



EFFECT OF THE ADDITION OF STYRENE–BUTADIENE RUBBER LATEX ON THE WATER ABSORPTION AND COMPRESSIVE STRENGTH OF CRUMB RUBBER-MORTAR

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Abstract: In this research different mixes were prepared with Cement-Sand ratio (1:3) and Water- Cement (0.5) by weight. Four sets were prepared by partially or full replacing the sand with crumb rubber tire to fabricate the Crumb Rubber-Mortar (CRM) mixtures. The first two sets include fine crumb rubber with particles size (0.3-1 mm), The other set include coarse crumb rubber with particles size (1.18-2.36 mm).The third and fourth sets were prepared as the same first sets but with the addition of (7%) Styrene–Butadiene Rubber(SBR) latex by weight of cement. Each set was consist of different percentage of replacing the sand by crumb rubber (10,30,50,100%) by volume. Tests were conducted, including water absorption and compressive strength. Several results obtained before and after the addition of Styrene-Butadiene Rubber(SBR) which shows an increase in crumb rubber percentage cause decrease in compressive strength and water absorption; while as the density increases the compressive strength and water absorption increased before the addition of SBR. After the addition of SBR to the crumb Rubber-Mortar the compressive strength and water absorption are improved. In general fine crumb Rubber-Mortar have better properties than coarse crumb Rubber-Mortar.

Keywords: *Crumb Rubber-Mortar, Styrene–Butadiene Rubber Latex, compressive strength, water absorption, particles size.*

دراسة تأثير اضافة مطاط الستايرين-بيوتادين على امتصاصية الماء ومقاومة الانضغاط للملاط - مفروم المطاط

الخلاصة: تناول البحث تحضير خلطات مختلفة للملاط بنسبة وزنية (1:3 أسمنت- رمل) ونسبة الماء الى الاسمنت (0.5) , حيث حضرت اربع مجاميع وذلك باستبدال جزئي او كلي للرمل مع مطاط الاطارات المفرومة لتصنيع خلطات ملاط - مفروم المطاط (CRM). تضمنت المجموعتين الاولى والثانية مفروم اطارات بدون اضافة مطاط الستايرين-بيوتادين (SBR) احدهما بحجم جزئي ناعم (0.3-1 mm) و الاخرى تضمنت مفروم اطارات خشن بحجم جزئي (1.18-2.36 mm). اما المجموعتين الثالثة والرابعة فحضرت بنفس مواصفات المجاميع الاولى ولكن بعد اضافة SBR (7%) من وزن الاسمنت. تم استبدال الرمل بمفروم المطاط (10,30,50,100%) استبدالاً حقيقياً لكل المجاميع الفحوصات التي اجريت تتضمن امتصاصية الماء ومقاومة الانضغاط. حيث تم الحصول على العديد من النتائج قبل وبعد اضافة (SBR) التي أظهرت ان الزيادة في نسبة المطاط تؤدي الى نقصان في امتصاصية الماء ومقاومة الانضغاط , في حين الزيادة في الكثافة تؤدي الى زيادة في امتصاصية الماء ومقاومة الانضغاط. بعد اضافة (SBR) الى ملاط - مفروم المطاط تم تحسين امتصاصية الماء ومقاومة الانضغاط. بصورة عامة فأن ملاط - مفروم المطاط الناعم يمتلك خواص افضل من ملاط - مفروم المطاط الخشن.

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Solid waste disposal is a major environmental issue on cities around the world. Rubber from scrap tires is one of the most recent waste materials investigated for its potential use in the construction field[1]. Like plastic wastes, rubber tire is non-degradable in nature at ambient conditions. This has generated massive stockpiles of used tire and is creating huge environmental problems including fire hazards. Recently many countries have forbidden land filling of scrap tires and therefore recycling of this material in the production of other products has immense importance[2].

Recycling is generally a more sustainable alternative to disposal and recycling alternatives have been introduced[3]. The reuse of rubber tires remaining from the retreading process can minimize environmental impacts and help the natural resources[4]. Rubber tire can be used in a variety of civil and non-civil engineering applications such as in road construction, in geotechnical works, as a fuel in cement kilns and incineration for production of electricity or as an aggregate in cement-based products[5]. Production of rubber-filled concrete composition is a possible area for a further expansion of usage of ground rubber tire (GRT).

