Non-Destructive Test on Self Curing Concrete and Partial Replacement of Coarse Aggregate with Betamcharla Stone

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ABSTRACT

Self-curing concrete represents a significant advancement over traditional concrete in terms of hydration and curing methods. Unlike conventional concrete, self-curing concrete is designed to retain its own moisture throughout the curing process. This is achieved by incorporating self-curing agents such as chemical admixtures that retain and slowly release water into the concrete matrix. The ability to cure itself makes self-curing concrete particularly advantageous in environments where traditional curing is challenging or costly, such as in areas with limited water resources or extreme weather conditions This study will investigate the performance of self-curing concrete using non-destructive testing (NDT) methods and explore the impact of partial replacement of coarse aggregates with Betamcharla stone. Natural marble is the main component of Betamcharla stone. It may be located in the Betamcharla area of Andhra Pradesh Kurnool district. Betamcharla waste stone is generated during the quarry's cutting and sizing processes and is typically found as overburden. Concrete, a binding material, consists of cement, water, and fine and coarse aggregates (M20). This project explores the impact of incorporating polyvinyl alcohol (PVA) at various percentages (0%, 0.03%, 0.06%, 0.12%, 0.24% by weight of cement) and partially replacing coarse aggregate with Betamcharla stone at different levels (0%, 10%, 20%, 30%, 40%, 50% by weight of coarse aggregate). Polyvinyl alcohol (PVA) is used as a self-curing agent. In this experimental work will determine the strengths of concrete using Non-destructive tests such as ultrasonic pulse velocity, rebound hammer will be employed to monitor the evolution of mechanical properties over time. Also determine the mechanical properties using compressive strength.

Keywords: Betamcharla Waste stone, Poly-vinyl Alcohol, Rebound Hammer Test, Ultrasonic Pulse Velocity Test, Compressive Test.

1. INTRODUCTION:

The rapid expansion of urban infrastructure has increased global demand for concrete, placing pressure on natural aggregates and water resources. Since coarse aggregate plays a vital role in the mechanical performance of concrete, the depletion of natural sources has encouraged the search for sustainable alternatives. Betamcharla stone, a limestone-based material abundantly available in the Kurnool district of Andhra Pradesh, is generated in large quantities as quarry and cutting waste. Utilizing this material as partial coarse aggregate replacement offers an environmentally responsible and resource-efficient solution.

Evaluating the performance of concrete containing alternative aggregates requires reliable testing methods. While the compressive strength test remains the standard destructive method for assessing concrete strength, Non-Destructive Testing (NDT) techniques are increasingly used to examine in-situ quality without damaging specimens. Among these, the Rebound Hammer Test provides an estimate of surface hardness, whereas the Ultrasonic Pulse Velocity (UPV) test assesses internal quality, detects voids, and determines concrete uniformity. This study investigates the behavior of concrete incorporating Betamcharla stone through a combined assessment using Rebound Hammer, UPV, and compressive strength tests at 3, 7, 14, 28, 56, and 90 days. The objective is to understand strength development, hydration progression, and internal quality over time, and to determine the suitability of Betamcharla stone as a sustainable coarse aggregate replacement. The study also aims to establish correlations between NDT results and compressive strength to support improved quality control in concrete construction.

1.1 SCOPE AND OBJECTIVES OF THE STUDY

This study investigates the use of Betamcharla stone as a partial replacement for conventional coarse aggregates and Polyvinyl Alcohol (PVA) as a self-curing agent in M20 grade concrete. Betamcharla stone is incorporated at 10%, 20%, 30%, 40%, and 50%, while PVA is added at 0.03%, 0.06%, 0.12%, and 0.24% of the mixing water. Concrete cubes are cast and tested at 3, 7, 14, 28, 56, and 90 days to determine compressive strength. Fresh concrete characteristics, such as slump, is also assessed. Non-destructive tests including Rebound Hammer and Ultrasonic Pulse Velocity (UPV) are performed to evaluate surface hardness, internal quality.

The objectives of this study are to:

- Assess the mechanical performance and workability of concrete containing Betamcharla stone and PVA.
- Evaluate the effectiveness of PVA in improving internal curing and reducing reliance on external water curing.
- Examine the feasibility of using Betamcharla stone as a sustainable coarse aggregate replacement.
- Identify optimal proportions that enhance strength, durability, and overall sustainability of M20 concrete.

