

# An Experimental Study on Self Curing Concrete with Bethamcherla Stone as Partial Replacement of Coarse Aggregate Under Sulphate Attack of $MgSO_4$ Environment

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## Abstract

Traditional concrete curing requires large amounts of water, posing challenges in high-rise construction and water-scarce regions. This research explores an alternative using self-curing concrete with polyvinyl alcohol (PVA). It investigates the use of Bethamcherla stone, marble waste found in the region of Bethamcherla, Kurnool district, Andhra Pradesh, as partial replacement of coarse aggregate in various amounts percentages (0%, 10%, 20%, 30%, 40%, 50% by weight of coarse aggregate) and the addition of polyvinyl alcohol at different percentages (0%, 0.03%, 0.06%, 0.12%, 0.24% by weight of cement) are evaluated for their effectiveness in self-curing. The experimental investigation focuses on the acid resistance of concrete in a  $MgSO_4$  solution. This research examines the concrete's resistance to acid by immersing M20 grade specimens in a 5%  $MgSO_4$  solution after initial curing period of 28 days, with additional tests conducted at 30,60, and 90 days.

**Key points:** Polyvinyl Alcohol, Bethamcherla Stone,  $MgSO_4$ , Compression Test, Split Tensile Test, Durability( $MgSO_4$ ).

## 1.Introduction

Concrete is a widely utilized construction material, is produced by combining cement, water, aggregates, and sometimes admixtures in specific ratios tailored to its intended use. Its characteristics can be adjusted based on these ingredients to meet various structural requirements. Concrete's effectiveness in shielding against radiation and withstanding heavy machinery relies significantly on its density, necessitating an increase in its mass for enhanced performance. Traditional curing methods which require substantial amounts of water, present challenges, especially in high-rise construction projects and regions with limited water availability. To address this issue, self-curing concrete offers a practical solution. 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. Additionally, the construction industry produces considerable amounts of solid waste as a by-

product of natural stone processing. In India, various natural stones, including sandstone,

granite, slate, basalt, marble, and quartzite, generate substantial waste. The investigation's main emphasis is the potential use of Bethamcherla waste stone, a by-product from these natural stones, as an alternative material to mitigate environmental impact and enhance sustainability in construction practices. The experimental research attempts to assess how well self-curing concrete incorporating bethamcherla waste stone under sulphate attack conditions. Specifically, it assesses the concrete's resistance to degradation when exposed to a magnesium sulphate ( $MgSO_4$ ) environment, which is known to adversely affect concrete durability. By integrating self-curing technology with the use of locally sourced waste materials, this study seeks to advance creating concrete that is more sustainable and long-lasting solutions.

## 2.Literature Review

**Ramesh Babu et al.(2017)** study highlight that Concrete's role in construction is critical due to its strength and versatility. As demand for construction materials grows, researchers are investigating alternative aggregates. This study explores the use of bethamcherla stone, a natural marble from Kurnool district, in M20 concrete as an alternative to conventional coarse aggregate. Compressive strength and the effects of different replacement rates (0%, 25%, 50%, 75%, 100%) acid resistance, with and without steel fibers, is examined. Results indicate that while steel fibers enhance compressive strength up to 31.42 Mpa with 2 % steel fiber- Bethamcherla stone aggregates reduce compressive strength and increase vulnerability to acid attack. This research underscores both the potential and challenges of using local materials in concrete[1].**Ajitha et al.(2017)** This study investigated polyvinyl alcohol (PVA) as self-curing agent to enhance water retention and strength in concrete. Concrete mixes with varying PVA percentages (starting from 0.03%) were compared to conventional mixes using locally available coarse aggregate. Testing at 3, 7, and 28 days showed that PVA improved water retention, compressive strength, and workability. Notably at 0.24% PVA mix achieved the highest flexural strength of 7.19 N/mm<sup>2</sup> and a peak split tensile strength of 6.8 N/mm<sup>2</sup> at 28 days, indicating its effectiveness in improving concrete performance[2]. **Ushasree et al.(2014)** Bethamcherla stone powder, used as a supplementary cementitious material, enhances concrete's resistance to sulphate attacks. Replacing up to This powder enhances Portland cement by 30%. compressive, split tensile, and shear strengths under both standard and magnesium sulphate curing conditions. This material not only strengthens concrete but also offers a sustainable alternative to traditional Portland cement[3]. **Rajesh et al.(2006)** This study investigates Bethamcherla waste stone, a by-product from marble quarries, can replace with up to 50% of natural coarse aggregates in concrete. While this substitution reduces workability, incorporating galvanized steel fibers improves performance, making it a viable option for sustainable construction[4].**VaseemAkram (2017)** investigated

