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Experimental Studies on Strength and Durability Properties of Concrete with Partial Replacement of Bethamcherla Stone Aggregate

V. Ramesh Babu[1], Dr.B. Ramesh Babu[2], Dr.C. Sashidhar[3], Dr. M.Vijaya Sekhar Reddy[4], K.Ashalatha[5]

[1]Assistant Professor, Department of Civil Engineering, Kandula Srinivasa Reddy Memorial College of Engineering, Kadapa, Andhra Pradesh, India. E-mail:Vramesh3131@gmail.com
[2]Principal, Ananthalakshmi College of Engineering, Anantapuram, Andhra Pradesh, India.
[3]Professor, Department of Civil Engineering, Jawaharlal Nehru Technological University, Anantapuramu, Andhra Pradesh, India. Email:sashigunt@gmail.com
[4]Head of the Department and Assistant Professor , Department of Civil Engineering , Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India.E-mail: skitce.hod@gmail.com
[5]Lecturer, Department of Civil Engineering, Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India.E-mail: k.ashalatha.56@gmail.com

ABSTRACT
Concrete is an extraordinary and key structural material in the human history. Increase in construction activities has lead to an increase in demand for various raw materials in concrete. This lead to researchers to make use of alternate materials as ingredients of concrete those are in no way inferior to the conventional materials. By partially replacing the normal aggregate with Bethamcherla stone aggregates in different proportions, the strength of concrete can be determined. Based on the proportion of ingredients used in concrete, its properties can also be changed. In most of the building works normal conventional concrete is used. The present experimental work focused on effective use of bethamcherla waste materials in place of coarse aggregate in concrete mix since these materials are naturally and abundantly available in Kurnool district. Concrete grade of M20 is exercised with various replacement levels of coarse aggregate with 20mm bethamcherla stone aggregates like 0%, 25%, 50%, 75%, 100% to study the compressive strength and acid resistance of cubes with addition of steel fibers.
Keywords: Bethamcherla Stone Aggregate, Compressive Strength, Concrete, Coarse Aggregate.

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I. INTRODUCTION

Concrete is the most popular building material in the world. Based on the global usage, concrete is placed at second position after water. It is a widely used construction material consisting of cementing material, fine aggregate, coarse aggregate and required quantity of water. Where in the natural aggregate is an essential component of concrete. Natural aggregate is becoming expensive due to scarcity. The world wide consumption of natural aggregate as coarse aggregate in concrete production is very high and several developing countries have encouraged some demand in the supply of natural aggregate in order to meet the increasing needs of infrastructural development in recent years. In particular, the demand of natural aggregate is quite high in developing countries owing to rapid infrastructural growth.

In the recent years, the growth in industrial production and the consequent increase in consumption have lead to fast decline in available natural resources on the other hand; a high volume of production has generated a considerable amount of coarse material which has adverse impact on the environment. The Civil Engineering construction industry is to be one of the most potential consumers of mineral recourses, thus generating a great amount of solid waste as a bye product stones. Stones have perhaps the noblest material from nature used by men for his artistic expression. There are many natural stone wonders the earth offers us which we must pamper as unique treasures. India offers a variety of a natural stone viz; granite, sandstone, slates, marbles, quartzite, bethamcherla marble stones in multi colors, shapes and size [1].

Bethamcherla stones are basically flaggy lime stone, it is natural splitable and when fitted in compact slabs and tiles. Kurnool district of Andhra Pradesh has been gifted by nature with huge deposit of bethamcherla stone. It is excellent flooring stone which is unique with geo mechanical properties required for flooring stones. When polished it gives glossy finish even as good as galaxy granite. Natural stone sector has grown from an almost manual activity to a highly industrialized business in last decades. The sector has gone full cycle, technologically. Improved production / processing system has greatly aided in reducing cost and offering very competitive price. This has in turn lead to greater consumption of natural stone. In spite of introducing most appropriate mining technology large quantity of waste is generated and also of some quantity of waste is generated while cutting and sizing bethamcherla stone slabs / tiles at quarry floor.

In this situation, some developing countries are facing a shortage in the supply of natural aggregate. Therefore, it is necessary to replace natural aggregate in concrete by alternate materials either partially or completely without compromising the quality of concrete. Also, it is desirable to obtain cheap, environmentally friendly substitutes for coarse aggregates that are preferably by-product in recent years, there is a growing interest in the use of marble waste obtained from quarries in some countries where natural aggregate is not widely available. Marble/Granite/Kotastone has been commonly used as a building material since the ancient times. Use of stone waste in various engineering applications can solve the problem of disposal of stone waste and other purposes. Stone waste can be used in concrete to improve its strength and other durability factors. Stone waste can be used as a partial replacement of cement or replacement of fine and coarse aggregate and as a supplementary addition to achieve different properties of concrete.

