Mechanical Properties of River Sand Mortar

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Abstract : There are large quantities of river sand not conforming to Iraqi specifications. This research was carried out to establish the effect of river sand on compressive and tensile strength of mortar and the ability to improve these mechanical properties by using Styrene Butadiene Rubber, and accelerated curing. The results show that the using of river sand instead of AL-Ekadir sand increased water demand for mortar and therefore the mechanical properties of mortar decreased. The addition of SBR to mixes improve the performance of mortar by better and easier workability, reduced water demand and increases the compressive and tensile strength for all mortar mixes. Result also demonstrated that, the specimens cured at heightened temperature showed superior performance to those specimens cured normally. The strength of mortar is also affected by the amount of cement in the matrix and the ratio of sand to cement.

1. Introduction

Cement mortar is basically a binding agent that is composed of cementitious material, fine aggregates and water. The main purpose of the mortar is to sew masonry units (blocks /bricks) into single integral unit. Conventionally used mortar is cement sand mortar in the proportion 1:1 or 1:2.

Over the past few decades man has exploited the natural resources at a severe rate. Good quality sand stands first in the list of construction materials that are in the verge of extinction due to, excessive and unnecessary consumption in construction process. One has to adapt to alternative materials that can be used as an effective replacement over sand in masonry mortar without affecting its efficiency.

Thus the use of river sand as alternatives to natural sand for mortars in masonry construction would deliver an efficient-economical and sustainable structure.

2. Characteristics of suitable sand for mortar

Sand is cheaper than cement and it is, therefore economical to put into the mix, but economy is not the only reason for using sand. It confers considerable technical advantages on mortar, which has a higher volume stability and better durability than hydrated cement alone.

We can summarize the important characteristics of suitable sand. It is graded with fineness modules between (3-3.5).

The British specification No.882 limits four zones which are special for suitable sand-graded for concrete. When sand-graded is within one of these zone's it will be suitable in the mixes of the known ordinary ratio.

The sand of zone (4) is very fine and isn't suitable for the reinforced concrete works, but it can be used in finishing works and building mortar.[1]

3. Gap-Graded Aggregate

Gap graded can be defined as a grading in which one or more intermediate size fractions are omitted; the term continuously graded is used to describe conventional grading when it is necessary to distinguish it from gap-grading. On a grading curve gap-grading is represented by a horizontal line over the range of size omitted gap-graded aggregate show greater proneness to segregation.

So when there is a significant tendency for the large and fine particles in mix to become separated for this reason (segregation), gap-graded is recommended mainly for mixes of relatively low workability, such mixes respond well to vibration, good control and, above all, care in handing so as to avoid segregate.

4. Materials

4.1 Cement

Ordinary portland cement was used in this work. The chemical composition and physical properties of such cement are presented in Table (1) and (2) respectively. Test result indicated that the cement conformed to the Iraqi specification No 5/1984.[2]

Table 1. Chemical composition and main compounds of cement used in this work

Oxide	Content percent	Limit of Iraqi specification No-5/1984[2]
CaO	61.7	
SiO_2	21.9	
AL_2O_3	4.6	
Fe_2O_3	2.8	
SO_3	2.3	$\leq 2.8\%$
MgO	3	$\leq 5\%$
K_2O	0.4	
Na_2O	0.21	
L.O.I	2	$\leq 4\%$
I.R	1.4	$\leq 1.5\%$
L.S.F	0.9	0.66-1.02
Main compounds (Bogue's eg.)		
C_3S	42	
C_2S	33	
C_3A	7.1	$> 5\%$
C_4AF	13.7	

Table 2. Physical properties of cement used in this work

Physical properties	Test Result	Limit of Iraqi specification No.5/1984
Specific Surface area Blain method, cm^2/gm	2700	$\geq$ 2300
Soundness Autoclave	0.3%	$\leq$ 0.8%
Setting time (vicats method) Initial setting, hrs:min	2:25	$\geq$ 45min
Final setting, hrs:min	3:30	$\leq$ 10hr
Compressive strength of mortar 3 days N/mm^2 7 days N/mm^2	 16 26	 $\geq$ 15 $\geq$ 23

4.2 Natural sand:

The fine aggregate was AL-Ekadir natural sand passing from $4.75\ mm$ was used in this work. Table (3) and Fig (1) illustrate the grading of natural sand aggregate. Test results indicated the sand conformed to the Iraqi specification. No45/ 1984 [3].

