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Influence of Fiber Types on the Mechanical Properties and Physical Behavior of Polymer-Based Repair Mortars

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Abstract – This research investigates the performance of repair mortars using cement modified with 5% styrene-butadiene rubber (SBR) based on various properties, including spreading and wet density, mechanical strength (flexural and compressive), and transfer properties (total shrinkage). The mortars were further enhanced by the addition of vegetable and glass fibers at rates of 0.1, 0.3, and 0.5% relative to the total volume. The vegetable fiber employed in this study is hemp, which was pre-treated with 5% NaOH for 2 hours. Additionally, 10% silica fumes were used as a cement additive in all the mixtures.
The findings demonstrate that the polymer mortar reinforced with 0.5% hemp fibers exhibited a notable increase of 14% and 9.5% in flexural and compressive strength, respectively, at 28 days when compared to polymer mortars without fibers. In terms of total shrinkage, mortars containing 0.3% or 0.5% hemp fibers showed superior long-term dimensional stability in comparison to those with glass fibers.
These results strongly suggest that incorporating plant fibers, such as hemp, into cement materials modified by a polymer like styrene-butadiene rubber holds great promise for future applications.

Keywords – Repair Mortar, Styrene-Butadiene Rubber (SBR), Hemp Fiber, Glass Fiber, Mechanical Performance, Shrinkage,

I. Introduction

For almost two centuries, concrete has held significant importance in civil engineering and architectural constructions [1]. However, various factors such as chemical attack, thermal or mechanical shock, etc., can lead to concrete degradation [2]. Fortunately, there is a wide array of specialized products available for repairing deteriorated structures, and among these materials, latex-modified polymers stand out.

Studies, including [3] have shown that the presence of polymers in repair mortars enhances fluidity and toughness while reducing water absorption. This improvement is attributed to the film-forming properties of the polymers, which effectively fill gaps between the base materials, leading to increased adhesion and cohesion in cementitious mortars and concretes [4]. It is essential to note that the properties of polymer mortars (PM) can be influenced by various factors, such as the type of polymer used, the cement/polymer ratio, water/cement ratio, and curing conditions [5]. In recent years, styrene-butadiene rubber (SBR), styrene-acrylic ester

(SAE), and polyacrylic ester (PAE) have been the primary types of polymers utilized. Research by [6] indicates that SBR latex-modified cement mortars, with incorporation rates ranging from 0% to 20% by weight of the cement, exhibit superior properties concerning flexural and compressive strength, weight loss, and capillary adsorption compared to SAE and PAE latex-modified mortars.

Notwithstanding the benefits of polymer-modified cement mortars, there are some drawbacks associated with them [7].]. Studies conducted by [8] and [7] reveal that polymer mortars tend to be brittle, leading to relatively low resistance against crack propagation. In response to this limitation, researchers have turned their attention to incorporating fibers in mortars and concretes to enhance their properties, increase ductility, and restrict crack propagation [8]. Various types of fibers have been explored for composite reinforcement, including metallic, organic (polypropylene, glass), and vegetable fibers such as hemp, sisal, and date palms [9]. Research conducted by [10] demonstrated that the addition of 1% polypropylene fiber and 20% SBR latex significantly enhances the flexural strength, fragility index, and resistance to shedding abrasion of cementitious mortar. The polymer matrix forms a strong bond with the fibers due to the presence of thin polymer films that gradually fill the voids between the composite particles, resulting in improved tensile strength and toughness of polymer-based mortars [9].

In addition to polypropylene, glass fibers have also been used as reinforcements in polymers due to their mechanical qualities and stiffness in the cement matrix [11]. According to [7] the incorporation of fiberglass increases tensile strength, flexural strength, and compressive strength by approximately 8%-10% in polymer mortars. Furthermore, [12] discovered that the inclusion of glass fibers changes the failure mode of polymer mortars, making it more ductile. However, it should be noted that the cost of these fibers is high, and their production emits a significant amount of CO2 gases while utilizing non-renewable resources [13].

