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Some Properties of Cement Mortar Modified by Styrene Butadiene Rubber

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ABSTRACT

This research studies the effect of adding five different percentages of polymer (2, 4, 6, 8, and 10% of cement weight) on cement mortar's fresh and hardened properties, which was cured at laboratory temperature for 7, 14, and 28 days. Workability increases with increasing polymer. The workability value was lowest (25.6 and 29.4) % in mixtures containing 2% and 4% of (SBR). Increasing polymer ratios significantly decreased mechanical properties (compressive and flexural strength). Therefore, the best results were at 2% SBR and 4% SBR at 28 days of age. An inverse relationship was recorded between the increase in SBR ratios and polymer-modified cement mortar's compressive and flexural strength values. In general, the highest improvement in the water absorption and dry density resulted in better results with a decrease in the proportion of the polymer for all specimens of cement mortar containing 4% SBR polymer relative to the reference mixture.

Keywords: Styrene-Butadiene Rubber (SBR), Compressive strength, Flexural strength, Polymer Cement Mortar (PCM), Density.

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بعض خواص مونة السمنت الحاوي على مطاط الستايرين بيوتادين

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قسم الهندسة المدنية، كلية الهندسة، جامعة بغداد، بغداد، العراق

الخلاصة

في الآونة الأخيرة ، اجتذب الأداء المتميز لمونة السمنت المعدل بالبوليمر (PMM) اهتماماً متزايداً من كل المجتمعات العلمية والهندسية. أثناء تصلب المونة ، يمكن للبوليمر أن يشكل شبكة أخرى في المادة ، والتي تملأ المسام في طور السمنت وتحسن الترابط بين الركام وعجينة السمنت. اليوم ، تعد المونة المعدل بالبوليمر والخرسانة المعدلة بالبوليمر من أكثر المواد استخداماً في مجال البناء والتشييد. يدرس هذا البحث تأثير اضافة خمسة نسب مختلفة من البوليمر (10،8،6،4،2 من وزن السمنت)٪ على الخواص الطرية والمتصلبة لمونة السمنت ، وعولجت ضمن درجة حرارة الغرفة لمدة 7 ،14 و28 يومًا. تزداد قابلية التشغيل مع زيادة البوليمر. تم العثور على قيمة قابلية التشغيل لتكون الأدنى (25.6 و 29.4)٪ في الخلطات التي تحتوي على 2٪ و 4٪ من (SBR). أظهرت الخواص الميكانيكية (مقاومة الانضغاط والانحناء) انخفاض ملحوظًا عند زيادة نسب البوليمر ، وبالتالي فإن أفضل النتائج التي تحققت هي عند نسبة SBR 2% و بنسبة SBR 4% بعمر 28 يومًا. تم تسجيل علاقة عكسية بين زيادة نسب (SBR) وقيم الانضغاط وقوة الانثناء لمونة السمنت المعدلة بالبوليمر. بشكل عام فان اعلى تحسن في فحص امتصاص الماء ، الكثافة الجافة نتائجاً افضل مع انخفاض نسبة البوليمر ، لجميع نماذج مونة السمنت المتضمنة على 4% بوليمر ال SBR نسبة للخلطة المرجعية) .

الكلمات المفتاحية: مطاط ستايرين بوتادين (SBR)، مقاومة الانضغاط، مقاومة الانثناء، مونة اسمنت البوليمر (PCM)، الكثافة.

