

# Performance of Bethamcherla Stone Powder Concrete under Sulphate Curing

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**Abstract** - Sulphate permeability of concrete is the relative ease with which sulphate ion can penetrate in to the pores of concrete. The study of sulphate permeability in concrete is of importance when concrete is subjected to sulphuric atmosphere such as saline nature, sulphuric manufacturing plants etc. The penetration of sulphate ions into concrete may lead to the corrosion of reinforcement and hence weaken the structures and also adversely affect durability of concrete. Therefore a detailed study has been required to find the sulphate permeability of concrete. The aim of our study is to get acquainted with these Supplementary Cementitious Materials (SCM's) and to examine some features. The most interesting feature is to increase chemical resistance of concrete. The present work studied the performance of Bethamcherla stone powder on sulphate attack.

Supplementary cementitious materials can be used for improved concrete performance in its fresh and hardened state. They are primarily used for improved workability, durability and strength. These materials allow the concrete producer to design and modify the concrete mixture to suit the desired application. Concrete mixtures with high Portland cement contents are susceptible to cracking and increased heat generation. These effects can be controlled to a certain degree by using supplementary cementitious materials. Supplementary cementitious materials such as red mud, Bethamcherla stone powder, slag and silica fume enable the concrete industry to use hundreds of millions of tons of by product materials that would otherwise be land filled as waste. Furthermore, their use reduces the consumption of Portland cement per unit volume of concrete. Portland cement has high energy consumption and emissions associated with its manufacture, which is conserved or reduced when the amount used in concrete is reduced. One main objective of this work is to study the experimental investigation on performance of blended concrete of M<sub>30</sub> grade. The Bethamcherla stone powder percentage for replacement of cement is varied as 0%, 10%, 20%, 30%, and 40%.

**Keywords** – Bethamcherla stone powder, Supplementary Cementitious Materials, Sulphate curing.

## I. INTRODUCTION

### *1. General*

Concrete technologists throughout the world are making constant efforts to find innovative materials which can partially or fully replace the ever demand and expensive building material, cement. Use of industrial wastes like silica fume, ground granulated blast furnace slag, metakaolin, rice husk ash, which possess pozzolanic property are tried to replace cement partially. Substitution of waste materials will conserve dwindling resources and will avoid the environmental and ecological damages caused by quarrying and exploitation of the raw materials for making cement. The output of these waste materials suitable as cement replacement such as slag, fly ash, silica fume, rice husk ash etc is more than double that of cement production. Use of industrial waste products is not only a partial solution to environmental and ecological problems, it significantly improves the microstructure and consequently the durability properties of concrete, which are difficult to achieve by the use of pure Portland cement alone. The aim is not only to make the cements and concrete less expensive, but to provide a blend of tailored properties of waste materials and Portland cements suitable for specified purpose. The combination of different pozzolanic materials to produce cheaper and more durable building materials will solve to some extent the ecological and environmental problems. Pozzolanas or supplementary cementitious materials improve the consistency and

workability of fresh concrete because an additional volume fines is added to the mixture. Concrete with silica fume is typically used at low water contents with high range water reducing admixtures and these mixtures tend to be cohesive and stickier than plain concrete. Fly-ash and slag generally reduce the water demand for required concrete slump. Concrete setting time may be retarded with some supplementary cementitious materials used at higher percentages. Cement production consumes large quantities of energy. Replacement of cement can give considerable energy savings. These waste does not need an additional energy input before use. It is clear that the energy savings for cement replacement by such admixture in concrete will be in direct proportion to cement used. Ordinary Portland cement is the most commonly used building material throughout the world and it will retain its status in near future also because of demand and expansion of construction industry all over the world. Further the greatest challenge before the concrete construction industry is to serve the two pressing needs of human society, namely the protection of environment and meeting the infrastructure requirements of our growing population Structures which are constructed in the marine areas are liable to be subjected to acidic attack. One of such major problems is sulphate ion attack against concrete structures. The weight loss and deterioration of concrete under such attack needs investigation and an alternate solution should be brought out. It is in this context the protection and enhancement of durability of concrete assumes importance. It has been recognized for a long time that sulphate ions particularly in soil and water cause severe damage to concrete structures. There have been numerous field studies on the distress caused to concrete structures generated by sulphate attack. Sulphate attack has often been discussed in the terms of reaction of cement hydrate with sulphate ions. The superior resistance of the concrete mix against sulphate attack can be brought in by the pore refinement process and densification of transition zone occurring due to conversion of lime forming from the hydration of cement in to additional binding material through pozzolanic activity. One of the main causes of deterioration in concrete structures is the distress of concretes due to its exposure to harmful chemicals that may be found in natures, such as in contaminated ground waters, industrial effluents and sea waters. The most aggressive chemicals that effect durability of structures are chlorides and sulphates. Many research studies have also been carried out to unravel this complex phenomenon through immersion tests in the laboratory as well as in field. In recent years the use of blended cements particularly the bethamcherla stone powder based variety has shown a sharp increase. This is mainly on the account of ecological benefits and the improvements in the long-term durability of concrete. Generation of bethamcherla stone powder in huge quantities as a byproduct in the stone polishing industries and poses gigantic problem in its disposal. Bethamcherla stone powder is a great environmental threat. The present experimental work discusses the effect of sulphate attack on High Volume Bethamcherla stone powder concrete in Ordinary, Standard and higher grades. Now-a-days the most suitable and widely used construction material is concrete. This building material, until these days, went through lots of developments. The definition of concrete is the mixture of cement, water, additives or sometimes super-plasticizers. It is artificial material. In the beginning it is soft, ductile or fluid, and gradually will be solid. We can consider this building material as an artificial stone. The most important part of concrete is cement. The production process of this raw material produces a lot of CO<sub>2</sub>. It is well known, that CO<sub>2</sub> emission initiates harmful environmental changes. Nowadays researchers make efforts to minimize industrial emission of CO<sub>2</sub>. The most effective way to decrease the CO<sub>2</sub> emission of cement industry is to substitute a proportion of cement with other materials. These materials called supplementary cementing materials (SCM's). Usually used supplementary cementing materials are Ground Granulated Blast Furnace Slag (GGBS), fly ash (FA), Silica Fume (SF), Trass or Metakaolin (MK). These are typically industrial by-products, hence the application of SCM's results less CO<sub>2</sub> during cement production. The SCM's provide other advantages and that is why the usage in the concrete technology is more and more general.