The advantages of using GRT in the cement-concrete structure are an increased crack, freeze-thaw and impact resistance, shock wave absorption, reduced heat conductivity, and increased resistance to acid rain. However, an addition of rubber particles to concrete has shown to reduce the compressive and flexural strengths. Concerning the effect of the size of rubber particles on the compressive strength, the results are contradictory[6]. In cement paste and concrete it was observed that the specimens with tire rubber have less water absorption than the reference specimens. That may occur because the rubber does not absorb water [7].

2. Aims

This work investigates the influence of crumb rubber, obtained from used automobile tires, on the water absorption and compressive strength of mortar. Before and after the addition of styrene-butadiene rubber (SBR) emulsion.

3. Experimental Procedure

3.1. Materials

3.1.1 Cement

The cement that used is ordinary Portland cement produced at northern cement factory (Tasluja-Bazian). It was stored in dry place to minimize the effect of humidity on cement properties and it was tested by (National Center for Laboratories and Construction Research). Tables (1) show the chemical composition and physical properties of the cement used throughout this work. It is matched by the Iraqi Reference Guide indicative number (198) and the Ministry of Planning / Central Agency for Standardization and Quality Control Manual 198/1990.[8]

Table (1): Chemical composition and physical properties of Ordinary Portland cement[8] .

Chemical composition			Physical properties		
Item	Content %	Limit of Iraqi specification No.5/1984	Physical properties	Test result	Specimens Limit
CaO	63.19	---	Fineness (m ² /kg)	370	230
SiO ₂	20.60	---	Autoclave exp.	0.32	0.8%
AL ₂ O ₃	4.10	---	Compressive strength		

Fe ₂ O ₃	4.48	---	(MPa)	29.5	15.0
SO ₃	1.98	< 2.8%	3-days age		
MgO	2.28	≤ 5%	Compressive strength	35	23.0
L.O.I			(MPa)		
Loss on Ignition	2.45	≤ 4%	7-days age		
			Time of setting Initial	35	45
			(min.)		
I.R			Time of setting		
Insoluble Residue %	0.47	≤1.5%	Final (hour)	5.25	10 Max.

3.1.2 Fine Aggregate

Al-Ekhaider natural sand with fineness modulus of (2.84) and Specific gravity (2.65) is used as fine aggregate with maximum size of (3.35mm) is used in making the specimens. The grading of the fine aggregate is shown in Table (2). Results indicate that the fine aggregate grading is within the requirements of the Iraqi Specification No.45/1984[8].

Table (2): Grading of fine aggregate.

mesh size (mm)	% Passing by Weight	Specific Limit
4.75	95.3	90-100
2.36	83.7	70-100
1.18	71.9	55-90
0.60	58.1	53-59
0.30	21.2	8-30
0.15	4.7	0-10
Percentage of salts%	0.4	≤0.5

3.1.3 Crumb rubber

The crumb rubber used in this work was provided by Babylon Tires factory. Two different sizes of crumb rubber were used, namely fine rubber its particles size (0.3-1 mm) and coarse rubber its particles size (1.18-2.36 mm) as shown in Fig. (1). The chemical and physical properties of crumb rubber used throughout this work are given in Table (3).



Fig. 1 different sizes of crumb rubber

Table (3): chemical composition and physical properties of crumb rubber*

Chemical composition		Physical properties	
Rubber hydrocarbon	Content %	Physical properties	Test result
Rubber hydro Carbon (SBR)	48%	Density	0.95 g/cm ³
Carbon black	31%	Ultimate tensile strength	9 MPa

Acetone extract	15%	Elongation at break	150%
ash	2%	Hardness shore A	64
Residue chemical balance	4%		

*based on the results of Babylon Tires factory laboratory.

3.1.4 styrene-butadiene rubber

styrene-butadiene rubber (SBR) emulsion, commercially known (Nitobond SBR) from (FOSROC) company. The chemical and physical properties of Nitobond (SBR) used are given in Table (4).

Table(4): Typical properties of SBR latex admixture*

Color	White
Shape and appearance	Emulsion
Density	1.00 g/cm ³ at 20 °C
Fire	Non – Flammable
PH	9.0 - 10.0
Boiling Point/Range °C	100
Melting Point/Range °C	0

*Based on the results of FOSROC company.

