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Strength and Durability Studies on Self Curing Concrete with Bethamcharla Stone Waste under Sulphuric Acid Attack

Mude Sumanth Naik[1], Dr. H. Sudarsana Rao[2], Dr. Vaishali.G. Ghorpade[3]

M. Tech Student, JNTUA College of Engineering, Anantapur, AP, India[1]

Professor, JNTUA College of Engineering, Anantapur, AP, India[2]

Professor, JNTUA College of Engineering, Anantapur, AP, India[3]

ABSTRACT: Concrete is a frequently utilized building material because it is affordable and strong Concrete is ranked second after water due to its widespread use. The most widely used building material is concrete, which is also the second most consumed substance globally. Aggregates add a major volume to concrete. The aggregates make up around 70-80% of the volume of the structural concrete, with coarse aggregate (CA) accounting for 40-50% and fine aggregate for 25-30%. Bethamcherla stone at 0%, 10%, 20%, 30%, 40%, and 50% by weight of coarse aggregate is used as coarse aggregate allows us to create a combination that is as economical as possible. Concrete can self-cure by adding polyvinyl alcohol at concentrations of 0.03%, 0.06%, 0.12% and 0.24%.

KEYWORDS: H_2SO_4, Poly-vinyl Alcohol, Split-tensile strength, Compressive Strength, Bethamcherla Stone.

I. INTRODUCTION

Concrete's cost-effectiveness, durability, and adaptability make it one of the most commonly used building materials in the world. Conventional concrete, however, has drawbacks, especially when it comes to durability and the requirement for sufficient curing to attain ideal mechanical qualities. The creation of self-curing concrete has drawn interest recently as a potential remedy for some of these drawbacks. Self-curing, often referred to as internal curing, is the technique of incorporating substances into the concrete matrix that have the ability to collect and hold water, releasing it gradually to maintain the hydration process. A synthetic polymer with exceptional water-retention qualities and the capacity to enhance cementitious material hydration is polyvinyl alcohol (PVA). Concrete's internal curing process may be increased, which will increase the material's strength and longevity, by adding PVA. However, PVA's concentration in the concrete mix determines how well it works as a self-curing agent. For concrete to be developed sustainably, waste materials must be used in part place of traditional aggregates, along with the inclusion of self-curing chemicals. As a waste product of the stone-cutting business, Bethamcherla waste stone offers a way to lessen the dependency on natural coarse aggregates. This encourages the preservation of natural resources in addition to aiding in waste management. This study looks at how the mechanical characteristics of self-curing concrete are affected by different proportions of Bethamcherla waste stone and polyvinyl alcohol. The study specifically aims to assess the split tensile and compressive strengths of concrete mixtures including varying amounts of PVA and Bethamcherla waste stone. The goal of the study is to create a concrete mix that maximizes strength while improving sustainability by figuring out the best combination of these elements. The research has importance as it has the ability to progress the technology of self-curing concrete and promote the sustainable utilization of waste materials in buildings. It is anticipated that the results will give significant perspectives on the real-world use of PVA and Bethamcherla waste stone in concrete, paving the door for more robust and environmentally responsible building techniques. The outcomes of this study should open up new avenues for the development of more resilient and ecologically friendly building techniques by shedding light on the useful uses of waste materials and self-curing agents in concrete. This study is especially important for infrastructure projects in acid-attack-prone locations since it suggests that adding PVA and Bethamcherla waste stone to concrete mixes might increase performance in harsh settings.

