Study the Addition of Styrene–Butadiene Rubber Latex on the Workability and Flexural 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 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. Tests were conducted, both in fresh and in hardened state. fresh state test included workability, while hardened state test included flexural strength. Several results were obtained and it was including that the fineness of Crumb Rubber-Mortar play a major role in measuring workability and flexural strength and the addition of SBR to Crumb Rubber-Mortar improve the properties also the increase in crumb rubber percentage cause decrease in flexural strength and workability of fine Crumb Rubber-Mortar, while the increase in crumb rubber percentage cause increase in workability of coarse Crumb Rubber-Mortar.
Keywords: Mortar, Recycled Crumb Rubber, Styrene–Butadiene Rubber, Workability, Flexural Strength, Particles Size.

1.Introduction

The tremendous growth of automobile industry and the increasing use of car as the main means of transportation have increased its production, thus generating huge amounts of tire rubber wastes[1].

Unfortunately a large part of these tires often gets illegally discarded at dumpsites and since tires are not biodegradable, they will remain in landfill with very little degradation over time, presenting a continuing environmental hazard[2].

Tires are bulky, and 75% of the space a tire occupies is void, so that the land filling of scrap tires has several difficulties:

- Whole tire landfilling requires a large amount of space.
- Tires tend to float or rise in a landfill and come to the surface.
- The void space provides potential sites for the harboring of rodents.
- Shredding the tire eliminates the above problems but requires high processing costs[3].

Several attempts have been made to incorporate waste tire particles in the form of coarse, fine and a combination of both in concretes and mortars for the past two decades and recently in the form of ash. Improved efficiency in the performance of the composite has been recorded, especially in terms of density, thermal conductivity, electrical resistivity, ductility, …etc.[4]. One of the largest potential recycling routes is in building and construction, but usage of waste tires in civil engineering is currently very low . This is due to the lack of high volume applications and products involving recycled tires[5]. Out of several management options, the use of waste scrape tire in the production of cement mortar and concrete is a promising path[1]. The workability is also another property affected by the tire rubber addition[6]. the rubberized concrete mixtures possess lower density, increased toughness
and ductility, lower compressive and tensile strength and more efficient sound insulation[7].

2. Aims

This work investigates the influence of the percentage and particles size of crumb rubber, obtained from used automobile tires, on the workability and flexural strength of mortar. Before and after the addition of styrene–butadiene rubber (SBR) latex.

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 and physical properties of Ordinary Portland cement.

Chemical composition			**Physical composition**		
Item	**Content %**	**Limit of Iraqi specification No.5/1984**	**Physical properties**	**Test result**	**Spec. Limit**
CaO	63.19	---	Fineness (m^2/kg)	370	230
SiO_2	20.60	---	Autoclave exp.	0.32	0.8%
AL_2O_3	4.10	---	Compressive strength (MPa) 3-days age	29.5	15.0
Fe_2O_3	4.48	---			
SO_3	1.98	$< 2.8\%$	Compressive strength (MPa) 7-days age	35	23.0
MgO	2.28	≤ 5%			
L.O.I Loss on Ignition	2.45	≤ 4%	Time of setting Initial (min.)	35	45
I.R Insoluble Residue %	0.47	≤1.5%	Time of setting 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	51.8	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).