2. REVIEW OF LITERATURE

Neeraj et al. (2024) investigated the performance of self-curing high-strength M50 concrete incorporating Betamcharla waste stone (BMC) as a partial replacement of coarse aggregate, along with polyvinyl alcohol (PVA) as a self-curing agent and 10% silica fume as a supplementary cementitious material. Betamcharla stone was used at replacement levels of 10, 20, 30, 40 and 50%, while PVA was added at 0.03, 0.06, 0.12, and 0.24% by weight of cement. The study reported that both compressive and split tensile strengths improved up to an optimum combination of 30% BMC and 0.12% PVA, beyond which strength and workability declined due to increased water absorption and altered aggregate grading. The authors concluded that Betamcharla waste stone, when combined with PVA and silica fume, can be effectively used to produce sustainable self-curing high-strength concrete with reduced dependence on external curing water

Rajesh. G., ArunaKanthi (2016). How Betamcharla Waste Stone Behaves with Fiber Reinforced Concrete's Mechanical and Workability Properties. The purpose of the paper is to investigate the mechanical and workability properties of fiber-reinforced concrete for M20 grade concrete, using Betamcharla marble stone in place of natural aggregate. Steel fiber is added to the natural coarse aggregate in varying amounts for all mix batches with volume percentages of 0%, 1%, and 2%. The natural coarse aggregate is 100% substituted with Betamcharla waste stone aggregate. Better concrete quality was the only reason it was advised to restrict the replacement level to "BWSA 50%."

Ghorpade, V.G et al (2013)., influence of recycled coarse particles on the shear strength and workability of fiber-reinforced high-strength concrete. This work aims to investigate the properties of fiber reinforced plastic's workability and shear strength. Use of recycled coarse aggregates from demolished construction trash results in High Strength Concrete. Various mixtures were made, ranging from 0% to 100% recycled coarse aggregate in place of natural coarse aggregate. A 1% steel fiber addition is also made to the concrete to increase strength. Recycled coarse aggregate should not be used to replace more than 20% of the natural coarse aggregate.

B. Ajitha et al. (2017) conducted a study on the evaluation of self-curing concrete properties using polyvinyl alcohol (PVA). According to their findings, the flexural strength of the concrete mix increased gradually as PVA addition percentage increased, peaking at 0.24% PVA. Past this focus, As the amount of PVA grew, the flexural strength increased further. This indicates that incorporating PVA enhances the concrete's flexural strength, making it more effective for applications requiring improved durability and performance.

Daliya Joseph et al. **(2016)** carried out research on the topic of "Effect of Self-Curing Compounds on the Mechanical Features of Concrete." Based on the study, the concrete's slump value increased together with the proportion of polyethylene glycol (PEG), suggesting that the workability of the material was improved. In contrast, a drop in slump value indicated decreased workability when the amount of polyvinyl alcohol (PVA) increased. Furthermore, the research observed that while PEG enhanced workability, both PEG and PVA, when used in higher percentages, resulted in a decrease in the strength properties of the concrete. This suggests that although self-curing agents like PEG and PVA can improve certain properties, their excessive use might adversely affect the concrete's overall strength and performance.

3. EXPERIMENTAL WORK

3.1 MATERIALS USED

A. Cement: The study utilized 53-grade ordinary Portland cement, or OPC, had a particular gravity of 3.15. The cement's properties, tested as per IS 8112:1989, were as follows: fineness of 287 m^2/kg, normal consistency of 33%, initial setting time of 35 minutes, and final setting time of 585 minutes. These numbers attest to the cement's appropriateness for use in high-strength concrete applications.

B. Fine Aggregate: For this study, high-quality fine aggregate which was sieved through a 4.75mm mesh was used, the sand's properties tested to have a gravity value of 2.74 and a modulus of fineness 4.80, and a bulk density of 15.90 KN/m^3. The sand exhibited a bulking value of 21.10% and was classified as Zone-II.

C. Coarse Aggregate: The coarse materials used in this study are 20 mm natural stone aggregates, locally sourced. Laboratory tests were conducted as per IS: 2386 (Part III)-1963 finding out the coarse aggregate's properties resulting in the following values: 2.68 specific gravity and fineness modulus flakiness index of 11.61%, elongation index of 13.88%, crushing value of 19.42%, impact value of 13.69%, and water absorption of 1.2%.

