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Investigation on Strength Properties of Self Curing Concrete with Bethamcherla Waste Stone under HCl Attack

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ABSTRACT: Concrete is most popular and widely used construction material consisting of Cementitious material, Fine aggregate, Coarse aggregate and Water. The demand for various constituent materials led to make use of alternative materials which resembles the properties of conventional materials. M-20 Grade concrete is designed by partially replacing the coarse aggregate with Bethamcherla stone of 0%,10%,20%,30%,40%,50% by weight of coarse aggregate. By using Bethamcherla waste stone we can do mix as cost effective. For Self-curing of concrete, addition of Polyvinyl Alcohol of 0 %,0.03%,0.06%,0.12%,0.24% by weight of cement is to be done as it reduces water requirement for curing, so ultimately, we can save the precious water required for curing. The fresh property such as Workability, is determined and compared to standard properties. The hardened properties such as Compressive Strength, Split Tensile Strength are analysed at 30 days and 60 days and 90 days of Curing in 5% HCl Solution. HCl acid represents effects of acids on concrete.

KEYWORDS: Bethamcherla Stone, Poly-vinyl Alcohol, Compressive Strength, Split-Tensile Strength, HCl Acid.

I. INTRODUCTION

Concrete, a substance associated with durability and strength, has become the go-to building material for the infrastructure requirements of the modern world. The ingredients for concrete are running out because of how much of it has been used in this century. The use of waste materials as alternative aggregates is becoming more and more popular, and extensive research has been done on the subject. Examples of these materials include Bethamcherla waste stone and various industrial wastes. The use of waste materials as alternative aggregates is becoming more and more popular, and extensive research has been done on the subject. Examples of these materials include Bethamcherla waste stone and various industrial wastes. These waste products can address a few issues. Coming to Bethamcherla waste stone is brought from the place as its name indicates Bethamcherla, a city near Nandyal district. That city has well known for large quarrying stone locations, therefore there has been produced waste stones in large quantity.so they are coming nearly at no cost as compared to normal standard SSD Conditioned aggreagates.in addition to that coarse aggregate's replacement, we have been carried out HCL acid attack on resultant concrete obtained of M20 Grade. In overall study explores the feasibility and effectiveness of using Bethamcherla waste stone as a partial replacement for coarse aggregates in self-curing concrete. The research aims to assess the strength properties, durability, and overall performance of the modified concrete, providing valuable insights into its potential applications in sustainable construction.

II. LITERATURE REVIEW

Pushpalatha R Gadag, Dr. Vaishali.G Ghorpade, Dr. H. Sudarsana Rao (2022). The project paper "Durability Study of Nano Influenced Metakaolin Concrete to Acid Attack" by Pushpalatha R. Gadag, Vaishali G. Ghorpade, and H. Sudarsana Rao (2022) explored the enhancement of metakaolin concrete's durability against acid attack through the addition of nanomaterials like nano-silica. The study found that these nanomaterials significantly improved acid (HCl,

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H_2SO_4, $MgSO_4$) resistance by refining the concrete's microstructure and reducing porosity. The HPC mixes resisted acid attack in HCl, H_2SO_4, and $MgSO_4$ better than conventional concrete at all ages of immersion. When compared to HCl and $MgSO_4$ acids, H_2SO_4, acid causes HCl acid immersion results in the least loss of compressive strength of the three acids.

Beulah M., Prahallada M. C. The effects of substituting metakaolin for cement on the characteristics of high-performance concrete (HPC) subjected to hydrochloric acid (HCl) are investigated in the study by Beulah M. and Prahallada M. C. By improving the microstructure and lowering the calcium hydroxide concentration of HPC, metakaolin has been shown to increase the material's compressive strength, permeability, and acid resistance. As a result, metakaolin becomes more durable in acidic conditions, which makes it a useful additional cementitious element to improve concrete performance. The study confirms that metakaolin is a useful tool for increasing the life of concrete buildings under harsh circumstances.