Due to economic and environmental considerations, the construction industries have sought alternatives to organic and synthetic fibers [14]. Natural fibers have emerged as a viable option since they are readily available in nature, renewable raw materials, and cost-effective compared to conventional fibers [15]. In 2016, the annual production of natural fibers exceeded 100 million tonnes, and this number was projected to reach around 115 million tonnes by 2021, underscoring the economic and ecological significance of these fibers. [16]

Studies have indicated the positive impact of incorporating natural fibers, such as sisal fiber, in polymer mortars, leading to improved tensile strength and toughness of the composites [17]. Likewise, the addition of 1.5% bamboo fiber to 10% latex resulted in favorable performance in terms of compressive, tensile, and flexural strength [4]. Moreover, the utilization of 2.5% processed pineapple fiber was found to be highly effective in enhancing the flexural and compressive strength of polymer-modified mortars [16]. The inclusion of commercial acrylic latex in the cementitious matrix was also found to enhance the bond between chemically pretreated hemp fibers and the matrix, leading to reduced water porosity in the composite [18].

This paper focuses on investigating the impact of varying the rates of glass and hemp fibers on the physical and mechanical behavior of cement mortars modified with 5% styrene-butadiene rubber (SBR). Different dosages of hemp fiber or glass fiber (0.1%, 0.3%, and 0.5% relative to the total volume) were used to reinforce the polymer mortars. The study analyzed the mechanical properties (compressive, flexural, and cohesive strength) and physical properties (density, adsorption, shrinkage) of the fiber-reinforced and control mortars at different hardening periods of 7, 28, and 60 days.

II. Materials and Method

II.1. *Materials*

Portland cement CEMI 42.5, with a fineness of 3400 cm2/g and a density of 3150 kg/m3, served as the primary cement in this study. Additionally, silica fume was utilized as a cement additive. Table 1 provides the chemical composition and physical properties of both the cement and silica fume.

Two types of fibers, namely vegetable fibers (hemp) and organic fibers (glass), were employed in the research. The sand used in the study was a class 0/4 silico-calcareous sand, possessing a density of 2680 kg/m3 and a sand equivalent coefficient of 86%. For the latex polymer, a styrene-butadiene rubber (SBR) type produced by SIKA was chosen.

Table 2 presents the physical and chemical characteristics of this latex polymer.

Table 1. Chemical composition and physical properties of cement and silica fume.

Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Cl^-	P.A.F	Absolute density(kg/m³)	The finesse (cm²/g)
Cement (%)	21.79	4.29	5	64.37	/	2.11	0.24	/	0.87	3150	3400
Silica fume (%)	88.72	0.78	2.54	/	3.7	1.06	2.81	0.1	/	2200	8755

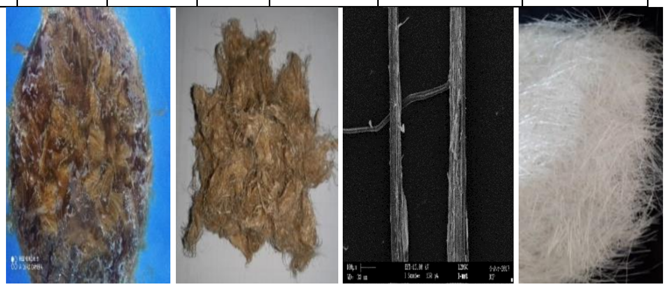
Table 2. Physical characteristics of the latex polymer used (SBR).

Nature	Styrene-butadiene rubber (SBR)
Color and shape	White and Viscous
Density (g/cm³) à (20°C)	1.02
Percentage of solid (%)	45
PH	9.65

The fibers utilized in this research consist of hemp fiber, derived from the Cannabis plant, which is an annual plant reaching heights between 1 to 3 meters and bears resemblance to flax [20] [18]. Hemp is predominantly cultivated in China, Canada, and Europe. Notably, this fiber boasts a high tensile strength ranging between 600 and 1100 MPa, making it suitable for various applications, including the paper industry and reinforcement of cementitious materials like concrete.