1. INTRODUCTION

Polymers have quickly become an integral aspect of modern life. The huge benefits they provide have led to their widespread adoption. **(Mohesson and Abbas, 2020)**. Polymers may be categorized based on molecular weight, structure, and content. Rubber and the third form of plastic, which is pliable when heated, fall into this category of synthetic industrial origin and are thus heat resistant. **(Sabar and Farhan, 2018)**. The plasticizing effect of the addition, which improves the workability of polymer-modified concrete, is only one of the many acknowledged benefits of polymer-modified concrete over traditional concrete. Since SBR doesn't dry up in the fresh mix as water does, greater workability results in a lower water-cement ratio **(Zhong and Chen, 2002)**. Polymer addition improves the water resistance of concrete, and the total entry of water is reduced compared to the water resistance of regular concrete **(Siddiqi et al., 2013)**. The strength of concrete may be diminished by using too much polymer in the mixture **(Ramalho et al., 2019)**. When added to an unaltered cementitious system, SBR's 1% increase in compressive strength is the most noticeable difference **(Doğan and Bideci, 2016)**. However, there seems to be a maximum polymer level beyond which losses in these properties offset further gains in SBR-modified concrete's tensile and flexural strengths **(Park et al., 2004; Atiyah et al., 2016)**. When

added to a cementitious system, SBR helps reduce total voids, which increases durability and resistance to destructive effects. By increasing the density of the microstructure, SBR-modified concrete exhibits increased resistance to chloride ion penetration, leading to enhanced corrosion resistance **(Patel et al., 2019).** Also improved is the concrete's resilience to sulfates once it has set **(Shaker et al., 1997)**. SBR greatly aids the early hydration of cement. The early heat of hydration is mitigated by the addition of SBR, which decreases the exothermicity of the process. This quality makes the mix weaker immediately after it is made, and it also promotes delayed strength **(Qu and Zhao, 2017).** Increasing the proportion of SBR in concrete significantly reduces the thickness of the interfacial transition zone (ITZ), a feature highly valued in this material. Consequently, the hydration products are enhanced, and the synthesis of calcium hydroxide is somewhat inhibited **(Rossignolo, 2009)**. SBR-modified concrete outperforms regular concrete in terms of durability and abrasion resistance because it is subject to lower shrinkage stresses **(Moodi et al., 2018)**. SBR-modified concrete's improved properties suit cutting-edge techniques like 3-D concrete printing **(Kim et al., 2019)**. SBR polymer enhanced the characteristics and behavior of no-fine concrete with particles up to 10 mm in size. The polymer was mixed in at 5%, 7.5%, and 10% by weight of cement. The density, compressive strength, and flexural strength of polymer-modified no-fines concrete were significantly higher than those of the reference no-fines concrete **(Al-Hadithi, 2000.)**. Researched how exposing polymer-modified self-compacting concrete to kerosene and gas oil affects its properties. Compressive strength values for oil-exposed PMSCC (15% P/C ratio) declined less than those for reference concrete. All concrete mixes, regardless of age or polymer component %, see present-day gains in flexural strength. When exposed to oil products, a 15% P/C ratio of PMSCC performed better than the reference concrete mix in total water absorption **(Fawzi and Weli, 2016)**. The mechanical characteristics of concrete reinforced with steel fibers and acrylic polymer were investigated. According to his findings, the compressive strength of polymer-reinforced concrete made with steel fibers rose by (44.81-86.64), the splitting tensile strength by (102.4% -124.79), and the flexural strength by (24.2% - 48.3%) **(Subhi, 2008.)**.The results of using superplasticizer and SBR in lightweight aggregate concrete with porcelainize were investigated. She determined that a cement concentration of 550 kg/m3 was employed, with a density and compressive strength at 28 days between 1965.05 and 1818 kg/m^3 and 17.08 and 34.8 MPa, respectively **(Al-Duleimy, 2005)**.
This work aims to study the effect of incorporating polymer latexes in mortar to enhance the desired properties and produce durable structures. This research attempts to determine the fresh and hardened properties of SBR-modified mortar by varying the polymer content in percentages of 2, 4, 6, 8, and 10. Much research on polymer-modified mortar has been done previously, but this research aims to study the effects of greater SBR addition in mortar and comment on its usefulness and compatibility with mortar.

