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Developing Sustainable Pavement Concrete By Using Polymer Additives

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Abstract
Polymer additives are key components that can significantly modify the properties of concrete. The present study seeks to fill the informational voids concerning the specific enhancing techniques for pavement applications utilizing polymer and SBR additive properties. The mechanical properties of cement incorporating 0 to 2.0% (by mass) polyvinyl alcohol (PVA) and 0 to 30% Styrene-Butadiene Rubber (SBR) were investigated experimentally. The present investigation indicated that the slump test findings imply that the addition of PVA to normal concrete elevates its slump value by under 1%. Nonetheless, an increment over 1% leads to a decline. The ideal workability of the control mix was demonstrated by a droop value of 148 mm after the incorporation of SBR. The combination of PVA and SBR yields a 92.5% increase in collapse. The ideal mechanical characteristics of the concrete compositions are consistently attained by integrating 1% PVA. The findings indicated that the mechanical properties enhanced with 30% SBR, albeit they did not reach the level of PVA. Diverse reactions are noted in the correlation between density and water absorption of the hybrid concrete that integrates PVA and SBR. The concrete's low density will diminish water absorption. The use of PVA and SBR can enhance the strength of concrete by as much as 51.8%.
Keywords: *PVA, SBR, sustainable concrete*

1, INTRODUCTION

Enhancing the concrete pavement structure is crucial for protecting road surfaces and textures from reflection and distortion caused by varying loads. Novel approaches for road design, construction, and maintenance have emerged in reaction to substantial challenges in road development [1]. A pavement consists of several layers of interconnected and compacted materials. The principal role of a pavement is to convey traffic loads to the sub-base while minimizing deformation of both the sub-base and the pavement structure. Many researchers. examines the feasibility of stabilizing paving concrete roads with high-density polyethylene (HDPE). The ideal pavement was determined to contain a suitable HDPE proportion of 5% by aggregate weight [2]

Sustainable concrete is produced using environmentally friendly materials and techniques to mitigate its negative environmental impact. The components encompass minimizing carbon emissions, conserving natural resources, and enhancing the durability and resilience of concrete structures [3-5]. Sustainable concrete promotes an environmentally sustainable future by diminishing the carbon footprint of the construction industry. Strategies for producing sustainable concrete encompass the use of alternative materials in manufacturing, the use of energy-efficient methods, and adherence to sustainable design principles. Thus, sustainable concrete represents a substantial alternative for recycling some waste materials and alleviating waste disposal challenges. The recycled materials include of rubber, plastic, glass, and industrial waste[6,7]. The organic aggregates comprise bamboo, coconut fiber, and nanocellulose.

This document clarifies the additives that can improve the quality of concrete used in road construction. This paper will focus on a concrete mixture that includes a polymer, which improves its qualities, owing to the effectiveness of polymeric materials in optimizing concrete formulas.

2, RELATED WORKS

Contemporary concrete comprises aggregates, cement, water, and admixtures. Polymer additions substantially modify the properties of mortar and concrete. The predominant polymer additives comprise superplasticizers, latexes, and redispersible powders. Researchers have investigated the enhancement of concrete-based composite admixtures by the incorporation of polymer fibers and recycled polymers. The enhancements augment fracture resistance. All enumerated polymeric materials are frequently utilized in construction. Various polymeric fibers have captivated researchers for the enhancement of concrete. Polyamide, polyethylene, polyvinyl alcohol, and polyethylene terephthalate (PET) have been evaluated as replacements to steel fibers in concrete production. Recently, reclaimed polymer materials have demonstrated potential as substitutes for synthetic fibers [8]

A variety of polymers are utilized as chemical admixtures. Examples include polyvinyl acetate, ethylene-vinyl, styrene-butadiene, styrene-acrylic, and polyacrylic ester. Numerous reports have addressed these materials. Modern cement comprises polymers such as water-soluble homo- or copolymers, liquid resins, latexes, and dispersible particles. The type and form of polymer are contingent upon the concrete's application and the required strength, durability, and chemical resistance. The characteristics of the composite are contingent upon the polymer [9]

Recent advancements in polymer additives underscore the distinct advantages of organic and inorganic chemicals. Latexes, epoxy resins, and superplasticizers enhance the workability, adhesion, and water resistance of concrete. These compounds reduce the water-cement ratio, enhancing the density and strength of the concrete matrix.

In [10], the authors employed in situ polymerization of monomers and cement hydration to establish an organic-inorganic network inside the cement matrix, enhancing its flexural strength and toughness while preserving a comparable compressive strength to Portland cement. Modifying the proportions of acrylic acid, methacrylic acid, and acrylamide enhanced the flexural strength of the cement paste by 86%, while maintaining compressive strength similar to that of Portland cement. The in situ generated organic-inorganic (polymer-cement) network enhanced mechanical strength by imparting flexibility and rigidity. The AMA copolymer postponed cement hydration, evidenced by the shift in peak hydration temperature. In situ polymerization of monomers enhanced fluidity and mechanical strength more effectively than direct polymer insertion.

The authors propose a liquid blend of nanometric, amorphous silica (SiO_2) to enhance cement paste reactivity and a polysaccharide to improve suspending properties. Authors illustrate that fluid concrete devoid of bleeding or segregation can be manufactured at a reasonable expense. The improved kinetic setting decreases demoulding time, resulting in smooth and homogeneous cured concrete, with ultimate strength values comparable to high-strength concrete [11]

Polymer additives in concrete work because they change the cement paste microstructure. Sealing concrete pores with organic polymers prevents water intrusion and improves freeze-thaw resistance. Inorganic polymers interact with calcium hydroxide to form calcium silicate hydrate, which fills concrete cavities and strengthens it. Traditional coatings use organic groups to give hydrophobicity and polarity at the solid surface, which make them water-sensitive [12]

Self-cleaning and anti-icing in severe settings require superhydrophobic coatings. A sustainable and self-adhesive polydopamine coating was inspired by mussel adhesion and improved for growth by precise formula regulation [13]. A textured surface structure and surface energy minimization yielded an ideal contact angle of 162.7° and a roll-off angle of 5.5° in tests. Mechanical and wear resistance tests showed resilience due to polydopamine-steel metal-chelating interactions.