Ghantasala Nirupama, Jyothi Kumari Ganta: Journal intendedly describes the strength parameters of concrete in which coarse aggregate is replaced partially with Bethamcherla waste stone with percentages 0,10,20,30,40 and the results were shown significant strength increase for some proportion of replacements and done with desirable out come with 40% replacement of coarse aggregate, however it may be doubtful beyond that proportion. The conclusion is justified as the Bethamcherla waste stone is made of granite as like our normal aggregates the came favourably.

Dr. S. Reddy and Dr. P. Kumar (2022) investigated using Bethamcherla waste stone as a coarse aggregate in concrete, finding that up to 50% replacement yielded satisfactory mechanical properties, workability, and durability. The study highlighted benefits in terms of waste reduction and cost savings. Further research is recommended to address quality variability and standardization.

Chakraborty et al. (2023) explored the effect of hydrochloric acid (HCl) treatment on Bethamcherla waste stone to enhance its properties as a concrete aggregate. The study showed that HCl treatment improved the surface texture and bonding characteristics of the waste stone, resulting in enhanced compressive strength and durability of concrete. The research also noted the importance of optimizing acid concentration and treatment duration to balance performance gains with environmental and safety considerations.

Rao and Patel (2021) investigated the effects of hydrochloric acid (HCl) treatment on Bethamcherla waste stone, they discovered that using a 10% HCl solution for two hours greatly increased the concrete's compressive strength, improving performance by as much as 20% when compared to untreated aggregates. The aggregate's durability and cement-bonding properties were also enhanced by the treatment. To solve environmental and safety concerns, more research is required.

Waleed A. Abbas, Ikbal N. Gorgis, and Mahdi J. Hussien The article "Self-Curing Cement Mortar Composite by Using Polyvinyl Alcohol" by Abbas, Gorgis, and Hussien investigates the use of polyvinyl alcohol (PVA) as a self-curing agent in cement mortars. The study finds that PVA enhances hydration, improves compressive and flexural strength, and reduces shrinkage by retaining moisture within the mortar. These benefits lead to better durability and performance, particularly in environments where traditional curing is challenging. Additionally, PVA offers environmental and economic advantages by reducing the need for external water curing. Overall, the research promotes PVAmodified mortars as a sustainable and efficient building material.

Shintaro Miyamoto et al. The article "Deterioration Rate of Hardened Cement Caused by High Concentrated Mixed Acid Attack" by Shintaro Miyamoto et al. investigated how highly concentrated sulfuric and hydrochloric acids accelerated the degradation of hardened cement. The study revealed that sulfuric acid caused severe damage by forming expansive gypsum crystals, while hydrochloric acid primarily led to mass loss. The findings underscored the need for improved durability in cementitious materials exposed to acidic environments, particularly in industrial settings.

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III. SCOPE AND OBJECTIVES

The purpose of this study is to ascertain the participation of course aggregate and its proportion in strength properties of concrete. As the coarse aggregate comprises large percentage and cost in preparation of concrete it should be replaced with cheaply availed material. In most of the places, commonly used coarse aggregate material is granite pebbles. So far this context Bethamcherla waste stone is considered for the partial replacement for coarse aggregates which are available at Bethamcherla, a small city near Kurnool(district), Andhra Pradesh. The main reasons for choosing this material are costing lower than the commonly used granite pebbles and abundant waste stone availability. The process of partially substituting Bethamcherla waste for coarse aggregates in self-curing concrete include identifying regions where the waste is easily accessible, assessing its chemical and physical characteristics, and creating concrete mix designs that use it in different ratios. Within this scope, it will be examined how Bethamcherla waste affects the properties of concrete that cure on their own. It will also assess the mechanical qualities and longevity of the finished product and draw comparisons with conventional and self-curing concrete. Furthermore, possible uses in infrastructure and building development are identified, and the viability from an economic and environmental standpoint is evaluated. By lowering the need for natural aggregates and efficiently handling Bethamcherla waste, these alternative aims to improve sustainability in the construction industry.

The main objectives of this study are

- To find optimum level of percentage of Bethamcherla waste stone incorporation into the concrete so that it can sustain in acid environment surrounded.
- To Know the Effect of Self curing Agent (Polyvinyl Alcohol) on Mechanical properties of Concrete.
- To Estimate the durability effect on concrete by the environment of Acid Attack.