the effects of adding self-curing agents, specifically PVA at 0.5%, 1%, 1.5%, and 2%, to M30 grade concrete mixtures. The study found that these additions led to increased compressive and split tensile strengths[5]. **Hardik S. Mistri (2020)** investigated self-curing agents like PEG 400 and PVA enhance concrete properties by improving water retention and hydration. Studies show that PEG 400 at 1% and PVA at 1.5% significantly increase how well-suited and robust the material is M20 grade concrete, achieving maximum strengths of 29.10 MPa and 22.53 MPa, respectively, after 28 days[6]. **Aiad Hassan et al.(2013)** this study evaluates magnesium sulphate (MS) attack's effects on self-curing concrete (SCC) with various supplementary cementitious materials (SCM) like Grinding granular blast furnace slag (GGBS), fly ash (FA), and rice husk ash (RHA). Results shows that SCC with SCM demonstrates higher strength and lower mass loss compared to the control mixture, with reduced length changes during curing. The addition of SCM improves sulfate resistance, attributed to increased pozzolanic activity and finer SCM particles[7].**Sekar (2019)** Ultrasonic pulse velocity (UPV) testing measures the speed of ultrasonic pulses through concrete to assess its quality, with higher velocities indicating better density and uniformity. Research shows that replacing up to 30% of discarded Cuddapah stone combined with coarse aggregate enhances compressive and flexural strengths compared to conventional concrete. Optimal results were achieved with 30% replacement, showing significant improvements in strength, while higher replacement percentages led to diminished performance[8]. **Stella Evangeline M (2014)** Self-curing concrete,using materials like polyvinyl alcohol, improves hydration and strength by enhancing water retention and reducing weight loss compared to conventional mixes. Polyvinyl alcohol boots compressive, tensile, and flexural strengths, through further study is needed on its durability against chemical attacks and its effectiveness in hot climates[9]. **Elahi M (2021)** explains that extra cementitious materials (SCMs) like metakaolin, fly ash, slag, and silica fume can enhance concrete's protection against sulphate assault by improving the characteristics of the hydrated paste. The review indicates that using

more than 10% fly ash, Slag (20%), silica fume (3–20%), and metakaolin (5–20%) generally reduces expansion in sodium sulfate environments. However, the effectiveness of these SCMs varies with different replacement rates and sulfate types, showing mixed results for metakaolin and silica fume in magnesium sulfate. The impact of SCMs is affected by their replacement levels and their specific chemical and physical properties[10].

**3. Objectives Of Study**

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

- To determine the strength characteristics of concrete specimens after immersed in magnesium sulphate solution after 28 days of self curing.
- To increase the chemical resistance of concrete.
- To determine the sulphate attack on self curing concrete.
- To minimize the coarse aggregate consumption by partially replacement of coarse aggregate with bethamcherla waste stone.
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**4. Methodology**

**4.1 MATERIALS**

In this experiment cement, fine aggregate, coarse aggregate, polyvinyl alcohol, bethamcherla stone, and water these materials are used.

**A. Cement:**

The building industry uses cement as a constricting agent because it stiffens and adheres access different resources. It possesses adhesive and cohesive qualities. Throughout the trail, 53- grade Ordinary Portland Cement (OPC) from locally available cement, a widely available brand, was used. It was lump-free.

**Table No. 1 Properties of Cement**

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 comprises particles smaller than 4.75 millimeters in diameter, including materials

like rock dust and sand. It is applied in construction in order to elevate the workability and concrete's strength and ability to mortar. It fills the spaces between larger particles, resulting in a more consistent and cohesive blend.

**Table No. 2 Properties of Fine aggregate**

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:**

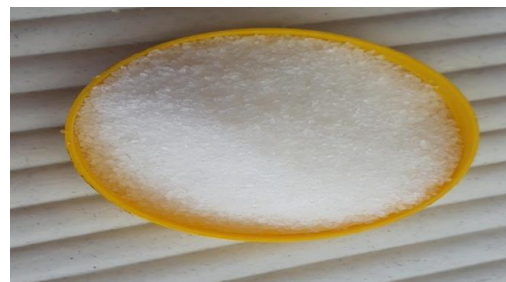
The use of coarse aggregate in concrete is essential. by offering resistance to deformation and cracking, as well as evenly distributing applied loads. For this project, angular The greatest size of the aggregates that are employed is 20 mm. These aggregates, which are crushed granite sourced from nearby quarries, have been tested in the lab.