Sulphate permeability of concrete is the relative ease with which sulphate ion can penetrate in to the pores of concrete. The study of sulphate permeability in concrete is of importance when concrete is subjected to sulphate atmosphere such as saline nature, sulphate manufacturing plants etc.,. The penetration of sulphate ions into concrete may lead to the corrosion of reinforcement and hence weaken the structures and also adversely affect durability of concrete. Therefore a detailed study has been required to find the sulphate permeability of concrete. The aim of our study is to get acquainted with these SCM's and to examine some features. The most interesting feature is to increase chemical resistance of concrete. We will focus in our examinations on Bethamcherla stone powder (BSP). In literature scientific experiments, they examine the influence of SCM's on weight loss, strength characteristics and on the resistance to penetration of chemical also.

#### *1.1 Advantages of using Blended Cement*

The engineering benefits likely to be derived from the use of mineral admixtures (blended cements and cement + mineral admixtures can be used interchanging) in concrete are improved resistance to thermal cracking because of lower heat of hydration, enhancement of ultimate strength, reduction in permeability due to pore refinement, and a better durability to chemical attacks such as chloride, sulphate water, soil and alkali-aggregate expansion.

i) *Temperature rise:* In large concrete pours like bridges, foundations and water retaining structures, it is vital to minimize the rise of early age thermal cracking by controlling the temperature rise caused by hydration. One method of doing this is by use of concrete containing blended cements.

ii) *Chloride resistance:* Blended cement concrete have a higher resistance to the penetration of chlorides. The table below shows typical diffusivity.

iii) *Reduction of diffusivity:* The diffusivity is substantially reduced in case of blended cement. This is due to two

mechanisms. Firstly, the incorporation of slag reduces the permeability of the concrete and secondly the hardened paste of slag cement bind greater amounts of chlorides than that of OPC, resulting in much lower portion of free chlorides in the pore solution.

*iv) Protection to steel corrosion:* The blended cement concrete is more resistant to Chloride penetration and thus provides protection in coastal areas against corrosion many more times than OPC concrete.

*vi) Sulphate resistance:* Blended cement with slag content more than 50%, exhibits better sulphate resisting properties. Depending upon the severity of the exposure to sulphate, limitations are placed on C3A content in cement.

*vii) Alkali-silica reaction:* Blended cement with high slag is a safe cement system for the use with reactive aggregate.

*viii) Resistance to sea water:* In marine exposures, concrete containing blended cements exhibit enhanced durability. The studies done in Belgium, Norway, Germany, England and France have found that blended cements with more than 50% GGBFS, have a better durability.

#### 1.2 Potential Benefits of Blended Cements

- a) Improved concrete workability.
- b) Lower risk of thermal cracking
- c) Improved concrete durability and long-term strength.
- d) Reduced overall concrete cost.

#### 1.3 Pozzolana

A pozzolana is a natural or artificial materials containing silica in a reactive form, they have little or cementitious values. However is in a finely divided form in the presence of moisture they will chemically react with alkali to form cementing compounds. Examples of pozzolonic materials are volcanic ash, pumice, opalineshales, and burnt clay.

#### 1.4 Types of pozzolanas

Pozzolanas are generally classified into two groups.

##### a) Natural pozzolanas:

The different natural pozzolanas are classified into four groups.

1. Clays or shale
2. Diatomaceous earth
3. Volcanic tuffs
4. Pumicities

##### b) Artificial pozzolanas

These are pozzolanas which are obtained by the industrial by products they are grouped in the following

1. Bethamcherla stone powder
2. Fly ash
3. GGBS
4. Silica fumes
5. Metakaoline

The artificial pozzolanas do not pass pozzolanic property within themselves but when they can in constructions moisture react with calcium hydroxide in cement and exhibit pozzolanic reaction hence they are called as supplementary cementitious materials (SCM).

#### 1.4.1 Artificial pozzolanas:

##### 1. Bethamcherla stone powder

This powder was obtained from stone polishing industries. During the finishing stage of marbles, the powder is generated and this is disposed into the environment as waste material. By physical observation it is observed that it has bonding nature (it appears in the form of lumps). The author aims that if it is mixed with cement it may possess better results for concrete.

#### 1.5 Effect of pozzolanas on the properties of concrete

##### 1.5.1 Fresh concrete

In general, pozzolanas or supplementary cementitious materials improve the consistency and workability of fresh concrete because an additional volume fines is added to the mixture. Concrete with silica fume is typically used at low water contents with high range water reducing admixtures and these mixtures tend to be cohesive and stickier than plain concrete. Fly-Ash and slag generally reduce the water demand for required concrete slump. Concrete setting time may be retarded with some supplementary cementitious materials used at higher percentages. This can be beneficial in hot weather. The retardation is offset in winter by reducing the percentages of cementitious material in the concrete. Because of the additional fines the amount and rate of bleeding of these concretes is often reduced. This is especially significant when silica fume is used. Reducing bleeding, in conjunction with retarded setting, can cause plastic shrinkage cracking and may warrant special precautions during placing and finishing.