Table 3. Grading, physical properties of Al-Ekadir natural sand.

Sieve size	Cumulative Passing %	Limit of Iraqi specification No. 45/1984, Zone3
4.75 mm	93	90-100
2.36 mm	88	85-100
1.18 mm	76.9	75-100
600 μm	63.5	60-79
300 μm	29	12-40
150 μm	6.8	0-10

Specific gravity = 2.63
Fineness modulus = 2.4
Sulfate content = 0. 13 % Max. 0.5%

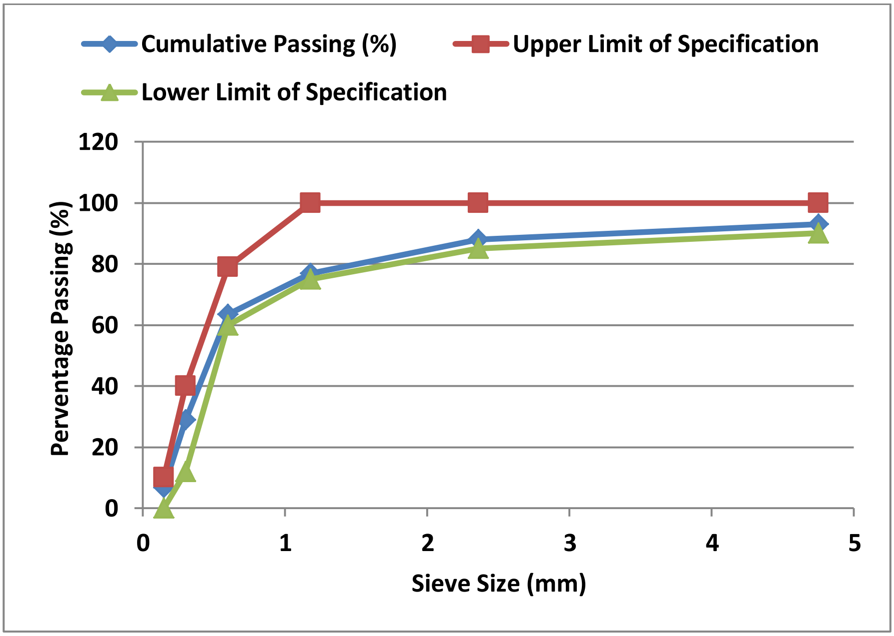

Figure 1. Grading curve for natural sand with grading limits in zone 3.

4.3 River sand:

The river sand used in this work from the banks of Tigris River. It was clean and the percentage of organic matter according to ASTM C40-99 was 0.36%, also the percentage of fine materials passing from sieve No.200 was 4%. The grading of river sand used in this work illustrated in Table (4). It is even finer than that of zone 4 grading.

Table 4. Grading, physical and chemical properties of river sand.

Sieve size	Passing %	Limit of Iraqi specification No. 45/1984, Zone4
600 μm	100	80 – 100
300 μm	95	15-50
150 μm	87	0-15

Specific gravity = 2.6
Fineness modulus = 0.18
Sulfate content = 0.06 % Max 0.5%

4.4 Styrene Butadiene Rubber

The advantages of Styrene Butadiene Rubber used in this work is to give better and easier workability, retarding properties and minimize cracking incidence, higher tensile and compressive strength of the cement mortar. The properties of S.B.R is shown in table (5).

Table 5. properties of Styrene Butadiene Rubber (data sheet)

Appearance	Liquid
Specific gravity	1.04
Solid by volume	29%
Chloride content	Nil
Compatibility with cement	All types of Portland cement

Complies with ASTMC-631. C-932.

4.5 Water

Tap water is used for mixing and curing mortar.

5. Mortar Mixes

Eight types of mortar mixes were investigated in this work. All types of mortar mixes consist of: 1 part of cement and different parts of natural sand or river sand by volume. S.B.R is added to the mortar with dosage of 10% of the cement weight. The proportion specification for all types of mortar mixes are shown in table (6). The water / cement ratio were adjusted to have a flow of 110 ∓ 5 in 25 drops of flow table according to $BS\ EN\ 1015-3$ [4]. All types of mortars were mixed by hand.