2. EXPERIMENTAL WORK

3.1 Materials

3.1.1 Cement

For the control batch, we utilized Portland cement made at the AL-Kebisa Factory, considered a typical variety. **Tables 1** and **2** show the results of a chemical analysis and a physical property test performed on the cement to verify that it conforms to the Iraqi requirements **(IQS No. 5, 2019) (type/ 42.5 N).**

Table 1. Chemical analysis of cement according to **(IQS No. 5, 2019)**

Oxides	Percentage %	Limitations of the Standard
Calcium Oxide (CaO)	62.6	
Silica oxide (SiO_2)	21	
Aluminum Oxide (Al_2O_3)	4.92	
Magnesium oxide (MgO)	3.33	5 (max)
Iron Oxide (Fe_2O_3)	3.08	-
Sulfur trioxide (SO_3)	2.16	2.8 (max.)
Loss of ignition (LOI)	1.5	4 (max.)
Insoluble residue (I.R.)	0.6	1.5 (max.)

Table 2. Physical tests of cement **(IQS No. 5, 2019)**

Characteristics	Result	Limitations of the Standard
Fineness (m^2/kg) by Blaine method	348	250
Setting time Initial (minute) Final (hour)	106 3:36	45 minutes (min.) 10 hours (max.)
loading strength rate (MPa) 2 days 28 days	12.5 33.63	10 (min.) 32.5 (min.)

3.1.2 Fine Aggregates

The fine aggregates met all the criteria, including a suitable gradation, the absence of contaminants that can skew test findings, and sieve-through-ness at 0.6 mm. **Tables 3 to 5** detail the grading of aggregates and their physical features; these aggregates satisfy the demands of **(ASTM C778, 2013),** the Iraqi specification **(IQS No.2080, 1998),** and the Iraqi standard **(IQS No.45, 1984),** respectively.

Table 3. The Requirements of **(ASTM C778, 2013)**

Sieve size(mm)	Passing by weight (%)	Limit of Passing percentage % according to ASTM C778-13
1.18 mm (No. 16)	100	100
850 µm (No. 20)	99.5	85 to 100
600 µm (No. 30)	4	0 to 5

Table 4. Iraqi Specification **(IQS No.2080, 1998)**

Sieve size(mm)	Passing by weight (%)	Limit of Passing percentage % according to IQS No.2080-98 Specification
850 µm (No. 20)	99.5	98 min
600 µm (No. 30)	4	10 max

Table 5. Properties of the Sand Used in This Work

Physical Properties	Test result	Limit of Iraqi specification No.45, 1984
Specific gravity	2.6	-
Absorption %	1	-
Sulfate content %	0.35	0.5%

3.1.3 Polymer

Polymer cement mortar mixes were made using unprocessed Styrene Butadiene Rubber (SBR) polymer (PCM). SBR polymer's physical properties are listed in **Table 6**.

Table 6. Physical properties of SBR polymer.

Specifications	Given by the Company
Appearance	White emulsion
Specific Gravity	1.02 ± 0.2 @ 250 ^{o}C
Chloride content	Nil (EN 934-2)
pH value	7 - 10.5

3.1.4 Mixing Water

In this investigation, researchers only utilized water that had been purified to remove any potentially dangerous chemicals **(IQS No. 1703, 1992)**.

3.2 Mix Proportions

The fine aggregate and cement were put into a mechanical mixer of capacity (0.1) operated by electrical power. Dry mixing was maintained until the dry mix became homogeneous, at which point the polymer (SBR) was added in various volume ratios by weight of cement (2%, 4%, 6%, 8%, 10%). This process is similar to the method employed by (**Ohama, 1997)**, using six different groups of mixes until all particles are thoroughly coated with a polymer and then adding water and mixing until a homogeneous mixture is achieved. **Table 7** displays the cement-to-sand ratios that are used in this study. Before usage, (**ASTM C192, 1988)** required that the molds be gently oiled with mineral oil. Multiple layers of casting were used to create cubes, cylinders, and prisms, with each layer measuring 50mm in thickness. To ensure that no air bubbles would rise to the surface of the mortar, we used a vibrating table to crush each layer for fifteen to thirty seconds before smoothing it out to the top of the molds. After 24 hours in the lab, the specimens were unmolded. They were placed in water for 72 hours, removed from the water, and kept in a controlled environment until testing.