##### 1.5.2 Strength

Concrete mixture can be proportioned to produce the required strength and rate of strength gain as required for application. With supplementary cementitious materials other than silica fume, the rate of strength gain might be

lower initially, strength gain continues for a longer period compared to mixtures with only Portland cement frequently resulting in higher ultimate strength. Silica fume is often used to produce concrete compressive strength in excess 70MPa. Concrete containing supplementary cementitious material, generally needs additional consideration for curing of both the tests specimens and the structure to ensure that the potential properties are attained.

### 1.5.3 Durability

Supplementary cementitious material can be used to reduced the heat generation associated with cement hydration and reduce the potential for thermal cracking in massive structural elements. These materials modify the micro structure of concrete and reducing its permeability their by reducing the penetration of water and water-borne salts into concrete. Water tight concrete will reduce various forms of concrete detritions, such as cohesion of reinforcing steel and chemical attack. More supplementary cementitious material can reduce internal expansion of concrete due to chemical reactions such as alkali aggregate reaction and sulphate attack. Resistance to freezing and thawing cycles requires the use of air-entrained concrete. Concrete with a proper air, void system and strength will perform well in these conditions. The optimum combinations of materials will vary for different performance requirements and the type of supplementary cementitious material. The ready mixture concrete producer, with knowledge of the locally available materials, can establish the mixture proportions for the required performance. Prescriptive restrictions on mixture proportions can inhibit optimization economy. While several enhancements to concrete properties are discussed above, these are not mutually exclusive and the mixture should be proportioned for the most critical performance requirements for the job with the available materials.

### 1.6 Positive effects of using industrial waste (SCM) in concrete

#### 1.6.1 Benefits to environment:

(a) Replacing 15% of cement world-wide by industrial waste will reduce carbon dioxide emissions by 227 million tones.

(b) Replacing 50% of cement world-wide by industrial waste will reduce carbon dioxide emissions by 750 million tones. This is equal to removing 1/4th of all automobiles in the world.

(c) Replacing industrial waste in concrete will reduce scarcity of place for dumping and also ground water contamination during monsoon.

#### 1.6.2 Minimizing greenhouse gas emission:

The challenge for the civil engineering community in the coming days will be to realize projects in harmony with the nature and the concept for sustainable development involving the use of high performance, eco-friendly materials produced at reasonable cost with the lowest possible environmental impact. Taking view of sustainable development, it is imperative that the industrial waste be used to replace large amount of cement in the concrete industry. Red mud is pozzolana can replace the cement, thus opening a new era in recycling and conservation.

#### 1.6.3 Saving in the energy requirements in the production of ordinary Portland cement:

The production of one ton of Portland cement requires 1.55 to 1.6 tons of raw materials. These materials are primarily of good quality limestone and clay. A conscious use of industrial waste such as red mud would conserve the natural resources. It would also save the energy and provide superior concrete structures.

#### 1.6.4 Economical benefits:

Cement production consumes large quantities of energy. Replacement of cement can give considerable energy savings. These waste does not need an additional energy input before use. It is clear that the energy savings for cement replacement by such admixture in concrete will be in direct proportion to cement used. Thermodynamic calculations reveal that 1 ton of cement replaced saves at least 6000MJ energy or 10% to 13% of the cost.

### 1.7 Sulfate attack

Sulfates may be present in groundwater, and are often of natural origin, but can also come from fertilizers and industrial effluents. Attack on concrete by such materials is a culmination of a series of reactions that occur in the presence of sulfate ions. Sulfate attack manifests itself in the form of loss in strength, expansion, surface spalling, mass loss, and eventually disintegration.

#### 1.8 Mechanism of sulfate attack

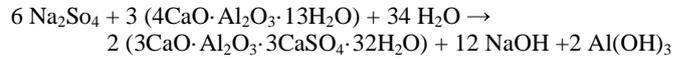
The common sulphates available from soils and ground water are those of calcium, sodium and magnesium. Industrial sites can introduce others. As well as the sulphate concentration, the pH of the soil or water is critical. At low pH these destructive reactions proceed more rapidly, because both sulphate attack and acid attack are involved. The various sulphate compounds attack concretes in different ways. Calcium sulphate is relatively insoluble in water. Its involvement is mainly as the expansive product of reaction between soluble sulphates and free lime in the concrete. Sodium sulphate is readily soluble and causes rapid reaction with the aluminates forming expansive ettringite. Because of the sodium ion, it introduces the additional risk of producing alkali-silica reaction. Magnesium sulphate also introduces a secondary effect from the presence of the magnesium ion. This ion is extremely aggressive and can attack concrete in its own right, forming Brucite and breaking down the strength of the calcium silicate hydrate gel by conversion to the equivalent magnesium salt which has no binding properties. Sulfate attack is often discussed in terms of reactions between solid hydration products in hardened cement paste (such as calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , and calcium aluminates hydrate,  $4\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 13\text{H}_2\text{O}$ ) and dissolved compounds such as sodium sulfate ( $\text{Na}_2\text{SO}_4$ ), magnesium sulfate ( $\text{MgSO}_4$ ), and calcium sulfate ( $\text{CaSO}_4$ ). Their reactions with the solid

phases in hardened cement paste are as follows:

*Sodium Sulfate (Na<sub>2</sub>SO<sub>4</sub>)*

Sodium sulfate solution reacts with calcium hydroxide to form gypsum and Na(OH):  $\text{Na}_2\text{SO}_4 + \text{Ca(OH)}_2 + 2 \text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + 2 \text{Na(OH)}$

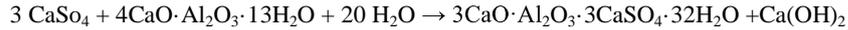
Sodium sulfate also reacts with calcium aluminates hydrate ( $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 13\text{H}_2\text{O}$ ) and results in the formation of ettringite:



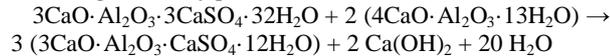
*Calcium Sulfate (CaSO<sub>4</sub>)*

In aqueous conditions, calcium sulfate reacts with calcium aluminates hydrate

( $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 13\text{H}_2\text{O}$ ) to form ettringite (Bensted 1983):

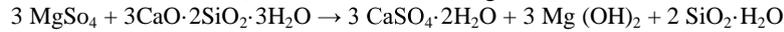


When the supply of calcium sulfate becomes insufficient to form additional ettringite, calcium aluminate hydrate ( $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 13\text{H}_2\text{O}$ ) reacts with ettringite already produced to form monosulfate (Bensted 1983):

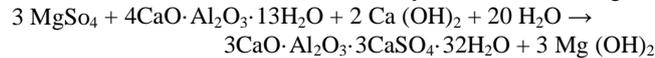


*Magnesium Sulfate (MgSO<sub>4</sub>)*

Magnesium sulfate attacks calcium silicate hydrate and  $\text{Ca(OH)}_2$  to form gypsum:  $\text{MgSO}_4 + \text{Ca(OH)}_2 + 2 \text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{Mg(OH)}_2$



Magnesium sulfate also reacts with calcium aluminate hydrate to form ettringite:



These reactions (to form gypsum and ettringite) are expansive in nature; therefore they exert internal pressure in hardened concrete and eventually cause deterioration. It may also be noted that the severity of sulfate attack depends on the concentration of sulfate solution, and the rate at which the sulfate ions are replenished. If the concrete is exposed to sulfate bearing water that is flowing rather than stagnant, it will undergo a higher rate of attack.

## II. OBJECTIVES OF THE EXPERIMENTAL WORK

### 2.1 Problem statement

To study the performance of M30 blended cement concrete under sulphate attack. The Supplementary Cementitious Materials (SCM's) as bethamcherla stone powder percentage for replacement of cement is varied as **10%, 20%, 30%, 40%** for both 28days water curing & 60days sulphate curing using 15% solution of  $\text{MgSO}_4$ .

### 2.2 Objectives of the study

The main objective of this experimental investigation is to study the effect of sulphate attack on blended cement concrete.

- To determine the strength of pozzolonic concrete.
- To determine the sulphate attack on the blended concrete.
- To determine the strength characteristics of concrete specimens after immersed in sulphate solution.
- To increase chemical resistance of concrete.
- To minimize the cement consumption by substitute a proportion of cement with the supplementary cementing materials.

## III-MATERIALS AND METHODOLOGY

### 3.1 Materials

The detailed description about the materials used is given below.

#### 3.1.1 Cement

In this experiment 43 grade Ordinary Portland Cement (OPC) with brand name of Ultra tech is used for all concrete mixes. The cement used is fresh and without any lumps. The testing of cement is done as per IS:81121989. The specific gravity of cement is found to be 3.15. The physical properties of cement used are as given in table 3.1

Table 3.1 Physical properties of cement

Sl. Nor.	Particulars	Experimental result		As per standard
1	Normal consistency (%)	34		28-35
2	Fineness	C.A	BSP	Not more than 3.5% for fine aggregate and Not more than 8% for coarse aggregate
		5.12 %	2.62%	
3	Setting time (minutes)			
3a)	Initial	45		Not less than 30
3b)	Final	290		Not more than 600

### 3.1.2 Bethamcherla stone powder

This powder was obtained from stone polishing industries. During the finishing stage of marbles, the powder is generated and this is disposed into the environment as waste material. By physical observation it is observed that it has bonding nature (it appears in the form of lumps). The author aims that if it is mixed with cement it may possess better results for concrete. This powder can be viewed in the fig.-----



### 3.1.3 Fine aggregate

The sand used in this investigation is ordinary river sand. The sand passing through 4.75 mm size sieve is used in the preparation of specimens. The sand conforms to grading Zone-II as per IS: 383-1970. The specific gravity of fine aggregate is found to be 2.65. The water absorption test on coarse aggregate is found to be 0.35%.

### 3.1.4 Natural coarse aggregate

The coarse aggregate used in the investigation is 20 mm down size locally available crushed stone obtained from quarries. Specifications for coarse aggregate are included in IS: 383-1970. The physical properties have been determined as per IS: 2386-1963. The specific gravity of coarse aggregate is found to be 2.68. The water absorption test on coarse aggregate is found to be 0.25%.

### 3.1.5 Water

The water used in the mix design was potable water and it's free from suspended solids and organic materials, which might have affected the properties of the fresh and hardened concrete. The water used for both mixing and curing of concrete should be free from impurities, injurious amounts of acids, alkalis, oils, salts, organic matter or other substances that may be deleterious to concrete or steel. The water should be colourless and odourless. The water for mixing and curing concrete shall be as per IS 456- 2000.

### 3.1.6 Superplasticizer

Conplast SP 430 is a super plasticizing admixture. Conplast SP430 is based on sulphonated naphthalene polymers

and is supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specially formulated to give high water reductions upto 25% without loss of workability and produce high quality concrete of reduced permeability. The property of SP as furnished by the manufacturer is shown in the table.3.2 and the SP is supplied in can of 3, 5 and 15 liters.

Table 3.2: Properties of Conplast SP 430

Properties	Conplast SP430
Composition	Sulphonated Naphthalene Polymers
Specific gravity	1.164 at 27°C
Chloride content	Nil
Air entrainment	<1.5%

The optimum dosage of Conplast SP430 to meet specific requirements should always be determined by trial mixes using the materials and conditions that will be experienced in use. In the experimentation suitable dosage of 0.5% is added to achieve high workability and slump value for flow ability.