Table 6. Mortars mixed proportions

Mortar type	Proportions by volume			S.B.R % by weight of cement	$\frac{w}{c}$
	Portland cement	Natural sand	River sand		
A	1	1	-	-	0.5
B	1	2	-	-	0.6
C	1	1	-	10%	0.4
D	1	2	-	10%	0.5
E	1	-	1	-	0.55
F	1	-	2	-	0.66
G	1	-	1	%10	0.45
H	1	-	2	%10	0.6

6. Preparations and casting of the test specimens

The moulds were well cleaned and the internal faces were oiled to avoid adhesion with the mortar after hardening. The casting was carried out in one layer and compaction was performed by means of vibrating table for a sufficient time to reach full compaction. Finally the mortar surfaces were leveled and specimens were warped with nylon sheets for 24 hours prior de molding to prevent moisture evaporation from the surfaces and to avoid plastic shrinkage cracking.

7. Curing of the test specimens

Two types of curing carried out on the test specimens:

- Normal curing by submerging demoulded specimens in curing water tanks with water temperature maintained at $23\,°C \mp 2$ and kept there until taken out just before testing.
- Accelerated curing by the submerging demoulded specimens in melting pot Fig (2) with water temperature at $370\,℃$ for twelve hours. After then, the specimens leaves in the air until the time of test.

Figure 2. Melting pot

8. Mortar Testing

8.1 Flow Test

The mortar flow test utilizes a specially designed table that repeatedly raises and drops a known quantity of mortar 25 times. During the test, the mortar will spread or flow to form a circular mass (shaped like a pancake), and the diameter of the mass is measured and compared to the initial size. For most mortars the required flow is 110 ∓ 5. The flow test is repeated, until the desired flow is achieved. This test based on BSEN 1015-3.

8.2 Compressive strength test

This test was measured on 50mm cube by using a standard testing machine. The test was performed at ages of 7, 28, 56, days. Each value obtained is an average of three readings measured on three specimens. This test based on BS EN 1015-11.[4]

8.3 Tensile strength test

The specimens will be prepared in briquet gang molds and measured according to ASTM-C-190 by using standard testing machine. The test was performed at ages of 7, 28, 56 days.

9. Results and Discussion

9.1 Compressive Strength

Results indicated that all types of mortar mixes exhibited continuous strength gain up to 56 days as shown in tables 7 and 8. This is mainly due to the progress in hydration process[5] . Figures 3 and 4 show the compressive strength for mix A and E is increased by about (46, 16)% respectively when compared with mix B and F. This increase may be due to the decreasing in sand cement ratio and w/c ratio.

The reduction in sand amount leads to decrease in total surface area and this requires less water, so the gel-space ratio decreases[6,7]. From Figs (3 and 4), it can be seen that there is a reduction in compressive strength at all ages of mortar specimens containing river sand, the percentage reduction in strength was 42% and 12% for mix E and F respectively when compared with mix A and B. This behavior may be attributed to the fact that the river sand is very fine particles, therefore the water demand increased. The increment of water in mix causes increasing calcium hydroxide which leads to reduction in compressive strength [8,9,10].

Results indicated, that the addition of 10% S.B.R by the weight of cement have many benefits. It is observed that not only in hardened state but also in its fresh state. The workability of the fresh mixture is improved over that of ordinary cement mortar, because of plasticizing effect of the S.B.R[11]. The modified system show higher water retention than the ordinary systems. Polymers are added to the fresh mixture as an aqueous dispersion. S.B.R dispersion consist of very small polymer particles, dispersed in water, and are generally formed by emulsion polymerization. The spherical particles with a high molecular weight are held in dispersion with the aid of surface active agents. The surfactants are not only added to allow emulsification during the production process of the dispersion but also to preserve stability of the dispersion until coalescence of the polymer particles in the material take place. After wards, the surfactants badly influence the hydration reactions of the cement, the quality of the formed hydrates and the S.B.R film formation. The favorable properties of the presence of the polymer at the interface between sand and binder can be counteracted by additional air entrainment due to the presence of the surfactants. The cement particles are better dispersed in the mixture and a move homogeneous material is formed [12].

From Table 8 it can be seen the increases in compressive strength mixes at all ages of concrete specimens curing at hot water as compared with normal curing for concrete specimens, table 7. At heightened temperature, the hydration process moves more rapidly and the formation of the calcium silicate hydrate crystals is more rapid. The formation of the gel and colloid is more rapid and the rate of diffusion gel is also higher [13,14].