**Table No.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 (PVA):**

Polyvinyl acetate is used to continuously produce polyvinyl alcohol. This compound appears as a clear, white granular powder. It dissolves in hot water and ethyl alcohol. Polyvinyl alcohol has emulsifying and gum-like properties and can be fully degraded and rapidly dissolved.



**Fig No.1 Polyvinyl Alcohol**

**E. Bethamcherla waste stone:**

Bethamcherla waste stone, is a natural marble found in Bethamcherla, Kurnool district, Andhra Pradesh. Known for its excellent flooring properties, it primarily comes in golden brown and buff grey, through other colours are available. This stone is produced as overburden and waste from quarrying and cutting process.



**Fig No.2 Bethamcherla waste stone**

**Table No.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%
4	Crushing value	15.02%
5	Impact value	13.28%

**Table No.5 Chemical composition of bethamcherla waste stone**

S.No	Particulars	% composition (Bethamcherla waste stone)
1	Silica(SiO <sub>2</sub> )	9.8
2	Magnesium oxide (MgO)	16.22
3	Magnesium Carbonate (MgCO <sub>3</sub> )	33.92
4	Calcium oxide (CaO)	29.62
5	Calcium Carbonate (CaCO <sub>3</sub> )	52.87
6	Iron Oxide (Fe <sub>2</sub> O <sub>3</sub> )	1.42
7	Alumina (Al <sub>2</sub> O <sub>3</sub> )	1.38
8	Loss of Ignition	40.56

**F. Water:**

Potable water clean, drinkable water is used for mixing the concrete. It should be free from impurities and contaminants that could affect the hydration process and the overall quality of the concrete.

**G. Magnesium Sulphate (MgSO<sub>4</sub>):**

Magnesium sulphate attack on concrete causes deterioration through chemical reactions with calcium hydroxide and calcium silicate hydrates, forming expansive gypsum and magnesium silicate hydrate. This leads to internal expansion, cracking, and reduced strength. The concrete surface may also suffer from scaling and damage. Understanding these effects helps in enhancing concrete durability against sulphate exposure.

**4.2 MIX PROPORTIONS**

To achieve M20-grade strength, the mix proportion ratio is 1:2.17:3.4; the concrete was designed according to IS 10262-2019, with a water-to-cement ratio of 0.55. the mixes included varying proportions of bethamcherla waste stone (0%, 10%, 20%, 30%, 40%, 50%) and polyvinyl alcohol (0%, 0.03%, 0.06%, 0.12%, 0.24% by weight of cement). Strength characteristics were evaluated through compressive and split tensile strength tests. For each mix, 9 cubes and 9 cylinders were cast and immersed in a magnesium sulphate solution after 28 normal curing (self curing) to test their hardened properties.

**5. Results & Discussion**

The impact of bethamcherla waste stone as a bare minimum substitute for coarse all together in one self-curing concrete (PVA) was assessed under a magnesium sulphate(5% MgSO<sub>4</sub>) environment.

**Compressive strength**

The concrete's compressive strength was evaluated at various curing periods to determine its performance and durability. The maximum load-bearing capability of the concrete can be found using compression Tests of strength are carried out. In order to perform a compressive test, we prepared cubes that were 150mm\*150mm\*150mm in size. Each mix contains nine samples of cubes for 30, 60, and 90 days compressive strength under magnesium sulphate attack.

