International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 3 Volume No.9 May - June – 2025
DOI:10.46647/ijetms.2025.v09i03.018 ISSN: 2581-4621

Durability properties of concrete as partial replacement of coarse aggregate with Bethamcherla stone adding self-curing admixture

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ABSTRACT
Conventional curing techniques require a significant amount of water.This becomes challenging While working on concrete highrise structures and in areas with limited water supplies.This techniq ue provides a method for concrete that doesn't require extra water to cure.Polyvinyl alcohol, or selfc uring concrete, will be utilised in this instance.Natural marble makes up the majority of Bethamcher la stone.It may be located in the Andhra Pradesh region of Bethamcherla in the Kurnool district. Bethamcherla waste stone is produced by the quarry's cutting and sizing operations and appears as overlying burden. Cement, water, and fine and coarse aggregates make up concrete, a binding substance. The impact of adding polyvinyl alcohol in different proportions (0, 0.03%, 0.06%, 0.12%, 0.24% by weight of cement) and partially substituting Bethamcherla stone for coarse aggregate at different percentages (0%, 10%, 20%, 30%, 40%, 50% by weight of coarse aggregate) is being Polyvinyl alcohol (PVA) is used as a self-curing agent. The experimental investigation focuses on the acid resistance of concrete in a MgSo4 solution. This study considers the concrete grade of M20 and curing periods of 30 days, 60 days, and 90 days for the concrete specimens in a 5% MgSo4 solution and H_2SO_4 solution, after normal curing of 28 days,60 days ,90 days.
Key points: Polyvinyl Alcohol, Bethamcherla Stone, $MgSo_4$, H_2SO_4, Compression Test, Split Tensile Test.

1.INTRODUCTION

Concrete, a popular building material, is made by blending cement, water, aggregates, and occasionally admixtures in specified ratios based on its intended application. Its properties may be modified based on these elements to satisfy a variety of structural needs. Concrete's ability to insulate against radiation and withstand heavy machinery is heavily reliant on its density, needing an increase in mass for optimal performance. Traditional curing procedures, which need large volumes of water, pose difficulties, particularly in high-rise construction projects and areas with limited water supply. To overcome this issue, self-curing concrete is a realistic approach. This type of concrete incorporates polyvinyl alcohol—a white, granular powder derived from polyvinyl acetate—which helps maintain moisture and ensures complete hydration without the need for additional water. Furthermore, the building sector generates a significant quantity of solid waste as a byproduct of natural stone production. Sandstone, granite, slate, basalt, marble, and quartzite are among the natural stones that create a significant amount of garbage in India. This study investigates the possible use of Bethamcherla waste stone, a byproduct of these natural stones, as an alternative material to reduce environmental impact and improve sustainability in construction operations.

2. LITERATURE REVIEW

V. Ramesh Babu et al.(2017) According to the study, concrete's strength and adaptability make it

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an important material in building. As demand for construction materials rises, experts are looking at alternative aggregates. This study investigates the use of Bethamcherla stone, a natural marble from the Kurnool area, as an alternative to standard coarse particles in M20 concrete. The effect of different replacement levels (0%, 25%, 50%, 75%, and 100%) on compressive strength and acid resistance is investigated, both with and without steel fibers. While steel fibers improve compressive strength (up to 31.42 MPa with 2% steel fiber), Bethamcherla stone aggregates decrease compressive strength and increase acid attack vulnerability. This study highlights the possibility and problems of employing local materials in concrete [1].

B. Ajitha et al. (2017) investigated This study looks at polyvinyl alcohol (PVA) as a self-curing agent for improving water retention and strength in concrete. Concrete mixes with different PVA concentrations (beginning at 0.03%) were compared to standard mixes with locally available coarse aggregates. PVA enhanced water retention, compressive strength, and workability in tests conducted after 3, 7, and 28 days. A 0.24% PVA mix had the maximum flexural strength of 7.19 N/mm² and peak split tensile strength of 6.8 N/mm² after 28 days, showing its usefulness in enhancing concrete performance [2].