Table 7. Results of compressive strength test under normal curing

Mortar type	Compressive strength (N/mm^2)		
	7 days	28 days	56 days
A	23.8	28.23	28.75
B	12.94	15.47	15.92
C	28.6	33.43	34.13
D	14.76	19.58	20.23
E	11.62	14.74	14.91
F	9.81	12.97	13.42
G	15.41	18.76	19.61
H	12.14	15.68	16.34

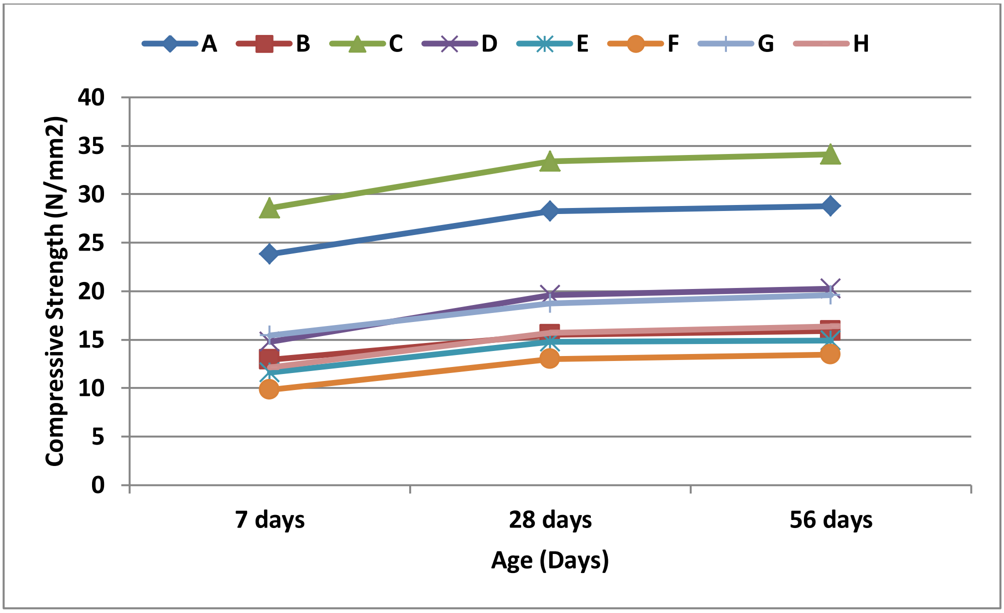

Figure 3. compressive strength of all types of mortars under normal curing

Table 8. Results of compressive strength test under accelerated curing

Mortar type	Compressive strength (N/mm^2)		
	7 days	28 days	56 days
A	30.15	35.56	35.9
B	15.69	19.17	20.1
C	36.12	38.52	38.95
D	19.96	23.29	24.1
E	17.32	20.46	20.78
F	15.92	18.42	19.1
G	24.1	26.62	26.9
H	17.8	20.05	21.01