Fibers with a length of approximately 1.5 cm were employed in this study. To enhance the adhesion between these reinforcements and the polymer matrix, the hemp fibers underwent a treatment process. They were immersed in a solution containing 5% sodium hydroxide (NaOH) at a temperature of 20°C for a duration of 2 hours. Following this treatment, the fibers were dried at 40°C. This chemical process effectively eliminates lignin and waxy substances that coat the outer surface of the fiber cell wall [17]. Sodium hydroxide (NaOH) is widely used as a chemical agent to bleach and cleanse the surface of plant fibers [17].

Figure 1 displays the treated hemp fibers and fiberglass, both of which were utilized at a length of 1.5 cm. Additionally, Table 3 presents the physical, chemical, and mechanical properties of both hemp and glass fibers.



Hemp in 5% NaOH solution — Hemp after treatment — Glass

Fig1. Photos of different fibers used.

Table 3. Physical, chemical, and mechanical characteristics of hemp and glass fibers.

Fiber properties	Glass [7]	Hemp [21]
Absolute density (Kg/m³)	2600	1580
Lignins (%)	/	6
Cellulose (%)	/	56.1
Hemicelluloses (%)	/	10.9
Ash (%)	/	/
Tensile strength (MPa)	3400	619.2
Maximum deformation (mm)	/	0.682
Absorption of water (%)	/	158
Diameter (µm)	13−15	110
Length (cm)	1.5	1.5

II.2. Mixture proportions

In the experimental study, various proportions (0.1%, 0.3%, and 0.5% relative to the total volume) of hemp and glass fibers were added to the mortars containing 5% latex (SBR) by weight of dry extract.

This 5% latex dosage was determined as the optimal amount based on laboratory tests, showing favorable compressive and flexural strength. The total solid contents of the latex were considered in calculating this dosage (refer to Table 4).

The obtained results were then compared to two types of mortars. The first type was the control mortar (CM), which did not include the resin and fibers. The second type was a mortar based on 5% SBR (M5R).

For the preparation of these mortars, a binder/sand (B/S) ratio of 1/3 (by weight) was employed. The water/binder (W/B) ratio used for the control mortars was 0.5. To adjust the W/B ratio of the polymer mortars, the quantity of water was reduced based on its existing content in the SBR.

The components of the fiber-containing polymer-modified mortars were mixed following the procedure outlined in [22]. To assess the mechanical and physical parameters, the molds containing the mortars were covered with plastic film and kept in the laboratory. After 24 hours, the samples were removed from the molds and immersed in water for 6 days at a temperature of 20 ± 3°C. Subsequently, they were exposed to open air conditions at 20 ± 3°C with a relative humidity (RH) of 55 ± 10% until the testing dates at 7, 28, and 60 days. This curing method has been established as the most effective for achieving optimal mechanical and physical performance in polymer-modified mortars, as indicated by [1] and [5].

On the other hand, the substrate samples used for adhesion testing were made of cementitious materials (cement+sand+water). These samples were stored in water at 20 ± 3°C until the day of testing. The different compositions of our mixtures are detailed in Table 4.

Table 4. Compositions of the various mixtures of mortars used.

Designation mixtures	Cement (g)	SF (g)	Sand (g)	SBR (g)	Water (g)	Fiber (g)
CM	405	45	1350	0	225	0
M5R	405	45	1350	50	197.5	0
M5R-0.1H	405	45	1350	50	197.5	1.34
M5R-0.3H	-	-	-	-	-	4.03
M5R-0.5H	-	-	-	-	-	6.71
M5R-0.1G	-	-	-	-	-	2.34
M5R-0.3G	-	-	-	-	-	7.06
M5R-0.5G	-	-	-	-	-	11.77

II. Samples preparation and tests methods

The fluidity of cementitious materials is an essential characteristic commonly assessed on construction sites to determine their rheological behavior, particularly their consistency. For this purpose, the fluidity test was conducted using the shaking table test in accordance with ASTM C 1437-20 [23]. A frustoconical mold meeting the standard's requirements, with diameters of 70 mm and 100 mm and a height of 50 mm, was utilized. Each composition underwent three tests.