3.1.5 Water

Distilled water was used for the specimens in casting and curing.

3.2. Experimental work

Different mixes were prepared with Cement-Sand ratio (1:3) and Water- Cement (0.5) by weight. Four sets were prepared by partially or full replacing the sand with crumb rubber tire to fabricate the crumb Rubber-Mortar mixtures. The first two sets include fine crumb rubber with particles size (0.3-1 mm), The other set include coarse crumb rubber with particles size (1.18-2.36 mm).The second two sets were prepared as the same first sets but with the addition of (7%) SBR latex by weight of cement.

Each set was consist of different percentage of replacing the sand by crumb rubber (10,30,50,100%) by volume. The crumb Rubber-Mortar mixture are illustrated in Table(5).

Table(5) mix design proportions for fine and coarse recycling rubber specimens.

Specimen No.	Rubber %	Cement Kg/m ³	Sand Kg/m ³	Crumb Rubber Kg/m ³	WaterL/m ³
A	0	512.8	1538.4	-	256.4
B	10	512.8	1384.5	55.3	256.4
C	30	512.8	1076.8	166.2	256.4
D	50	512.8	769.2	277	256.4
E	100	512.8	-	554	256.4

To achieve a homogenous distribution of the materials ,Sand, cement and rubber were placed in the pan at the same time and dry-mixed by hands for 2-3 min. The materials were mixed with water by electrical mixer (Automix, Controls Co. Italy) for additional 4 min according to (ASTM C305)[9],as in Fig.(2). In the case of SBR addition , both water and SBR

were mixed to form the Specimens .After complete mixing, the crumb Rubber-Mortar was poured in molds ,which were coated with mineral oil to prevent adhesion with crumb Rubber-Mortar. Crumb Rubber-Mortar casting was accomplished in three layers. Each layer was compacted by using a vibrating device (Viatest Co. German) for 1-1.5 minutes until no air bubbles emerged to the surface of the casting



Fig.2 Electrical mixer (Automix, Controls Co. Italy)

4. Tests

The tests were carried out with cubic specimens after 28 days which continuously cured at 20°C in water bath as in Fig. (3).



Fig. 3. Water bath Rig.

4.1. Water Absorption Test

The water absorption test was determined according to ASTM C642-97[10]. The specimens dry in oven at a temperature of 100 to 110°C for not less than 24 h. After removing each

specimen from the oven, allow it to cool in dry air to a temperature of 20 to 25°C and determine the Oven-Dry Mass (A). And then Immerse the specimen in water at approximately 21°C for not less than 48 h and Surface-dry the specimen by removing surface moisture with a towel, and determine the surface-dry mass after immersion (B) according to equation(1).

$$\text{Absorption after immersion, \%} = [(B - A)/A] \times 100(1)$$

where:

A = mass of oven-dried specimen in air, g

B = mass of surface-dry specimen in air after immersion, g

4.2. Compression Test

The compression test was determined according to American Society for Testing and Materials. ASTM C109/C109M-05 compressive strength of hydraulic cement mortars (Using 2-in. or [50-mm] cube Specimens)[11]. The specimens are loaded uniaxially by the universal compressive machine (Sercomp, Controls Co. Italy) of 250 kN capacity at loading rate of 2.5 kN per second. as shown in Fig. (4).



Fig.4. Universal compressive machine(Sercomp, Controls Co.) Italy.

5. Results and Discussion

5.1. Water Absorption Test

The water absorption of crumb Rubber-Mortar specimens were measured, as shown in Figs. (5) and (6). The results show that the water absorption decrease with increase in rubber percentage and fine crumb Rubber-Mortar have lower water absorption than coarse crumb Rubber-Mortar. The water absorption increase with increase in density. The observed reduction in the water absorption was due to the lower porosity of the material, which occurred as the replacement of crumb rubber by sand.