IV. MATERIALS USED

4.1 Cement: Cement that is taken in Experimentation is ordinary Portland cement of 53 grade (Nagarjuna Cement) which is locally availed in the JSW Cements dealers. Physical properties were checked and got satisfied results and chemical properties are as follows

Table 1. Properties of Cement

S. No	Property	Result
1	Specific Gravity	3.15
2	Normal Consistency	30%
3	Initial Setting Time	60 min
4	Final Setting Time	450 min

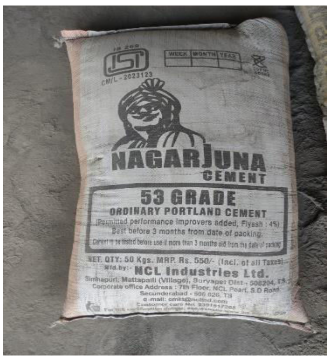

Figure 1. Cement Used for Experimentation.

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4.2 Fine Aggregates:
Locally available river sand was taken to investigate which was passed through 4.75 mm sieve with 95% accuracy. Eventually the gradation of sand was found to be of Zone -II.

4.3 Coarse Aggregate:
Generally used granite coarse aggregates of Nominal max site of 20 mm is used. Keen supervision has done to evaluate the surface condition of coarse aggregates, initially there was some moisture on them. However, after keeping them for two days under sun, it has been found those attained SSD
(saturated surface dry) condition. Specific gravity of coarse aggregate's was calculated through pycnometer test and obtained as 2.72.

4.4 Bethamcherla Waste Stone:
The waste stone from the mining and processing of Bethamcherla stone, known as Bethamcherla waste stone, has several qualities that make it a viable substitute for coarse aggregates in construction. These aggregates were used as partial replacement for natural granite coarse aggregates. The percentages of replacement are 0%, 10%, 20%, 30%, 40%, 50%.

Table 2. Physical Properties of Bethamcherla Waste Stone.

S. No	Property	Result
1	Colour	Light red & Dark green
2	Specific Gravity	2.60
3	Crushing Value	19.42 %
4	Impact Value	17.80 %
5	Nominal Max Size	20 mm

Figure 2. Bethamcherla Waste Stone.

4.5 Poly vinyl alcohol:
There are many self-curing agents in the market. As one from those, we adopted poly vinyl alcohol (PVA) as the self-curing agent which helps concrete to retain the water content from getting evaporated. PVA was ordered from Isochem laboratories, Angamaly, Kochi.

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Table 3. Properties of Poly-Vinyl Alcohol.

S.No	Property	Result
1	Degree of polymerization	1700- 1800
2	Viscosity	25-32 cps
3	pH of aqueous Solution	5-7

4.6Water:
Water used for in this investigation was potable water available locally.

4.7 Hydrochloric acid:
Hydrochloric acid was used as simulation for acidic environments in which specimens are to be put under observation. The percentage of HCl used was 5% as dilution in water. Acid used in this investigation was ordered from Maheswari dyes and chemicals, Anantapur.

Table 4. Properties of HCl Used.

S. No	Property	Result
1	Molecular weight (HCl)	36.46 grams
2	Weight per ml at 20 ˚C	1.18 grams
3	Purity	35 (conc)

4.8 Superplasticizer: Superplasticizer used in this experimentation is FOSROC Conplasta SP 430 by 1 % of water is used to maintain average level of slump. It is just added to water without replacing water. So, there won't be any factor for strength attainment.