Numerous research employs inorganic mineral additives that mimic cement clinker minerals to enhance the performance characteristics of cement-based products. These additives regulate the hydration of clinker minerals to produce a high-density cement matrix and a stable, high-strength, dense cement stone composed of calcium hydrocyclates with diminished base content in cement systems ([14-17] Amorphous microsilica (SiO_2) is a commonly utilized active mineral additive. in [20] discovered that nano-SiO_2 (NS) in cement matrices substantially reduces the setting time of concrete.

NS's unsaturated bonds enhance its reactivity and nucleation capacity during mixing, leading to increased water absorption and less concrete shrinkage. In [21] nanosilica (NS) to silica fume (SF) in hardened cement paste (HCP) using compressive and bond strength metrics. Their findings indicate that 3% NS fractures CH crystals, diminishing their orientation and size in the interfacial region and enhancing bonding more effectively than SF.
A separate study evaluated mineral additions of 0%, 2.5%, 5%, 7.5%, and 10% by cement weight across nine concrete formulas. The scientists discovered that 10% mineral additives enhanced the compressive strength of concrete by 0.99% compared to the control mixture. Incorporating mineral additives at a concentration of 10% diminished water absorption and improved freeze-thaw durability. [22].
Numerous studies indicate that using microsilica into concrete production enhances its properties. In [23] examines the hardened silicate matrix containing "cement-dispersed shungite particles." This method enhances concrete strength while decreasing heat and moisture treatment duration.

3, MATERIALS AND METHOD

A three-step sample generation technique. The first phase involves global requirements and quantitiMixing sand, gravel, and Portland cement produced thin concrete samples.
The of concrete sample mechanical properties that may lead to significant research advances. A triadic methodology for sample production. The initial phase encompasses worldwide requirements and quantities. The combination of sand, gravel, and Portland cement yielded thin concrete samples. A comprehensive examination of the mechanical properties of concrete samples that could result in substantial research advancements. Initially, testing adheres to international standards and scales. These are the reference samples. Subsequently, samples incorporating polymers are produced. This experiment utilized PVA powder composites. Ultimately, assess the influence of the SBR. The characteristics of concrete were evaluated using three different quantities of SBR. SBR and PVA were subsequently incorporated into the mixing design schedule to evaluate their effects. The amalgamation of the two components enhances the concrete's durability and formulation characteristics. Experimental data presented in Table 1.

Table 1: table of experiments

	cement kg	W/C	sand kg/m3	aggregate kg/m3	PVA kg	SBR %
CONTROL	309	0.4	602	1279	0	0
CP1	309	0.4	602	1279	1.55	0
CP2	309	0.4	602	1279	3.1	0
CP3	309	0.4	602	1279	6.2	0
CS1	309	0.4	602	1279	0	10%
CS2	309	0.4	602	1279	0	20%
CS3	309	0.4	602	1279	0	30%
CPS1	309	0.4	602	1279	1.55	10%
CPS2	309	0.4	602	1279	3.1	20%
CPS3	309	0.4	602	1279	6.2	30%

The concrete's behavior can be anticipated by proportioning the components in accordance with these principles. The study focusses on determining the optimal ratio of SBR and PVA to create a cost-effective concrete mixture that meets stringent standards. Conventional materials OPC type I constitutes one of its components. Ordinary Portland cement (OPC) consists primarily of gypsum and clinker, with few additives. Clinker possesses cementitious properties due to the chemical reactions that transpire when limestone and other minerals are subjected to heat. The majority of

cement is Type 1 Portland cement, sometimes referred to as general-purpose cement. Its standard heat generation rate and strength development render it suitable for applications that do not necessitate specialized cement properties. These comply with Iraqi Standard 5/1984. Sand constitutes the fill, base, and surface of the pavement. They are utilized in mortar, bitumen, concrete, and blocks. They constitute fine aggregates in the preceding two operations. They are capable of producing gypsum, reinforced concrete, and various block or masonry structures. The grain structure and pattern of this sand exhibit greater consistency and smoothness.
The shape, texture, bulk unit weight, specific gravity, reactivity, size gradation, and moisture content render coarse aggregate a favored construction material. Crushed gravel from AL-Nibaee, with a maximum particle size of 10 mm, was utilized in the research. Prior to utilization, the aggregates were cleansed and air-dried until moisture was eliminated.

3,1 properties of additives

Translucent and odorless poly(vinyl alcohol) granules are white or cream-colored. Semi-crystalline, hydrophilic, biodegradable, and non-toxic polyvinyl alcohol (PVA). Applications encompass textile sizing, paper coating, dialysis membranes, controlled drug delivery systems, wound dressings, artificial skin, and flexible water-soluble packaging films. Numerous applications get advantages from its tensile strength, flexibility, and capacity to form films, emulsify, and attach. PVA completely melts when fully hydrolyzed at 230°C and partially melts at 180–190°C. Thermal breakdown and pyrolysis transpire at temperatures exceeding 200°C. Acetaldehyde resulting from tautomerization is more stable than vinyl alcohol at ambient temperature. Consequently, the manufacture of PVA via polymerization does not utilize vinyl alcohol monomer. Vinyl acetate constitutes the primary component of PVA. Upon the polymerization of vinyl acetate (VA), an acid or base hydrolyzes polyvinyl acetate (PVAc) into polyvinyl alcohol (PVA).

Butadiene-derived elastomer Utilizing Styrene It was produced by polymerizing suspended butadiene and styrene monomers. This polymerization is effective for SBR. SBR experimented with weight ratios of cement to concrete. Concrete repairs and repair frequently utilize SBR. Adhesion and durability of repair mortar, grout, and overlays are enhanced.