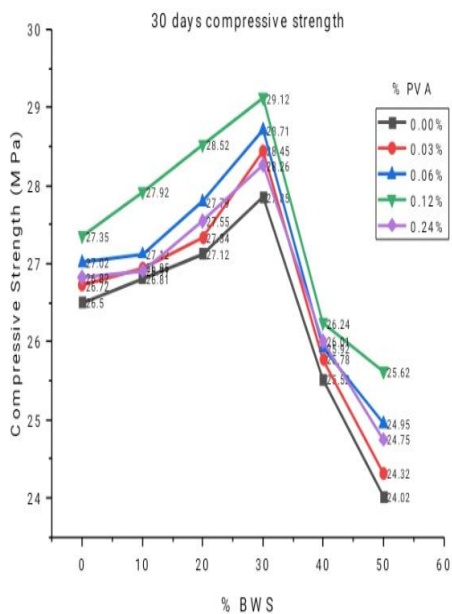


Fig No.3 Variation of Compressive strength after 30 days of MgSo4 curing

Fig No.3 represents variation a 30-day period following the implementation of magnesium sulphate curing, concrete containing high compressive strength at 30% bethamcherla waste stone and 0.12% PVA is 29.12 MPa, surpassing the control mix strength of 26.5 MPa. This increase is likely due to PVA's positive impact on bond strength and resistance to MgSo<sub>4</sub>. However, mixes with more than 30% waste exhibited reduced strength, suggesting that while PVA enhances concrete performance, excessive waste stone replacement can diminish overall strength.

Fig No.4 displays a change in compressive strength Concrete that has been let to cure in MgSo<sub>4</sub> for 60 days has up to 30% Bethamcherla waste stone replacement achieves a higher compressive strength 28.24 MPa compared to the conventional mix, which peaks at 26.22 MPa. This indicates improved resistance to magnesium sulphate with moderate waste stone replacement and 0.12% polyvinyl alcohol. However, higher waste stone levels (40% and 50%) lead to reduced strength, dropping below that of the conventional mix. The addition of 0.12% PVA consistently enhances strength, demonstrating its effectiveness in improving concrete durability.

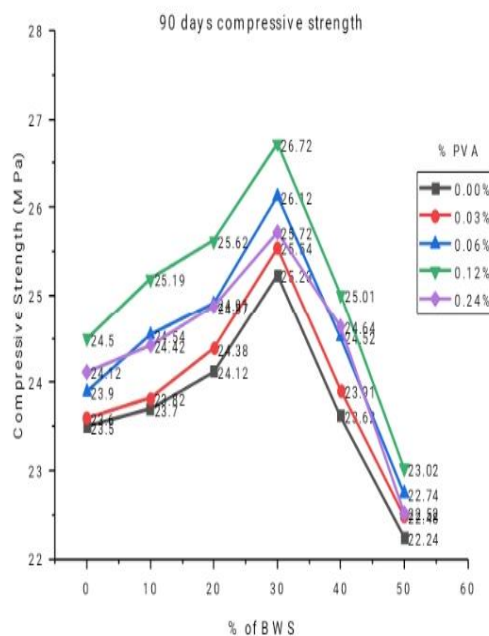


Fig No.5 Variation of compressive strength after 90 days of MgSo4 curing

Fig No.5 shows 90 days compressive strength variation of concrete with 30% bethamcherla waste stone (BWS) replacement reaches a maximum compressive force of 26.72 MPa with 0.12% polyvinyl alcohol, exceeding the conventional mix highest strength of 24.5 MPa. Increased waste stone levels, specifically at 40% and 50%, lead to reduced strength, indicating that excessive replacement undermines performance. The addition of 0.12% PVA consistently enhances strength, highlighting its effectiveness in boosting concrete durability under magnesium sulphate exposure.

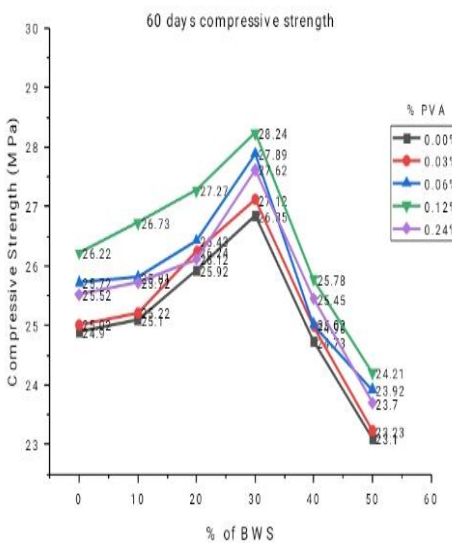
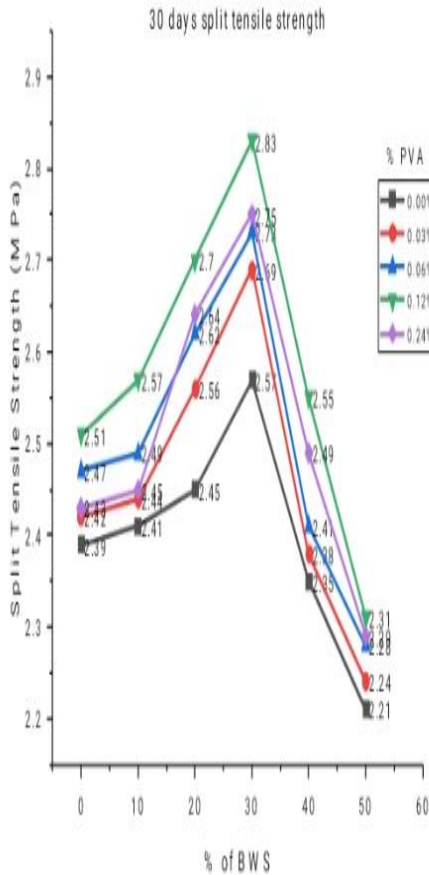