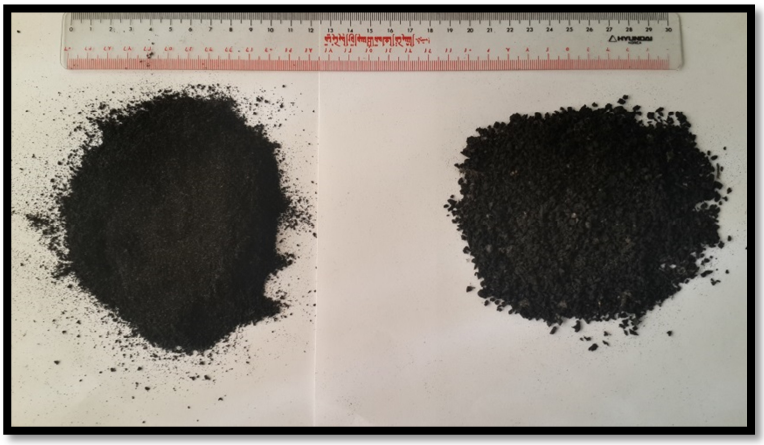

Fig. 1 Different sizes of crumb rubber

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

Chemical composition		**Physical composition**	
Rubber hydrocarbon	**Content %**	**Physical properties**	**Test result**
Rubber hydro Carbon (SBR)	48%	Density	0.95 g/cm3
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) latex, 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 at 20 ^oC
Fire	Non - Flammable
PH	9.0 - 10.0
Boiling Point/Range ^oC	100
Melting Point/Range ^oC	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**	**Water L/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 wit 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 as in fig.(3).

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

Fig. 3. Vibrating table (Viatest Co. German).

4. Tests

Different properties of Crumb Rubber-Mortar were conducted, both in fresh and in hardened state. fresh state test included workability, while hardened state test included water absorption.

4.1 Workability:

Workability of Crumb Rubber-Mortar is measured according to the Flow Table Test of Hydraulic Cement ASTM C230[10] as in fig.(4). The standard flow tests uses a standard conical frustum mold of (50 mm in height, internal diameter: base 100 mm - top 70 mm). Carefully wipe the flow table clean and dry, and place the flow mold at the center. Place a layer of mortar about 25 mm (1 in.) in thickness in the mold and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling of the mold. Then fill the mold with mortar and tamp as specified for the first layer. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straightedge or the edge of the trowel with a sawing motion across the top of the mold. Wipe the table top clean and dry, being especially careful to remove any water from around the edge of the flow mold. Lift the mold away from the mortar 1 min after completing the mixing operation. Immediately drop the table 25 times in 15 s, measure the diameter of the mortar along the four lines scribed in the table top, recording each diameter to the nearest millimeter.

Fig. 4. flow table test

4.2 Flexural Strength Test

The test methods was carried out according to ASTM C348[11]. A standard prisms (40 × 40 × 160) mm rests on two supports and is loaded by means of a loading nose midway between the support (one point load), according to equation(1). Using calibrated testing machine (Sercomp, Controls Co. Italy) of 15 kN capacity at loading rate of 50 N per second. as shown in fig. (5),

$$\sigma_f = 3PL/2bd^2 \quad \text{………………….. Eq. (1)}$$

where:
σ_f = flexural strength (MPa);
P = load applied in the middle of the prism (N);
L = distance between supports (mm);
b = specimen width (mm);
d = specimen depth (mm).

Fig. 5. Calibrated flexural testing machine (Sercomp, Controls Co.) Italy.

5. Results and Discussion

5.1 Workability

The workability of Crumb Rubber-Mortar specimens were measured, as shown in fig (6). The results show that the workability of fine Crumb Rubber-Mortar decrease with increase in rubber percentage while the workability of coarse Crumb Rubber-Mortar increase with increase in rubber percentage. This behavior is due to fine crumb rubber has a large surface area lead to agglomeration and cause less flow i.e.(decrease in workability).Unlike the coarse crumb rubber.

