for conventional concrete .

Another study was made by **[AbduL Amir, 2008]** who investigate the effect of using sodium benzoate, potassium dichromate as corrosion inhibitors in three concentrations (1%, 2% and 3%) by weight of cement and SBR (Styrene-Butadiene-Rubber) emulsion in three concentration (10%, 15% and 25% by volume of water is studied on concrete properties; compressive strength, splitting tensile strength, flexural strength and absorption. The results show that the use of SBR emulsion in concentrate 25% by volume of water made a significant improvement in all mechanical properties of concrete mixes including increase in; compressive strength about 8%, 11% and 7% at ages 28, 60 and 90 days respectively, splitting tensile strength and flexural strength about 37%, and cased a maximum 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 ,porosity ,permeability and penetration of sulfate ion tests were investigated for reference, HRWR, SBR and HRWR+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 compressive 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.

According to the results of some studies on the effect of filler materials on the properties of concrete, [**Soroka and stern 1976**] concluded that fillers affect

strength through their accelerating the cement hydration . Another investigation carried out by **[Soroka and Setter1977]**stated that fillers affect on strength is primarily accelerating on the cement hydration. This improvement in strength can also be attributed to the increase in the density of the concrete due to increasing filler content in the mix.

[Malhotra and curette 1985] studied the properties of concrete incorporating various percentages of Limestone dust as a partial replacement for fine aggregate. The results showed that there is a significant increase in strength with increasing the amount of limestone dust in lean concrete mixes. However, this is not evident in concrete mixes which are relatively rich in cement.

Experimental Work

Materials

1. Cement

Ordinary Portland cement (O. P. C) manufactured by the new cement plant of Kufa was used throughout this investigation. This cement complied with the Iraqi specification No. 5 : 1984. The chemical composition and physical properties are presented in Tables (1) and (2).

Table(1): Physical properties of the cement

Physical Properties	Test results	IQS 5: 1984 Limits
Fineness, Blaine, cm^2/gm	3060	≥ 2300
Setting time, Vicat's method		
Initial hrs: min.	1:54	≥ 1: 00
Final hrs: min.	3:35	≤ 10: 00
Compressive strength of 70.7 mm cube, MPa		
3 days	20.5	≥ 15
7 days	29.0	≥ 23

Table(2): Chemical composition of the cement

Oxide	(%)	IQS 5: 1984 Limits
CaO	61.26	
SiO_2	20.80	
Fe_2O_3	3.20	
Al_2O_3	6.12	
MgO	4.40	≤ 5.0
SO_3	2.33	≤ 2.8
Free lime	0.76	

L.O.I.	1.75	≤ 4.0
I.R.	0.61	≤ 1.5
Compound composition	**(%)**	**IQS 5: 1984 Limits**
C_3S	35.88	
C_2S	32.56	
C_3A	10.80	
C_4AF	9.73	
L.S.F.	0.88	0.66-1.02

Fine Aggregate (Sand)

Al-Akaidur well-graded natural sand was used. The physical and chemical properties of the sand listed in Table (3). Its grading conformed to Iraq. Specification No .45 :1984.

Table(3): Properties of the sand

Sieve size (mm)	**Percent passing**	**IQS 45: 1984 Limits, Zone 3**
9.5	100	100
4.75	100	90-100
2.36	94	85-100
1.18	84	75-100
0.6	66	60-79
0.3	37	12-40
0.15	3	0-10
Properties	**Test results**	**IQS 45 : 1984 Limits**
Sulfate content, SO_3 (%)	0.40	≤ 0.5
Specific gravity	2.60	
Absorption (%)	1.5	

Coarse aggregate gravel

The coarse aggregate was Al-Nibaee gravel. The gravel used conforms to the Iraqi specification No . 45 : 1984. The grading and other properties of this type of aggregate are listed in Table (4).

Table(4): Properties of the gravel

Sieve size (mm)	Percent passing	IQS 45 : 1984 Limits
40	100	100
19	100	95-100
9.5	56	50-85
5	6	0-10
Properties	**Test results**	**IQS 45: 1984 Limits**
Sulfate content, SO_3 (%)	0.08	≤ 0.1
Specific gravity	2.64	
Absorption (%)	0.8	

Cempatch SBR

Cempath SBR is a single component styrene butadiene rubber latex. It is designed 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 produce- polymer modified screed and floor toppings. The chemical and physical properties of cempatch SBR used are given in Table (5). [**Cempatch SBR, DCP**].