3.3 Tests

3.3.1 Compressive Strength

A material's ability to bear axially directed forces may be gauged by measuring its compressive strength. At 7, 14, and 28 days old, we used ELE compression testing equipment with a 2000 K.N. capability to measure the compressive strength of 50 mm cube specimens. The (**ASTM C109/C109M, 2020)** standard was used for the compressive strength test. Each kind of mortar (water, partly water, and air cured) had its strength evaluated using three cube examples.

Table 7. The used Mixes in this work.

Mixes	Cement: sand	Water: cement%	Polymer: cement%
Mix 1	1:3	0.58	0
Mix 2	1:3	0.4	2
Mix 3	1:3	0.4	4
Mix 4	1:3	0.4	6
Mix 5	1:3	0.4	8
Mix 6	1:3	0.4	10

3.3.2 Flexural Strength

The Prisms measuring (40*40*160) mm and meeting (**ASTM C348, 2008)** standards were used to measure the flexural strength (modulus of rupture). Ages 7, 14, and 28 days were used to determine the central point load system of three prisms for each blend. For the flexural test, digital electric testing equipment from ELE was used, having a capacity of 10 kilonewtons.

3.3.3 Dry Bulk Density

The American standard conducted the paper's density test (**ASTM C642, 2013).** Density was found by dividing the cube's weight by the cube's volume. The samples' ages were 7, 14, and 28 days.

3.3.4 Absorption

There were three samples from each curing condition, and they were all dried in a 105 °C oven for a day. The (**ASTM C1403, 2015)** prescribed procedure called for oven-dried samples to be submerged in water for 24 hours. The weight change following water immersion allowed us to determine how much water was absorbed by the dry samples.

4. RESULTS AND DISCUSSIONS

4.1 Compressive Strength

Figs. 1 and 2 show the compressive strength findings for regular mortar and PMM specimens for all mixes and the development of strength with age, respectively.

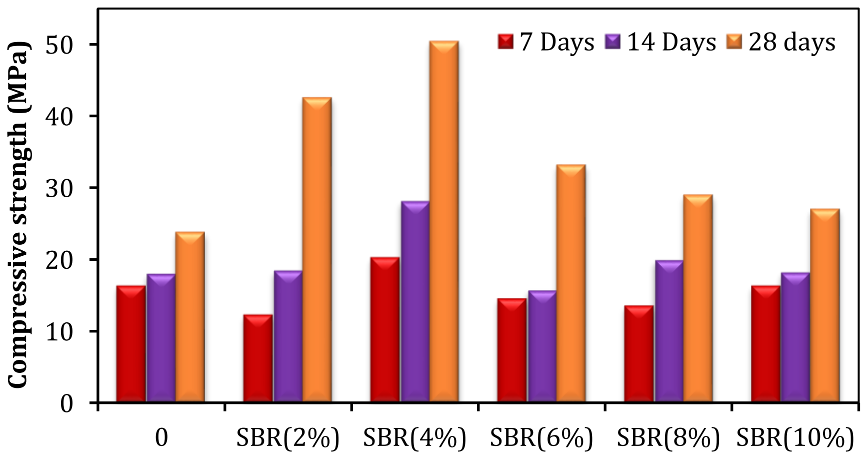

Figure 1. Compressive strength and SBR are related.