V. EXPERIMENTAL WORK

The mix has been designed for M20-grade concrete using the IS method (IS 10262:2019). Initially, a trial mix was done to get an idea of the normal strength of M20-grade concrete with normally available ingredients. The results were noted down to analyse the results obtained after exposing acidic environments. After that, various combinations of Bethamcherla Waste Stone (BWS) and PVA (Poly Vinyl Alcohol) are made to form different mixes. The information required for the combination was collected from various sources to understand the performance of the equipment. In this study, the M20 quality mix was followed by IS 10262(2009), coarse aggregates were replaced by different types of BWS stones, and the water cement ratio was maintained at 0.55. Prepare the concrete mix as per the design mix and perform the slump cone test and test mix of the new mix to understand the performance of the concrete. 36 cubes measuring 150 x 150 x 150 mm are collected for every 10%,20%,30%,40%,50% replacement of coarse aggregate in the experimental activity. To remove any dust or hard particles that may have adhered to the specimens, thoroughly wash the mould with water. To make the process of de-moulding cube specimens easier, machine oil is sprayed all over the inside surfaces of the cube moulds. High plasticity and higher early and final strengths are required when using Conplasta Sp 430 super plasticizing action offers exceptional workability at extremely low water-to-cement ratios. 1% of super plasticizing agent was used for the casting in order to get the required slump and workability. For a specific mix, batching of aggregates and proportionate ingredients of concrete are taken. water we kept as soon as we mix all ingredients on dry basis after that mixing has been done in prepared cubes. Compacting had been done manually by tamping with tamping rod such that each layer gets 25 blows.

After that care is taken to place the casted cubes in neat place and well aerated place. Each specimen (cubes, cylinders) was demoulded with care. After 28 days of self curing at a place at room temperature. Soon after completion of self curing specimens are taken to chemical attack observation, in which we actually keep specimens in 5 % concentrated

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HCl solutions. Different specimens were kept under HCl attack for different periods which are 30days ,60 days and 90 days from the instant of keeping specimens in HCl Solution.

5.1 Tests Conducted:

i). **Slump cone test**

The most used technique for determining the consistency of concrete is the slump test. Although the slump test "won't give degree of workability of concrete," it can be helpful in determining how fresh concrete differs from older concrete and in identifying differences in batch-to-batch homogeneity in the concrete mix. The most well-known cause of droop in concrete is its water content, however other elements like aggregate grading and particle form can also affect it. Slump test equipment is easy to use, portable, and appropriate for both in-lab and field testing. The freshly mixed concrete was used for the slump test after it had been thoroughly mixed. The slump value for each mix with percentage of BWS is displayed in results below.

ii). **Compressive Strength**

Following the immersion time, the cubes were taken out of the HCl solution. To get rid of any remaining acid, the cubes were washed with water. A compression testing machine was used to evaluate the cubes' compressive strength in accordance with conventional protocols (e.g., ASTM C39). Records of the compressive strength findings were made. A control set of cubes that were not submerged in HCl solution was used to compare the outcomes. To ascertain the effect of HCl exposure on the characteristics of the concrete, the data were evaluated. Specimens for different mixes were examined for compressive strength and tabulated as below.

Figure 3. Compressive Strength testing machine (CTM).

iii). **Split Tensile Strength Test**

Following the designated immersion time, the cylinders were taken out of the HCl solution. After completely rinsing the cylinders with water to get rid of any remaining acid, they were let to dry. In order to ensure correct alignment throughout testing, the cylinder's longitudinal axis was marked.

Along the cylinder's length, two diametrically opposed lines were drawn. Between the testing machine's loading platens, each cylinder was positioned horizontally. To guarantee that the weight was applied along the diameter, the cylinder was marked with lines. There was no shock and the weight was delivered continually. The load rate was set between 1.2 MPa/min and 2.4 MPa/min, generally, in accordance with the applicable standards (such as ASTM C496/C496M).

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VI. RESULTS AND DISCUSSIONS

6.1 Slump cone Test:

The findings of the slump cone test show that the workability of the concrete mixtures that substitute natural coarse aggregates with different percentages of Bethamcherla waste stone (BWS) consistently decreases as the BWS content increases. With 0% BWS, the control mix showed the maximum slump value of 85 mm, indicating a comparatively higher workability. Slump values gradually dropped to 82 mm, 74 mm, and 65 mm, respectively, as the BWS replacement rose to 10%, 20%, and 30%. This decrease in slump suggests that adding BWS causes the concrete mix to become less fluid. This might be explained by the waste stone from Bethamcherla having a different surface roughness and absorption properties than natural aggregates.