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II. LITERATURE REVIEW

Jyothishnaidu (2020): Jyothishnaidu evaluated Bethamcherla marble stone (BMS) as a partial replacement for conventional aggregates in concrete and discovered that the compressive strength of the **V** mixture declined as the BMS content increased, particularly over 25%. Despite this decrease, the study emphasized the financial and environmental advantages of employing BMS and suggested more research into the long-term durability of the concrete. **Ghantasala Nirupama and Jyothi Kumari Ganta** (**2024**): In their research, Ghantasala Nirupama and Jyothi Kumari Ganta discovered that substituting waste stone from Bethamcherla by 40% increased compressive strength and promoted sustainable building practices. They emphasized the importance of precise proportioning to prevent strength loss and suggested further investigation into the concrete's long-term performance and durability. **S. Narayana Reddy et al (2023):** According to research by S. Narayana Reddy et al., using Bethamcherla stone powder 20% instead of cement might improve compressive and split tensile strengths. This makes Bethamcherla stone powder a more environmentally friendly substitute for typical cement since it uses less cement and makes use of industrial waste. They underlined the necessity of cautious mix design to prevent adverse effects on strength and suggested more investigation into the longevity and functionality of the modified concrete. Giridhar **N. Narule and Nathu D. (2022):** In their 2024 study, Narule and Thombare highlighted the importance of material selection and proportioning in challenging environments and discovered that optimizing concrete mix designs with 30.82% fly ash and certain admixtures improved sulphate and chloride resistance, enhancing compressive strength by 5.12%. **K. Vybhav Reddy, M. Praveen Kumar and Dr. T. Suresh Babu (2016):** According to the study, when M20-grade self-curing concrete is augmented with 1% polyvinyl alcohol (PVAC), it outperforms conventional concrete in terms of split tensile strength and compressive strength, increasing by 27.5% and 23.5%, respectively. This illustrates the self-curing concrete's improved hydration and strength development, providing insightful information for improving concrete compositions. **V. Chaitanya and K. Deepthi (2019):** In comparison to conventional concrete, a 0.4% PVA dosage leads to 1.8% lower compressive strength, 9.2% greater split tensile strength, and 2% lower flexural strength in M25 grade self-curing concrete that incorporates fly ash as a partial cement substitute. These results highlight fly ash's capacity to enhance performance and sustainability in concrete applications. **S.P. Kanniyappan, B. Tamilarasan and M. Sivakumar (2016):** According to the study, the combination of ground granulated blast furnace slag (GGBS) and self-compacting concrete (SCC) greatly increases durability by lowering permeability and fending off sulphate and chloride assaults. At 40%, 50%, and 60% GGBS substitution, SCC with GGBS exhibits enhanced long-term performance in demanding settings with less weight loss from sulphate assaults. **A. Joshna1, M. Sri Priya (2019):** According to Joshna and Sri Priya's research, adding 10% fly ash and 10% GGBS to self-compacting concrete (SCC) instead of full replacement of ingredients improves durability by decreasing water absorption and boosting resistance to chemical assaults. Nevertheless, compressive strength is reduced when the proportions are increased beyond this ideal blend, emphasizing the necessity for a balance that would extend the lifespan and enhance the performance of SCC. K. Nithya, **K. Ranjitha and P. Kumar (2017):** The research on self-curing concrete shows that it may be made to function similarly to conventional concrete by adding self-curing chemicals, especially at a level of 0.5% PVA, which improves hydration, water retention, and strength development. The results indicate that self-curing techniques greatly increase the performance and durability of concrete, particularly under difficult circumstances. Membrane curing is shown to be more successful than wrapped curing.

III. SCOPE AND OBJECTIVE

Optimize the design of the concrete mix to obtain the required durability and strength properties. Test self-curing concrete specimens in a laboratory setting thoroughly, looking at things like permeability, microstructural alterations, and compressive strength.

1. This study aims to assess the strength characteristics of self-curing concrete of M20 grade under sulfuric acid assault.
2. To make concrete more resistant to chemicals.
3. identifying the sulfuric assault on the mixed concrete.

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IV. MATERIALS

4.1 Cement:

Ordinary Portland Cement (OPC) of 53 Grade, which was particularly obtained from Nagarjuna Cement, was the main binder employed in this investigation. This cement is approved for use in high performance concrete applications due to its exceptional early strength and compliance with IS: 12269 requirements. The OPC that was utilized assured dependability in the trial outcomes because it had a specific gravity of 3.15 and was renowned for its constant quality.

4.2 Fine Aggregate:

Particles sized 4.75 mm and smaller were employed as fine aggregate in the concrete mix. With a specific gravity of 2.74, this sand was compatible with the other materials in concrete and had a sufficient density. To improve the workability and strength of the concrete, the aggregate was carefully graded.