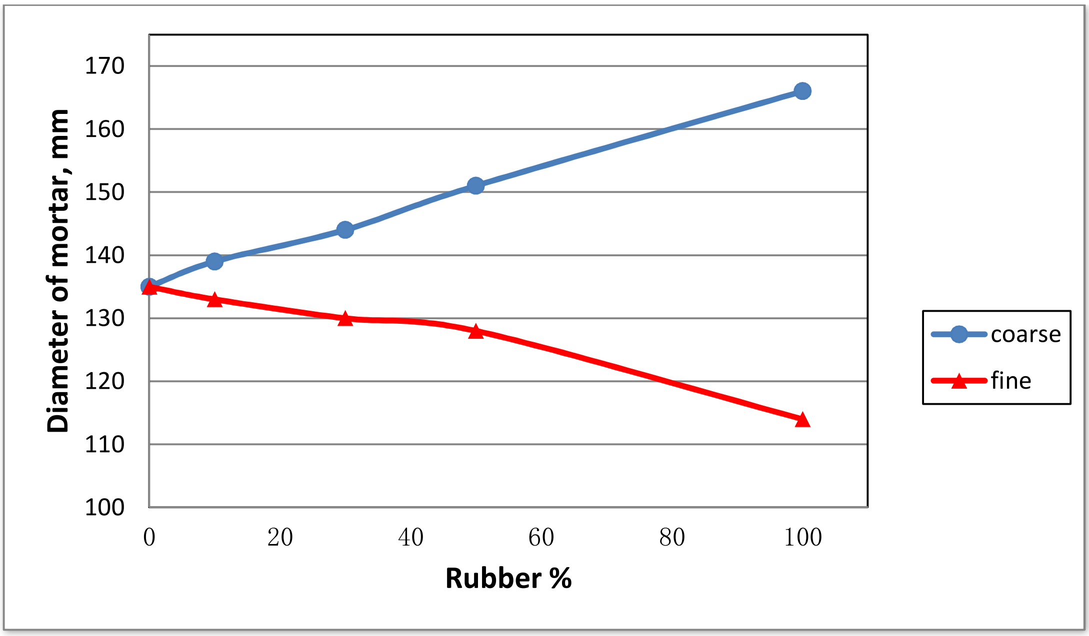

Fig. 6. Effect of different crumb rubber percentage on the Workability of Crumb Rubber-Mortar.

The workability of Crumb Rubber-Mortar specimens with addition SBR latex were measured, as shown in fig (7). An increase in workability was also noted after the addition of SBR latex with percentage change.

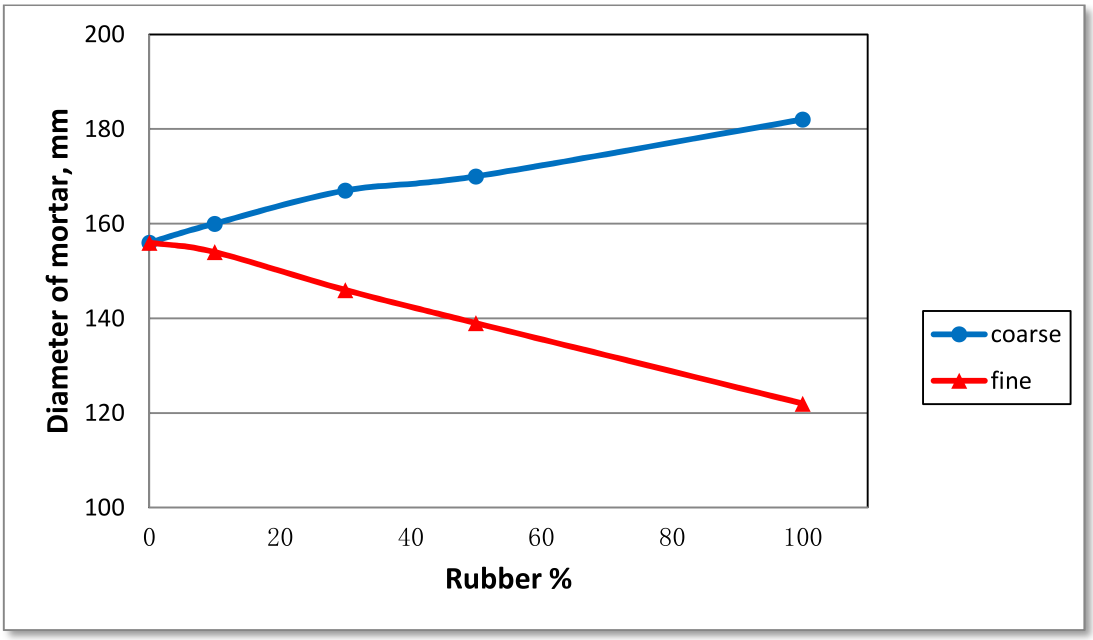

Fig. 7. Effect of different crumb rubber percentage on the workability of Crumb Rubber-Mortar with SBR latex.