To determine the wet densities of the mixtures, a cylindrical vessel with a volume of 83 cm^3 was used. As a result, the apparent densities were calculated based on the masses of the apparent volume of the cured product from prepared samples measuring dimensions of 40 mm × 40 mm × 160 mm.

The evaluation of compressive strength and flexural strength was carried out at 7, 28, and 60 days following the guidelines of standard EN 196-1 [22]. The samples used for these tests had dimensions of 40 mm × 40 mm × 160 mm.

For the measurement of total shrinkage, prismatic test specimens with dimensions of 40 mm × 40 mm × 160 mm were used. The measurements were performed longitudinally using a refractometer with an accuracy of ± 0.001 mm. The specimens were stored in the open air at a temperature of 25 ± 2°C and a relative humidity of 55% ± 10%. The starting point of measurements was taken as the time of demolding, which occurred 24 hours after the preparation of the test specimens.

III. RESULTS AND DISCUSSIONS

III.1. Fresh state

Figure 2 displays the wet density and the diameter of the spread for various mixtures.

As evident from Figure 5, the incorporation of 5% SBR latex in the cementitious mortars led to a substantial 38% increase in fluidity compared to the control mortar (CM) without SBR. Simultaneously, the W/C ratio decreased from 0.5 to 0.43 (refer to Figure 6). Several research studies have consistently demonstrated that the presence of polymer, particularly in the form of latex, in Portland cement mortar and concrete enhances their workability while requiring a lower amount of added water [5] [24]. [25] demonstrated that the presence of SBR latex in cementitious mortars acts as a lubricant. Furthermore, research conducted by [25, 26] suggests that SBR latex exhibits a set retarding effect, attributed to the attachment of polymer particles to cement particles, forming a physical barrier that hinders the reaction with water.

The introduction of hemp and glass fibers in polymer mortars leads to a reduction in fluidity, which varies depending on the fiber type and content. For example, mortars like M5R-0.1H, M5R-0.3H, and M5R-0.5H exhibit flow-spread diameters of 198.5 mm, 146.5 mm, and 124 mm, respectively, while M5R (without fibers) has a flow-spread of 210 mm. Similarly, M5R-0.1G, M5R-0.3G, and M5R-0.5G mortars show flow-spread diameters of 180 mm, 145 mm, and 123 mm, respectively. This indicates that the water absorption effect of plant fibers on polymer mortars is negligible, as their results are comparable to mortars with fiberglass. The alkali pretreatment of hemp fibers effectively removes water-absorbent particles.

Additionally, the presence of fibers in cementitious materials enhances cohesion and homogeneity in the mixtures, leading to a decrease in fluidity. The wet densities of M5R and CM are 1995 kg/m3 and 2128 kg/m3, respectively. The incorporation of 5% SBR latex causes a 6% decrease in the wet density due to the air-entraining effect of the SBR latex (refer to Figure 5) [24] [27]. Conversely, the wet densities of the fiber-based polymer mortars increase based on the fiber rate and type, confirming good compatibility between the fibers and the polymer matrix. For example, the M5R-0.5H mixture exhibits a 3% higher density compared to M5R.

[28] provided a comprehensive explanation of the mechanism behind SBR latex in wet cementitious mortars. Macromolecular polymers consist of elongated chains, and SBR contains hydrophilic and hydrophobic groups. These groups facilitate the incorporation of air into the cement paste and trap microbubbles of air during the mixing process. Consequently, air entrainment not only enhances the fluidity of the cement paste but also influences its density.

The study revealed that mixtures containing 15% SBR experienced a significant 31.1% reduction in density compared to cement paste without SBR, indicating the air-entraining effect of SBR latex in the mortars. This phenomenon can be attributed to the ability of SBR to draw in air and entrap microbubbles, resulting in a decrease in overall density.