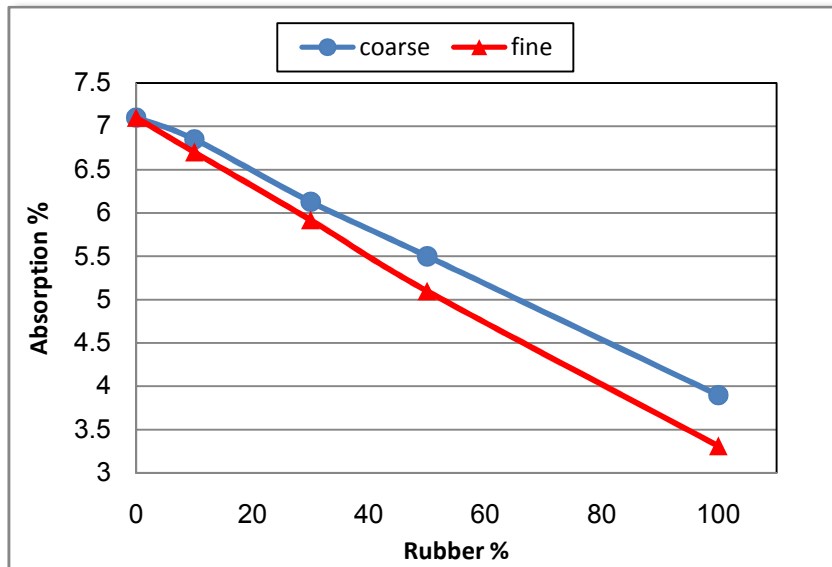


Fig. 5. Effect of different rubber percentage on the water absorption of crumb Rubber-Mortar.

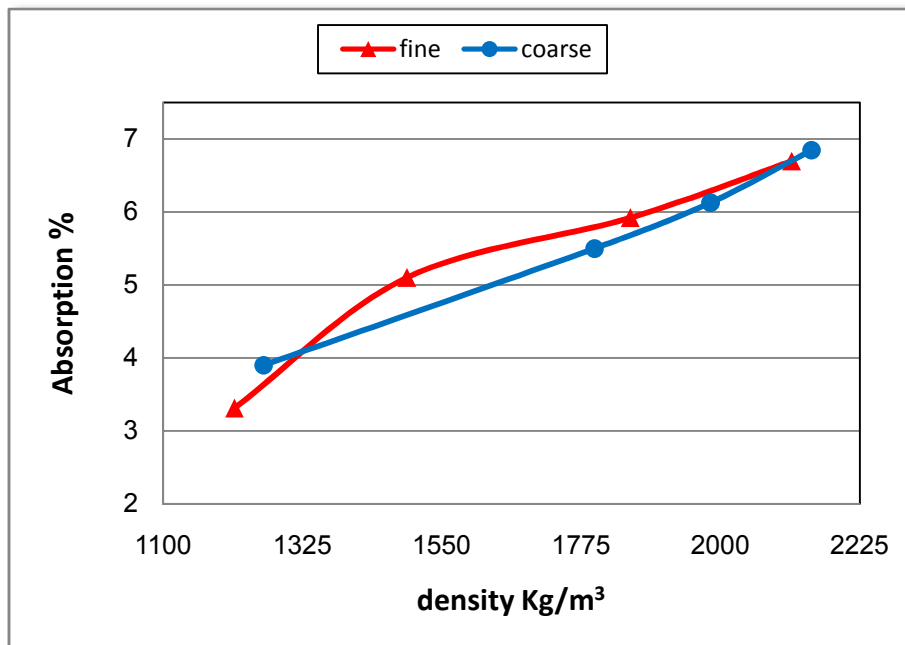


Fig.6. Effect of density difference on the water absorption of crumb Rubber-Mortar.

The water absorption of crumb Rubber-Mortar specimens with addition (SBR) latex were measured, as shown in Fig. (7) and (8). An decrease in water absorption was also noted after the addition of (SBR latex) with percentage and density change.