### 3.2 Mix design

The mix design procedure adopted to obtain a M30 grade concrete is in accordance with IS 10262- 2009. The specific gravities of the materials used are as tabulated in the table 3.3.

Table 3.3 Specific gravities of materials used

Material	Specific gravity
Cement	3.15
Fine aggregate	2.65
Coarse aggregate	2.68

The design steps are as follows

**Step 1:** Determination of the target strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65s$$

Where,  $f'_{ck}$  = target mean compressive strength at 28 days

$f_{ck}$  = characteristics compressive strength at 28 days

$s$  = standard deviation.

From IS 456-2000, Table 8,  $s = 5\text{MPa}$

$$\text{Target strength} = 30 + (1.65 \times 5) = 38.25\text{MPa.}$$

**Step 2:** Selection of water- cement ratio

Referring IS 456-2000, Table 5, W/C ratio = 0.45

**Step 3:** Selection of water content

Referring IS 10262- 2009, Table 2,

Maximum water content for coarse aggregate of size 20mm = 186 kg/m<sup>3</sup>. (For 20mm to 50 mm slump range)

**Step 4:** Calculation of cement content

$$\text{W/C ratio} = 0.45$$

$$\text{Therefore, cement content} = 186/0.45 = 413 \text{ kg/m}^3$$

Referring to IS 456- 2000, Table 5,

Minimum cement content for Moderate exposure condition = 300 kg/m<sup>3</sup>

$$\text{Therefore, } 413 \text{ kg/m}^3 \geq 320 \text{ kg/m}^3$$

Hence the cement content is adequate.

**Step 5:** Determination of the volume of coarse and fine aggregates

Referring IS 10262- 2009, Table 3, volume of coarse aggregate per unit volume of concrete corresponding to a maximum size of coarse of 20mm and fine aggregate corresponding to grading zone II and water – cement ratio of 0.45,

$$\text{Volume of coarse aggregate} = 0.63$$

Volume of fine aggregate = 1 - 0.63 = 0.37

**Step 6: Mix Calculations**

The mix calculations per unit volume of concrete shall be as follows.

a) Volume of concrete = 1 m<sup>3</sup>

b) Volume of cement = (Weight of cement / Specific gravity of Cement)  
 = 413 / (3.15 x 1000)  
 = 0.1312 m<sup>3</sup>

c) Volume of water = (Weight of water / Specific gravity of Water) X (1/1000)  
 = 186 / 1000  
 = 0.186 m<sup>3</sup>

d) Volume of all in aggregate = [1-(Volume of cement + Volume of water )]  
 = [1 - (0.1312 + 0.186)] = 0.682 m<sup>3</sup>

e) Mass of coarse aggregate = (d) x volume of coarse aggregate x specific gravity of C.A x 1000  
 = 0.682 x 0.63 x 2.68 x 1000  
 = 1151.48 kg

f) Mass of fine aggregate = (d) x volume of fine aggregate x specific gravity of F. A. x 1000  
 = 0.682 x 0.37 x 2.65 x 1000 = 668.70 g

**Step 7:** The mix proportion obtained are as shown in the table 3.4

Table 3.4: Mix proportion

W/C ratio	Cement	Fine aggregate	Coarse aggregate
0.45	413	668.70 kg/m <sup>3</sup>	1151.48 kg/m <sup>3</sup>
	1	1.61	2.78

**3.3 Work Plan**

The present experimental programme includes casting and testing of specimens for Compression, Split tensile and Shear strength. Specimens are prepared with M30 grade of concrete. Total of 90 specimens (shown in table 3.5) with various percentages of Bethamcherla stone powder are cast and tested.

Table 3.5: Number of specimens for each mix

Admixtures	28+60 Days water curing			28 Days water + 60 Days Mgso4 curing		
Bethamcherla stone powder (%)	No. of specimens			No. of specimens		
	Cubes	Cylinders	Shear	Cubes	Cylinders	Shear
0%	3	3	3	3	3	3
10%	3	3	3	3	3	3
20%	3	3	3	3	3	3
30%	3	3	3	3	3	3
40%	3	3	3	3	3	3

Table 3.6: Overall specimens

Sl. no.	Specimens	No. of specimens
1	Cubes	30
2	Cylinders	30
3	Shears	30
	Total =90	

### 3.4 Casting of specimens

Cement, sand and aggregate were taken in mix proportion 1:1.61:2.78 which correspond to M30 grade of concrete. Cement is replaced with bethamcherla stone powder as 10%, 20%, 30%, and 40%. All the ingredients were dry mixed homogeneously. To this dry mix, required quantity of water was added ( $W/C = 0.45$ ) and the entire mix was again homogeneously mixed. This wet concrete was poured into the moulds which was

compacted through hand compaction in three layers and then kept into the vibrator for compaction. After the compaction, the specimens were given smooth finishes and were covered with gunny bags. After 24 hours, the specimens were demoulded and transferred to curing tank, where in they were allowed to cure.

#### 3.4.1 Slump test (IS: 1199-1959):

This test is conducted to determine the consistency/workability of concrete. The sample of freshly prepared concrete of given mix design, is taken. The internal surface of the mould is thoroughly cleaned and freed from any set concrete before commencing the test. The mould is placed on a level smooth and nonabsorbent surface such as metal plate. The mould is filled in 3 equal layers with the fresh sample. Each layer is compacted with 25 strokes of 16mm diameter steel rod, 600mm long and bullet pointed at the bottom. The strokes should be applied uniformly over the entire area and with such a force that the rod just penetrates the full depth of the layer being compacted. Once the mould is fully filled the surplus concrete is struck off with a trowel or tamping rod. The mould is vertically lifted with utmost care. The operation is carried out at a place free from vibration and within a period of 2 minutes after sampling. The Slump measured is recorded in terms of millimeters of subsidence of the specimen during test. Any slump specimen, who collapses or streams off laterally, gives incorrect result and if this occurs the test is operated with another sample. The test is repeated for different w/c ratios.