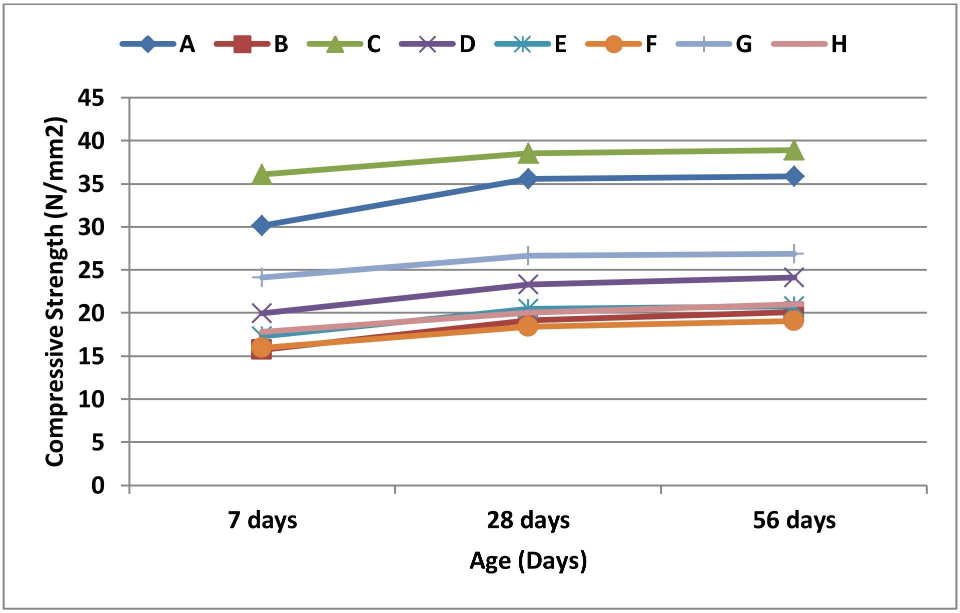

Figure 4. compressive strength of all types of mortars under accelerated curing

9.2 Tensile strength

The effect of using river sand, the using of S.B.R., and the effect of the types of curing on the tensile strength are presented in tables 9, 10 and Figs (5,6). Generally the result demonstrate that all mortar specimens exhibit considerable increases in tensile strength which increases with age as a result of progress in hydration process. The tensile strength of mortars specimens at age 28 days for mix (A) and (E) is increased approximately (32,30)% when compared with mix (B) and (F) for two types of curing. This behavior may be due to the increasing in cement – sand (natural or river) ratio[15,16]. So mortar specimens at 28 days age Fig (5,6) and for mixes E and F containing river sand is reduced by a bout (57,52)% respectively from mixes A and B containing natural sand. This reduction in tensile strength may be associated with content of fine materials in river sand, this tends to decrease the bond strength in cement paste which tends to reduction in tensile strength. Besides, the fine materials absorb much of water, so they tend to swell and obtained internal stress decreasing tensile strength.

The result also show that there is an effect of using S.B.R. as a percentage of cement weight on the tensile strength of mortar specimens containing different sand types for different mixes. From Table (9,10) and Figs (5,6) generally it can be seen that there is increase in tensile strength of all mortar specimens containing S.B.R. this behavior is mainly attributed to mechanism of polymer modification of Portland cement paste [17]. Table 9 and 10 also show that the tensile strength increased with the mortar specimens under accelerated curing. Because the formation of the gel and colloid is more rapid and the rate of diffusion gel is also higher at heightened temperature.

Table 9. Result of tensile strength test under normal curing

Mortar type	Tensile strength (N/mm^2)		
	7 days	28 days	56 days
A	0.97	1.35	1.44
B	0.71	1.00	1.18
C	1.31	1.88	1.9
D	0.89	1.19	1.21
E	0.72	0.99	1.1
F	0.51	0.61	0.66
G	0.95	1.26	1.28
H	0.55	0.73	0.81

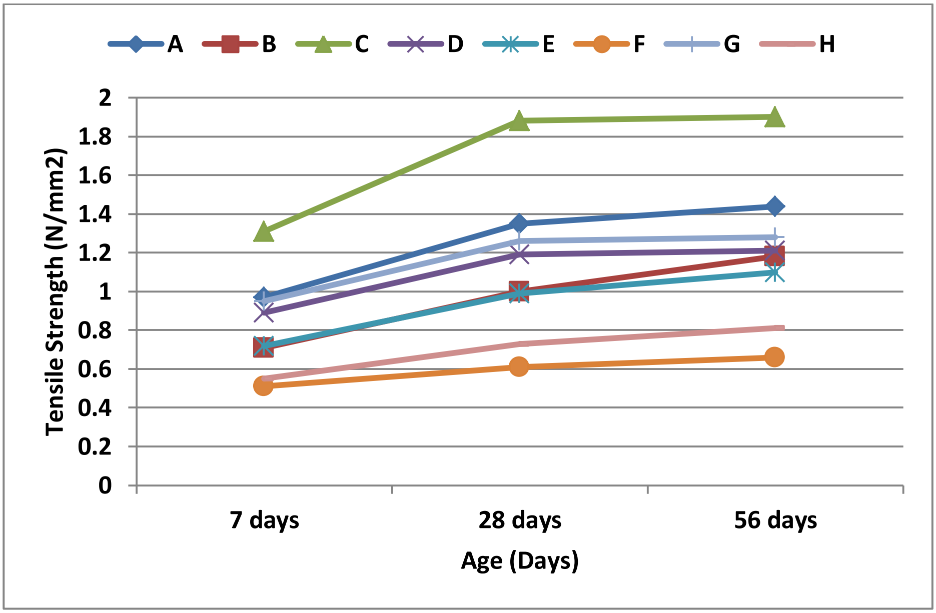

Figure 5. Tensile strength of all types of mortars under normal curing

Table 10. Result of tensile strength test under accelerated curing

Mortar type	Tensile strength N/mm^2		
	7 days	28 days	56 days
A	1.57	1.86	1.98
B	0.86	1.15	1.33
C	1.76	2.1	2.45
D	1.19	1.36	1.58
E	0.9	1.04	1.15
F	0.61	0.81	0.88
G	1.13	1.66	1.84
H	0.71	1.00	1.09