D. Betamcharla Waste Stone Aggregate: The waste stone material used in this study is sourced from tile manufacturing industries, where significant waste is generated during the production. Due to its size, this waste cannot be directly used in concrete. Therefore, it must be processed into graded aggregate suitable for concrete applications. This involves transporting the waste to crushing units to achieve the desired aggregate size. For this study, the aggregate, it is kept on a 20 mm IS screen after passing through 10 mm IS sieve, was utilized to ensure effective use and proper placement in concrete. The following tables provide specific information on the marble stone aggregate's chemical and physical characteristics.

Table 1: Physical properties of Betamcharla stone.

S. No	Property	Test Result
1	Specific gravity	2.65
2	Fineness modules	5.80
3	Flakiness index	34.97%
4	Elongation index	44.6%
5	Crushing value	22.67%
6	Impact value	23.1%
7	Water absorption	1.5%

E. Polyvinyl Alcohol (PVA): The self-curing agent utilized in this investigation is polyvinyl alcohol (PVA), which is applied at weight percentages of 0.03%, 0.06%, 0.12% and 0.24%. PVA is known for its excellent water-retention properties, which help to reduce water evaporation during the curing process. By incorporating PVA into the concrete mix, it enhances hydration and improves the overall strength of the concrete. This addition aims to address water management issues and contribute to more efficient curing practices.

F. Superplasticizer (Conplast SP 430): Conplast SP 430 was used in the present study as a high-range water-reducing admixture to improve the workability of concrete without increasing the water content. It is a sulphonated naphthalene formaldehyde (SNF)–based superplasticizer supplied in liquid form. The admixture was dark brown in colour and completely soluble in water. The specific gravity of Conplast SP 430 was approximately 1.18, and it exhibited a near-neutral pH value.

G. Water: Concrete must be mixed with clean water that has no dangerous quantities oils, organic compounds, acids, and alkalis or other deleterious chemicals. In this investigation, we used portable tap water from the JNTUA college campus water plant that met the IS456-2000 standards for casting concrete and curing the specimens.

3.2 MIX PROPORTION: To achieve M20 grade concrete, the mix was designed in accordance with IS 10262-2009. In this study, Betamcharla stone was used partially in place of coarse aggregate to the extent of 0%, 10%, 20%, 30%, 40%, and 50% of the cement weight. Additionally, PVA was added as a self-curing reagent at 0.03%, 0.06%, 0.12%, and 0.24% of the cement weight. To analyze the properties, six cubes were cast for each mix. These specimens were subjected to tests at 3,7,14 28 56 and 90 days. The goal was to determine the optimal proportions of Betamcharla stone and PVA for improved concrete performance.

3.3 CASTING OF SPECIMENS: A thorough cleaning was performed on the moulds used to cast cubes. To avoid concrete adhesion and leakage, a thin coating of oil was put to the moulds interior surface. Subsequently, the lubricated moulds (cubes) were filled with concrete using a tamping rod. In tests, the ages of 3,7,14 28 56 and 90 days were involved.

3.4 SELF-CURING:

Self-curing is an innovative method used in concrete construction to enhance the hydration process without the need for traditional water-curing methods. In this approach, materials known as self- curing agents are added to the concrete mix to promote water retention within the concrete matrix, ensuring that sufficient moisture is available for the hydration of cement. This method is particularly beneficial in regions where water conservation is crucial, or when curing large-scale projects where maintaining continuous water curing is impractical.

This work uses synthetic polymer Polyvinyl Alcohol (PVA) in different weight percentages of cement (0.03%, 0.06%, 0.12%, and 0.24%) as a self-curing agent. PVA helps retain moisture within the concrete, reducing the evaporation rate and allowing the cement to continue hydrating, which is essential for developing the concrete’s strength and durability. By incorporating PVA, the reliance on external curing methods is minimized, leading to potential benefits such as reduced water usage, improved curing efficiency, and enhanced long-term performance. Self-curing also contributes to maintaining consistent internal moisture levels throughout the curing process, preventing shrinkage, cracking, and other defects that can arise from uneven or insufficient curing. The use of self-curing agents like PVA enables the concrete to achieve optimal strength, especially in conditions where conventional curing is challenging or limited.