J. Ushasree et al. (2014) Bethamcherla stone powder, used as a supplemental cementitious ingredient, improves concrete resistance to sulphate assaults. This powder replaces up to 30% of Portland cement, improving compressive, split tensile, and shear strengths under both conventional and magnesium sulphate curing conditions. This substance not only strengthens concrete, but it also provides a sustainable alternative to standard Portland cement [3].

G. Rajesh et al. (2006) This study analyzes how Bethamcherla waste stone, a byproduct of marble quarries, may substitute up to 50% of natural coarse aggregates in concrete. While this substitution diminishes workability, the addition of galvanized steel strands enhances performance, making it a feasible choice for sustainable construction[4].

Mr. Vaseem Akram (2017) The effects of self-curing agents, specifically PVA at concentrations of 0.5%, 1%, 1.5%, and 2%, on M30 grade concrete mixtures were investigated. The study discovered that these modifications resulted to higher compressive and split tensile strengths [5].

]. **Hardik S. Mistri (2020)** investigated Self-curing chemicals such as PEG 400 and PVA improve concrete characteristics by increasing water retention and hydration. According to studies, PEG 400 at 1% and PVA at 1.5% greatly enhance the workability and compressive strength of M20 grade concrete, with maximum strengths of 29.10 MPa and 22.53 MPa after 28 days, respectively[6].

Aiad Hassan, et al. (2013) This study assesses the effect of magnesium sulfate (MS) attack on self-curing concrete (SCC) with different supplementary cementitious materials (SCM), such as fly ash (FA), rice husk ash (RHA), and ground granulated blast furnace slag (GGBS). The results suggest that SCC with SCM has a stronger strength and less mass loss than the control mixture, as well as less length variations after curing.

M.Sekar (2019) Ultrasonic pulse velocity (UPV) testing assesses the quality of concrete by measuring the speed of ultrasonic pulses through it; greater velocities indicate better density and homogeneity. According to research, substituting up to 30% of the coarse aggregate with waste Cuddapah stone improves compressive and flexural strength when compared to traditional concrete. The best results were obtained with 30% replacement, which showed considerable gains in strength, but larger replacement percentages resulted in decreased performance [8].

Stella Evangeline M (2014) Self-curing concrete, which incorporates ingredients such as polyvinyl alcohol, enhances hydration and strength by increasing water retention and decreasing weight loss when compared to standard mixes. Polyvinyl alcohol improves compressive, tensile, and flexural strength, while further research is needed on its resistance to chemical assaults and usefulness in hot climates [9].

Elahi M (2021) describes how supplemental cementitious materials (SCMs) including fly ash, slag, silica fume, and metakaolin can improve the hydrated paste's sulfate resistance. The review found that employing more than 10% fly ash, 20% slag, 3-20% silica fume, or 5-25% metakaolin inhibits expansion in sodium sulfate settings. However, the efficiency of these SCMs varies depending on replacement rate and sulfate type, with inconsistent findings for metakaolin and silica fume in magnesium sulfate. The influence of SCMs is determined by their replacement rates as well as their individual chemical and physical properties [10].

3. OBJECTIVES OF STUDY

The primary goal of this experimental study is to determine the effect of sulphate attack on self-curing concrete replacement of coarse aggregate with bethamcherla waste stone.

- To assess concrete sample' strength following immersion in magnesium sulphate solution.
- Improved chemical resistance of concrete.
- To assess sulphate attack on self-curing concrete.
- Reduce coarse aggregate use by partially replacing it with bethamcherla waste stone.

4. METHODOLOGY

4.1 MATERIALS

The ingredients utilized in this experiment are cement, fine aggregate, coarse aggregate, polyvinyl alcohol, bethamcherla stone, and water.

A. Cement:

Cement is used in construction as a binding agent because it hardens and binds to other materials. It contains adhesive and cohesive properties. Throughout the study, 53-grade Ordinary Portland Cement(OPC) from a readily accessible brand was utilized. It was fresh new and devoid of lumps.