Table(5): Typical properties of SBR admixture

Color	white
Shape and appearance	Emulsion
Solid in aqueous	45%
Specific gravity	Around 1@ 25 C^o
Fire	Non - Flammable
PH	9.5
Packaging	5liter , 25 liter , 200liter

Limestone powder

Finely crushed limestone which has been brought from local market is used. The chemical composition of this limestone is show in Table (6).

Table(6): Chemical analysis of the limestone powder

Oxide	Content %
SiO_2	1.34
Fe_2O_3	0.12
Al_2O_3	0.69
CaO	55.13
MgO	0.13
SO_3	1.7
L .O.I	40.56

The Experimental Program

In this test concrete including (SBR + limestone powder) was used in (1: 1.5:3) (cement : sand: gravel) with (w/ c) ratio (0.5), four types of concrete mixes were prepared throughout this study: one reference concrete mix without any admixture and there concrete mixes containing (SBR + limestone powder) in concentration of (10% + 2%), (15% + 2%) and (20% + 2%) by volume of water and by weight of cement consequently , obtaining (water + SBR) / cement ratio = 0.5

Table (7) illustrates the proportion of concrete mixtures and some properties of concrete.

Table (7): The proportion of concrete mixtures and some properties of fresh concrete

Type of mix			Slump in mm
Symbol of mix	Type of admixture	%of adding	
N Reference	No adding	Nil	10
(SBR 10 + LS.P 2)	(Styrene – Butadiene Rubber)+ (Lime stone Powder)	10% by volume of water + 2% by weight of cement	6.5
(SBR 15 + LS.P 2)	(Styrene – Butadiene Rubber)+ (Lime stone Powder)	15% by volume of water + 2% by weight of cement	4.5
(SBR 20 + LS.P 2)	(Styrene – Butadiene Rubber)+ (Lime stone Powder)	20% by volume of water + 2% by weight of cement	3.5

Test Procedures

Slump Test

The slump of fresh concrete mixes was conducted according to ASTM C 143-90a.

Compressive Strength Test

The compressive strength of concrete was determined according to BS. 1881-pant 116-1989. (150 mm) cubes were testing using standard testing machine with the capacity of 2000 KN. The test was conducted at ages of 7, 28, 60 days. All specimens were cured in water until the age of testing. Each result of compressive strength obtained is the average for three specimens.

Splitting Tensile strength

The splitting tensile strength was measured with (100 * 200) mm cylinders. This test was determined according to ASTM C 496-86. Cylinders were cast, demolded and cured in a similar way as the cubes. Each splitting tensile strength result was the average of strength for two specimens. The splitting tensile strength is calculated from the equation:

$$\delta = \frac{2P}{\pi LD}$$

Where:

δ =Tensile strength (NImm^2) , L = The cylinder length (mm)

P = The applied compressive load (N) , D = The cylinder diameter (mm).

Absorption Test

Cube specimens with 100 mm 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± 5 C^o) for (72 hours), then the specimens were immersed in water for (24 hours).

The percentage of total absorption was calculated with the following equation;

Absorption (%) = (W2-W1) / W1) * 100

Where;

W1: The average weight of dry specimens (gm).

W2: The average weight of wet specimens (gm).

Drying Shrinkage Cracks Test

In this test (SBR + limestone powder) were used as admixture to cement mortar (1: 2) (cement: sand) in a concentration of (10% + 2%), (15% + 2%) and (20% + 2%) by volume of water and by weight of cement consequently. I-shaped steel moulds having a channel section shown in Fig (1) were used to study shrinkage cracking of restrained cement mortar members. This model devised by [Al-Rawi 1985]. These moulds were cleaned. Polythene sheet were put over the steel mould and oiled. For each mortar mix one shrinkage mould filled. The mortar mixes was cast in the mould in two layers. The beams were cured by covered them with Hessian and polythene sheet and wetted once day foe first 7 days, then air dried in laboratory conditions. The specimens were visually monitored on daily basis for cracking. The crack width was measured by using a portable microscope with magnification (40x).