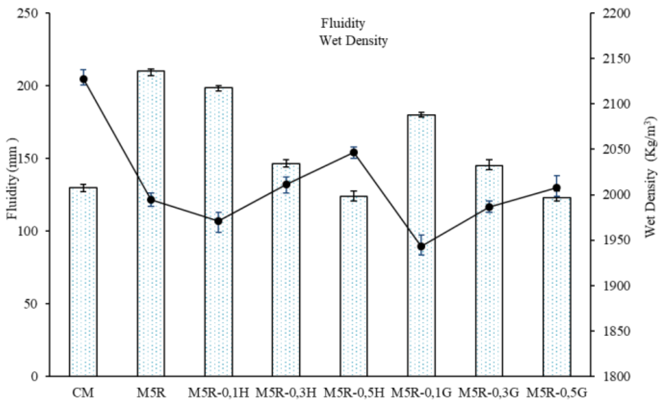


Fig2. Fluidity and wet density of different mixtures.

III.2. Flexural strength

Figure 3 presents the results of the flexural strength of both control and modified mortars concerning age and fiber content (glass and hemp). These results are averaged from four tests conducted on prismatic specimens measuring (40mm × 40mm × 160 mm).

Regarding flexural strength, most of the samples showed a positive impact with increasing hardening time. At 7 days, no significant improvement in the strength of the mortars containing 5% SBR was observed compared to the control without SBR. This is attributed to the delayed formation of the polymer film in the cement matrix [5] [29]. Conversely, the addition of glass and hemp fibers led to a notable increase in flexural strength by 25% and 20% for M5R-0.5H and M5R-0.5G, respectively, when compared to M5R and CM. This improvement can be attributed to the ductility and toughness of hemp and glass fibers, which enhance crack resistance by transferring stresses from the matrix to the fibers [4].

At 28 days, M5R exhibited a 13% increase in flexural strength compared to CM, primarily due to improved cohesion between the sand and the cement paste. This improvement results from the formation of both the polymer film and the co-matrix, which forms a network structure interpenetrating the hydrated cement phase and the polymer phase [3]. Moreover, latex-modified mortars containing fibers (hemp and glass) demonstrated superior flexural strengths when compared to CM and M5R. The degree of increase varied depending on the dosage and nature of the fibers. The optimal fiber content for hemp and glass fibers was found to be 0.5%, resulting in an approximate increase of 14% and 10%, respectively, compared to M5R.

Alkaline treatment of hemp fibers improved the interfacial bond between the fibers' cellulose chain and the calcium molecules of the hydrated cement. This enhanced bond led to the precipitation of cement in the exposed surface of the fibrils and fiber cavities, significantly improving crack resistance and reducing the propagation of composite cracks. Furthermore, research by [10] indicated that the polymer matrix exhibited good adhesion with glass fibers, thanks to the thin polymer film that fills voids between particles, consequently increasing the tensile strength and toughness of polymer-based mortars.

At 60 days, the flexural strength continues to develop, and mortars containing hemp fiber exhibit remarkable resistance compared to other mixtures. For instance, M5R-0.5H demonstrates a 12% increase in flexural strength compared to M5R. Furthermore, it surpasses CM with a strength increase of 13%. This development can be attributed to the evolving structure of hydrated cement, allowing the formation of a continuous polymer film. As a result, polymer particles come together, flocculate, gradually deform, and eventually coalesce. This film reacts with cement hydrates and the surface of silica aggregates, forming a layer of calcium silicate [30] [31].

[31] has demonstrated that the polymer film formed absorbs calcium, subsequently reducing the formation of Portlandite [32]. This reduction in Portlandite contributes to decreasing the degree of alkalinity, promoting the durability of hemp fibers in modified mortars. Additionally, [33] has highlighted that the degradation of natural fibers in the alkaline matrix is attributed to the attachment of Ca2+ (known as mineralization) to the fiber surface. However, when the surface of the fiber is enveloped by a polymer, the binding of Ca2+ is reduced, resulting in enhanced durability of the plant fibers.

Furthermore, the homogeneously dispersed network of high-tensile-strength SBR polymers functions as a bridge-transmitter between different parts of the mortar matrix [34]. This prevents microcracks from initiating and spreading effectively through deflection [23]. Research by [27] and [33] explains that the combined treatment of plant fibers (treatment with sodium hydroxide and polymer) leads to an improvement in the tensile strength of modified cement-based mortars by enhancing the crystallinity index. This increase in crystallinity index is achieved by removing the contents of pectin, wax, and hemicellulose in natural fibers.