5.2 Flexural Strength Test

The flexural strength of Crumb Rubber-Mortar specimens were measured, as shown in fig.(8) and (9). The results show that the flexural strength decrease with increase in rubber percentage. The flexural strength increase with increase in density. Also noted that fine Crumb Rubber-Mortar have higher flexural strength than coarse Crumb Rubber-Mortar.

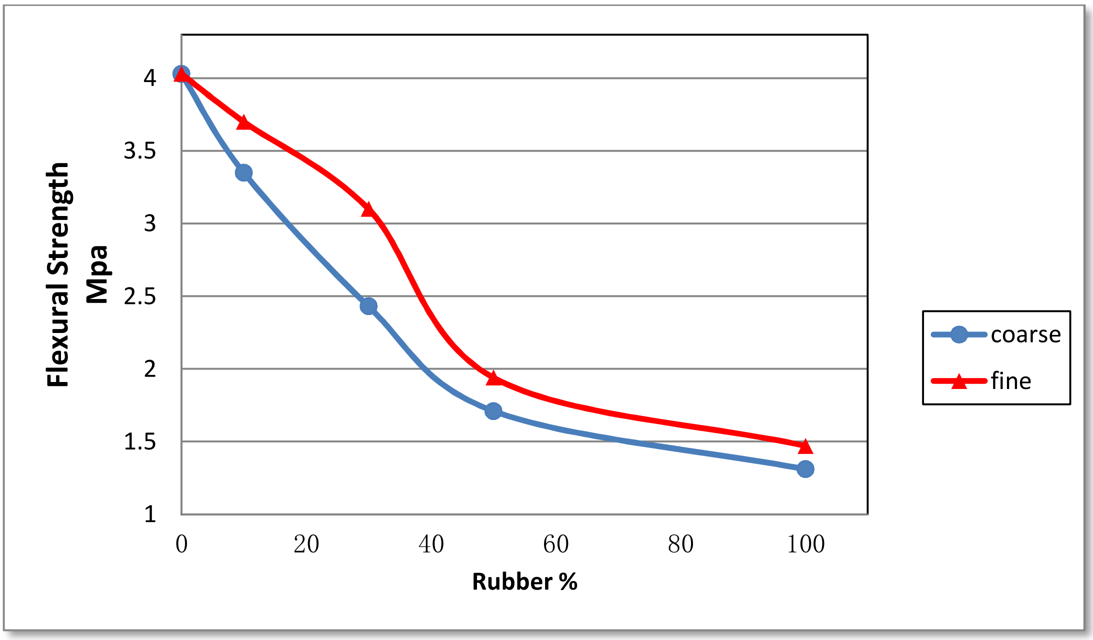

Fig. 8. Effect of different crumb rubber percentage on the flexural strength of Crumb Rubber-Mortar.