SBR enhanced the microstructure and density of concrete. SBR latex frequently obstructs silicate-aluminate reactions. Positively charged clinker and hydrates absorb Styrene-Butadiene Rubber (SBR). Concrete treated with polymers enhances flexural strength. Polymers influence the flexural strength of concrete. The microstructure of this concrete demonstrates that polymers diminish CaOH crystallization and function as flexible fillers and reinforcements. Interface transition zones vary with polymers. SBR latex forms a modified cement network in conjunction with hydrates. Flexural strength and impermeability increased, but strength and elastic modulus decreased. Research indicates that SBR latex enhances strength. SBR latex-treated concrete exhibits enhanced compressive and flexural strengths. The quantity of SBR latex must be tuned for optimal workability. Analysis indicates that reduced SBR latex in SBR-modified concrete may enhance high-strength concrete.

Composites were produced using three molds. Cubes measuring 15 cm per side, a cylinder with a diameter of 10 cm and a height of 20 cm, and a beam with dimensions of 10 cm by 10 cm by 50 cm serve as molds.

3.2 production and testing samples

The slurry was subsequently transferred to the molds to fabricate the panels. A rod was employed to achieve a level surface for each of the three poured concrete layers. The casting procedure included traditional molds and incorporated additives such as SBR and PVA. This indicated that the vibration process persisted. To get precise measurements of the modulus of elasticity, tensile strength, and compressive strength of the material, three specimens were prepared for each test. Upon completion of the vibration process with a vibrator, the concrete pouring procedure is concluded. Figures 1 shows the processes.

Figure 1: samples production

4, RESULTS AND DISCUSSION

The experimental findings on the fresh, mechanical, and durability characteristics of concrete mixtures are presented in this section. The properties of PVA and SBR concrete are also predicted using discussion and analytical relationship models.

4.1 slump test results

The behavior of a compacted inverted cone of concrete under the influence of gravity is measured by the results of the Slump test. It evaluates the concrete's moisture content or consistency, giving information on how workable the material is. A high slump value frequently indicates a mix with great workability, which is useful in specific scenarios like filling large areas with little elevation change. Generally speaking, a low slump value means that the mixture is too dry and can require the addition of admixtures or water. Figure 2 shows the varied responses to the slump test results for fresh concrete using PVA. Less than 1% more PVA is added to standard concrete, however more than 1% increases cause the slump value to decrease.

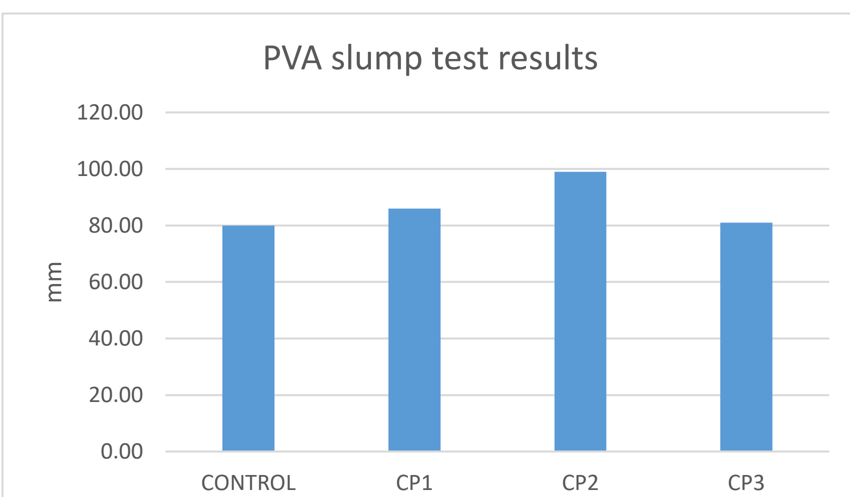

Figure 2: results of PVA slump test

The fresh properties of concrete mixtures, including SBR, were evaluated using the second test method, slump. The slump test has been used to evaluate their workability in concrete using a water weight range of 10% to 30%. As previously mentioned, all mixes maintained comparable proportions, with the exception of the addition of SBR. There was variability in the slump readings. The control mix had a slump value of 148 mm, indicating ideal workability.

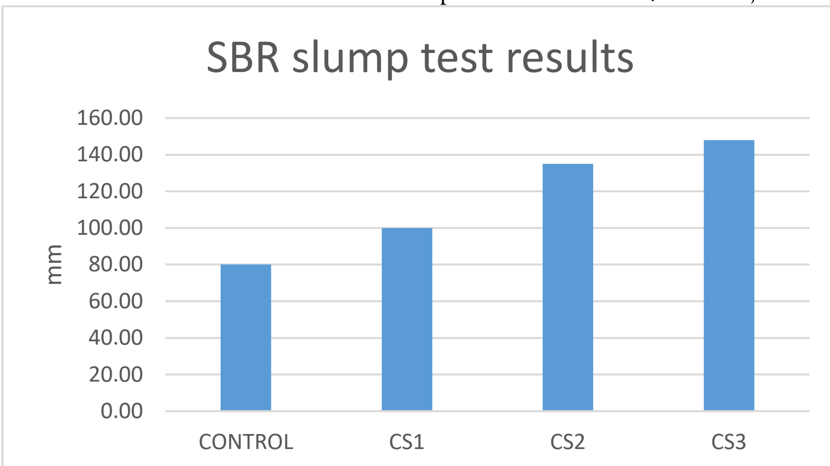

Figure 3: results of SBR slump test

The slump technique that followed used mixed blends of SBR and PVA. The results of the slump test for freshly mixed concrete including hybrid PVA and SBR mixtures depend on how these ingredients interact as well as the mix design. The slump test results are shown in Figure 4.