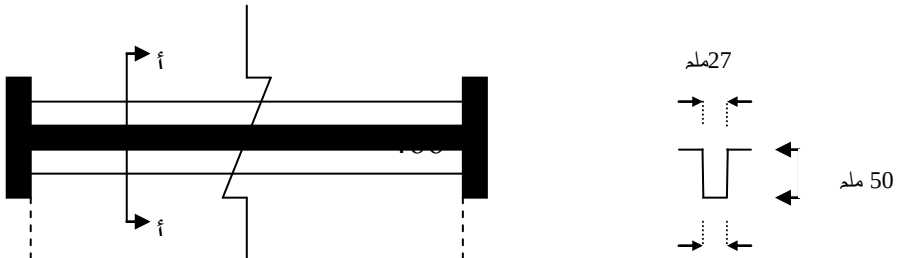

Fig (1): Schematic diagram of the I- shape mould

* Also SBR was used as bonding 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. Compressive strength test was conducted. Concrete cubes (150 × 150 × 150) mm cast in two layers. The bottom (1: 1.5: 3) concrete layer, with (w/c) ratio (0.48) 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: 1.5: 3) concrete Fig (2) shows the cubes. The cubes were moist cured until the age of testing (28,60) days, and the results were compared with the compressive strength of identically cast concrete cubes but without bound layer.

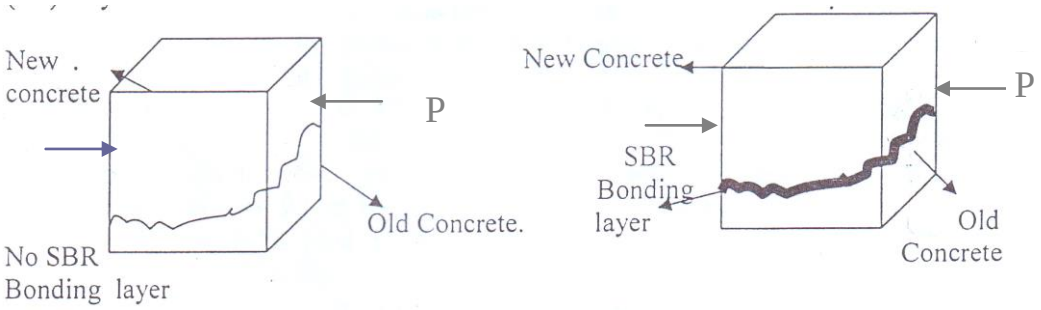

Fig (2) : Samples with and without SBR as a bonding mortar layer

Results And Discussion

From the results of compressive strength shown in Fig (3) it can be seen that the use of (SBR + limestone powder) as admixture to concrete in concentration of (10% + 2%) and (15% + 2%) cause slight increase in compressive strength by about [3 % , 1.9 % and 2 %] for ages (7 , 28 and 60) days respectively, and by about [6.3 % , 5.2 % and 4 %) for ages (7 , 28 and 60) days respectively, this is due to inclusion of SBR emulsion which works as a plasticizer , this is agree with **[Folic and Radonjanin ,1998]** who studied the mechanical properties and determined the optimal curing condition of [styrene butadiene rubber(SBR)]. The researcher used concrete modified with 2.5% , 5% and 7.5%polymer by weigh of cement . The results showed that the compressive strength was slightly increased with increase of the SBR cement –ratio (1% -7.5% by weigh of cement). **.** While the addition of (SBR + limestone powder) in concentration of (20% + 2%) cause a reduction in compressive

strength by about [10.6 %, 8.6 % and 9.5 %] for ages (7 , 28and 60) days respectively .

From Fig (4)It can be seen that the concrete with (SBR + Limestone powder) recorded an increase in splitting tensile strength by (3.4 %) , (6.9 %), and (7.9 %) for concentration of (10% + 2%) , (15% + 2%) and (20% + 2%) respectively at age 28 days , that's because the fact that (SBR) admixture used to reduce permeability, porosity, and improved the density of concrete, also limestone powder used to increased workability and density of concrete.