Table 3.7 Classification of slump values

Classification of concrete	Slump Value
Stiff	0
Poorly mobile	10-30 mm
Mobile	40-150 mm
Cast mix	>150 mm

3.4.2 Compressive strength test:

Specimens of dimensions 150x150x150mm were prepared. They are tested on 2000kN capacity compression testing machine as per IS 516-1959(fig 4.2 and 4.3). The compressive strength is calculated by using the equation,

$$F=P/A$$

Where, F= Compressive strength of the specimen (in MPa).

P= Maximum load applied to the specimen (in N).

A= Cross sectional area of the specimen (in mm<sup>2</sup>).

3.4.3 Split tensile strength test:

Cylindrical specimens of diameter 150mm and length 300mm were prepared. Split tension test was carried out on 2000 kN capacity compression testing machine as per IS 5816-1999. The tensile strength is calculated using the equation,

$$F= 2P/ (\pi DL)$$

Where, F = Tensile strength of concrete (in MPa).

P = Load at failure (in N).

L = Length of the cylindrical specimen (in mm).

D = Diameter of the cylindrical specimen (in mm).

3.4.4 Shear strength test:

L shaped specimens were prepared. A diagrammatic representation of the specimen is as shown in fig.4.4. These specimens were tested on 2000 KN capacity compression testing machine. A loading arrangement was made such that a direct shearing force was applied on the shorter arm of the L' shaped specimen (i.e. over an area of 150mmx60mm). The maximum applied load (P) was noted down. The failure load (F) due to the applied shear force is obtained by using the relation

$$\text{Failure load (F)} = P l_1 / ( l_1 l_2) \text{ Where, P = Failure load in KN}$$

$$l_1 = 25 \text{ mm}$$

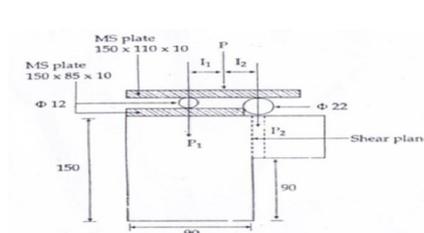
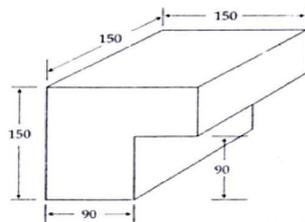
$$l_2 = 25 \text{ mm}$$

The shear strength is given by the relation

$$\text{Shear strength} = F/A$$

Where, F= Failure load

A = Area on which shear force is applied = 150 mmx 60 mm



IV EXPERIMENT AND RESULT

4.1 Slump

The slump test results are presented in Table 4.1. and Fig.4.1. From this table it is observed that the workability of concrete as measured from slump for concrete produced by replacing the cement by Bethamcherla stone powder goes on decreasing up to 40% as compared to the reference mix (0%) concrete, the higher slump is at 0% .This is

due to the fact that at 40% replacement level the Bethamcherla stone powder will induce flow properties because of its smooth texture and fineness. For all replacements of cement by Bethamcherla stone powder results in stiff concrete, since Bethamcherla stone powder starts absorbing water from the concrete. Thus it can be concluded that the workability of concrete is lower at a cement replacement level of 40% by Bethamcherla stone powder.

Table 4.1: Slump test results

Percentage Bethamcherla stone powder	Slump
0%	100
10%	97
20%	94
30%	92
40%	87

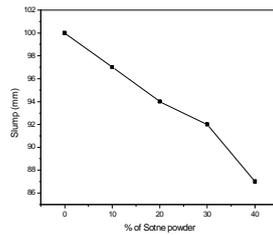


Fig.4.1 Slump vs. % of Stone powder

4.2 Compressive strength:

The compressive strength results are presented in Table 4.2 and Fig.4.2. The table gives the overall results of compressive strength of concrete produced by replacing cement by Bethamcherla stone powder in different percentages. The table also gives the percentage increase or decrease of compressive strength w.r.t. reference mix (0%). Variation in compressive strength is depicted in the form of graph as shown in figure 4.2. It is observed that the compressive strength of concrete produced with Bethamcherla stone powder based cement (28 days of water curing & 60 days of MgSo4 curing) goes on increasing up to 30% replacement. After 30% the compressive strength starts decreasing. At 30% replacement level the percentage increase of compressive strength is found to be +23.45 % & +30.76 % respectively (Fig 4.2 & Table 4.12). This is due to the fact that at 30% replacement level the Bethamcherla stone powder based cement (both curing conditions) can show higher pozzolonic reactivity. Thus blended cement produces strong and durable concrete provides significant advantages to both the plastic and hardened properties of concrete with cement there by inducing higher compressive strength. Thus it can be concluded that the compressive strength of concrete produced with Bethamcherla stone powder based cement (28+60 days water curing and 28+60 days MgSo4 curing) goes on increasing upto 30% replacement of cement by Bethamcherla stone powder and reaches peak at 30%. It is observed that the compressive strength of concrete produced with Bethamcherla stone powder based cement in water curing is less than compressive strength of concrete produced with Bethamcherla stone powder based cement in MgSo4 curing. This may be due to the fact that as the sulphate curing goes on increasing the strength properties of concrete gets a better replacement of cement by Bethamcherla stone powder in which hydration reaction can take place without any hindrance. Thus it can be concluded that as the MgSo4 curing goes on increasing concrete gains the compressive strength at 30% replacement level gives higher compressive strength.