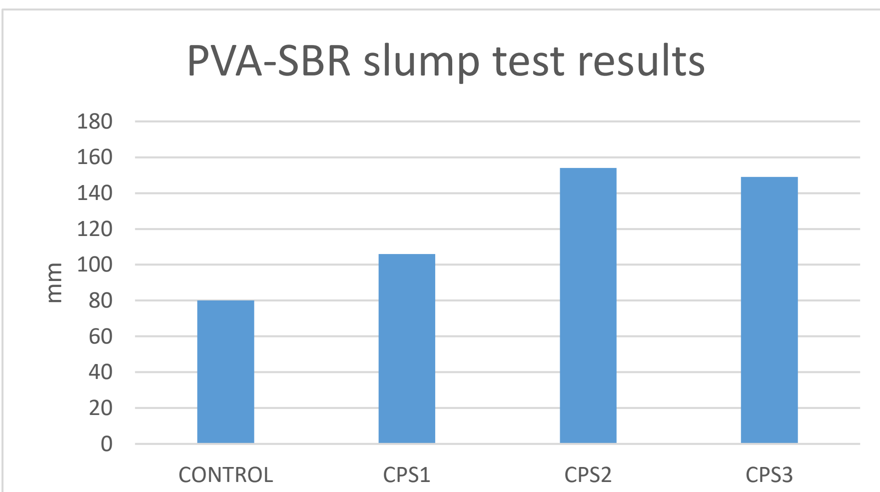

Figure 4: results of PVA-SBR slump test

In comparison to plain concrete, the results show that the combination of PVA and SBR increases slump by about 92.5%. This is because particles become more angular and regular than in natural aggregates, which improves followability and lowers interparticle friction.

4,2 compressive test results

The compressive strength of concrete mixtures of varying ages is shown to augment over time in experiments performed at ambient temperature. The compressive strength of the three concrete mixtures examined in this study improves over time. The compressive strength of the concrete mixture enhances over time owing to the inclusion of PVA and SBR. The incorporation of these polymers seals the voids in the concrete, so enhancing its strength. The progressive solidification of the cement paste may be responsible for the rise in compressive strength. This process yields a microstructure that is denser and more resilient.