4.3 Coarse aggregate:

The approximate maximum size of the coarse aggregate used is 20 mm, and it is made of locally accessible crushed stone that is mined. Its specific gravity is 2.74.

4.4 Bethamcherla waste stone:

When used in concrete at percentages of 10%, 20%, 30%, 40%, and 50%, Bethamcherla waste stone (BWS), which has a nominal maximum size of 20 mm, partially replaces coarse particles. This waste product improves the workability, strength, and durability of concrete and provides a sustainable substitute. In addition to perhaps improving the mix's qualities, the substitution has an impact on how well industrial byproducts are used overall. Locally derived from Bethamcherla village near Kadapa distract, Bethamcherla waste stone (BWS) recycles industrial by-products in the area to enable sustainable development. This local sourcing lessens the impact on the environment and transportation expenses. This stone can be changed to particular sizes easily.

Table 1: properties of Bethamcherla waste stone.

S.NO	Properties	results
1	Crushing value	20.19%
2	Test of attributes impact	16.73
3	Specific gravity	2.70
4	Water Absorption	0.2 %
5	Max Size	20mm

Figure 1. Bethamcherla waste stone.

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Table 2. Chemical properties of Bethamcherla waste stone.

S.NO	Composition of attributes	Percentages of compounds
1	Silicon dioxide	9.8
2	Oxide of iron	1.42
3	Aluminium trioxide	1.38
4	Oxides of Calcium	29.72
5	Oxides of Magnesium	16.32
6	Calcium Carbonate (CaCO3)	52.87
7	Magnesium Carbonate	33.82

4.5. Poly-vinyl alcohol (PVA):

Polyvinyl Alcohol (PVA) was added to the cement in the project at weight percentages of 0.03%, 0.06%, 0.12%, and 0.24% in order to act as an internal self-curing agent. This method was designed to improve the concrete's hydration and moisture retention. Compressive strength, split tensile strength, and durability were evaluated in order to determine the efficacy of PVA. The outcomes showed that concrete with the ideal PVA doses performed better and was more durable. Super Absorbent Polymer (SAP) from Isochem Laboratories in Angamaly, Kochi, was utilized in this investigation. Its superior binding and film-forming qualities also find use in adhesive properties.

Figure 2. Poly-vinyl alcohol.

Table 3. Properties of poly-vinyl alcohol.

S.NO	Properties	Results
1	Viscosity	25-32 cps
2	Hydrolysis	98-99 c
3	Degree of Polymerisation	1700-1800
4	pH of Aqueous solution (Mole)	5-7
5	Form	White powder

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4.6. Superplasticizer:

SP 430 is the super plasticizer that was utilized in this experiment. The FOSROC Company in India produces it. The workability has been enhanced by the addition of this super plasticizer.

4.7. Sulphuric acid (H_2SO_4):

Sulphate can originate from fertilizers and industrial effluents, but it can also be found in groundwater and is frequently found naturally. The cube and cylinder specimens are submerged in a solution of 5% sulphuric acid added to water. Sulphate attack, which shows up as mass loss, expansion, surface spalling, strength loss, and ultimately disintegration, is the result of a sequence of events that take place in the presence of Sulphate ions and attack concrete.

Table 4. Properties of Sulphuric acid (H_2SO_4).

S.NO.	Properties	Results
1	Purity/Concentration	98%
2	Appearance	Colourless liquid
3	Form	Liquid
4	Grade	Industrial Grade

V. EXPERIMENTAL METHODOLOGY

The experimental investigation concentrated on M20 grade self-curing concrete with a partial substitution of natural coarse aggregates utilizing Bethamcherla waste stone and polyvinyl alcohol (PVA) as a self-curing agent. Various amounts of PVA (0% to 0.24%) and Bethamcherla waste stone (0% to 50%) were used in the casting of cube and cylinder specimens. After 28 days of self-curing at room temperature, the workability was evaluated using the slump cone test. Compressive and split tensile strength tests were then performed on the specimens after they had been submerged in 5% diluted sulfuric acid for 30, 60, and 90 days.