3.5 TESTING METHODS

3.5.1 Workability test:

A widely used technique for gauging the reliability and fluidity of new concrete includes the Slump Test, and was utilized to assess the ability to work of the material. The test indicates the ease with which the concrete may be mixed, poured, and compacted without causing severe bleeding or segregation. In this test, a standard conical mold is filled with concrete and lifted, allowing the concrete to "slump" or settle under its own weight. The vertical displacement or reduction in the concrete mass's height is then determined, and used to assess its workability.

3.5.2 Compression test:

The testing protocol involved casting and evaluating concrete specimens in the form of 150 x 150 mm cubes. M20 grade concrete was prepared using Ordinary Portland Cement (OPC), natural river sand, coarse aggregate (ranging from 20mm to 4.75mm), Betamcharla (BMC), and PVA. Six specimens were made for each mix to determine the values for a curing period of 3,7,14,28,56 and 90 days.

Fig.2 Compression Test

3.5.3 Rebound Hammer test:

The Rebound Hammer test was conducted to assess the surface hardness and estimate the in-situ compressive strength of concrete. The hammer plunger was placed firmly against the smooth, clean surface of the cube, and rebound readings were recorded at multiple points to obtain an average value for each specimen. A total of six specimens per mix were tested at 3, 7, 14, 28, 56, and 90 days to monitor the strength development and compare the results with destructive compressive strength values.

Fig.3 Rebound Hammer Test

3.5.4 Ultrasonic Pulse Velocity (UPV) Test:

The Ultrasonic Pulse Velocity test was performed to evaluate the internal quality, uniformity, and integrity of concrete specimens. The UPV apparatus was positioned with its transducers on opposite faces of each cube, ensuring proper coupling using a gel medium to allow accurate transmission of ultrasonic pulses. For each mix, six specimens were tested at 3, 7, 14, 28, 56, and 90 days, and the pulse transit time was recorded. Velocity values were calculated to identify concrete quality, detect potential voids or cracks, and correlate results with compressive strength and rebound hammer readings.

Fig.4 Ultrasonic Pulse Velocity Test

4. TEST RESULT AND DISCUSSIONS

4.1 GENERAL

The tests were done on both freshly mixed and hardened concrete. The Fresh concrete mixture was tested for slump of workability. Tests on hardened concrete are conducted on Compressive strength test, Rebound Hammer test, & Ultrasonic Pulse Velocity tests.

4.2 FRESH PROPERTIES OF CONCRETE

We evaluated workability through a slump cone test. A decrease in workability was observed as Betamcharla stone replaced coarse aggregate and Polyvinyl Alcohol (PVA) was added as a self- curing agent. The results of these tests for various replacement levels are illustrated in the graph below.

The slump values observed indicate a slight reduction as the percentage of Betamcharla stone increases. This decrease in workability is explained by Betamcharla stone's greater tendency to absorb water as opposed to conventional coarse aggregates. As the proportion of Betamcharla stone rises, it absorbs more water from the mix, reducing the free water available, and consequently lowering the slump values. In contrast, the inclusion of Polyvinyl Alcohol (PVA) as a self-curing agent has a minimal effect on initial slump values. This is because PVA requires a longer reaction time to influence the curing process by retaining moisture within the mix. Its impact becomes more pronounced over time, aiding in moisture retention and hydration, but it does not affect the workability in the initial stages, as reflected in the slump measurements taken immediately after mixing.

% of BMC Stone	Slump Value mm	Workability
0% BMC	87	Medium
10% BMC	83	Medium
20% BMC	78	Medium
30% BMC	75	Medium
40% BMC	72	Medium
50% BMC	70	Medium

Table 4: Slump test results.