The results of using (SBR + limestone powder) as admixtures for concrete mixes show a better action .Fig (5) shows a high reduction in percentage absorption with increasing the concentration of (SBR + limestone powder). The concentration of (20% + 2%) by volume of water and by weight of cement is the best one which recorded (60%) reduction in percentage of absorption , because (SBR) emulsion has many advantages; water proofing action, improves adhesion and reduces permeability. This agrees with what stated by [**Folic and Radonjanin, 1998].**

From Table [8] it can be observed that the date of crack increases with increasing the concentration of (SBR + limestone powder). This may be related to the fact that these additions would decrease drying shrinkage , thus , the possibility of cracking will be decreased, this behavior may be due to the fact that the SBR emulsion itself has a lower shrinkage .The date of crack for normal mix occurs earlier after (9) days while for mortar with concentration of (20% + 2%) by volume of water and by weight of cement the date of crack is (27) days. This is compatible with the study carried out by **[Al-B derriy, 2001 and Al-KHAFAJ 2007]**.

From Fig (6) it was found that using SBR as a bonding mortar layer with ratio (1:1:3) (SBR: water: OPC) gives increasing in compressive strength compared with samples of old and new concrete but without bond layer.

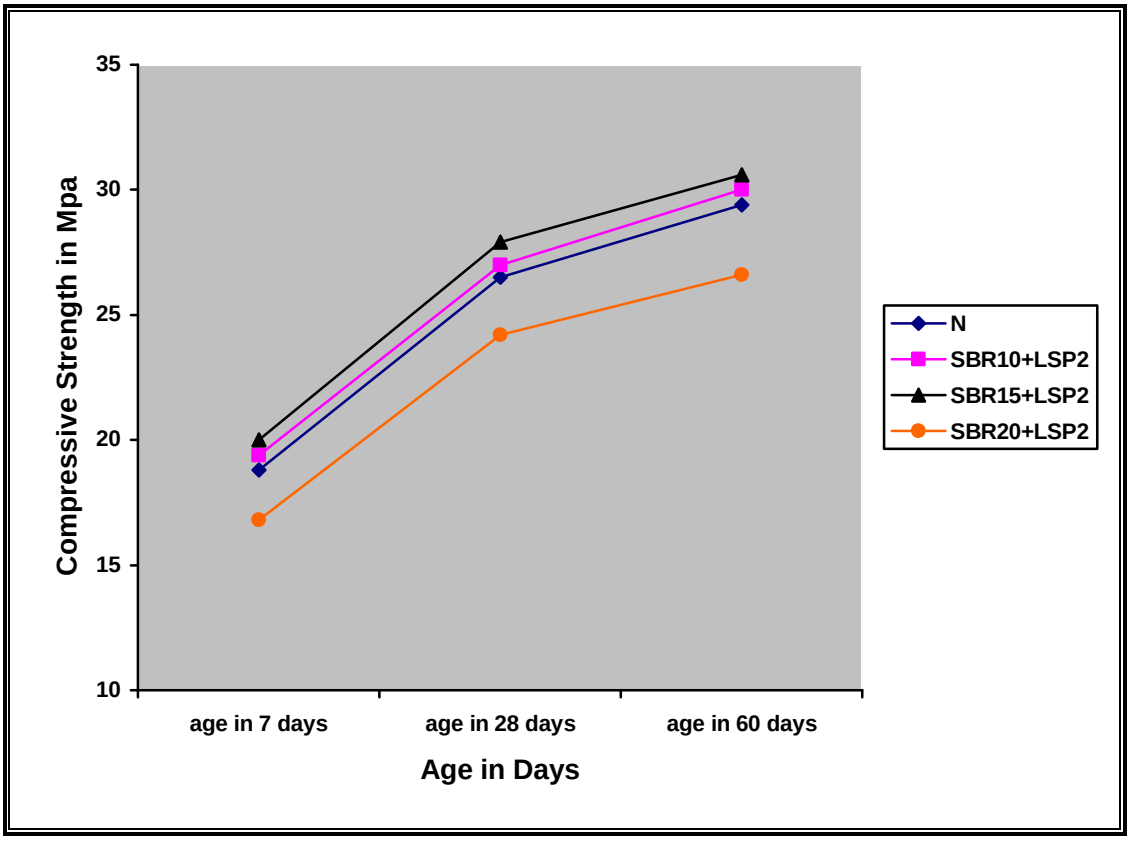

Fig (3) : Development of compressive strength with age for mixes with (SBR+ limestone powder)