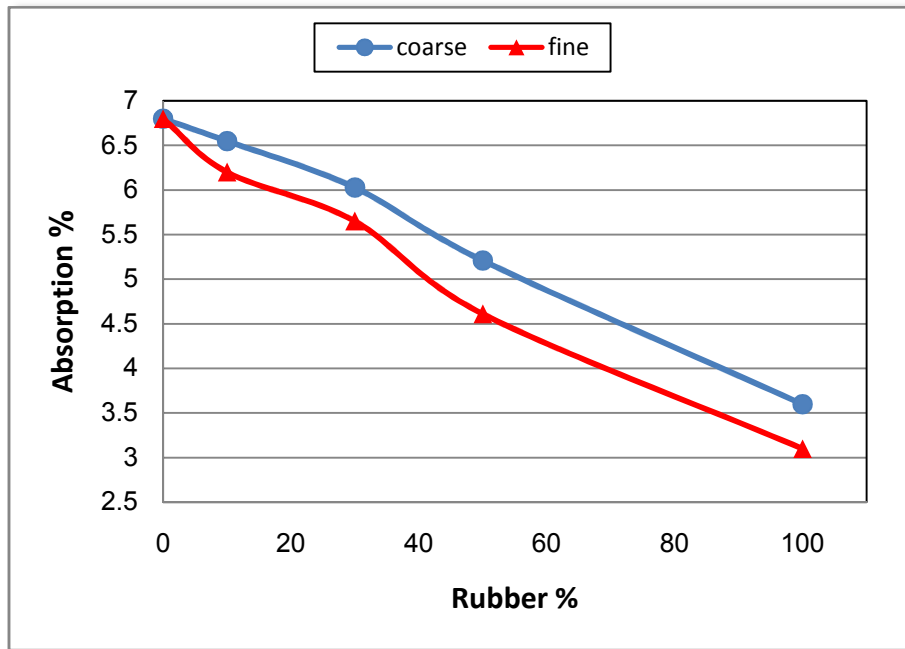


Fig.7. Effect of different rubber percentage on the water absorption of crumb Rubber-Mortar with SBR latex addition.

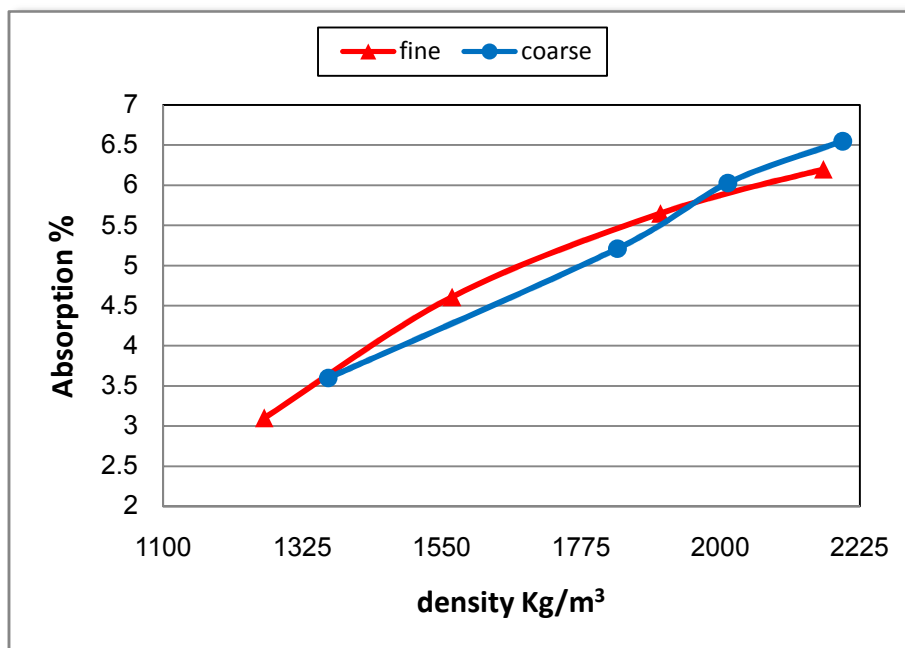


Fig.8. Effect of density difference on the water absorption of crumb Rubber-Mortar with SBR latex addition.

5.2. Compression Test

The compressive strength of crumb Rubber-Mortar specimens were measured, as shown in Figs. (9) and (10). The results show that the compressive strength decrease with increase in rubber percentage. The compressive strength increase with increase in density. Also noted that fine crumb Rubber-Mortar have higher compressive strength than coarse crumb Rubber-Mortar.