VI. RESULTS AND DISCUSSIONS

6.1 Workability Test

As the proportion of Bethamcherla waste stone rose, the slump test shows a trend toward diminishing workability. The average drop that was noted during the test is shown below. 85 mm was the maximum drop measured, while 68 mm was the lowest. For every batch of mix, the average slump was 75mm. Consequently, the goal slump, which has a range of 50 to 100 mm, has been reached. From 0% to 50% Bethamcherla waste stone, the workability was acceptable and could be handled effectively. The decrease in the range of 7–8 mm made the slump from 0% Bethamcherla waste stone to 50% Bethamcherla waste stone deemed considerable. Fresh concrete was placed and compacted without any issues. The mix containing 50% Bethamcherla waste stone (with a water cement ratio of 0.55), was the only one that had issues. Because there was only a 68mm droop, the workability was quite low. The great absorption capacity of the waste stone from Bethamcherla was the cause. The obtained result indicates that the workability decreased with an increase in the amount of Bethamcherla waste stone used.

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Table 5. Percentage of BWS V/s Slump.

S. No	% of BWS	Slump (mm)
1	0%	85
2	10%	80
3	20%	78
4	30%	75
5	40%	70
6	50%	68

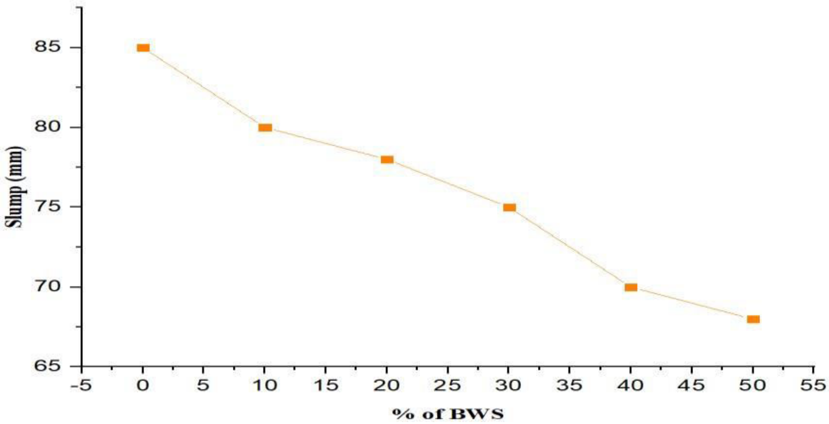

Figure 3. BWS percentage V/s slump.

6.2 Compressive Strength

An investigation of Self curing concrete's compressive strength was carried out using OPC as the source material. Bethamcherla Waste Stone was substituted for coarse aggregates in the mix proportions of 10%, 20%, 30%, 40%, and 50% for specimens evaluated at 30, 60, and 90 days. The findings are displayed in Fig. 3. Based on the data, it can be seen that using Bethamcherla in place of CA produces very positive outcomes. At 30 and 60 days of age, Bethamcherla waste stone replaced CA with a 30% increase in compressive strength. Similarly, in order to replace CA by 30% of Bethamcherla waste stone as optimally as possible, polyvinyl alcohol was substituted for cement in the amounts of 0%, 0.03%, 0.06%, 0.12%, and 0.24%, respectively. The results are displayed in Figures 4,5 and 6. Strength is significantly increased when polyvinyl alcohol is used in place of cement. This indicates that an optimal replacement of 0.12% for cement is also provided. cement is also provided. polyvinyl alcohol is used in place of cement. This indicates that an optimal replacement of 0.12% for cement is also provided.

6.2.1 Effect of Bethamcherla waste stone (BWS):

The strength of the concrete was affected by the use of Bethamcherla waste stone as a substitute for coarse aggregate. Strength-wise, compressive strengths can be enhanced by up to 30% replacement, with 30% providing the best results. But going beyond 30% resulted in a loss of strength, perhaps because the cement matrix diluted and the aggregate-cement connection was weakened.