Table 4.2: Compressive strength

Percentage replacement of cement by Bethamcherla stone powder(BSP)	Compressive strength of concrete produced by replacing BSP 28+60 days water curing(MPa)	Percentage increase or decrease of compressive strength w.r.t.reference mix	Compressive strength of concrete produced by replacing BSP 28(wc)+60 days(MgSo4) curing(MPa)	Percentage increase or decrease of compressive strength w.r.t.reference mix	Percentage increase or decrease of compressive strength of concrete produced by MgSo4 curing
0%(reference mix)	38.62	-	40.44	-	+4.71
10%	40.77	+5.56	42.07	+4.03	+3.91
20%	43.4	+12.37	44.88	+10.97	+3.41
30%	47.62	+23.45	52.88	+30.67	+10.91
40%	42.36	+9.68	40.88	+1.04	-3.49

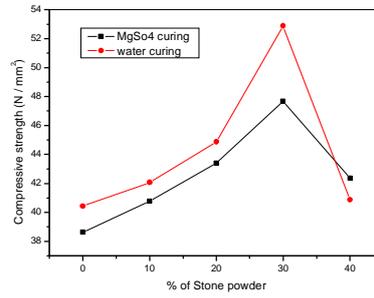


Fig 4.2: Compressive strength vs. % of stone powder

4.3 Split Tensile strength

The split tensile strength results are presented in Table 4.3 and Figure 4.3. The table gives the overall results of Split tensile strength of Concrete Produced by replacing cement by Bethamcherla stone powder in different percentages. The table also gives the Percentage increase or decrease of Split tensile strength w.r.t. reference mix (0%). Variation in Split tensile strength is depicted in the form of graph as shown in figure 4.3

It is observed that the Split tensile strength of concrete produced with Bethamcherla stone powder based cement (28+60 days of water curing & 28+60 days of MgSo<sub>4</sub> curing) goes on increasing upto 30% replacement. After 30% the Split tensile strength starts decreasing. At 30% replacement level the percentage increase of Split tensile strength is found to be +34.22 % & +43.62 % respectively (Fig 5.3 & Table 4.3). This is due to the fact that at 30% replacement level the Bethamcherla stone powder based cement (both curing conditions) can show higher pozzolonic reactivity. Thus blended cement produces strong and durable concrete provides significant advantages to both the plastic and hardened properties of concrete with cement there by inducing higher Split tensile strength.

Thus it can be concluded that the Split tensile strength of concrete produced with Bethamcherla stone powder based cement (88 days water curing and 88 days MgSo<sub>4</sub> during) goes on increasing up to 30% replacement of cement by Bethamcherla stone powder and reaches peak at 30%. It is observed that the Split tensile strength of concrete produced with Bethamcherla stone powder based cement in water curing is less than Split tensile strength of concrete produced with Bethamcherla stone powder based cement in MgSo<sub>4</sub> curing. This may be due to the fact that as the sulphate curing goes on increasing the strength properties of concrete gets a better replacement of cement by Bethamcherla stone powder in which hydration reaction can takes place without any hinderence. Thus it can be concluded that as the MgSo<sub>4</sub> curing goes on increasing concrete gains the Split tensile strength at 30% replacement level gives higher Split tensile strength.

Table 4.3: Split tensile strength

Percentage replacement of cement by Bethamcherla stone powder(BSP)	Compressive strength of concrete produced by replacing BSP 28+60 days water curing(MPa)	Percentage increase or decrease of compressive strength w.r.t.reference mix	Compressive strength of concrete produced by replacing BSP 28(wc)+60 days(MgSo <sub>4</sub> ) curing(MPa)	Percentage increase or decrease of compressive strength w.r.t.reference mix	Percentage increase or decrease of compressive strength of concrete produced by MgSo <sub>4</sub> curing
0%(reference mix)	2.63	-	2.82	-	+7.22
10%	2.82	+7.22	3.39	+20.21	+20.21
20%	3.06	+16.35	3.71	+31.56	+21.24
30%	3.53	+34.22	4.05	+43.62	+14.73
40%	3.01	+14.45	2.97	+5.32	-1.33

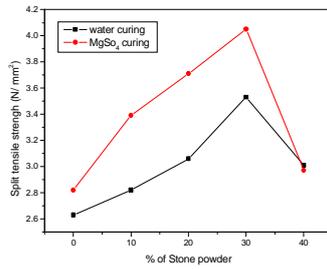


Fig 4.3: Split tensile strength vs. % of stone powder

4.3.1 Relation between split tensile strength and compressive strength.

The split tensile strength is often used to obtain the tensile strength of concrete, rather than by a direct tensile strength test, because the former is easier to perform. In practical applications, the tensile strength of concrete is often estimated from the compressive strength. The IS456-2000 code does not provided any formula for estimation of split tensile strength in terms of compressive strength. Hence there is a necessity to find the relation between split and compressive strengths to ease estimate. A regression analysis was performed to the obtained test results and the following regression equation is deduced with correlation coefficient R is 0.99756 and SD is 0.216 for water curing and R is 0.9195 and SD is 0.343 forMgSO<sub>4</sub> curing specimens.

$f_{sp} = 0.46 \sqrt{f_{ck}}$  .....Water curing

$f_{sp} = 0.51 \sqrt{f_{ck}}$  .....MgSO<sub>4</sub> curing

Comparison between the test results and that predicted by proposed equation is presented in Table 4.4(a) and (b). The ration between EXP/RM is about 0.86 to 1.11. From this it came to know that the proposed equation has good agreement with the experimental results.