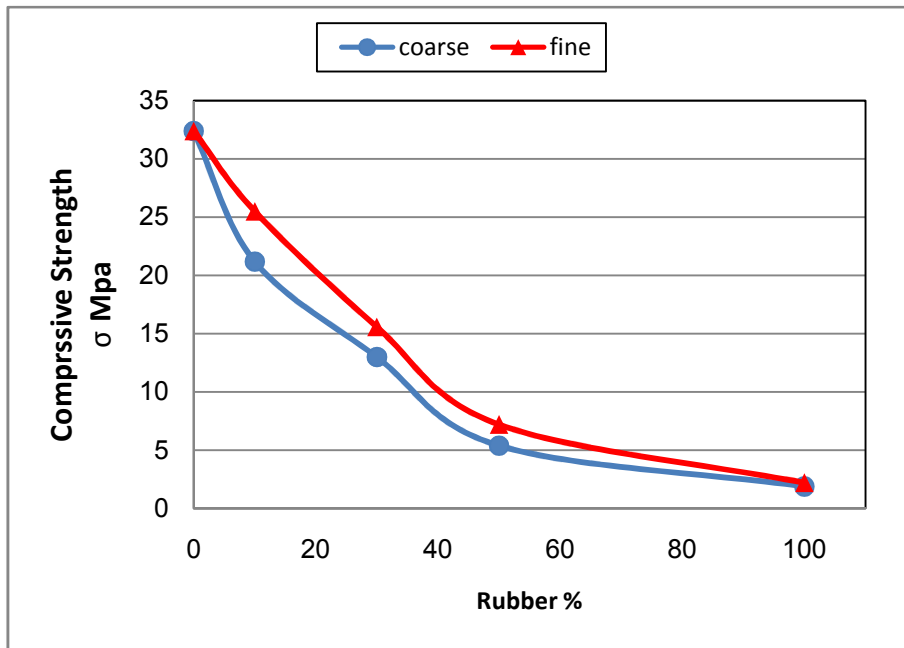


Fig.9. Effect of different rubber percentage on the compressive strength of crumb Rubber-Mortar.

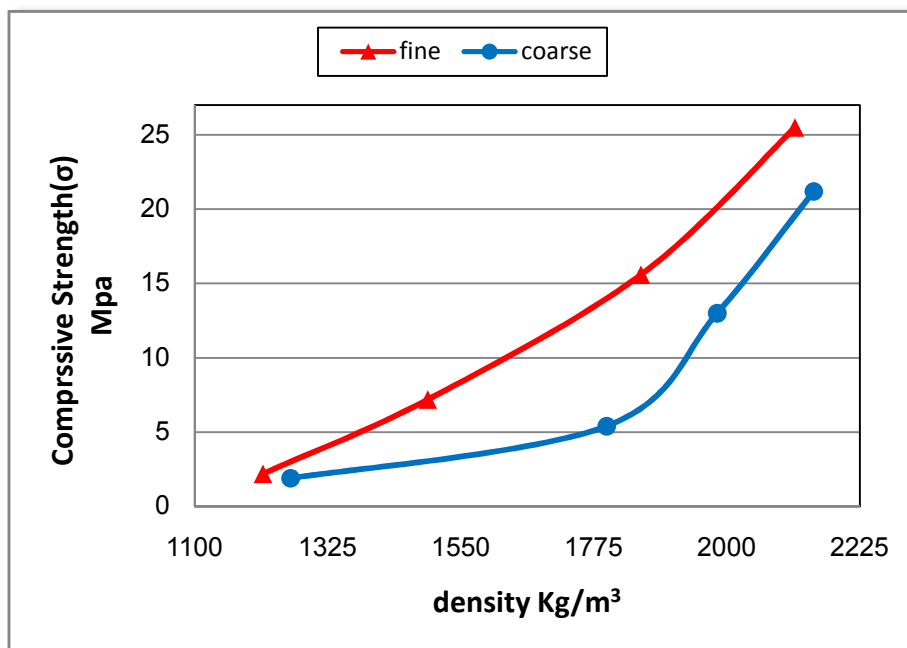


Fig.10. Effect of density difference on the compressive strength of crumb Rubber-Mortar.

The compressive strength of crumb Rubber-Mortar specimens with addition (SBR) latex were measured, as shown in Figs. (11) and (12). An increase in compressive strength was also noted after the addition of (SBR latex) with percentage and density change.