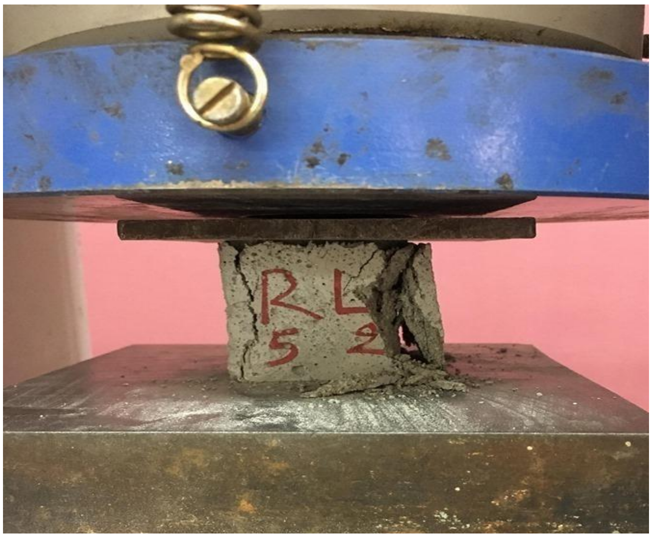

Figure 2. Testing cubic concrete sample.

Table 8 displays the results of a compressive strength test conducted on 5 mm cement mortar cubes after 7, 14, and 28 days of curing at a range of powder-to-binder (p/c) ratios. As the percentage of polymer in the mix grows, the compressive strength also rises; however, once the percentage of polymer drops to 4%, the mix's compressive strength drops but is still greater than that of the reference mix. There are three possibilities for this boost in compressive strength. For starters, the lower w/c ratios in (PMM) result in greater strength. In addition, the polymer's strong bonding characteristics also build continuous three-dimensional networks of polymer molecules throughout the concrete, increasing the binder system. Finally, pores may be partially filled with polymer, decreasing porosity and enhancing strength **(Al-Hadithi et al., 2010; Ali et al., 2012).**

Table 8. Compressive Strength Test Results**.**

Mix type	Compressive strength (MPa)		
	Age of specimens (day)		
	7	14	28
SBR0%	16.3	18	23.8
SBR2%	12.3	18.5	42.6
SBR4%	20.2	28.1	50.5
SBR6%	14.5	15.7	33.2
SBR8%	13.6	19.9	29
SBR10%	16.3	18.1	27.03

4.2 Flexural Strength

Table 9 displays the flexural strength results for the different mortar specimen types at ages 7, 14, and 28. **Figs. 3 and 4** show the correlation between flexural strength and p/c ratios of polymers of varying molecular weights. When the polymer was added, flexural strength increased to a certain point (4%) but dropped off. The same factors contributing to a rise in compressive strength are responsible for this. Up to a ratio of 4%, flexural strength also rises. The flexural strength drops after (4%), but it's still higher than the reference mix.

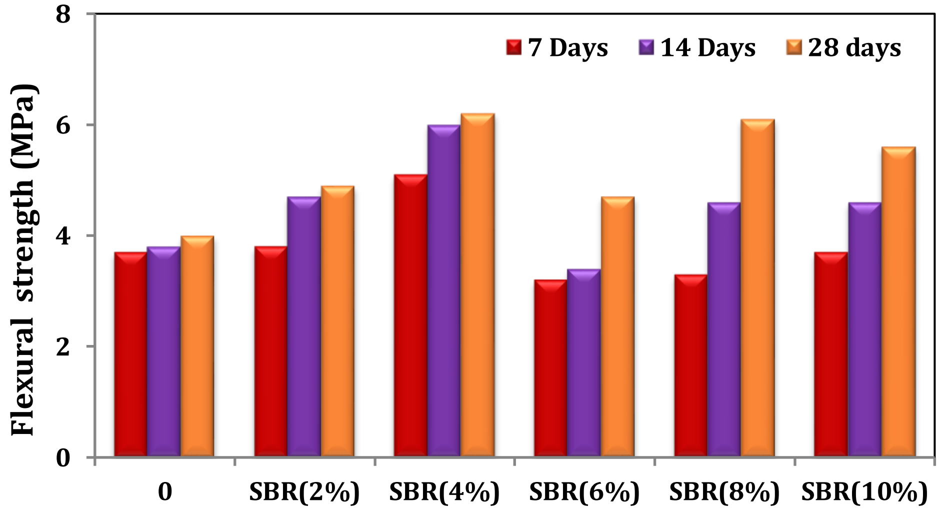

Figure 3. Relationship between Flexural strength and SBR.