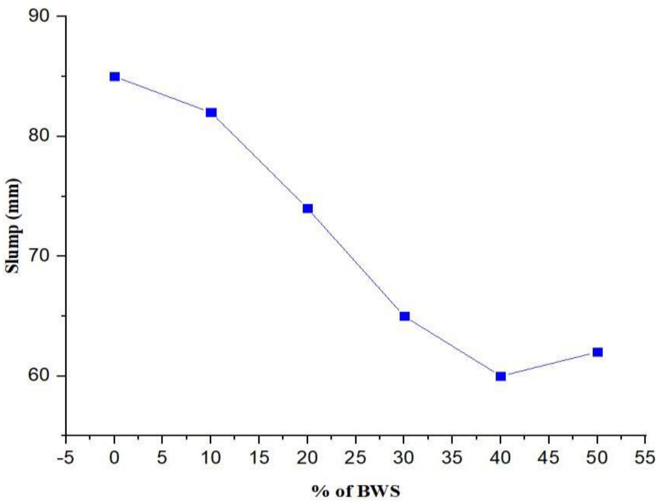

Figure 4. Variation of slump with BWS percentage.

Remarkably, the slump value increased to 60 mm at 40% BWS, indicating a more marked decline in workability. Nevertheless, a little rise to 62 mm was noted at 50% BWS, which could be the result of the high replacement level of BWS potentially changing the mix's aggregate grading and water need. Overall, the trend indicates that waste stone from Bethamcherla may be substituted for coarse aggregate, but its effect on workability should be carefully considered, especially when replacing a larger amount of material. The findings highlight the need for mix design optimization in order to combine mechanical characteristics and workability for real-world applications with BWS-containing concrete.

Table 5. Effect on slump for BWS percentage.

MIX ID	SLUMP (in mm)
BWS 0%	85
BWS 10%	82
BWS 20%	74
BWS 30%	65
BWS 40%	60
BWS 50%	62

6.2 Compressive Strength Results

By altering the proportion of Bethamcherla waste stone and polyvinyl alcohol (PVA) used to partially substitute coarse particles, the compressive strength of the self-curing concrete was assessed. The findings showed a distinct pattern in the way strength changed as composition did.