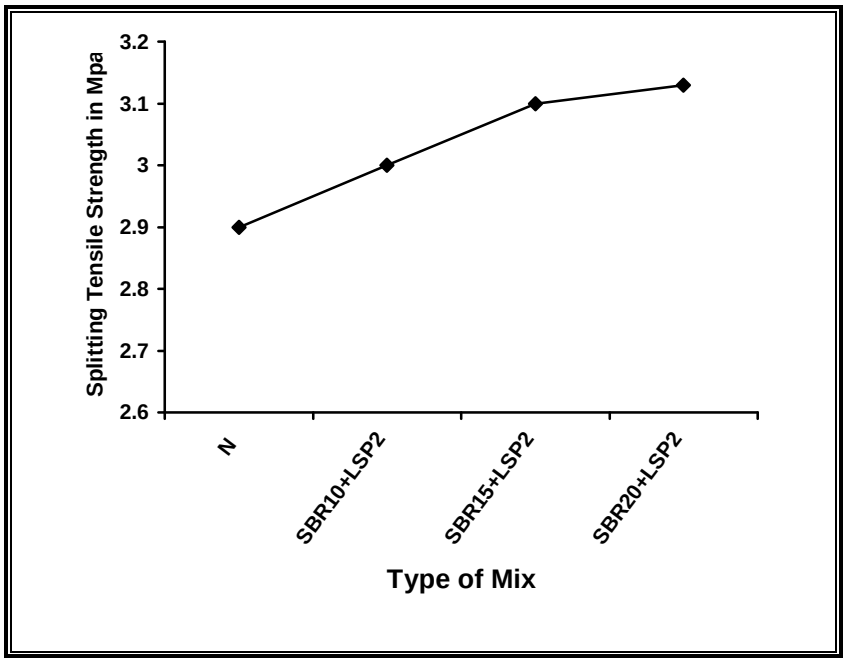

Fig (4) : Splitting tensile strength for different concrete mixes at age 28 days

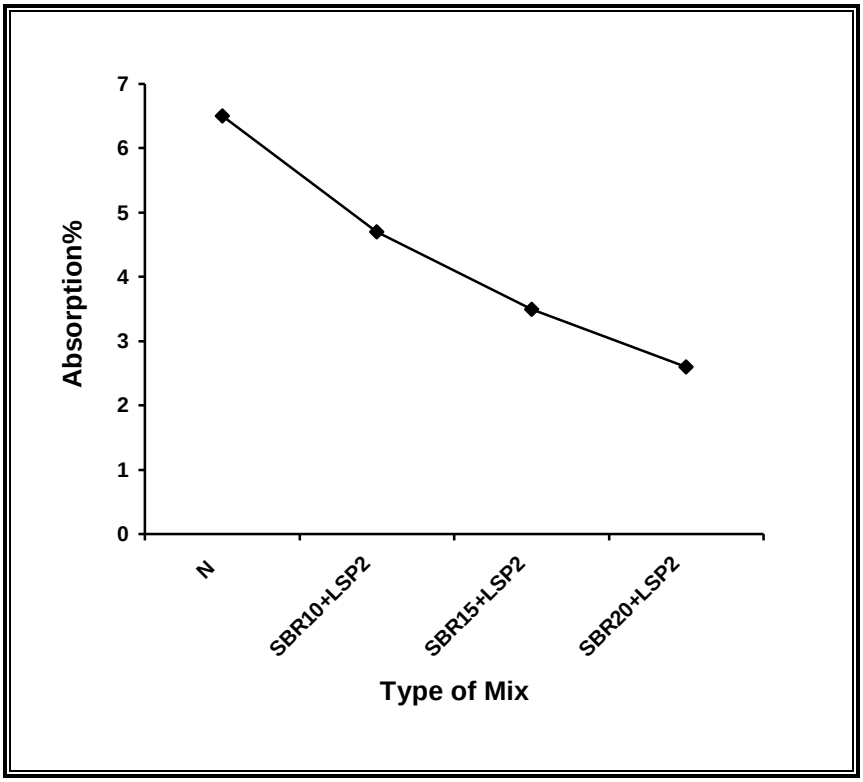

Fig (5) : Absorption for different concrete mixes

Table(8): Properties of restrained beam

Symbol of mortar mix	Date of crack (day)	Width of crack (mm)
N	9	0.2
SBR10+LSP2	18	0.22
SBR15+LSP2	25	0.23
SBR20+LSP2	27	0.24

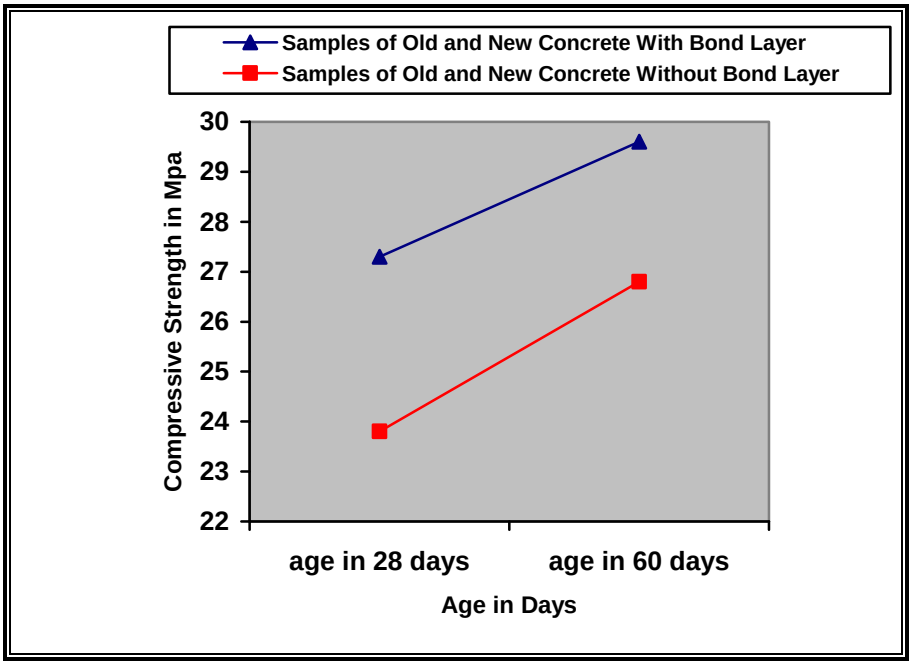

Fig (6) : Development in compressive strength with age for concrete samples with and without bond layer of SBR

Conclusions

1- The addition of (SBR + limestone powder) to concrete in a concentration of (10% + 2%) and (15% + 2%) cause slight increase in compressive strength by a bout [3 % , 1.9 % and 2 %) for ages (7,28 and 60) days respectively , and by about [6.3 %, 5.2 % and 4 %) for ages (7,28 and 60) days respectively , while the addition of (SBR + limestone powder) to concrete in concentration of (20% + 2%) cause a reduction in compressive strength by about [10.6 % , 8.6 % and 9.5 %] for ages (7,28 and 60) days respectively .

2- The concrete including (SBR + limestone powder) with a concentration of (10% +2%), (15% +2%) and (20% +2%) cause slight increase in splitting tensile strength .

3- The concrete including (SBR + limestone powder) with a concentration of (10% +2%) , (15% +2%) and (20% +2%) cause a reduction in absorption by about (27.7 %) ,(46 %) and (60 %) consequently.

4- The cracking time in restrained beam for normal cement mortar mix occurs earlier after (9)days, while the cement mortar with a concentration of (20% + 2%) the cracking time is (27) days.

5- Using SBR as bond layer between old and new concrete brings good results by increasing compressive strength about (12.9)%, and (9.5 %) at ages 28 and 60 days.

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