In India, stone dust is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the stone dust in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. Some attempts have been made to find and assess the possibilities of using waste marble and granite powder in mortars and concretes and results about strength and workability were compared with control samples of conventional cement sand mortar/concrete. Stone waste can be used as a partial replacement of cement or replacement of fine aggregate and as a supplementary addition to achieve different properties of concrete. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment. Pozzolans are the siliceous and aluminous material which in itself possesses little, or no cementitious properties but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing tri cementitious properties. A pozzolana is a cement extender improving the strength and durability of the cement or even reducing the costs of producing concrete.

II. LITERATURE REVIEW

Dinakar et al., 2008 investigated that the chemical resistance of the concretes was studied through chemical attack by immersing them in an acid solution. After 90 days period of curing the specimens were removed from the curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial weights were measured and the specimens were identified with numbered plastic tokens that were tied around them. The specimens were immersed in 3% H_2SO_4 solution and the pH was maintained constant throughout. The solution was replaced at regular intervals to maintain constant concentration throughout the test period. The mass of specimens were measured at regular intervals up to 90 days,
and the weight losses were determined [2].

Kazuyuki Torii and Mitsunori Kawamura et al., 1994, have conducted an experimental study on the effect of fly ash and silica fume on the properties of concrete subjected to acidic attack and sulphate attack. Changes in physical and chemical properties in the mortars with different replacements by fly ash and silica fume when immersed in 2% H_2SO_4, 10% Na_2SO_4 and 10% $MgSO_4$ solutions for 3 years were investigated [3].

III. EXPERIMENTAL PROGRAM

Based on the Indian Standard (IS: 10262-2009), design mix for M20 grade of concrete was prepared by partially replacing coarse aggregate with five different percentages by weight of bethamcherla aggregate (0%, 25%, 50%, 75%, and 100%). The results are compared with control concrete without stone waste.

IV. MATERIAL PROPERTIES

This section will present the chemical and physical properties of the ingredients. Bureau of Indian Standards (IS) and American Society for Testing and Materials (ASTM) procedures were followed for determining the properties of the ingredients in this investigation.

4.1 Cement

Ordinary Portland cement Zuari-53 grade conforming to IS: 12269-1987 [4] was used in concrete.
The physical properties of the cement are listed in Table 1.

Table 1: Physical Properties of Zuari-53 Grade Cement.

Sno	1	2	3	4	5		
Properties	**Sp. Gr**	**Normal Consistency**	**Initial Setting Time**	**Final Setting Time**	**Compressive Strength (Mpa)**		
Values	3.15	32%	60 min	320 min	3 days	7 days	28 days
					29.4	44.8	56.5

4.2 STEEL FIBERS

The utilization of steel fibres in concrete improves greater structural strength, reduces cracking and helps protect against extreme cold.By incorporation of steel fibers with 0%, 1% & 2% by volume is used in all mixes. Steel fibers were collected from M/S. Jeetmull Jaichandlall Madras Private Limited, Chennai, TamilNadu, India.

4.3 Aggregates

4.3.1 Fine Aggregate

Natural sand with specific gravity of 2.60 was used as fine aggregate conforming to zone- II of IS: 383-1970 [5]. The individual aggregates were blended to get the desired combined grading.

4.3.2 Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20 mm was used in our work. The specific gravity of coarse aggregate is 2.76. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per Indian Standard Specifications IS: 383-1970 [5].

4.5 Water

Potable water was used for mixing and curing of concrete cubes.

4.6 Bethamcherla Waste Stone Aggregate

Bethamcherla waste stone aggregate which is used in our investigation is a Bethamcherla floor slab aggregate bought from Kurnool district. The physical properties and Chemical composition of bethamcharla stone waste aggregate was represented in Tables 2&3.