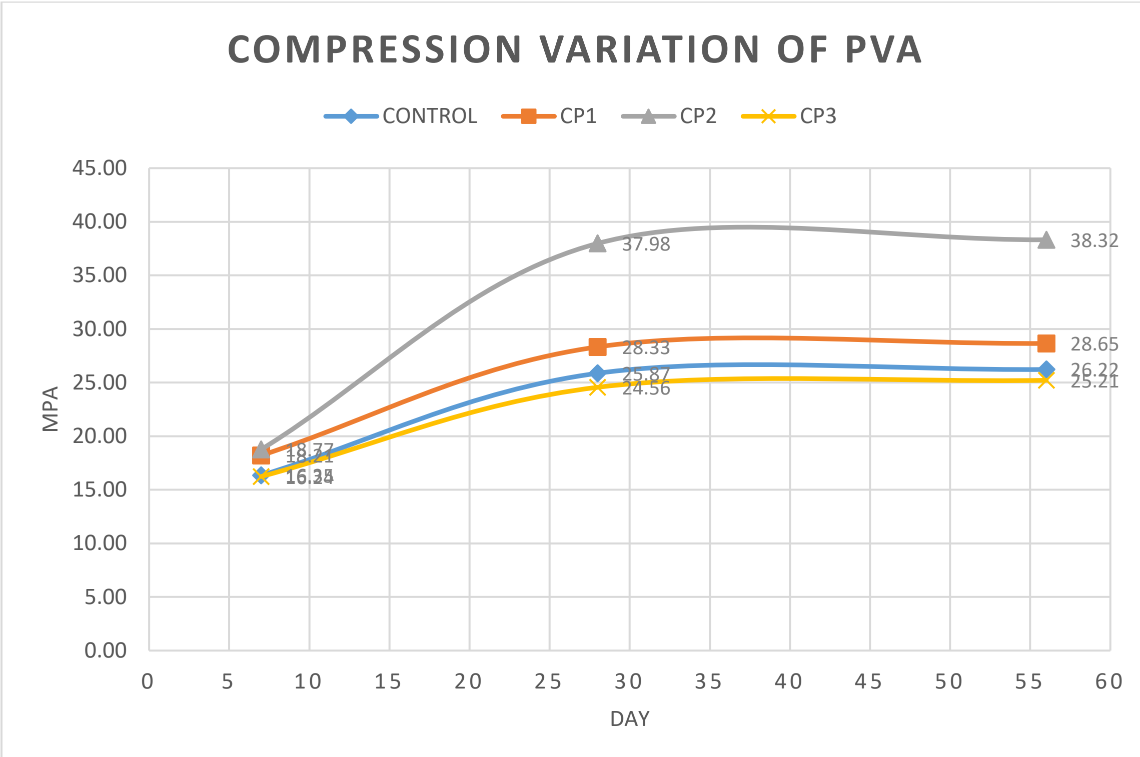

figure 5: results of PVA compressive test

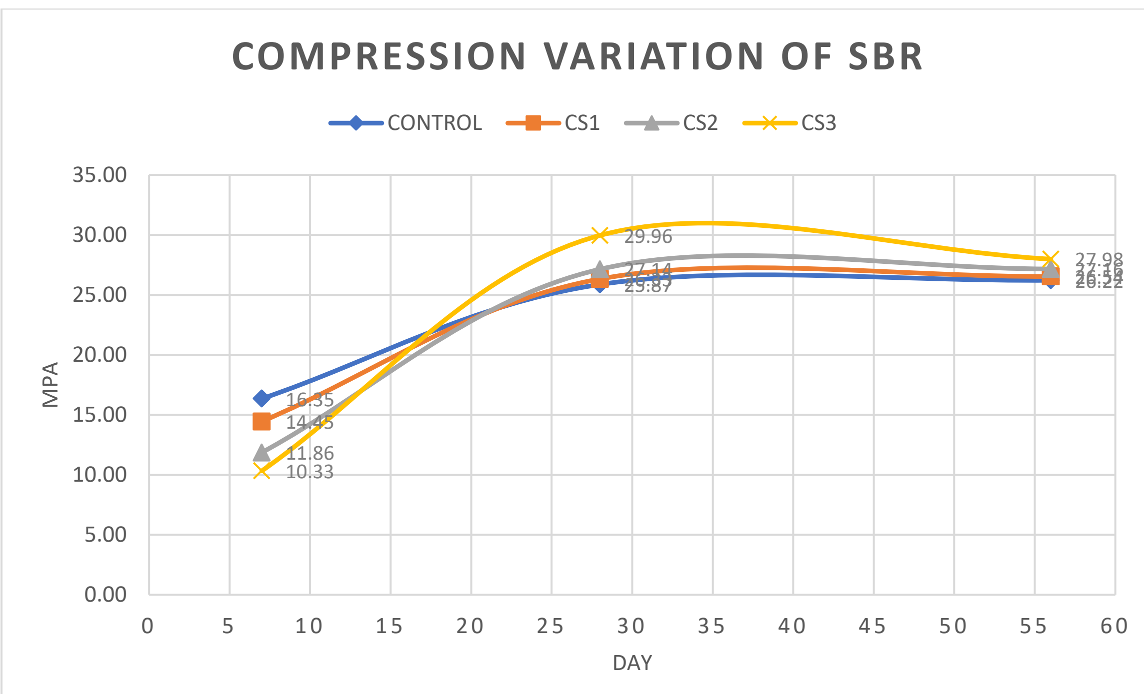

figure 6: results of SBR compressive test

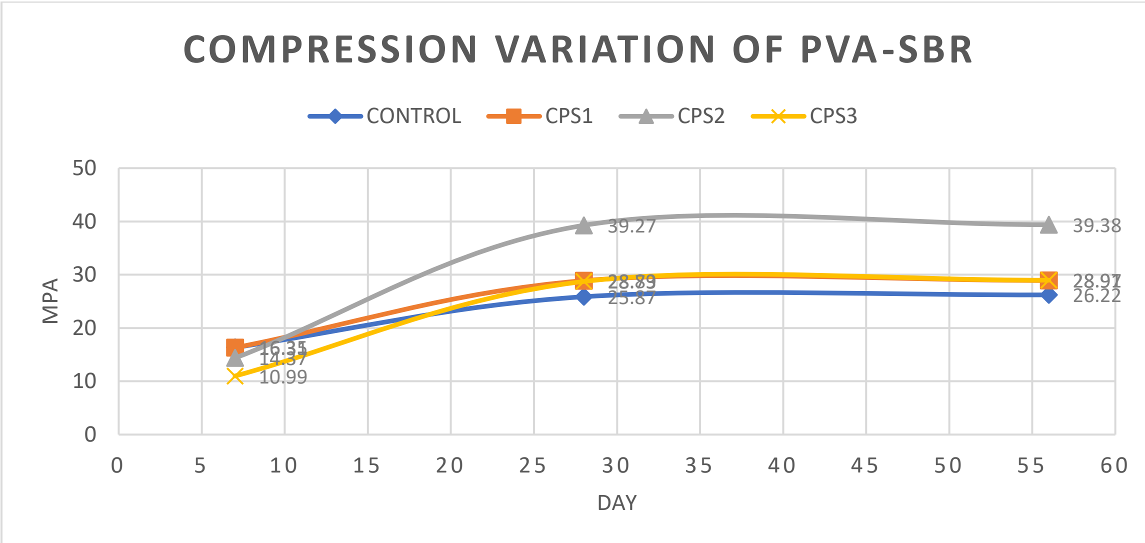

figure 7: results of PVA-SBR compressive test

When combining PVA with SBR, the results present a high performance concrete with a CPS2 samples.

4,3 flexural test results

Both compressive and flexural strengths must be considered when evaluating the durability of concrete. A concrete structure's bending and cracking characteristics are influenced by its flexural tensile strength. Research shows that the flexural tensile strength of concrete is influenced by a number of variables, including age, size, stress intensity, and confinement to a concrete flexural element. Age, confinement, and stress intensity are some of the variables that need to be taken into account while evaluating the flexural tensile strength of concrete. The estimation of flexural strength across a range of concrete strengths, including confinement conditions and concrete age, is experimentally investigated in this thesis. The age of the concrete and confinement conditions are two factors that must be taken into account in the flexural strength proportionality formulas. The focus of this work has been on the variables that affect concrete's flexural strength. The effects of adding polymers to concrete components on flexural strength, SBR in lab settings, and the combined PVA-SBR's synergistic effect on building sites have all been investigated and proven. There are notable differences in the concrete specimen results, which vary from one figure to another.