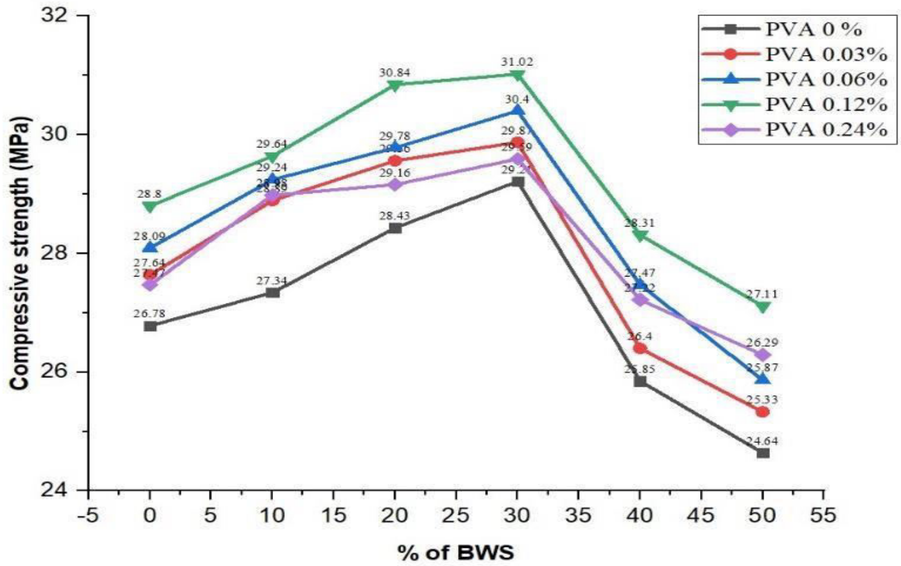

Figure 5. Effect of BWS and PVA on Reduced

Compressive strengths after 30 days of HCl Attack

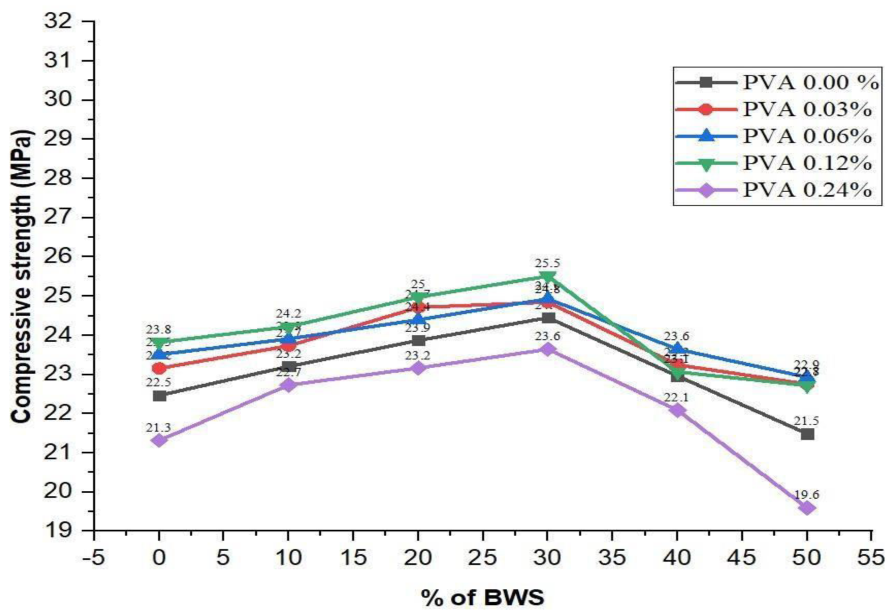

Figure 6. Effect of BWS and PVA on Reduced Compressive strengths after 60 days of HCl Attack.

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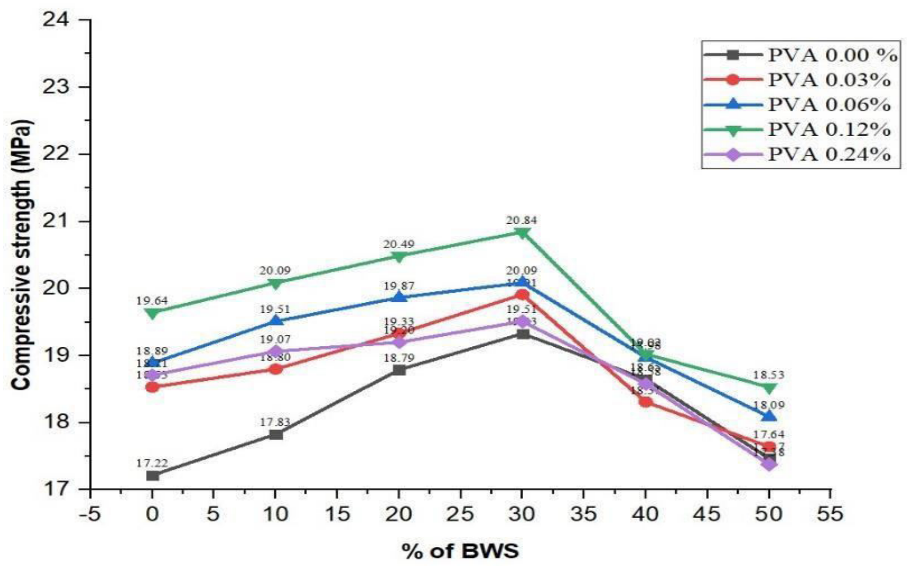

Figure 7. Effect of BWS and PVA on Reduced

Compressive strengths after 90 days of HCl Attack

6.2.1 Effect of Bethamcherla Waste Stone: A gradual rise in compressive strength was seen when Bethamcherla waste stone was substituted for coarse aggregates up to a 30% ratio. It appears that the waste stone successfully filled the gaps and added to a denser concrete matrix because the strength peaked at this replacement level. Strength decreased with replacements higher than 30% (i.e., 40% and 50%). A weaker bond inside the concrete may have resulted from the changed aggregate interlock and decreased compatibility between the cement paste and the larger volumes of waste stone.