Table 9. Flexural Strength Test Results.

Mix type	Flexural Strength (MPa) Age of concrete (day)		
	7	14	28
SBR0%	3.7	3.8	4
SBR2%	3.8	4.7	4.9
SBR4%	5.1	6	6.2
SBR6%	3.2	3.4	4.7
SBR8%	3.3	4.6	6.1
SBR10%	3.7	4.6	5.6

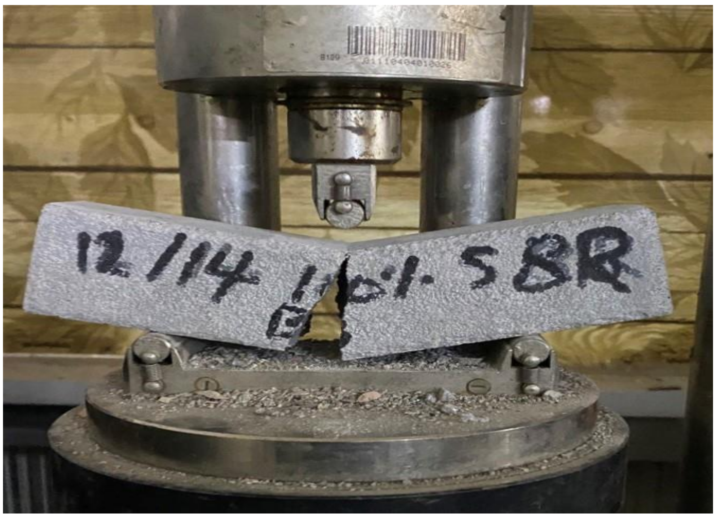

Figure 4. Testing a prismatic concrete sample.

4.3 Density

Table 10 displays the rise in density at the age (of 28) for various mixture types. The density is shown to grow with age. The major causes of this growth are the constant polymer layer development and the hydration products of concrete. Increasing polymer amounts lead to higher densities, as seen in **Fig. 5**, which shows an initial jump in density at (p/c = 2%) followed by a dip before rising again. This boost is attributable to a combination of factors, including a decreased (w/c) ratio, increased compaction, and higher voids **(Al-Hadithi, 2005).**

Table 10. Density Strength Test Results

symbol	Density (kg/m^3) 7 days	Density (kg/m^3) 14 days	Density (kg/m^3) 28 days
R	2213	2240	2288
SBR2%	2357	2365	2272
SBR4%	2208	2220	2104
SBR6%	2200	2200	2184
SBR8%	2320	2264	2208
SBR10%	2373	2309	2320

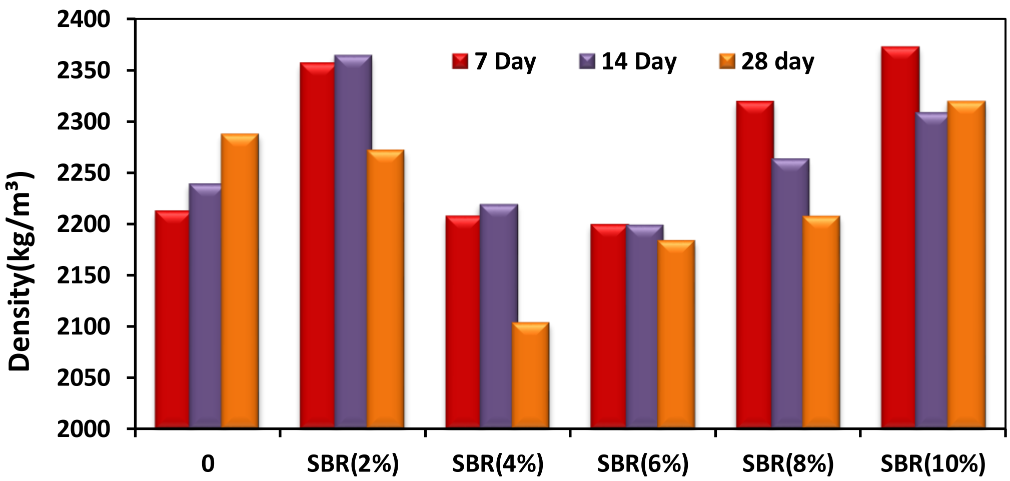

Figure 5. Relationship between density and SBR.