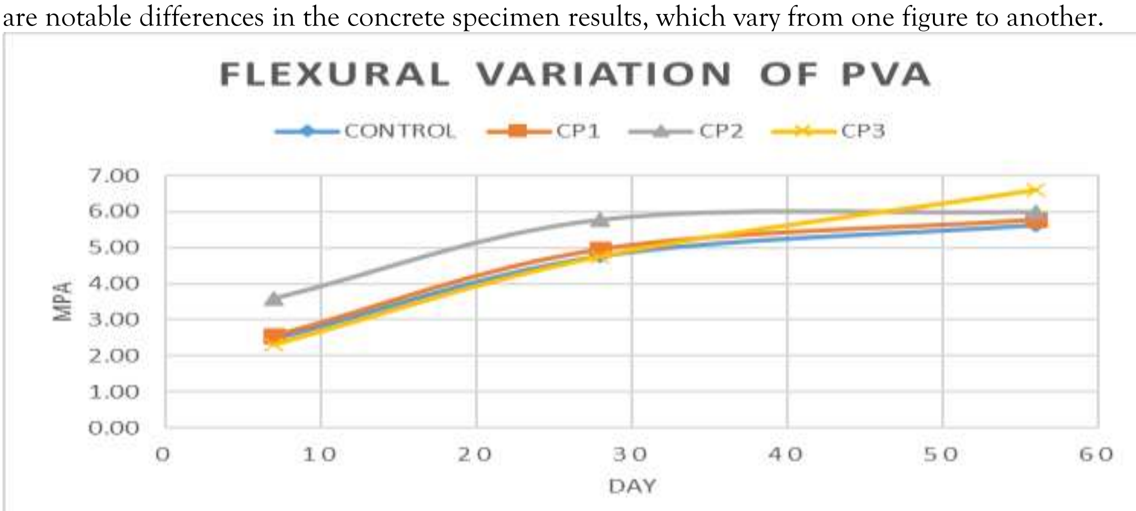

figure 8: results of PVA flexural test

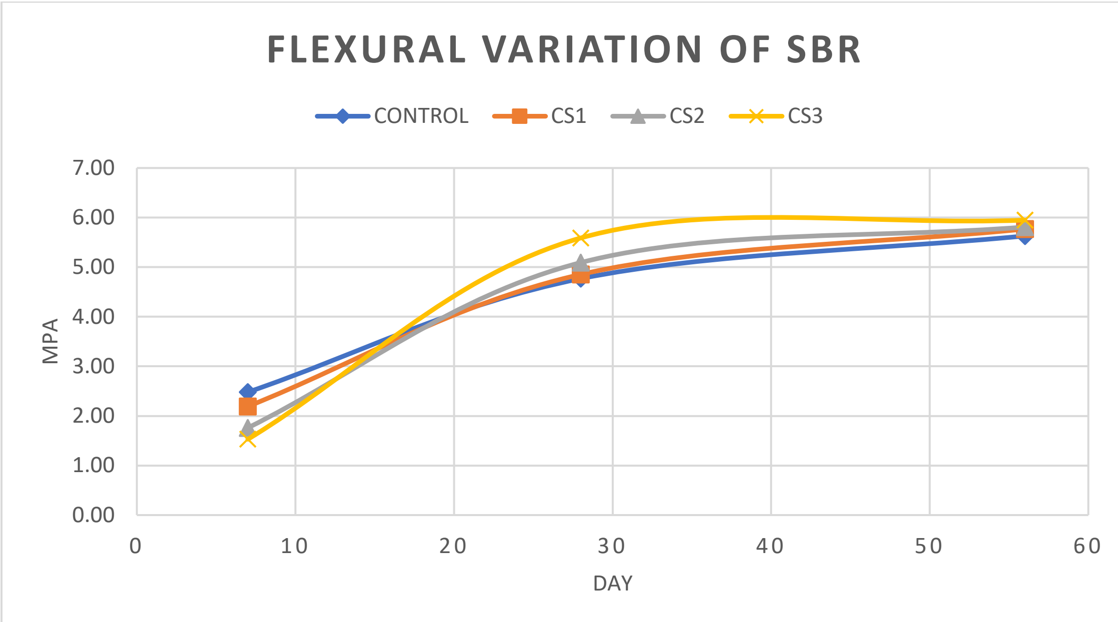

figure 9: results of SBR flexural test

As shown in flexural tests, adding 30% SBR present a unique result in age of 28 days, but in age 7 days, all samples present lower flexural values.

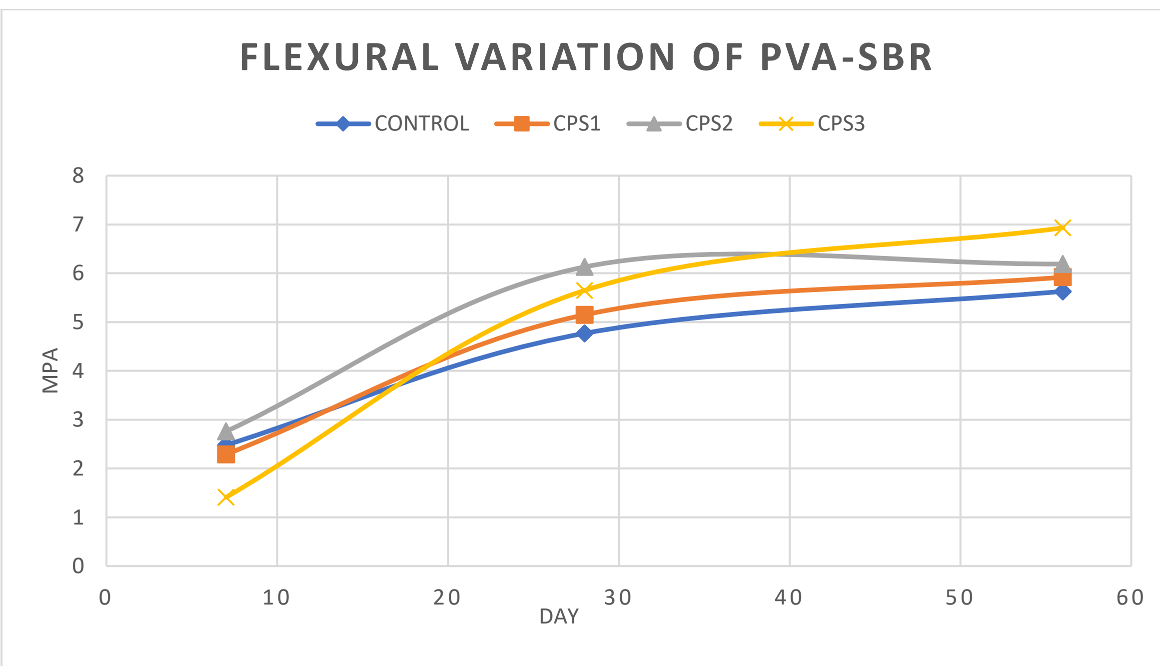

figure 10: results of PVA-SBR flexural test

When mixing PVA with SBR different responses appear. At 28 days, CPS2 samples presents a higher flexural values, but with 56 days, CPS3 presents the optimum results.