Table 4.4(a): Performance of Regression Modal for water curing

S.No.	Nomenclature	Experimental shear strength	Regression Model shear/Regression	Exp.flexure strength/Regression
1	0	2.63	2.85	0.92
2	10	2.83	2.93	0.96
3	20	3.06	3.02	1.01
4	30	3.53	3.17	1.11
5	40	3.01	2.99	1.00

Table 4.4(b): Performance of Regression Modal for water curing

	Nomenclature	Experimental split tensile strength	Regression Model split tensile strength	Exp.flexure strength/RegressionModel
1	0	4.62	5.89	0.78
2	10	5.53	6.06	0.91
3	20	6.47	6.25	1.03
4	30	7.40	6.55	1.12
5	40	6.66	6.17	1.07

4.4Shear Strength

Percentage replacement of cement by Bethamcherla stone powder(BSP)	Compressive strength of concrete produced by replacing BSP 28+60 days water curing(MPa)	Percentage increase or decrease of compressive strength w.r.t.reference mix	Compressive strength of concrete produced by replacing BSP 28(wc)+60 days(MgSo4) curing(MPa)	Percentage increase or decrease of compressive strength w.r.t.reference mix	Percentage increase or decrease of compressive strength of concrete produced by MgSo4 curing
0%(reference)	2.63	-	2.82	-	+7.22

mix)					
10%	2.82	+7.22	3.39	+20.21	+20.21
20%	3.06	+16.35	3.71	+31.56	+21.24
30%	3.53	+34.22	4.05	+43.62	+14.73
40%	3.01	+14.45	2.97	+5.32	-1.33

The shear strength results are presented in Table 4.4 and Figure 4.4. The table gives the overall results of Shear strength of Concrete Produced by replacing cement by Bethamcherla stone powder in different percentages. The table also gives the Percentage increase or decrease of Shear strength w.r.t. reference mix (0%). Variation in Shear strength is depicted in the form of graph as shown in figure 4.4

It is observed that the Shear strength of concrete produced with Bethamcherla stone powder based cement (28+60 days of water curing & 28+60days of  $MgSO_4$  curing) goes on increasing upto 30% replacement. After 30% the Shear strength starts decreasing. At 30% replacement level the percentage increase of Shear strength is found to be +60.17 % & +61.43 % respectively (Fig 4.4 and Table 4.4). This is due to the fact that at 30% replacement level the Bethamcherla stone powder based cement (both curing conditions) can show higher pozzolonic reactivity. Thus blended cement produces strong and durable concrete provides significant advantages to both the plastic and hardened properties of concrete with cement there by inducing higher Shear strength. Thus it can be concluded that the Shear strength of concrete produced with Bethamcherla stone powder based cement (88 days water curing and 88 days  $MgSO_4$  curing) goes on increasing upto 30% replacement of cement by Bethamcherla stone powder and reaches peak at 30%. From the results it is observed that the Shear strength of concrete produced with Bethamcherla stone powder based cement in water curing is less than Shear strength of concrete produced with Bethamcherla stone powder based cement in  $MgSO_4$  curing. This may be due to the fact that as the sulphate curing goes on increasing the strength properties of concrete gets a better replacement of cement by Bethamcherla stone powder in which hydration reaction can takes place without any hinderence. Thus it can be concluded that as the  $MgSO_4$  curing goes on increasing concrete gains the Shear strength at 30% replacement level gives higher Shear strength.

Table 4.4: Shear strength.

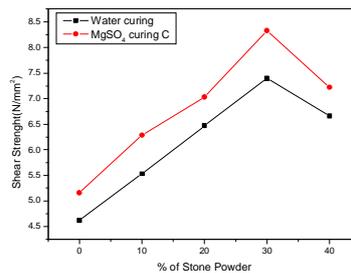


Fig 4.4: Variation of Shear strength

## V CONCLUSIONS

Following conclusions can be drawn based on the studies made.

1. Workability of concrete is lower up to cement replacement level of 40% by Bethamcherla stone powder.
2. Compressive strength of concrete produced with Bethamcherla stone powder based cement (28+60 days water curing and 28+60 days  $MgSO_4$  curing) goes on increasing up to 30% replacement of cement by Bethamcherla stone powder and reaches peak at 30%.
3. Magnesium sulphate ( $MgSO_4$ ) curing goes on increasing concrete gains the compressive strength at 30% replacement level gives higher compressive strength.
4. Split tensile strength of concrete produced with Bethamcherla stone powder based cement (28+60 days water curing and 28+60 days  $MgSO_4$  curing) goes on increasing up to 30% replacement of cement by Bethamcherla stone powder and reaches peak at 30%.
5. Magnesium sulphate ( $MgSO_4$ ) curing goes on increasing concrete gains the Split tensile strength at 30% replacement level gives higher Split tensile strength.
6. Shear strength of concrete produced with Bethamcherla stone powder based cement (28+60days water curing and 28+60 days  $MgSO_4$  curing) goes on increasing upto 30% replacement of cement by BSP and reaches peak at 30% .
7. Magnesium sulphate ( $MgSO_4$ ) curing goes on increasing concrete gains the Shear strength at 30% replacement level gives higher Shear strength.
8. The proposed regression models here in thesis, to estimate the split and shear strengths with the function of compressive strength is best suited.
9. In over view, the bethamcherla stone powder can be used as pozzolanic material for concrete works.

## VI SCOPE FOR FURTHER STUDIES

Following studies can be made in future

1. Experimental investigation on performance of Blended concrete on the shrinkage properties of concrete.
2. Experimental investigation on performance of Blended concrete on the creep properties of concrete.
3. Effect of chloride attack on the properties of Blended concrete produced by replacing cement by Bethamcherla stone powder and GGBS.
4. Effect of acidic attack on the strength properties of Blended concrete produced by replacing cement by Bethamcherla stone powder and GGBS.
5. Effect of sulphate attack on the strength properties of Blended concrete produced by replacing cement by Bethamcherla stone powder and GGBS.
6. Effect of alternative wetting and drying on the strength properties of Blended concrete produced by replacing cement by Bethamcherla stone powder and GGBS.

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