Regarding mortars with fiberglass, a slight increase was observed in M5R-0.5G compared to M5R.

In conclusion, mortars with 5% SBR exhibit favorable flexural strength compared to CM at all ages. Additionally, the inclusion of vegetable fibers enhances strength, controls cracking, and provides post-cracking ductility in the fiber-reinforced mortar.

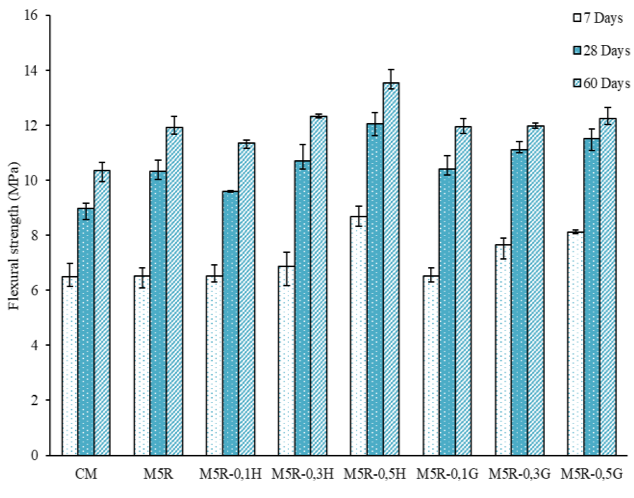


Fig.3. Flexural strength of differently prepared mortars.

III.Compressive strength

Figure 4 illustrates the compressive strength of both the control mortar (CM) and SBR latex modified mortars with respect to age and fiber content (glass and hemp). The presented results represent the average of six tests conducted on fragments recovered from the flexural strength test.

An initial analysis of the results reveals that the compressive strength of the mortar containing 5% SBR latex is reduced by approximately 14% and 25% at 28 and 60 days, respectively, compared to CM. Various studies have shown that the presence of polymers has a limited impact on compressive strength, and in some cases, it may even have a negative effect [34] [35]. [3] attributes this decrease to the higher amount of air introduced into the modified mortars due to the presence of polymers [34]. Additionally, [35] has demonstrated that the introduction of SBR latex in cementitious mortar results in reduced compressive strength due to the lower mechanical capacity of the latex compared to cement mortar. Moreover, [34] noted that this strength reduction could be attributed to the lower modulus of elasticity of the polymer molecules compared to those of the various hydration products of cement.

Furthermore, the inclusion of 0.5% hemp fibers in PM leads to an increase in compressive strength by 14%, 9.5%, and 10% at 7, 28, and 60 days, respectively, compared to M5R. Similarly, the presence of 0.3% glass fiber in PM causes an increase of 13.5%, 6%, and 0.6% at 7, 28, and 60 days, respectively. Beyond this percentage, a slight decrease in the compressive strength of M5R-G compared to M5R is observed. This strength improvement can be attributed to the development of the latex film within the internal structure of the cement, creating a transitional bridge between the cement, sand, and fiber particles. This transitional bridge enhances adhesion between the fiber and the matrix [27, 36].

[37] has demonstrated that coating jute fabric with the polymer improves the bond between the fiber and the matrix [9]. Moreover, they observed that using pozzolanic addition consumes calcium hydroxide, leading to an increase in the matrix density and consequently providing protection to plant fibers [38].

A recent study by [18] revealed that the chemical pretreatment of hemp fibers effectively removes hemicelluloses, lignin, and waxes, resulting in a clean fiber surface [39]. They concluded that the addition of acrylic latex to the cementitious matrix improves the bond with pretreated hemp fibers, leading to enhanced compressive strength properties.