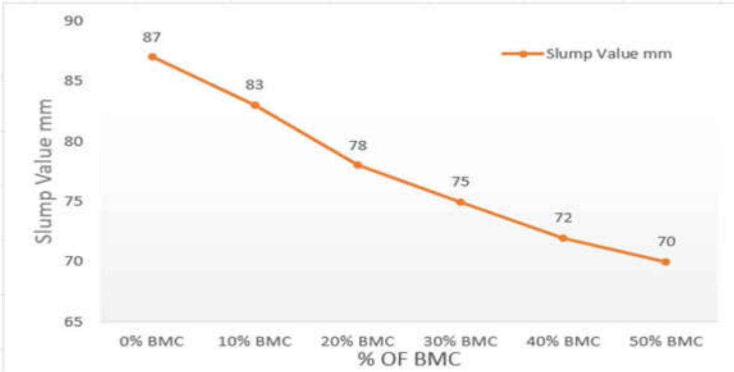

Fig.5 Slump Values

4.3 HARDENED PROPERTIES OF CONCRETE

Testing hardened concrete is essential for evaluating the quality, strength, and performance of cement concrete after hydration has progressed and sufficient maturity has been attained. The hardened properties reflect the effectiveness of material selection, mix proportioning, compaction, and curing practices, and therefore play a critical role in determining the suitability of concrete for structural applications. Testing methods adopted for hardened concrete should be reliable, precise, simple, and easy to apply so that consistent and meaningful results can be obtained. While destructive tests such as compressive strength provide a direct measure of load-carrying capacity, non-destructive testing techniques offer a practical means of assessing surface hardness, internal quality, and uniformity of concrete without causing damage. In the present study, the hardened properties of concrete are evaluated using compressive strength, Rebound Hammer, and Ultrasonic Pulse Velocity tests to obtain a comprehensive understanding of strength development, internal integrity, and overall quality of concrete.

4.4 COMPRESSIVE STRENGTH TEST

It is a key property of cement that has hardened. concrete's compressive strength development mostly depends on the type, size, shape, and proportion of BMC stone utilized in concrete mixes. The compression testing equipment was used for the compressive test, and the failure load and cube compressive strength were evaluated at 3, 7, 14, 28, 56, and 90 days after curing.

Table 5: Compressive strength test results for PVA 0.12% Dosage.

Dosage PVA 0.12%						
	CTRL MIX	BWS 10%	BWS 20%	BWS 30%	BWS 40%	BWS 50%
3 DAYS	10.6	20	25.4	28	19.4	12.43
7 DAYS	17.3	27.7	30.7	33.7	29.5	22.5
14 DAYS	22.6	29.1	32.1	35.1	30.9	23.9
28 DAYS	23.68	34.02	37.02	40.0	35.8	28.82
56 DAYS	26.13	36.46	39.46	42.4	38.2	31.26
90 DAYS	28.33	38.97	41.96	44.9	40.7	33.77

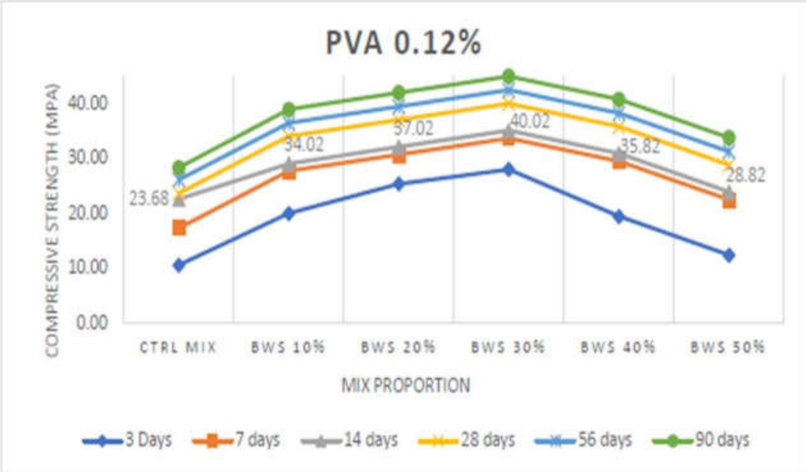

Fig.6 Compressive Strength Results

Figure 6 illustrates the variation in compressive strength for concrete incorporating different proportions of Betamcharla Waste Stone (BWS) at a constant PVA dosage of 0.12%. The test results indicate a clear enhancement in strength with increasing BWS content up to an optimum level. Among all the mix proportions, the concrete containing 30% BWS as a partial replacement of coarse aggregate exhibited the highest compressive strength at 28 days, achieving a peak value of 40.02 MPa. This improvement may be attributed to the better interlocking, surface texture, and densification effect offered by the BWS particles, which contribute to improved mechanical performance. Initially, increasing the proportion of Betamcharla stone enhances the strength due to improved aggregate performance and better hydration. However, beyond the 30% replacement level, further increases lead to a decline in strength, likely due to altered aggregate grading and mix proportions. Similarly, PVA optimally contributes to strength development at 0.12%, with deviations from this amount either too low or too high negatively impacting the curing process, thereby preventing the concrete from achieving its maximum strength at 28 days.