Fig: 1 Bethamcharla Stone Aggregate

Table 2: Properties of Bethamcherla Stone Aggregate

S.No	PROPERTIES	TEST RESULTS
1	Specific gravity	3.0
2	Water absorption	0.2%
3	Bulk density	1615 kg/m^3
4	Aggregate impact test	16.73
5	Crushing value test	24.04
6	Elongation index	28%
7	Flakiness index	30%

Table 3: Chemical Composition of the Bethamcherla Waste Stone Aggregate

Composition (% by mass)/property	Bethamcherla Waste Stone Aggregate
Silica (SiO_2)	9.8
Alumina (Al_2O_3)	1.38
Iron oxide (Fe_2O_3)	1.42
Calcium oxide (CaO)	29.62
Magnesium oxide (MgO)	16.22
Magnesium Carbonate ($MgCO_3$)	33.92
Calcium Carbonate($CaCO_3$)	52.87
Loss on Ignition	40.56

V. MIX PROPORTIONING

In the present work, proportions for concrete mix design of M20 were carried out according to IS: 10262-2009 [6] recommendations. The mix proportions are presented in Table 4.

Table 4: Mix proportion for M20 Concrete

PARAMETERS	Percentage Replacement of Bethamcharla Stone Aggregate In Coarse Aggregate				
	CONTROL MIX	MIX 1 (25%)	MIX 2 (50%)	MIX 3 (75%)	MIX 4(100%)
W/C Ratio	0.5	0.5	0.5	0.5	0.5
Water kg/cu.m	191.6	191.6	191.6	191.6	191.6
Cement kg/cu.m	383	383	383	383	383
Fine aggregate kg/cu.m	546	546	546	546	546
Coarseaggregates kg/cu.m	1188	891	594	297	0
Bathemcharla stone aggregate kg/cu.m	0	297	594	891	1188

VI. RESULTS AND DISCUSSIONS

6.1 Compressive Strength

The tests were carried out as per IS: 516-1959 [7]. The 150mm size cubes of various concrete mixtures were cast to test compressive strength. The cubes specimens after de-moulding were stored in curing tanks and on removal of cubes from water the compressive strength were conducted at 7days, 28 days and the results are represented in Tables 5 , 6 & 7 and Figs 2, 3 & 4. The test results were compared with controlled concrete.

Table 5: Compressive Strength of Cubes With 0 % Steel Fibers

Percentage Replacement of Bethamcherla stone aggregate	Compressive Strength N/mm^2	
	7 Days	28 Days
CONTROL MIX	18.33	27.49
MIX 1	17.79	26.68
MIX 2	14.37	21.56
MIX 3	13.35	20.03
MIX 4	11.81	17.71

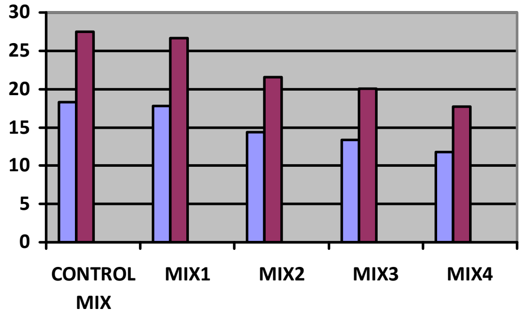

Fig 2: Compressive Strength of Cubes With 0% Steel Fibers

Table 6: Compressive Strength of Cubes With 1% Steel Fibers

Percentage Replacement of Bethamcherla stone aggregate	Compressive Strength N/mm^2	
	7 Days	28 Days
CONTROL MIX	19.37	29.05
MIX 1	18.42	27.63
MIX 2	15.65	23.47
MIX 3	13.95	20.93
MIX 4	12.35	18.53

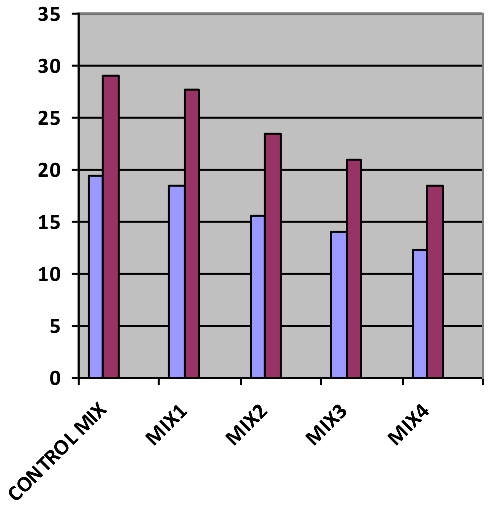

Fig 3: Compressive Strength of Cubes With 1% Steel Fibers

Table 7: Compressive Strength of Cubes With 2.0% Steel Fibers

Pe percentage replacement of of Bethamcherla stone aggregate	Compressive Strength N/mm^2	
	7 Days	28 Days
CONTROL MIX	20.95	31.42
MIX 1	19.91	29.87
MIX 2	16.74	25.11
MIX 3	15.07	22.61
MIX 4	13.22	19.83