Table 1 Cement Properties

S. No	Properties	Results
1	Normal Consistency	32%
2	Specific gravity	3.11
3	Fineness	9%
4	Initial Setting Time	60 Minutes
5	Final Setting Time	350 minutes

B. Fine aggregate:

Fine aggregate consists of particles smaller than 4.75 millimeters in diameter, such as sand and crushed stone. It is used in construction to increase the workability and strength of concrete and mortar. It fills the gaps between bigger particles, creating a more uniform and cohesive mix.

Table 2 Fine Aggregate Properties

S.No	Properties	Results
1	Specific gravity	2.70
2	Fineness modulus	3.20
3	Bulking of sand	23.4
4	Bulk density	20%
5	Grading of sand	Zone - Two

C. Coarse aggregate:

For this project, angular aggregates with a maximum size of 20 mm are used, which are crushed granite from a nearby quarry. Coarse aggregates are essential in concrete because they resist deformation and cracking while also evenly distributing applied loads. These aggregates were tested in the lab.

DOI:10.46647/ijetms.2025.v09i03.018 ISSN: 2581-4621

Table 3 Properties of coarse aggregate

S.No	Properties	Results
1	Nominal size	20 mm
2	Specific gravity	2.74
3	Fineness modulus	3.50
4	Crushing value	15.02%
5	Water absorption	0.5%
6	Impact value	12.80%

D. Polyvinyl alcohol:

Polyvinyl acetate is used to constantly manufacture polyvinyl alcohol. This chemical is visible as a transparent, white granular powder. It dissolves in both hot water and ethyl alcohol. Polyvinyl alcohol possesses emulsifying and gum-like characteristics, and it degrades completely and dissolves quickly.

Fig No.1 Polyvinyl Alcohol

E. Bethamcherla stone:

Bethamcherla waste stone, having a specific gravity of 2.85, is a natural marble discovered in Bethamcherla, Kurnool district, Andhra Pradesh. It is known for its outstanding flooring characteristics and is available in a variety of hues, including golden brown and buff grey. This stone is formed as overburden and debris from the quarrying and cutting processes.

Fig No.2 Bethamcherla waste stone

Table 4 Properties of Bethamcherla waste stone Aggregate

S.No	Properties	Results
1	Nominal size	20 mm
2	Specific gravity	2.85
3	Water absorption	0.2%

DOI:10.46647/ijetms.2025.v09i03.018 ISSN: 2581-4621

4	Crushing value	15.02 %
5	Impact value	13.28 %

Table 5: Chemical composition of bethamcherla waste stone

S.NO	Particulars	% Composition (Bethamcherla waste stone)
1	Silica(SiO_2)	9.8
2	Magnesium oxide (MgO)	16.22
3	Magnesium Carbonate ($MgCO_3$)	33.92
4	Calcium oxide (CaO)	29.62
5	Calcium Carbonate($CaCO_3$)	52.87
6	Iron oxide (Fe_2O_3)	1.42
7	Alumina(Al_2O_3)	1.38
8	Loss of Ignition	40.56

F. Water:
Potable water. Clean, drinking water is utilized to mix the concrete. It should be devoid of impurities and pollutants that may interfere with the hydration process and the overall quality of the concrete.
G. Magnesium sulphate: Used to imitate sulphate attack circumstances in an experimental setting. Magnesium sulphate is used to test the concrete's resilience to chemical assault and the effectiveness of self-curing concrete under these conditions**.**