4.5 Rebound Hammer Test

The surface hardness of concrete was assessed using the Rebound Hammer Test, which provides an indirect measure of compressive strength. The test was conducted after 28 and 90 days of self-curing in accordance with IS 13311 (Part 2): 1992.

Concrete specimens were tested by applying a controlled impact on the surface using a Schmidt rebound hammer, and the rebound numbers were recorded at different points on each specimen. The average rebound value for each mix was used to estimate surface hardness and corresponding strength. The rebound numbers obtained for all mixes are graphically represented in the following figures, which illustrate the measured rebound index values.

Figure 7 presents the rebound index values obtained from the Rebound Hammer Test for different BWS mix proportions at 0.12% PVA dosage. A progressive increase in rebound numbers was observed with increasing BWS content, indicating improved surface hardness and corresponding strength development of concrete. Notably, the mix with 30% BWS recorded the highest average rebound value of 27.3Mpa at 28 days, reflecting superior surface integrity and compaction characteristics. This trend aligns with the compressive strength results, confirming the positive influence of BWS on surface hardness and early-age strength properties.

Table 6: Rebound Hammer strength test results for PVA 0.12% Dosage.

Dosage PVA 0.12%						
	CTRL MIX	BWS 10%	BWS 20%	BWS 30%	BWS 40%	BWS 50%
3 DAYS	7.4	11.33	13.13	15.43	10.15	5.9
7 DAYS	12.68	15.1	16.03	18.33	13.05	8.35
14 DAYS	17.43	20.23	22.1	24.2	20.1	14
28 DAYS	23.45	22.52	25.7	27.3	21.22	16.52
56 DAYS	25.2	24.42	26.8	28.32	23.04	18.24
90 DAYS	26.2	26.8	27.98	29.92	24.64	19.94

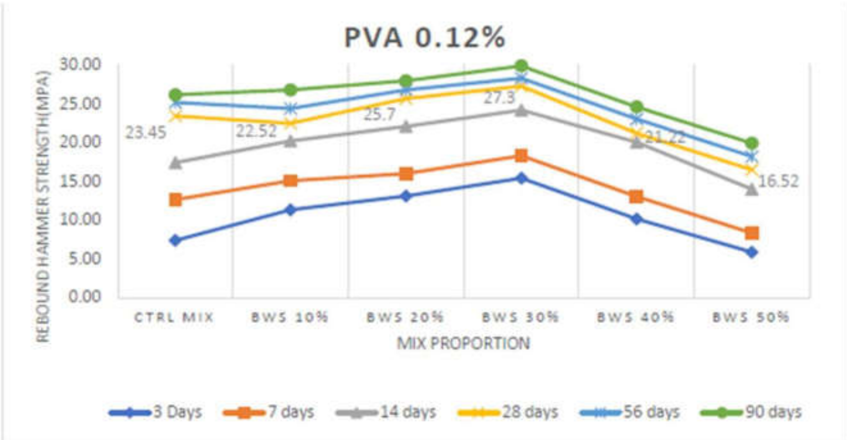

Fig.7 Rebound hammer Strength Results

4.6 Ultrasonic Pulse Velocity (UPV) Test

The quality and uniformity of concrete were evaluated using the Ultrasonic Pulse Velocity Test. The test was performed on 150 × 150 × 150 mm cubes after 3,7,14,28,56 and 90 days of self-curing, following the guidelines of IS 13311 (Part 1): 1992. In this method, an ultrasonic pulse was transmitted through the concrete specimen using a pair of transducers, and the time required for the pulse to travel across the specimen was recorded. Pulse velocity was then calculated and used to assess concrete quality, homogeneity, and presence of internal defects.

The measured pulse velocity values for different mixes are plotted in the subsequent figures, showing the variation in ultrasonic pulse travel time and corresponding pulse velocities.