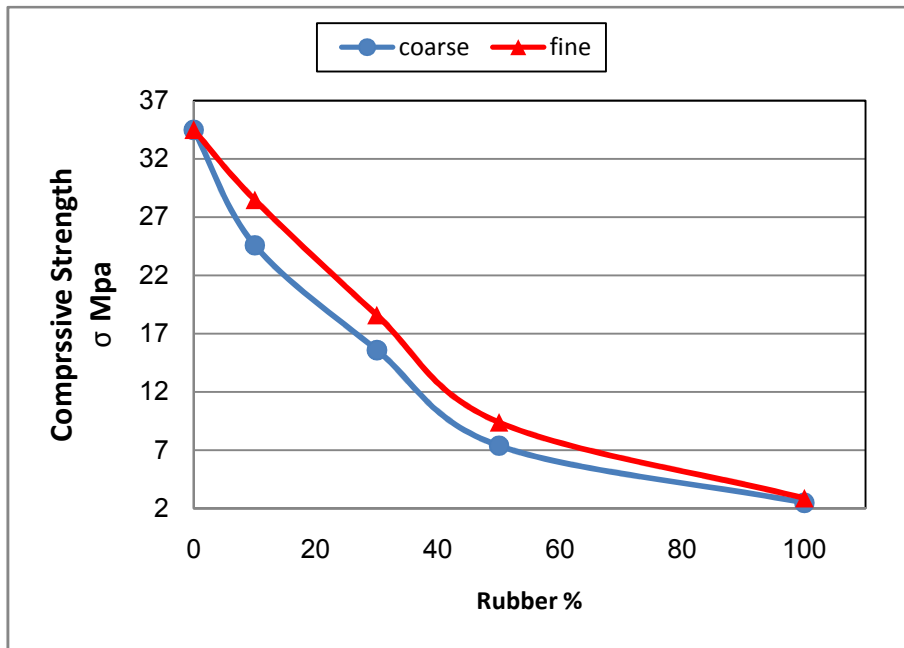


Fig.11. Effect of different rubber percentage on the compressive strength of crumb Rubber-Mortar with SBR latex addition.

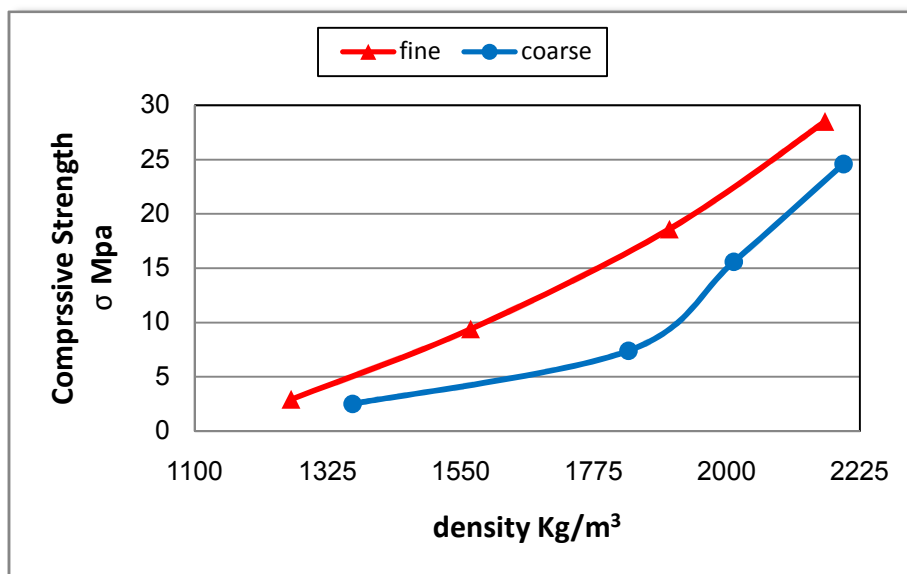


Fig.12. Effect of density difference on the compressive strength of crumb Rubber-Mortar with SBR latex addition.

A reduction in water absorption due to the fact that tire crumb does not absorb water and only the hydrated parts of the matrix retain water. The decrease in absorption when SBR latex are added lead to lowering the void content causing less absorption of water during hydration as in Fig. (13). High results of compressive strength were obtained after the addition of (SBR latex) compared with crumb Rubber-Mortar only, as in Fig. (14) .The decrease in compressive strength, is attributed to the lack of bond between rubber particles and the cement matrix. The addition of SBR latex cause an improve in adhesion between the polymer films that form and

cement hydrates. This action gives less strain compared to ordinary mortar and improves the compressive strength of crumb Rubber-Mortar[12].