Fig No.4 Variation of compressive strength after 60 days of MgSo4 curing

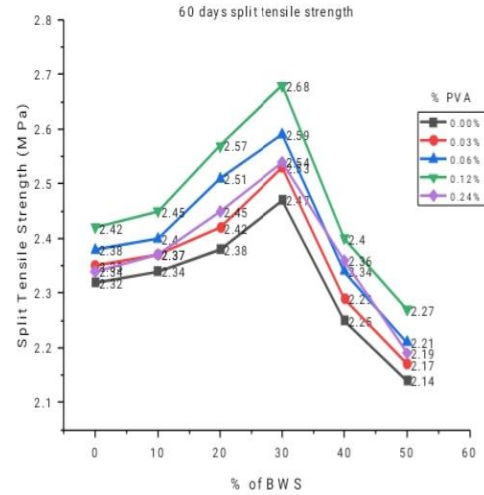
**Split Tensile Strength**

Tensile strength tests are conducted to assess how materials respond to various stresses or conditions. In this case. To evaluate the splitting tensile strength, nine 150 mm in diameter and 300 mm in height cylindrical specimens are prepared for each mix. These specimens are tested for their splitting tensile strength after 30, 60, and 90 days of exposure to magnesium sulphate.



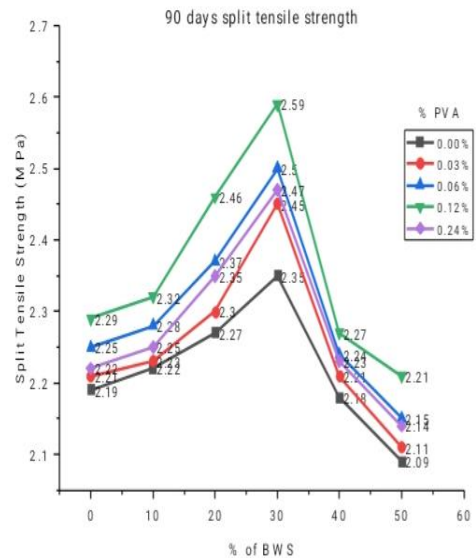
**Fig No.6 Variation of split tensile strength after 30 days of MgSO<sub>4</sub> curing**

Fig No.6 shows variation of 30 days after MgSO<sub>4</sub> curing, the split tensile force of the concrete concrete with 30% bethamcherla waste stone and 0.12% PVA achieves the highest split tensile strength of 2.83 MPa, outperforming the conventional mix's strength of 2.51 MPa. Strength decreases with higher waste stone levels (40%, 50%), suggesting diminishing returns with increased replacement. The addition of 0.12% PVA consistently improves tensile strength, highlighting its effectiveness in enhancing concrete performance in magnesium sulphate conditions.



**Fig No.7 Variation of split tensile strength after 60 days of MgSO<sub>4</sub> curing**

Fig No.7 illustrates the changes in compressive strength during 60 days of incubation in MgSO<sub>4</sub>. While there is a little reduction in power as a result of sulphate exposure, the mixes generally maintain superior durability compared to those with higher replacement levels. Concrete incorporating 30% bethamcherla stone and 0.12% PVA achieves high split tensile strength is 2.68 MPa. The benefits of self-curing are evident, with these mixes showing either consistent or only lower strength relative to the control.