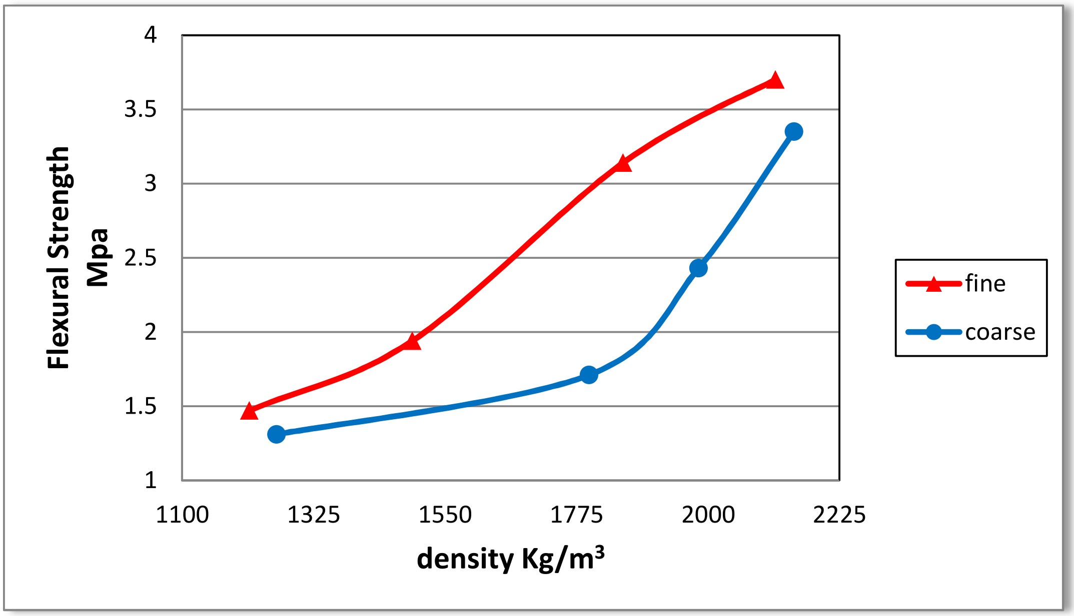

Fig. 9. Effect of density difference on the flexural strength of crumb Rubber-Mortar.

The flexural strength of Crumb Rubber-Mortar specimens with addition SBR latex were measured, as shown in fig (10)and (11). An increase in flexural strength was also noted after the addition of SBR latex with percentage and density change.

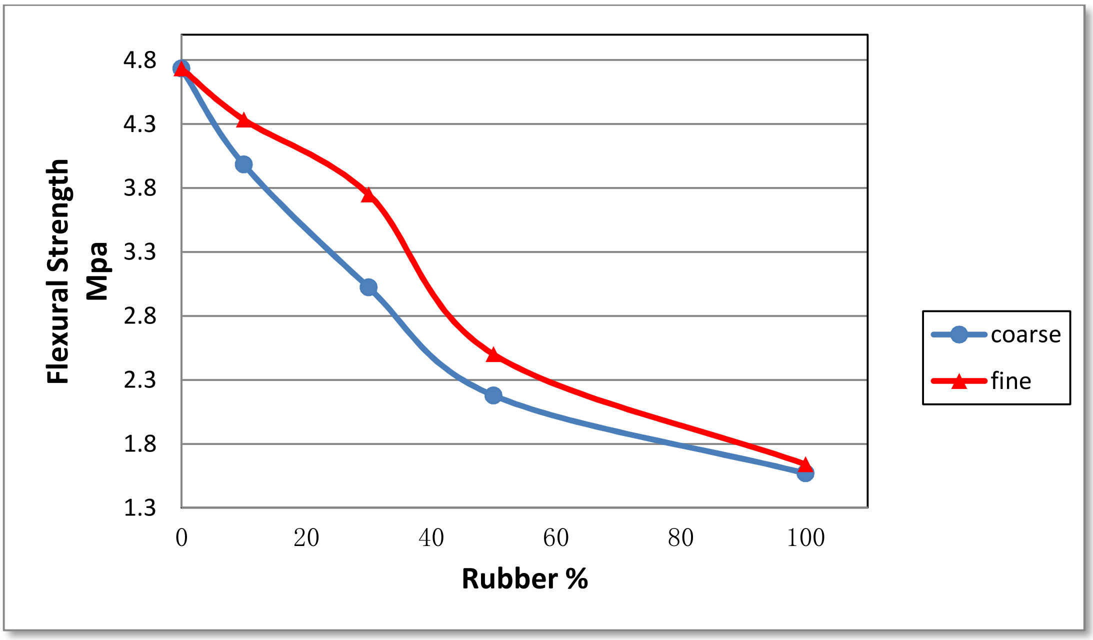

Fig. 10. Effect of different crumb rubber percentage on the flexural strength of Crumb Rubber-Mortar with SBR latex.