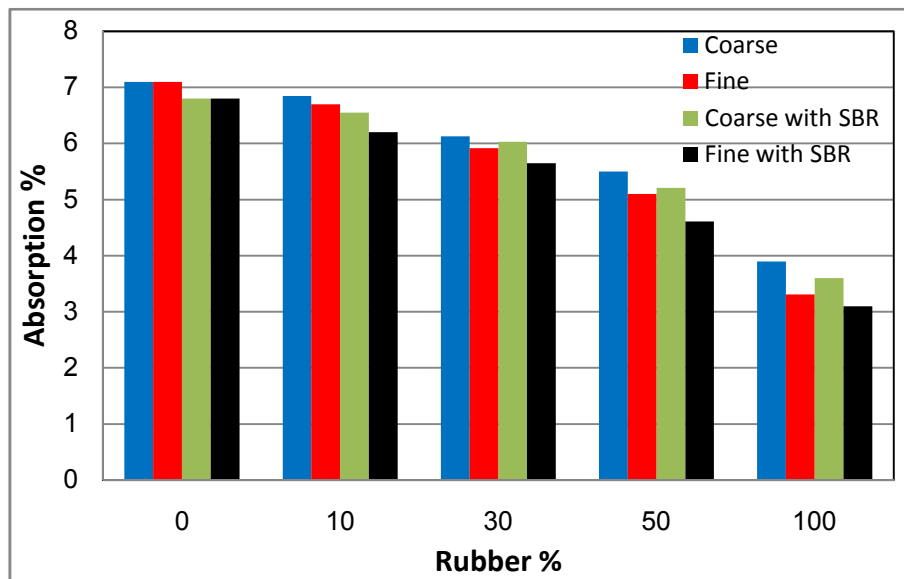


Fig.13. Comparison of water absorption and rubber percentage of Crumb Rubber-Mortar before and after the addition of SBR latex.

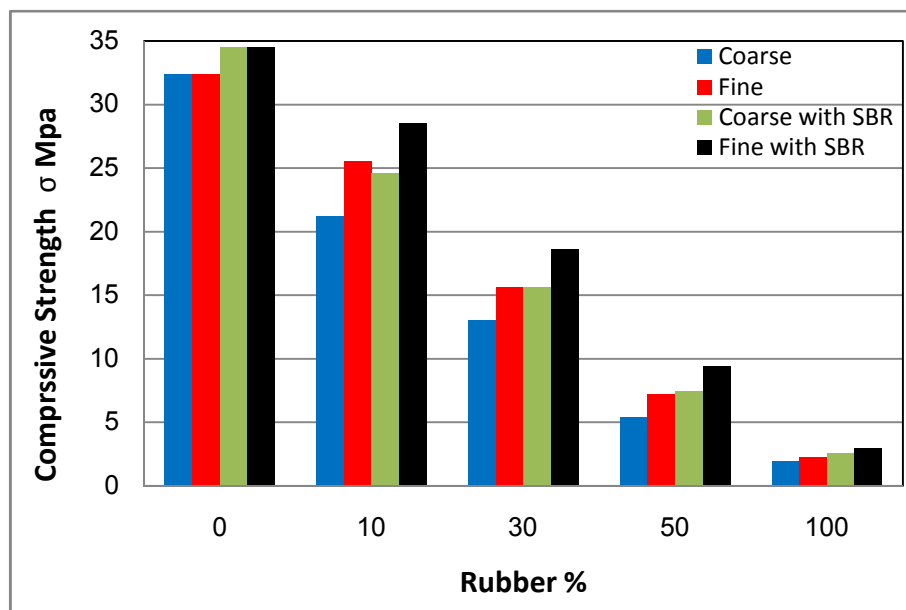


Fig.14. Comparison of compressive strength and rubber percentage of Crumb Rubber-Mortar before and after the addition of SBR latex.

6. Conclusions

The following main conclusions are achieved from this work is:

- 1- An increase in crumb rubber percentage cause decrease in compressive strength and water absorption.
- 2- As the density increases the compressive strength and water absorption increased before the addition of SBR.

- 3- After the addition of SBR to the crumb Rubber-Mortar the compressive strength and water absorption are improved.
- 4- In general fine crumb Rubber-Mortar have better properties than coarse crumb Rubber-Mortar.

6. References

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