6.2.2Effect of Polyvinyl Alcohol (PVA): As the percentage of PVA increased from 0% to 0.12%, there was a noticeable increase in compressive strength. This can be attributed to the enhanced hydration process facilitated by PVA, which improves the internal curing mechanism. Beyond 0.12% PVA, particularly at 0.24%, the compressive strength began to decline. This decrease is likely due to an excess amount of PVA leading to a possible reduction in the compactness of the matrix, resulting in microstructural defects.

6.2.3 Optimum Combination: The blend of 0.12% PVA and 30% Bethamcherla waste stone produced the maximum compressive strength. The best balance between accelerated internal curing, better matrix density, and ideal aggregate bonding was probably provided by this combination.

6.2.4 Split Tensile Strength Results

The split tensile strength data, which show the overall integrity and bond strength within the concrete matrix, trended similarly to the compressive strength data.

6.2.5 Effect of Polyvinyl Alcohol (PVA): Split tensile strength improved when the PVA concentration was raised to 0.12%. This is consistent with PVA's improved curing action, which improves hydration and lessens shrinkage-induced cracks. Nevertheless, the split tensile strength started to decline at 0.24% PVA, which was inconsistent with the compressive strength findings. This might have been caused by an excess of PVA altering the homogeneity of the concrete mix.

6.2.6 Effect of Bethamcherla Waste Stone: The split tensile strength increased significantly with up to 30% of Bethamcherla waste stone substituted for coarse pebbles, suggesting that the waste stone interlocks and offers sufficient

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support inside the concrete matrix. The deterioration of the aggregate paste bond and the increased brittleness brought on by the surplus waste stone may be the reasons for the decline in split tensile strength at replacement levels over 30%.

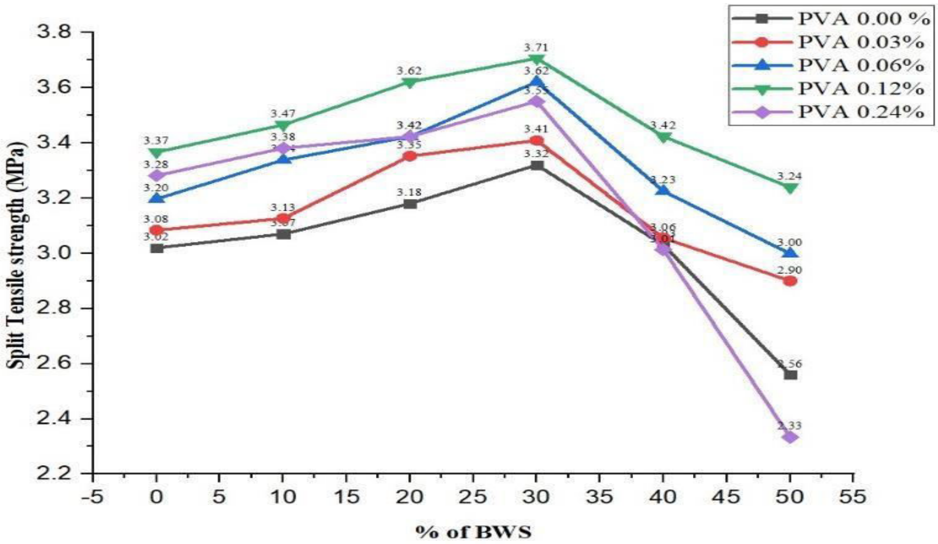

Figure 8. Effect of BWS and PVA on Reduced

Split Tensile strengths after 30 days of HCl Attack.