6.2.2 Effect of Polyvinyl Alcohol (PVA):

Using polyvinyl alcohol (PVA) as a self-curing agent improved hydration and decreased moisture loss in the concrete mixture greatly. Based on the findings, the best concentration of 0.12% PVA was found to yield the highest strength. After 30, 60, and 90 days of immersion in 5% diluted sulfuric acid, PVA increased the concrete's durability at this dosage, especially against sulphate attack, with compressive strengths of 29.73 N/mm², 31.35 N/mm², and 28.78 N/mm².

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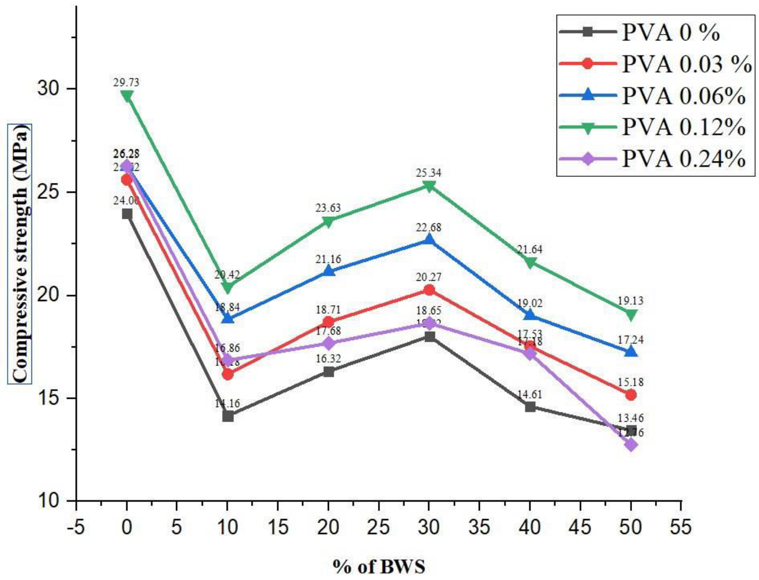

Figure 4. Variation of Compressive strength of SCC for % of BWS replacement at 30 days H_2SO_4 attack.

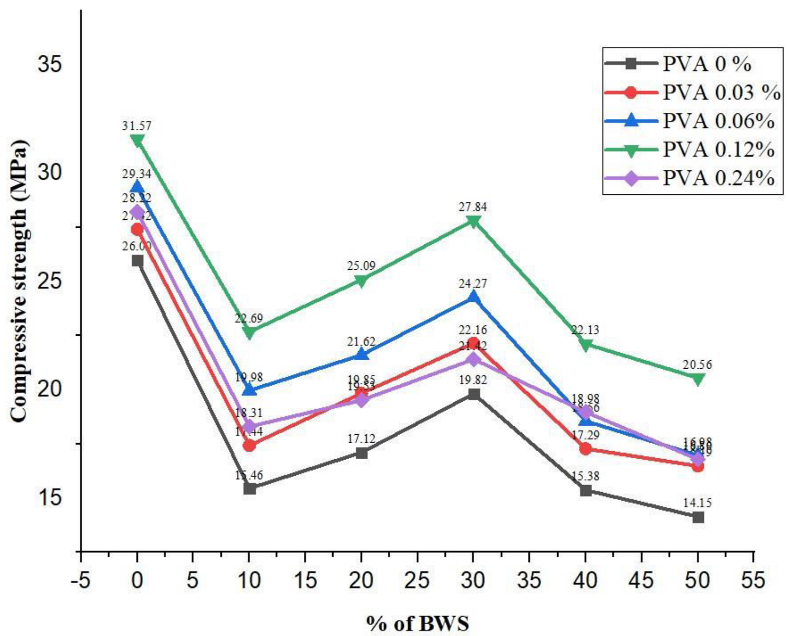

Figure 5. Variation of Compressive strength of SCC for % of BWS replacement at 60 days H_2SO_4 attack.