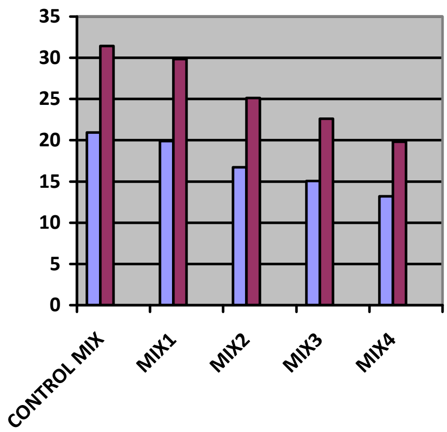

Fig 4: Compressive Strength of Cubes With 2% Steel Fibers

6.2 Acid Attack Test

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 90 days after 28 days of curing. Hydrochloric acid (HCL) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pHwas maintained throughout the period of 90 days. After 90 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water. Acid attack test results were represented in Table 8. Figure 5 represents the the percentage loss in strength of M20 (with 0% steel fibre) due to acidity. Figure 6 represents the Percentage loss in strength of M20 (with 1% steel fibre) due to Acidity. Figure 7 represents the Percentage loss in Strength of M20 (with 2% steel fibre) due to Acidity respectively.

Table 8: Acid Attack test results with 0%, 1%, 2% Steel Fibers

Percentage Replacement of Bethamcherla stone aggregate	Acid Attack Test		
	0%	1%	2%
CONTROL MIX	26.87	28.21	30.02
MIX 1	24.79	26.75	27.93
MIX 2	20.45	22.18	23.35
MIX 3	18.78	19.27	20.72
MIX 4	14.26	17.06	18.93

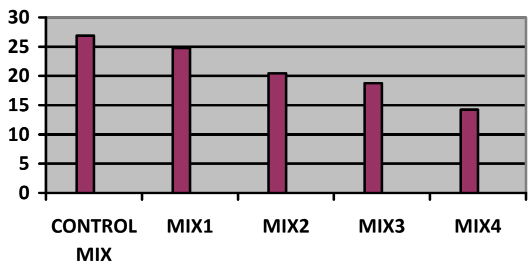

Fig 5: Percentage loss in Compressive strength of cubes with 0% steel fibers

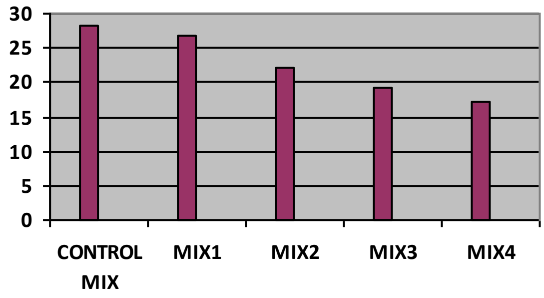

Fig 6: Percentage loss in Compressive strength of cubes with 1% steel fibers

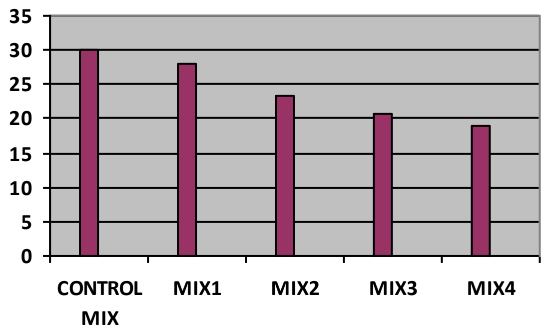

Fig 7: Percentage loss in Compressive strength of cubes with 2% steel fibers

VII. CONCLUSIONS

- The experimental results reveals that the maximum compressive strength of M20 conventional concrete for seven and 28 days curing period are 18.33 and 27.49 MPa with 0% addition of steel fibre.
- The experimental results reveals that the maximum compressive strength of M20 conventional concrete for seven and 28 days curing period are 19.37 and 29.05 Mpa with 1% addition of steel fibre.
- The experimental results reveals that the maximum compressive strength of M20 conventional concrete for seven and 28 days curing period are 20.95 and 31.42 Mpa with 2% addition of steel fibre.
- The compressive strength results shown decreasing trend with all replacement levels of coarse aggregate by bethamcharla stone aggregate and also addition of various percentages of steel fibres.
- It is also observed from the results that the maximum percentage reduction in compressive strength due to acid attack for M20 grade (with 0%, 1% and 2% addition of steel fibres) concrete are 26.87%, 28.21% and 30.02% .

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