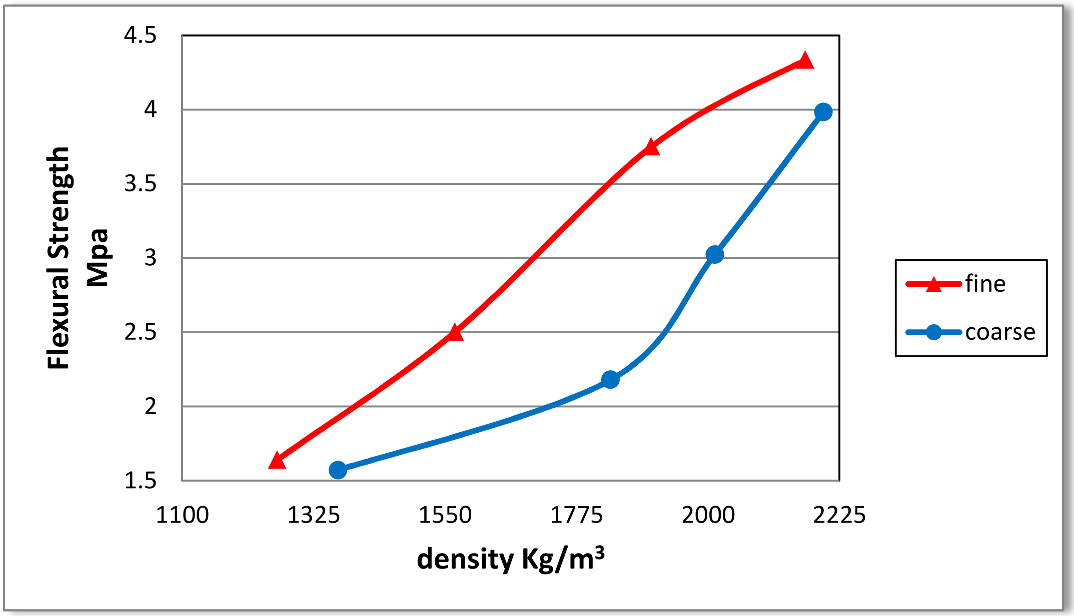

Fig. 11. Effect of density difference on the flexural strength of Crumb Rubber-Mortar with SBR latex.

Generally, Crumb Rubber-Mortar with SBR latex provide a good workability over conventional Crumb Rubber-Mortar. This is mainly interpreted in terms of improved consistency due to the ball bearing action of polymer particles among cement particles[12]as fig.(12). The decrease in flexural 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 flexural strength of Crumb Rubber-Mortar as in fig.(13).