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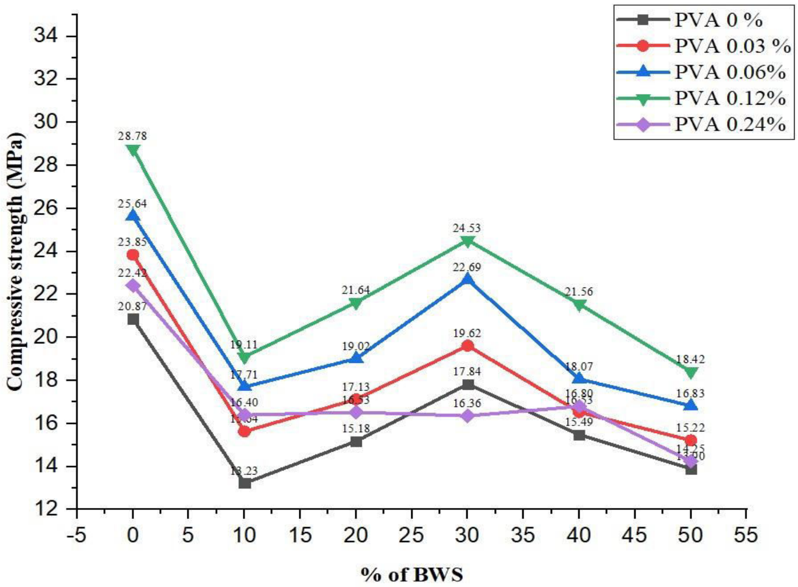

Figure 6. Variation of Compressive strength of SCC for % of BWS replacement at 90 days H_2SO_4 attack.

6.2.3. Combined effect of both Bethamcherla waste stone and Polyvinyl Alcohol:

30% Bethamcherla waste stone and 0.12% PVA were used to get the best compressive strength as you can see in figure. This blend produced improved strength by achieving a balance between the aggregates efficient packing and the PVA's increased hydration. The compressive strength was 25.34 N/mm² following a 30-day self-curing period. After 60 days of immersion in sulfuric acid, the strength rose to 27.84 N/mm², but after 90 days, it significantly fell to 24.53 N/mm², demonstrating the mix's resistance to acidic environments.

6.3. Split Tensile Strength

This optimal PVA concentration also yielded the highest split tensile strength, demonstrating its effectiveness in enhancing both initial strength development and long-term durability. The OPC was used as the source material for this investigation on the split tensile strength of self-curing concrete. Bethamcherla Waste Stone was substituted for coarse aggregates in the mix proportions of 10%, 20%, 30%, 40%, and 50%, respectively, for specimens evaluated at 30, 60, and 90 days. The findings are displayed in Figures 7,8 and 9. Based on the findings, it can be seen that using Bethamcherla Waste Stone in place of coarse aggregate produces very positive outcomes. Bethamcherla Waste Stone was used in place of coarse aggregate at a 30% increase in split tensile strength after 30 and 60 days. It's evident that using Bethamcherla Waste Stone in place of coarse aggregate increased the tensile strength of the concrete. Similarly, in order to replace coarse aggregate by 30% of Bethamcherla Waste Stone, the following percentages of polyvinyl alcohol were substituted for cement: 0%, 0.03%, 0.06%, 0.12%, and 0.24%, respectively. Results are comparatively comparable when polyvinyl alcohol is used in place of cement. The use of Bethamcherla Waste Stone coarse aggregate and polyvinyl alcohol cement enhanced the behaviour of the concrete under strain.

6.3.1. Effect of Bethamcherla waste stone (BWS):

Because of excellent packing and a strong connection with the cement, using Bethamcherla waste stone as a partial substitute for natural coarse aggregates in self-curing concrete increased the split tensile strength up to a 30% replacement level. But at 30%, the tensile strength began to decline, perhaps as a result of the cement and aggregates' weakened bond. The concrete's capacity to withstand tensile loads was compromised by the disruption of the particle packing, which resulted in decreased cohesiveness and the creation of minute spaces.