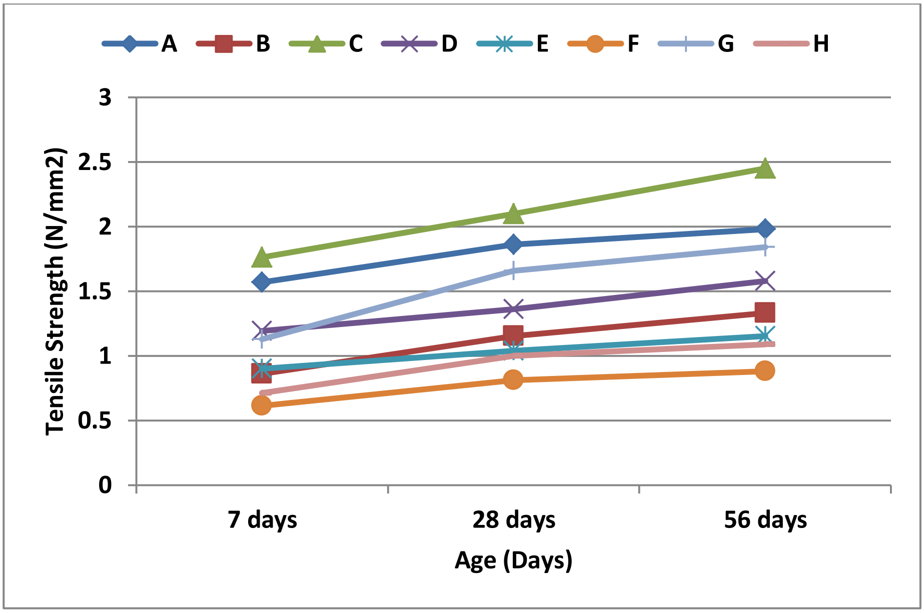

Figure 6. Tensile strength of all types of mortars under accelerated curing

10. Conclusion

The following conclusions can be drawn from the reported experimental study.

1. River sand has a large effect on the workability of fresh mortar and this effect will decrease through increasing water- cement ratio or cement-river sand ratio to get workability similar with AL Ekadir sand. River sand leads to increase the water content in all mixes .
2. S.B.R., improves the workability of all mortar mixes.
3. The compressive strength of mortar containing river sand has a reduction below all mixes containing AL-Ekadir sand. The percentage of reduction in strength was 42% and 12%.
4. River sand has an effect on tensile strength of mortar, so the tensile strength of mortar containing river sand is lower than that of good grading sand AL- Ekadir.
5. S.B.R. reduced water demand therefore enhances tensile and compressive strength.

6. The strength of mortar is affected by the amount of cement in the matrix and the ratio of sand to cementing material .
7. The mechanical strength (compressive strength and tensile strength) are significantly improved with the heat treatment at $370c°$ for all types of mortar mixes.

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الخواص الميكانيكية لمونة الرمل النهري

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المستخلص: توجد هناك كميات كبيرة من رمال الانهر والتي تكون غير مطابقة للمواصفة العراقية. في هذا البحث تم دراسة تأثير الرمل النهري على مقاومة الانضغاط والشد وامكانية تحسين الخواص الميكانيكية للمونة باستعمال (SBR) والمعالجة الحرارية لنماذج المونة. النتائج بينت ان استعمال الرمل النهري بدل من رمل الاخيضر يزيد من حاجة المونة للماء وبالتالي تقليل الخواص الميكانيكية للمونة. ان اضافة (SBR) الى المونة يؤدي الى تحسين اداء المونة عن طريق تحسين قابلية التشغيل والتقليل من احتياج المونة الى الماء وبالتالي زيادة مقاومة الانضغاط والشد لنماذج المونة. النتائج وضحت أن النماذج التي تم معالجتها حراريا بواسطة الماء الساخن تبدي أداءاً متفوقاً على النماذج التي تم معالجتها بالماء الاعتيادي. مقاومة المونة تتأثر كذلك بكمية الاسمنت الموجودة في الخلطة وكذلك نسبة الرمل الى الاسمنت.