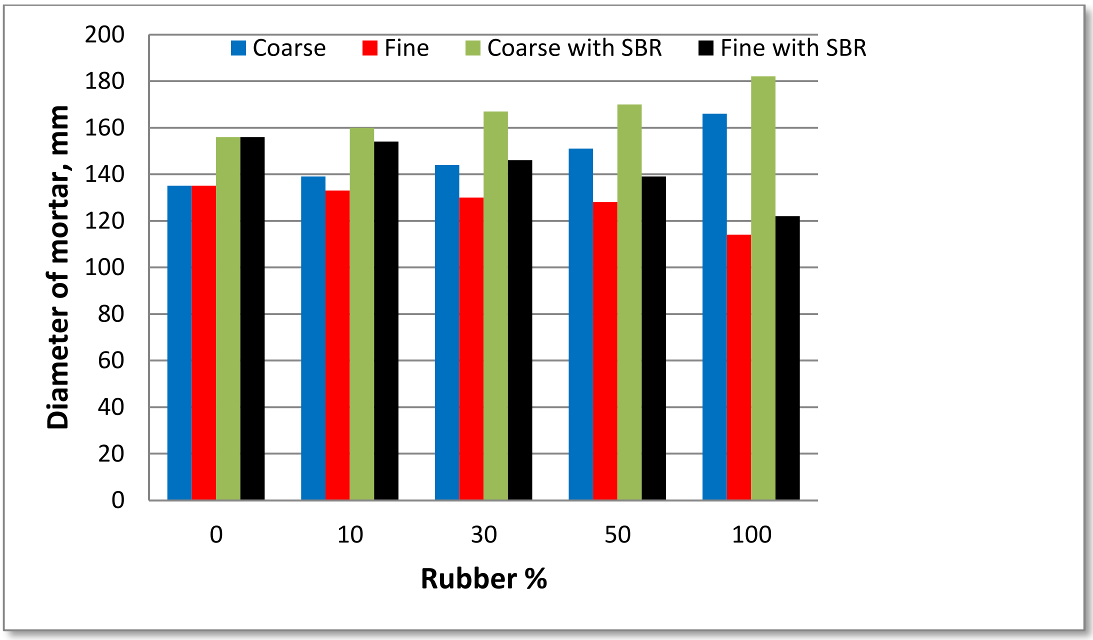

Fig 12. Comparison of workability and crumb rubber percentage of Crumb Rubber-Mortar before and after the addition of SBR latex.

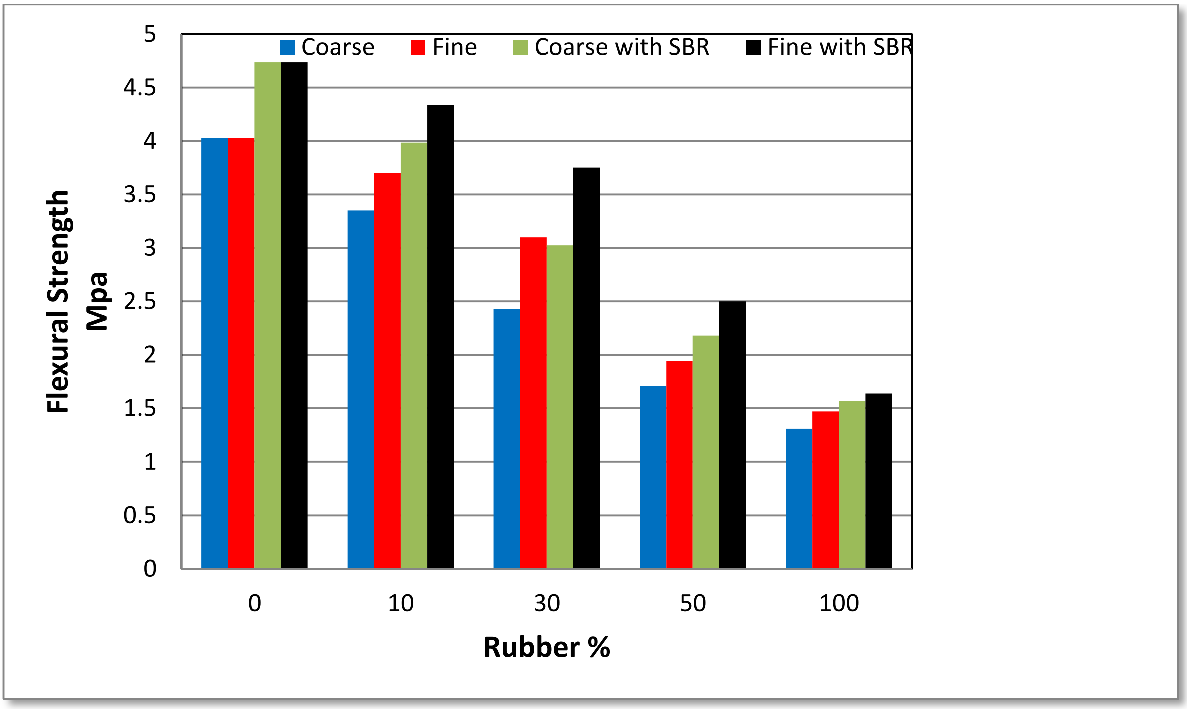

Fig 13. Comparison of flexural strength and crumb rubber percentage of Crumb Rubber-Mortar before and after the addition of SBR latex.

6. Conclusion

The following main conclusion were achieved from this work, fineness of Crumb Rubber-Mortar play a major role in measuring workability and flexural strength, the addition of SBR to Crumb Rubber-Mortar improve the properties, increase in crumb rubber percentage cause decrease in flexural strength and workability of fine Crumb Rubber-Mortar, while the increase in crumb rubber percentage cause increase in workability of coarse Crumb Rubber-Mortar.

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