4.4 Absorption

Polymer-to-cement ratio and how well polymeric concrete drains water. **Fig. 6** shows that the situation is as expected. The normal water absorption rate of polymeric concrete decreases with increasing polymer concentration. Since the polymers in polymeric concrete have converged into assemblies or bundles, a polymeric film is attached to the surfaces of the unhydrated cement particles in the concrete mix, allowing for a high water absorption rate. In keeping with what has been discussed, this membrane will assist in maintaining moisture and accelerating the hydration of cement. Therefore, SBR polymer particles, including aggregates of such polymers, will be present in concrete mixes at a high (polymer: cement) (more) ratio **(Sujjavanich et al., 1998).** This means the finished polymer films will have a more exposed area.

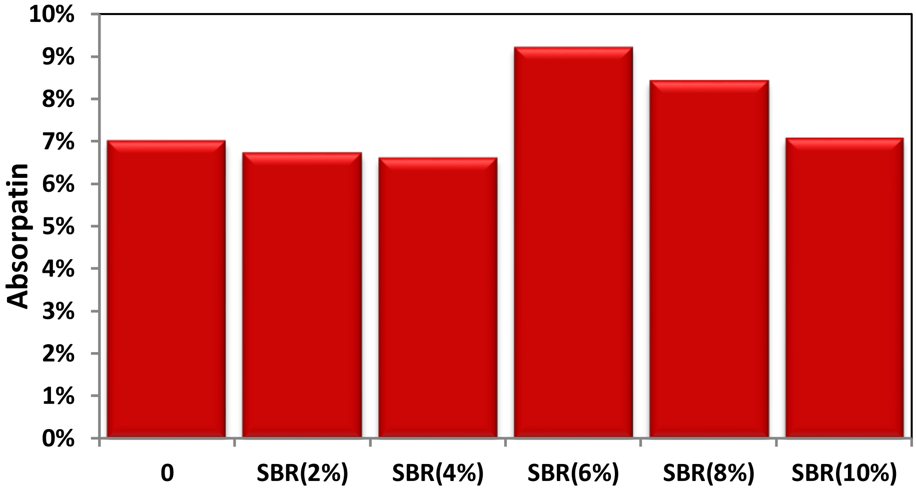

Figure 6. Relationship between absorption (%) and SBR at 28 days**.**

5. CONCLUSIONS

In this work, five PMM mixing formulations were developed to have optimum values in the physical and mechanical properties. Based on the experimental results presented in this work, these conclusions can be drawn:

1. By incorporating SBR into the PCM, the material gains improved compressive strength, flexural strength, thermal conductivity, and water absorption. It has been shown that a (polymer: cement) weight ratio of 4:1 is optimal for creating certain mechanical qualities, with the acrylic polymer content being 4% of the total mix.
2. The continuous polymer network created inside the mortar body, the enhanced link between hydration products and the polymer network, the partial filling of pores with polymer, and the decreased water content are all hypothesized to be responsible for the enhanced mechanical capabilities.
3. The highest compressive strength of 50.5 MPa was achieved at 28 days at SBR 4%.
4. The highest flexural strength of 6.2 MPa was achieved at 28 days at the ratio SBR 4%.
5. There is a little rise in mortar density due to the use of the polymer. After 28 days, the highest density of the polymer cement mortar was 2,320 kg/m^3 at the ratio SBR 10%. The lowest density of the polymer cement mortar was 2104 kg/m^3 at the ratio SBR 4%.
6. Water absorption is decreased by using a polymer. The optimum absorption percentage was 6.6%, at the ratio SBR 4%.

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