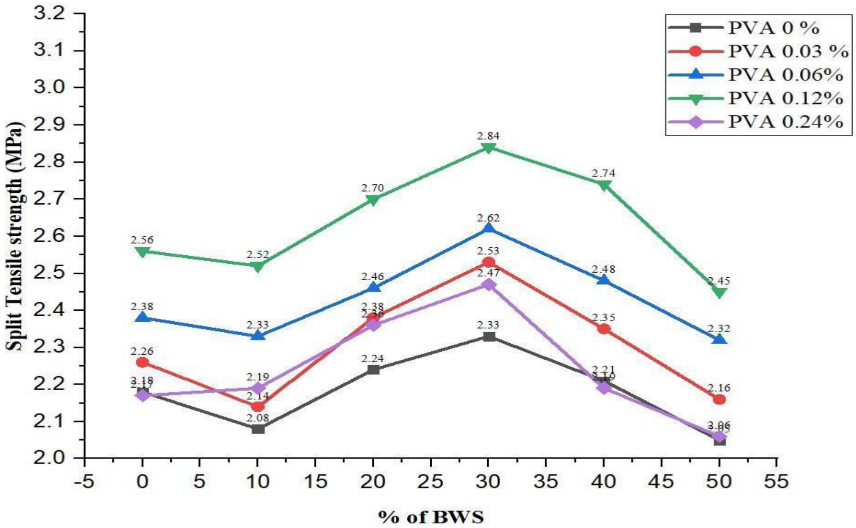

Figure 7. Variation of Split Tensile Strength of SCC for % of BWS replacement at 30 days H_2SO_4 attack.

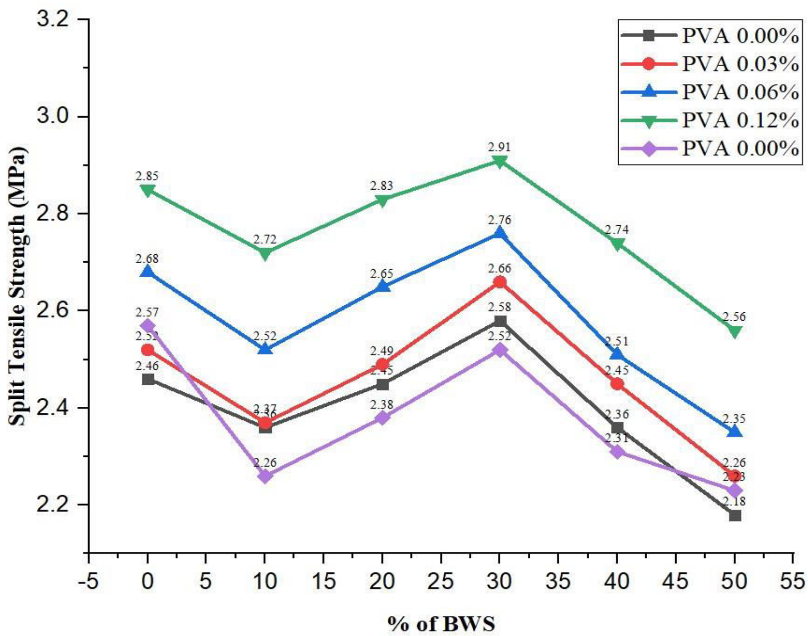

Figure 8. Variation of Split Tensile Strength of SCC for % of BWS replacement at 60 days H_2SO_4 attack.

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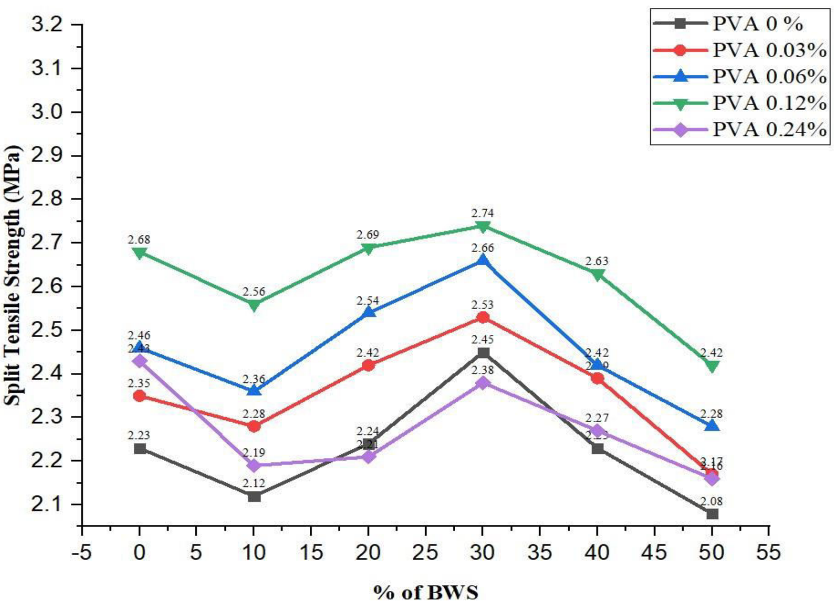