DOI:10.46647/ijetms.2025.v09i03.018 ISSN: 2581-4621

Magnesium Sulphate Curing of concrete specimens

H. Sulfuric acid (H 2 SO 4) : Groundwater typically contains sulphates (H 2 SO 4), which are usually naturally occurring but can also be introduced by industrial effluents and fertilizers used in agriculture. The high concentration of sulphates presents a serious threat to concrete buildings since these substances can cause a variety of degradation. Determining the long-term durability of concrete exposed to sulphates requires an understanding of the sources of sulphates. More severe deterioration may result from the introduction of sulphates into the environment, which can intensify the impacts of other harmful substances. Concrete specimens, namely cubes and cylinders, were submerged in a 5% solution of sulfuric acid, which was made by diluting strong sulfuric acid with water. The purpose of this controlled exposure is to mimic actual circumstances in which sulphate-rich surroundings could come into contact with concrete. The experiment aims to determine the degree of damage produced by sulphate assault and assess the durability of the concrete by submerging the samples in this solution. A detailed examination of the interactions between sulphate ions and the concrete matrix is made possible by the immersion procedure. A complicated sequence of chemical reactions inside the composition of concrete is initiated by the attack of sulphates on the concrete. Expandable chemicals that weaken the concrete& structural integrity and disturb its matrix can arise as a result of these processes. The hydration products and the sulphate ions react as the ions permeate the concrete, weakening the substance. Concrete and sulphate ions interact chemically, and this process emphasizes how crucial it is to comprehend these interactions .Loss of strength, expansion, surface spalling, mass loss, and, eventually, disintegration of the concrete is some of the visible characteristics that indicate the effects of sulphate assault.

Concrete specimens under sulphate attack.

4.2 MIX PROPORTIONS

To reach M20-grade strength, the mix percentage ratio is 1:2.17:3.4, and the concrete was developed using IS 10262-2019 with a water-to-cement ratio of 0.55. The mixes contained varied amounts of Bethamcherla waste stone (0%, 10%, 20%, 30%, 40%, 50%) and polyvinyl alcohol (0%,

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0.03%, 0.06%, 0.12%, and 0.24% by weight of cement). Compressive and split tensile strength tests were used to analyze the strength properties. To evaluate the toughened qualities of each mix, 9 cubes and 9 cylinders were cast and submerged in a magnesium sulfate solution. The table shows the intended proportions of the basic concrete components.

Table 6: Mix proportions

S.No	Materials	Quantities(kg/m^3)
1	Cement	345
2	Fine aggregate	750
3	Coarse aggregate	1170
4	W/C ratio	0.55
5	Bethamcherla Stone	0%, 10%,20%,30%,40%,50%
6	Polyvinyl Alcohol	0.03%,0.06%, 0.12%, 0.24%

4. RESULTS & DISCUSSION

H2SO4 : The results showed that the optimum strength was obtained by combining 0.12% PVA with 30%
Bethamcherla waste stone.

2. The workability of Bethamcherla waste stones in different quantities was determined, and the results indicated a pattern of steady decline from 85mm to 68mm as the percentage of Bethamcherla waste stones climbed from 0% to 50%.
3. When Bethamcherla waste stone was substituted for 30% of coarse aggregate and 0.12% ofcement by poly-vinyl alcohol, the maximum compressive strengths were achieved for 30, 60, and 90 days, respectively, at 25.34 N/mm², 27.84 N/mm², and 24.53 N/mm².
4. The maximum split tensile strengths were 2.84 N/mm², 2.91 N/mm², and 2.74 N/mm² for 30, 60,and 90 days, respectively, when Bethamcherla waste stone was substituted for 30% of coarse aggregate and 0.12% of cement by poly-vinyl alcohol.
5. When Bethamcherla waste stone was used in place of 50% of the coarse aggregate and 0.24% of the cement, the compressive strengths were lowest for 30, 60, and 90 days, at 12.76 N/mm², 16.8N/mm², and 14.25 N/mm², respectively.
6. When Bethamcherla waste stone was replaced for 50% of the coarse aggregate and 0.24% of the cement, the lowest split tensile strengths were observed for 30, 60, and 90 days, at 2.06 N/mm², 2.23 N/mm², and 2.16 N/mm², respectively.
7. If we limit our analysis to the impact of poly-vinyl alcohol on strength metrics, we find that there is a notable, steady rise in compressive and split tensile strength from 0% to 1% replacement levels, followed by a rapid decline in strength at the 0.24% replacement level.
8. If the impact of Bethamcherla waste stone alone is considered, then we find that compressive and split tensile strength significantly increased with time, from 0% to 30% replacement levels, and then abruptly decreased at 40% and 50% replacement levels.