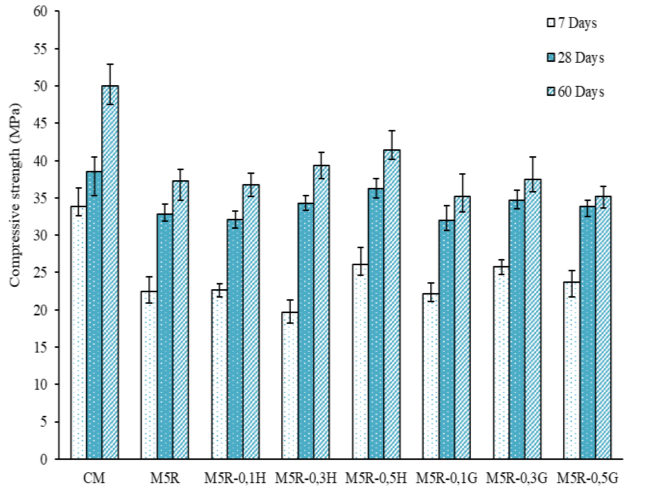


Fig 4. Compressive strength of the various prepared mortars.

The matrix fills the pores and significantly enhances the bond between the chemically pretreated hemp fibers and the matrix. Nonetheless, there is a similarity in compressive strength with other fiber grades, irrespective of their nature.

In conclusion, the incorporation of 0.5% hemp fiber leads to an enhancement in the compressive strength of SBR latex-based mortars.

II.4. Shrinkage

Shrinkage is a critical property affecting the dimensional stability of cementitious and polymeric materials. Incompatibility due to shrinkage can lead to internal stresses, potentially resulting in failure at the interface or within the material. Figure 6 displays the shrinkage results of different mixtures, specifically the shrinkage strain after 4, 30, and 60 days for various specimens.

The introduction of 5% SBR leads to a significant decrease in shrinkage, approximately 20%, compared to CM. Researchers [34] have indicated that the polymer particles or films can partially fill the capillary pores, effectively reducing drying shrinkage. The mechanism behind the decrease in shrinkage of polymer mortars compared to cement-based mortar was elucidated by [24]. They observed a reduction in the density of microcracks in the paste, either at the paste-aggregate interface or on the surface, due to the action of the polymer. Additionally, the presence of the polymer film enhances the water retention capacity within the paste, enabling the mortars to undergo a wet cure, which contributes to decreased drying shrinkage [6].

During the first 10 days, the shrinkage deformation of polymer mortars with glass and hemp fibers is higher (approximately 35% for M5R-0.5H and M5R-0.5G). This can be attributed to the significant humidity gradient between the tested material and the external environment. Furthermore, the presence of fibers in the mortars creates additional pores that facilitate the migration of water from the mortar to the exterior, leading to increased shrinkage. [40] found that natural fibers, such as bamboo fibers, are porous due to their fibrous structures, which can enhance water evaporation and consequently induce more drying shrinkage. Similarly, [41] observed a 40% increase in shrinkage with the presence of sisal fiber compared to the cement matrix without fibers. They attributed this rise in drying shrinkage to the extent, size, shape, and continuity of the capillary pores in hydrated cement pastes. Moreover, the porous nature of the fibers at the microstructure level creates more moisture paths in the matrices, contributing to the increased drying shrinkage [42]. Researchers [12] from the literature review justified the higher shrinkage in mortars with fiberglass due to the low rigidity of these reinforcements.

Subsequently, the values of shrinkage in fiber mortars differ based on the rate and nature of the fibers. For example, at 60 days, M5R-0.5H and M5R-0.3H present similar values to M5R. However, M5R-0.3G shows a slight increase in shrinkage, approximately 2%, compared to M5R. This phenomenon can be explained as follows: [include the explanation here, but it was not provided in the original text].

On one hand, the presence of 10% silica fume in mortars induces a long-term pozzolanic reaction, increasing the amount of C-S-H gel. This denser and more rigid gel reduces the porosity of the cementitious material, resulting in decreased shrinkage of the polymer-modified cementitious mortars [43]. On the other hand, researchers [44] observed that on the 14th day, lignin cellulose became enveloped by the hydration products of the cement. The shrinkage and expansion of the mortar were controlled by the cohesive bond between cellulose lignin and cement hydrates. Additionally, as per [5], the formation of polymer films occurs around 10 days of curing, and these films fill the pores of the fibers (particularly in the case of hemp fibers treated with NaOH), promoting strong adhesion between the fiber and matrix, enhancing fiber rigidity, and reducing porosity, ultimately leading to decreased shrinkage in polymeric mortars. Furthermore, [43] discovered that the introduction of fibers into a cementitious composite can mitigate the cracking caused by shrinkage.