4,4 splitting test results

The maximum load that concrete may endure before fracturing or cleaving under tensile forces applied perpendicular to its surface is referred to as its splitting tensile strength. Shear resistance and the requisite development length of reinforcement are essential considerations in structural construction. This is particularly applicable to scenarios using lightweight concrete. This test, referred

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to as the Brazilian tensile test or indirect tensile test, entails compressing a cylindrical concrete specimen until it fractures along its diameter. The thesis includes tests that analyzed the effects of curing age and aging degree on the tensile strength of concrete. Figures 11 to 13 illustrate the comparative splitting strengths of PVA, SBR, and combined additives. Experimental results indicate that the splitting strength of concrete enhances progressively over time, with a significant increase observed within the initial seven days.

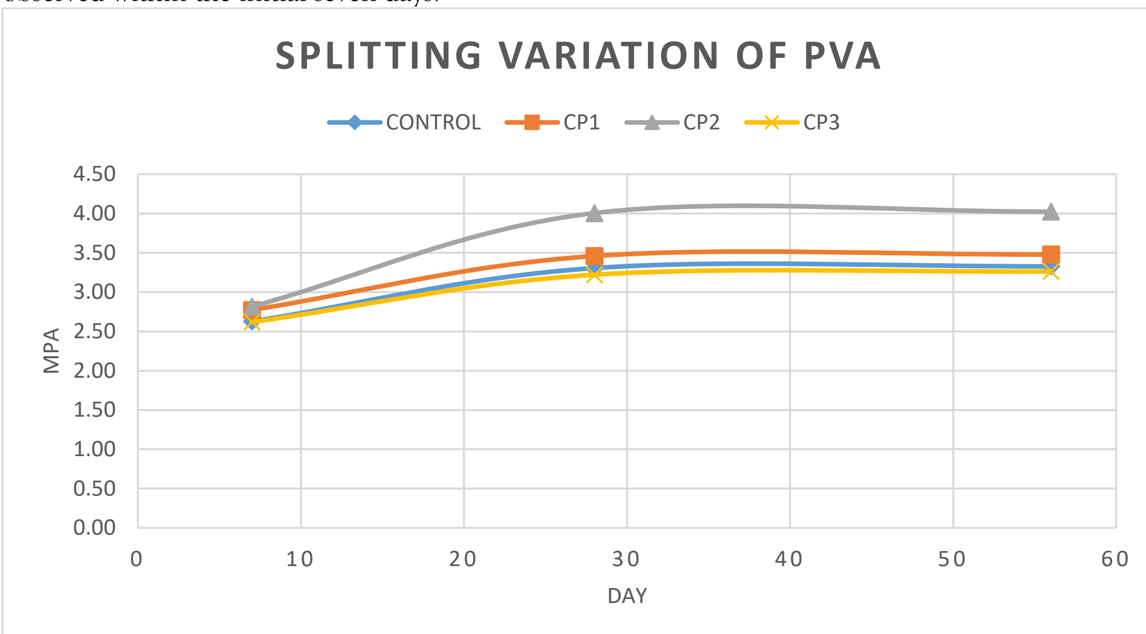

figure 11: results of PVA splitting test

Due to the direct correlation between the compressive strength and splitting strength, the results also observed that adding 1% percentage PVA present significant effect.

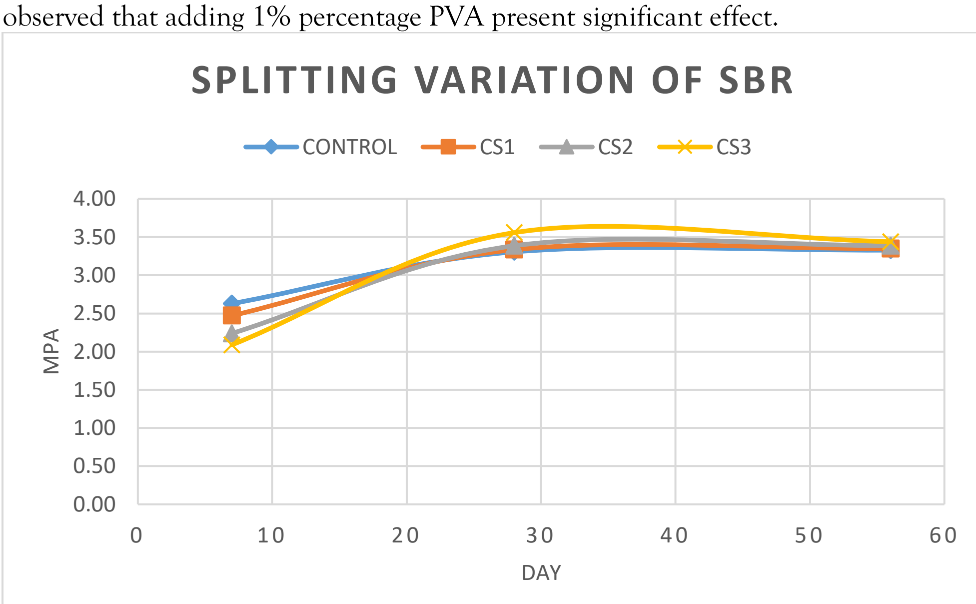

figure 12: results of SBR splitting test

also, adding 30% SBR present a higher result value in age of 28 days, but in age 7 days, all samples present lower flexural values.