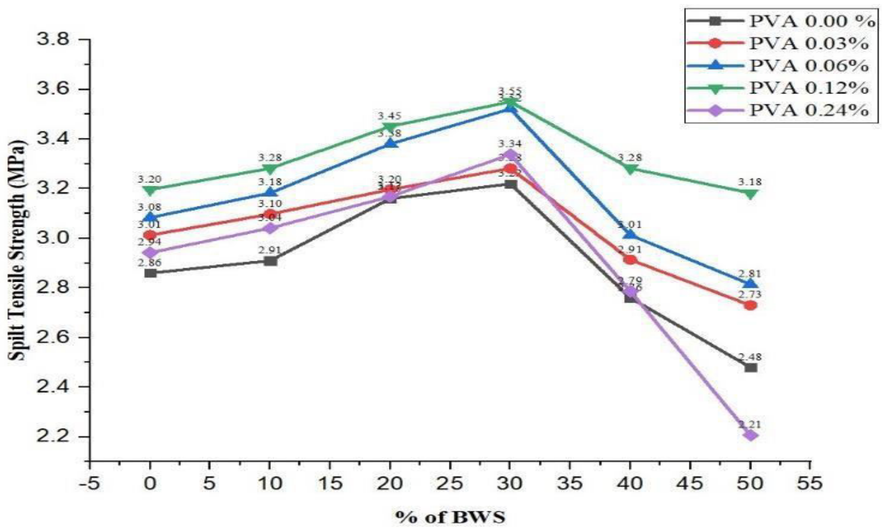

Figure 9. Effect of BWS and PVA on Reduced

Split Tensile strengths after 60 days of HCl Attack.

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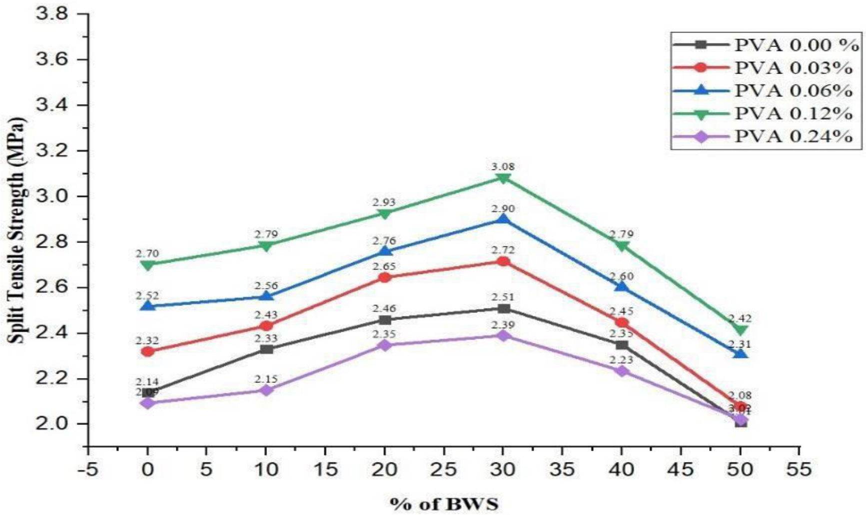

Figure 10. Effect of BWS and PVA on Reduced

Split Tensile strengths after 90 days of HCl Attack.

6.2.7 Optimum Combination: Additionally, a 0.12% PVA and 30% Bethamcherla waste stone combination produced the greatest split tensile strength. This shows this mix design has the highest tensile resistance, which is critical for concrete subjected to tensile pressures.

VII. CONCLUSIONS

1. Important results were obtained from the self-curing concrete experiment using Bethamcherla waste stone in place of the coarse aggregates. Desired results were obtained when Bethamcherla waste stone was used in replacement of coarse aggregates to the extent of 30%.
2. At optimal level (30%) of replacement, BWS strength obtained is 31.02, 25.51 and 20.84 N/mm^2 for 30 ,60 and 90 days of HCl immersion respectively, proving it as acid resistant concrete.
3. The concrete's self-curing qualities were successfully obtained at every replacement level, suggesting that the addition of Bethamcherla waste stone had no detrimental effects on the selfcuring process. As replacement Polyvinyl alcohol didn't result in significant changes in characteristic strength. However, it is suggested that 0.12 % of PVA by weight of cement addition is optimum.
4. By partially replacing waste stone from Bethamcherla, waste material may be recycled and the need for natural coarse aggregates is decreased. This procedure encourages sustainability and may result in cost cutting's in concrete production.
5. By various combinations of Polyvinyl alcohol and Bethamcherla waste stone was yielded significant changes in split tensile strength values of concrete. As a part mix with 30 % of BWS and 0.12 % of PVA gave significant results i.e. 3.71, 3.55 and 3.08 N/mm^2 after 30 days ,60 days and 90 days of HCl attack respectively. Therefore, result shows optimum level of Bethamcherla waste stone as 30% which had given desired result even after acid attack.

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