Figure 9. Variation of Split Tensile Strength of SCC for % of BWS replacement at 90 days H_2SO_4 attack.

6.3.2. Effect of Polyvinyl Alcohol (PVA):

Adding PVA resulted in an increase in split tensile strength, which peaked at 0.12%. The blend with the highest initial split tensile strength was found to be 30% Bethamcherla waste stone and 0.12% PVA. This confirms the mix's excellent effects. The concrete mix containing 30% Bethamcherla waste stone and 0.12% PVA attained a maximum split tensile strength of 2.56 N/mm² after 30 days in sulfuric acid, indicating significant initial resistance. With 60 days, the strength dropped to 2.85 N/mm², and after 90 days, it dropped even more to 2.68 N/mm², indicating that the acid influence was still there. In contrast to other combinations, the blend demonstrated better resistance and durability despite this reduction.

6.3.3. Combined effect of both Bethamcherla waste stone and Polyvinyl Alcohol:

At 30% Bethamcherla waste stone and 0.12% PVA, the split tensile strength likewise reached its maximum. PVA enhanced moisture retention and hydration, and the rough roughness of the waste stone probably helped connect inside the concrete matrix better. The split tensile strength was 2.84 N/mm² after 30 days in sulfuric acid immersion; it declined to 2.74 N/mm² after 90 days, then marginally increased to 2.91 N/mm² after 60 days. This mixture showed better long-term endurance than other blends, even with the gradual decline.

VI. CONCLUSION

1. According to the findings, a mixture of 0.12% PVA and 30% Bethamcherla waste stone produced the best strengths for self-curing concrete.
2. The workability for various proportions of Bethamcherla waste stones were ascertained and it showed a gradual decreasing trend from 85mm to 68mm as percentage of Bethamcherla waste stone increased from 0 % to 50 %.
3. The highest compressive strengths obtained for 30, 60, and 90 days were 25.34 N/mm², 27.84 N/mm², and 24.53 N/mm², respectively, when Bethamcherla waste stone has replaced for 30% of coarse aggregate and 0.12% of cement by poly vinyl alcohol.
4. The highest Split Tensile strengths obtained for 30, 60, and 90 days exposure were 2.84 N/mm², 2.91 N/mm², and 2.74 N/mm², respectively, when Bethamcherla waste stone replaced for 30% of coarse aggregate and 0.12% of cement by poly vinyl alcohol.

5. The lowest compressive strengths recorded for 30, 60, and 90 days exposure are 12.76 N/mm², 16.8 N/mm², and 14.25 N/mm², respectively, when 50% of coarse aggregate and 0.24% of cement were substituted with Bethamcherla waste stone and 0.24% PVA is used.
6. The lowest Split Tensile strengths recorded for 30, 60, and 90 days, as 2.06 N/mm², 2.23 N/mm², and 2.16 N/mm², respectively, when 50% of coarse aggregate substituted with Bethamcherla waste stone and 0.24% PVA is added.
7. If we take only the effect of poly vinyl alcohol on strength parameters, it shows significant gradual increase in compressive and split tensile strength from 0 % to 0.12 % levels and after that we can observe sudden fall of strength i.e. at 0.24% level.
8. If we take only the effect of Bethamcherla waste stone on strength parameters, it shows significant gradual increase in compressive and split tensile strength from 0 % to 30 % replacement levels and after that we can observe sudden fall of strength at 40% and 50% replacement levels.
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