Figure 8 shows the ultrasonic pulse velocity results measured for various concrete mixes containing different proportions of BWS at 0.12% PVA dosage. The pulse velocity values demonstrated a consistent improvement as the BWS content increased, indicating enhanced material density and uniformity. The mix incorporating 30% BWS achieved the maximum pulse velocity of 4.78 KM/s at 28 days, suggesting a denser internal structure and reduced void content. These findings corroborate the mechanical test results, highlighting that BWS contributes positively to the overall quality, homogeneity, and structural integrity of concrete.

Table 7: Ultrasonic Pulse Velocity test results at 28 days of age.

Dosage PVA 0.12%						
	CTRL MIX	BWS 10%	BWS 20%	BWS 30%	BWS 40%	BWS 50%
3 DAYS	3.1	3.32	3.7	3.8	3.34	3.14
7 DAYS	3.4	3.67	3.9	4.1	3.5	3.48
14 DAYS	3.6	3.8	4.1	4.5	4	3.8
28 DAYS	3.9	4.08	4.38	4.78	4.29	4.09
56 DAYS	4	4.2	4.5	4.9	4.35	4.15
90 DAYS	4.1	4.58	4.58	4.98	4.44	4.24

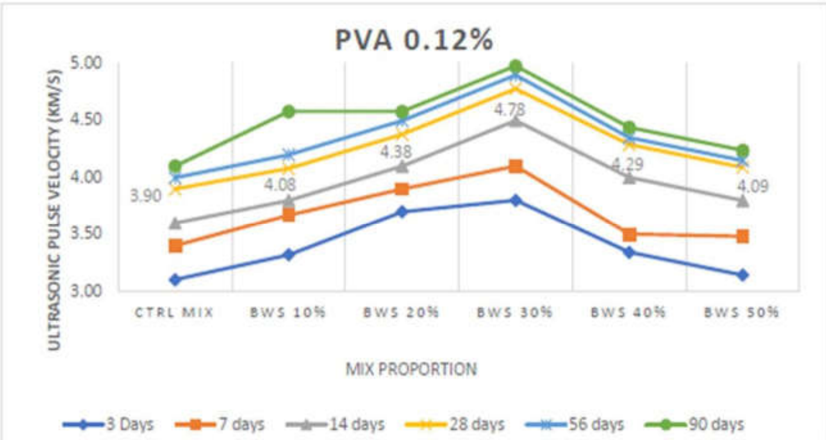

Fig.8 Ultrasonic Pulse Velocity Results

4 CONCLUSION

This study evaluated the influence of incorporating Betamcharla Waste Stone (BWS) as a partial replacement for coarse aggregate and Polyvinyl Alcohol (PVA) as a self-curing agent in M20 grade concrete. The performance of the concrete was assessed using workability tests, compressive strength, rebound hammer, and ultrasonic pulse velocity (UPV) at ages 3, 7, 14, 28, 56, and 90 days. Based on the experimental investigation, the following conclusions were obtained:

- **i.** The workability of concrete, indicated by slump value, decreased with increasing percentages of BWS and PVA. This reduction is attributed to the higher water absorption of BWS and the moisture-retaining characteristics of PVA. However, all slump values(Bws10-50%) remained within the acceptable range for medium- workability concrete.
- **ii.** The optimal value of 40.02 MPa Compressive strength is observed at 0.12% of PVA and 30% replacement of coarse aggregate with Betamcharla stone (waste) for 28 days**.**
- **iii.** Non-destructive test results supported the destructive test findings. Rebound hammer values and UPV readings increased up to 30% BWS, indicating improvements in surface hardness, internal density, and homogeneity. The UPV values classified the concrete as "excellent quality," confirming the densification effect contributed by BWS and internal curing by PVA.

iv. The optimal value of 27.3 MPa Rebound Hammer strength is observed at 0.12% of PVA and 30% replacement of coarse aggregate with Betamcharla stone (waste) for 28 days.

v. The optimal value of 4.78 Km/S Velocity is observed at 0.12% of PVA and 30% replacement of coarse aggregate with Betamcharla stone (waste) for 28 days.

vi. The study shows that BWS effectively enhances the mechanical and durability characteristics of concrete when used up to 30% replacement. Combined with an optimum PVA dosage of 0.12%, the concrete demonstrated improved hydration, reduced porosity, and superior long-term strength development.

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