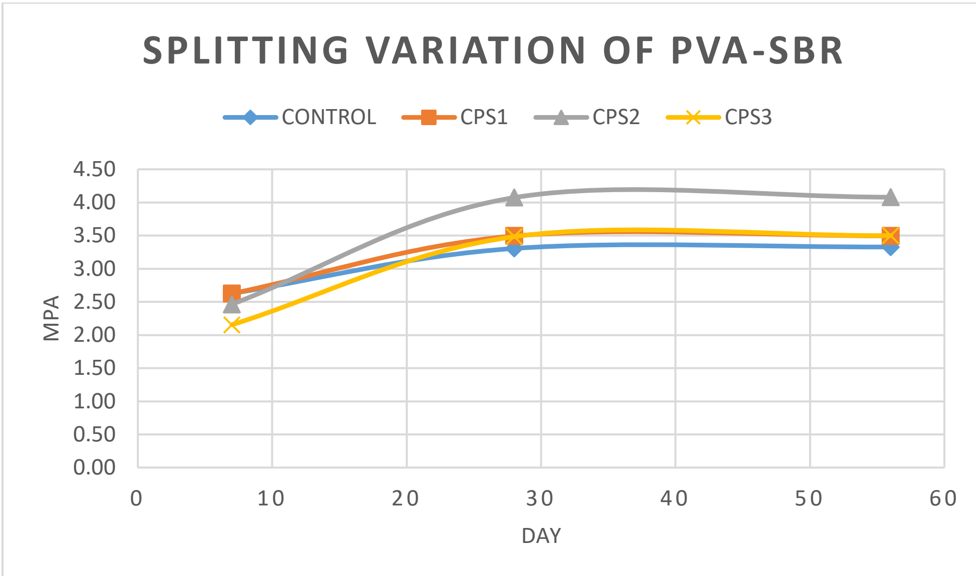

figure 13: results of PVA-SBR splitting test

In CPS2 samples, the combination of PVA and SBR shows a high splitting value at 56 days of age. One important performance metric for evaluating concrete's durability is splitting tensile strength. The standardized process for determining the splitting tensile strength of cylindrical concrete specimens is outlined in ASTM C496. The ability of a material to withstand splitting or fracturing when subjected to tensile pressures applied perpendicular to its surface is known as splitting tensile strength. In an indirect tensile strength test, also known as splitting tensile strength testing, the cylinder is held in place by two parallel platens. Until failure, a compressive force is applied perpendicular to the cylinder's axis. Tensile force applied perpendicular to the loading direction causes the specimen to fracture along its diameter. When designing structural concrete applications, such as beams, columns, slabs, and panels, elevated splitting tensile strength is crucial. To determine the development length of reinforcement and to evaluate concrete's ability to tolerate shear forces, engineers use splitting tensile strength.

The relationship between concrete's density and water absorption has responded differently to hybrid concrete that mixes PVA and SBR. Water absorption will be lessened by the concrete's low density. The prediction functions can be specified as in below:

1-The function of SBR effect

$y = -3.5046x^2 + 35.64x - 61.624$

2- The function of PVA effect

$y = 305.52x^3 - 2136.1x2 + 4978x - 3862.6$

3-The function of PVA-SBR effect

$y = 4.0888x^2 - 13.865x + 14.026$

from the equation above, the correlation can present the probability of concrete water absorption based on the concrete density.

The test was conducted on 28-day-old cubes under curing conditions. Three specimens were subjected to compression testing at each curing age; the results are presented in the figures. The incorporation of PVA into normal concrete, with a compressive strength of 25.87 MPa, influences its strength based on the proportion of PVA utilized. Furthermore, the incorporation of SBR into normal concrete affects its strength based on the proportion of SBR utilized.

For example, the incorporation of 1% PVA results in a marginal strength enhancement of 47%, whereas the addition of 30% SBR yields a marginal strength increase of 15.8%. This indicates the necessity of controlling microcrack propagation and ensuring optimal stress distribution inside the material. Combining PVA with SBR enhances the compressive strength of the mixture by 51.8%.

The flexural strength of concrete incorporating PVA and SBR is contingent upon several aspects, including: • Quality of SBR and PVA • Content of SBR and PVA • Adhesion between SBR, PVA, and the cement matrix

The results indicated that SBR and PVA bond with cement inconsistently. This results in inconsistent variations in flexural strength at a specific dosage.. The last mechanical evaluation is the splitting test. Split tensile strength is an indirect method for ascertaining the tensile strength of concrete by employing a cylinder that fractures along its vertical diameter upon failure. The splitting tensile strength of PVA typically exceeds that of ordinary concrete by 1% at an equivalent water-to-cement ratio. A systematic reduction in indirect tensile strength is shown with an increase in PVA over 2%.'

Investigating the relationship between residual compressive strength and concrete age is essential since age may significantly influence strength. This study examined the compressive strength of concrete sample at 7, 28, and 56 days of curing. In a controlled laboratory setting, specimens were made and cured in a water container for seven, twenty-eight, and fifty-six days to assess the compressive strength of concrete at the ages of 7, 28, and 56 days. The specimens underwent compressive strength testing after the initial curing phase, utilizing a uniaxial compressive strength machine with a constant loading rate of 0.6 ± 0.2 MPa/s, in accordance with EN 12390-3 criteria

CONCLUSION

1. To establish guidelines for the fabrication of resilient concrete composites incorporating polymer s, investigations were conducted to determine the correlation between significant physical propertie s and the primary mechanical parameter of concretes containing cement with 0% to 30% Styrene-Butadiene Rubber (SBR) and 0 to 2.0% (by mass) polyvinyl alcohol (PVA).

The investigation yielded various findings that could be valuable to the field of study.

2. The following results were derived from the current study:

3. 1. According to the slump test, PVA lifts ordinary concrete by less than 1% while lowering it by more than 1%.

Furthermore, when SBR was added to the control mix, it produced a slump value of 148 mm, indic ating greater workability. Finally, combining PVA and SBR results in a 92.5% jump in slump. Adding 1% PVA to concrete mixtures reliably produces optimal mechanical characteristics.

5. The enhancement was consistently lower to that of PVA; however, the addition of 30% SBR res ulted in higher mechanical properties.

6. Combining 4-PVA with SBR increases concrete strength by 51.8%.

7. There is always a precise relationship between density and water absorption.

The recent experiment clearly shows that including PVA-SBR can significantly increase concrete strength.

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