**Fig No.8 variation of split tensile strength after 90 days of MgSO<sub>4</sub> curing**

Fig No.8 illustrate the concrete's split tensile strength after ninety days Magnesium sulphate curing, concrete with replacement of bethamcherla waste stone and 0.12% PVA reaches

a peak 2.59 MPa split tensile strength, surpassing the conventional mix is 2.29 MPa. Higher waste stone levels (40% and 50%) show reduced strengths of 2.27 MPa and 2.21 MPa, respectively. This reduction confirms that excessive waste stone negatively impacts tensile strength over time. The consistent from 0.12% PVA underscores its effectiveness in enhancing long-term concrete durability and strength in MgSO<sub>4</sub> environment.

## 6. Conclusion

The study investigated the use of Bethamcherla stone as a partial replacement for coarse aggregate in self-curing concrete subjected to magnesium sulphate solution.

1. The study concluded that replacing 30% of coarse aggregate with bethamcherla stone, combined with 0.12% using polyvinyl alcohol for a self-curing agent resulted in the most effective performance in terms of durability and sulphate resistance. This mix achieved the maximum split tensile and compressive strengths when exposed to a magnesium sulphate environment.

2. This combination showed notable resistance to MgSO<sub>4</sub> sulphate attack, the minimal expansion and damage compared to traditional concrete and other tested mixes.

3. The enhanced performance was attributed to PVA's role in improving hydration and minimizing moisture loss during curing, leading to better concrete strength.

4. The use of bethamcherla stone and PVA not only boosts concrete durability and performance but also provides economic and environmental benefits, such as lower aggregate costs and reduced water usage. Further investigation is recommended to evaluate the long-term effects and practical applications of this mix in various construction scenarios.

## 7. References

[1]. Ramesh Babu, V., Ramesh Babu, B., Sashidhar, C., Vijaya Sekhar Reddy, M., & Ashalatha, K. (2017). Investigations into the durability and strength characteristics of concrete that substitute some Bethamcherla stone aggregate. *Research in Engineering and Applications International Journal*, 7(10), 59-64. ISSN: 2248-9622.

[2]. B. Ajitha, Ghantasala Nirupama (2017) "Using polyvinyl alcohol to evaluate the properties of self-curing concrete" *The International Journal for Advanced Engineering and Science Technology* Vol.No.5, Issue No.04 pp.752-758.

[3]. Ushasree, J., Venkataramana, N., & Bash, S. A. (2014). Function of the stone powder concrete from Bethamcherla under sulphate curing. *Innovative Engineering & Technology International Journal (IJJET)*, 4(4), 164-179. ISSN: 2319-1058.

[4]. Rajesh, G., & Arunakanthi, E. (2016). Effect of Bethamcherla wastes stone for the workability and mechanical characteristics of fiber-reinforced concrete. *The International Journal of Engineering and Science*, 7(3), 185-191. ISSN 2229-5518.

[5]. Vaseem Akram.N1, P. Balachandran2 "An Empirical Investigation of Self-Curing Concrete" *The International Journal of Research in Engineering Technology and Applied Science (IJRASET)*, ISSN 2321-9653, Volume 5, Issue X, (2017).

[6]. Hardik S. MistriBhimani, P.D., & Gorasiya, H. (2020). Using self-curing chemicals, an experimental investigation was conducted on concrete grade M20. *The Journal of Novel Research and Emerging Technologies (JETIR)*, 7(6), 2071. ISSN 2349-5162.

[7]. Hassan, A., Mahmud, H.B., Jumaat, M.Z., ALsubari, B., & Abdulla, A. (2013). Effects of magnesium sulphate for self-compacting concrete with additional cementitious ingredients. *Developments in the Engineering and Science of Materials*, 2013, Article ID 232371,1-8.

[8]. Sekar, M. (2019). Concrete's strength is assessed by partially substituting coarse aggregate with Cuddapah stone. *The International Journal of Reviews and Scientific Investigation*, 8(2), 2188-2196.

[9]. Evangeline, S. (2014). Concrete that cures itself and its intrinsic qualities. *The International Journal for Engineering Applications and Research*, 4(8), 66-71. ISSN: 2248-9622.

[10]. Elahi, M. M.A., Shearer, C.R., Reza, A. N. R., Saha, A.K., Khan, M. N, N., Hossain, M.M., & Sarker, P. K. (2021). A review of adding supplemental cementitious materials (SCMs) to concrete to increase its resistance to sulphate attack. *Building materials and construction*, 281, 122628.