Compressive Strength Test result

The influence of Bethamcherla stone as a partial substitute for coarse aggregate in self-curing concrete was tested under a magnesium sulphate (5 % $MgSO_4$) environment. The compressive strength of the concrete was measured at various curing intervals to determine its performance and durability. Compression strength tests are used to measure the maximum load-bearing capability of the concrete. To perform a compressive test, we created 150mm*150mm*150mm cubes. Each mix has nine cube samples tested for compressive strength after 30, 60, and 90 days of magnesium sulphate attack.

DOI:10.46647/ijetms.2025.v09i03.018 ISSN: 2581-4621

represent variation of compressive strength after 30 days of Magnesium sulphate curing Concrete containing 30% Bethamcherla stone and 0.12% PVA exhibits enhanced compressive strength and durability. After 30 days, these mixes often show better Figure 3 shows the fluctuation of compressive strength after 30 days of magnesium sulphate curing. Concrete with 30% Bethamcherla stone and 0.12% PVA has higher compressive strength and durability. After 30 days, these mixes frequently outperform ordinary concrete in terms of sulphate resistance due to greater moisture retention and less cracking.
to sulphate attack compared to standard concrete, thanks to improved moisture retention and reduced cracking.

Compressive Strength after 60 days of $MgSo_4$ curing
Figure 4 depicts the variance in compressive strength after 60 days of MgSo4 curing performance stabilization, with some modest strength loss due to sulphate exposure, although these mixtures usually preserve greater durability than those with higher replacement levels. The advantages of self-curing become obvious, with some mixtures exhibiting constant or slightly reduced strength compared to the control.
Compressive Strength after 90 days of $MgSo_4$ curing
compressive strength after 90 days of MgSo4 curing. By 90 days, concrete with these replacements had enhanced long-term resistance, demonstrating that adding 30% Bethamcherla stone and 0.12% PVA increases the concrete's capacity to withstand protracted sulfate assault. Due to excellent hydration and minimal sulfate degradation, these blends often have higher compressive strength and longer durability.
Split Tensile Test
Tensile strength tests are used to assess how a material will behave under specified conditions or loads. To determine splitting tensile strength, nine cylinders of 300mm height and 150mm diameter are made for each mix and tested for 30, 60, and 90 days under magnesium sulphate attack.

Split Tensile Strength after 30 days of $MgSo_4$ curing
Figure 6 illustrates the variation in split tensile strength after 30 days of MgSo4 curing. Concrete with 30% Bethamcherla stone and 0.12% PVA exhibits higher split tensile strength and durability. These combinations often outperform ordinary concrete in terms of sulphate resistance after 30 days due to improved moisture retention and reduced cracking.
Split Tensile Strength after 60 days of $MgSo_4$ curing
Figure 7 shows the variations in compressive strength after 60 days of curing in MgSO4. While sulfate exposure causes a little drop in strength, the mixtures are typically more durable than those with greater replacement levels. Concrete with 30% Bethamcherla stone and 0.12% PVA exhibits exceptional split tensile strength. The advantages of self-curing are obvious, since these mixtures exhibit either constant or very slightly decreased strength relative to the control.
Split Tensile Strength after 90 days of $MgSo_4$ curing
depicts the split tensile strength fluctuations after 90 days of curing in MgSO4. At this point, concrete with these additions exhibits enhanced long-term resistance, implying that 30% Bethamcherla stone and 0.12% PVA improve the concrete's durability against protracted sulfate assault. These blends often have better split tensile strength and longer overall durability because to improved hydration and less sulfate-induced degradation.

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DOI:10.46647/ijetms.2025.v09i03.018 ISSN: 2581-4621

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