In conclusion, the addition of 10% silica fume and 5% SBR latex in cementitious mortars containing 0.5% submerged hemp fibers treated with 5% NaOH results in favorable behavior of these composites concerning long-term shrinkage. Ultimately, this formulation effectively mitigates the adverse impact of vegetable fibers on the shrinkage of cementitious matrices.

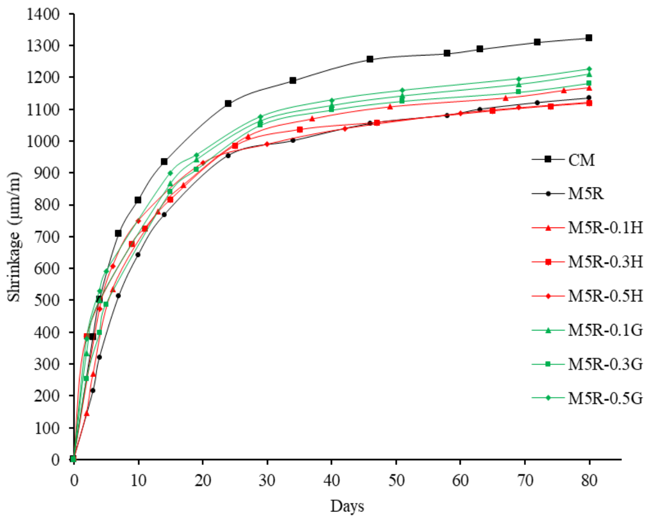


Fig.5. Total Shrinkage of the different mixtures.

IV. CONCLUSION

The following conclusions can be drawn based on the results obtained in this study:

- The incorporation of 5% SBR Latex in cement mortars significantly increases fluidity by 38% compared to CM, while reducing the W/C ratio from 0.5 to 0.43.
- The presence of hemp and glass fibers in polymer mortars leads to decreased fluidity, which is attributed to the enhanced cohesion and homogeneity of the fiber mixtures, resulting in reduced spreading.
- The addition of 5% SBR Latex causes a decrease in wet density by 6% due to its air-entraining effect. Conversely, the wet densities

of fiber-based polymer mortars increase, reflecting good cohesion between the fibers and the polymer matrix. M5R-0.5H exhibits the highest density, with a 3% increase compared to M5R.

- The flexural strength at 7 days shows improvement with the inclusion of fiberglass and hemp fibers, with M5R-0.5H and M5R-0.5G exhibiting 25% and 20% higher strength, respectively, compared to M5R and CM. This improvement is attributed to the ductility and tenacity of hemp and glass fibers, which enhance crack resistance by transferring stress within the fiber matrix. At 28 days, latex-modified mortars containing hemp and glass fibers demonstrate superior flexural strength compared to CM and M5R. The enhancement varies depending on the dosage and nature of the fibers, with an optimal fiber content of 0.5% for hemp and glass fibers, resulting in a 14% and 10% increase, respectively, compared to M5R.
- The addition of 0.5% hemp fibers in PM leads to a notable increase in compressive strength, showing improvements of 14%, 9.5%, and 10% at 7, 28, and 60 days, respectively, compared to M5R. Meanwhile, the inclusion of 0.3% glass fiber in PM results in an increase of 13.5%, 6%, and 0.6% at 7, 28, and 60 days, respectively.
- The combination of 10% silica fume and 5% SBR latex (matrix processing) in cementitious mortars containing 0.5% or 0.3% hemp fibers submerged in 5% NaOH (treated fibers) positively affects the long-term shrinkage behavior of the composites.
- This study emphasizes the significant role of vegetable fibers in enhancing the mechanical behavior and transfer properties of cemented mortars modified by SBR Latex. These fibers improve both short-term and long-term mechanical and physical performance, with hemp fibers generally demonstrating better behavior compared to glass fibers.

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