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EXPERIMENTAL INVESTIGATION OF STEEL FIBER REINFORCED CONCRETE WITH PARTIAL REPLACEMENT OF COARSE AGGREGATE BY CUPOLA SLAG

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Abstract - *Over the decades, there has been a significant increase in the use of fibers in concrete for improving its properties such as strength and ductility. Among many different types of fibers available today, steel fiber is a recent introduction in the field of concrete technology. The addition of these fibers into concrete mass adequately increase the compressive strength, split tensile strength, flexural strength and impact strength of concrete. Excavation of rocks from valley generally produces worst environmental impacts. Cutting and screening out of coarse aggregate makes the conventional concrete more expensive and scarce due to small sized limited quantity of natural materials which is used. Cupola slag can be used in construction industry as partial replacement of coarse aggregate. Over a period of time, waste management has become one of the most unavoidable complex and difficult problem in the world which is affecting the environment. Cupola slag is byproduct material which is gathered from cast iron manufacturing unit. It is produced when molten steel is separated from impurity in cupola furnace. Coarse aggregate is partially replaced by cupola slag at optimum percentage of replacement. The utilization of cupola slag for concrete making also reduces its disposal problems to a great extent. In this experimental investigation, the hooked ended steel fibers are added and cupola slag will be added in various proportions and their effect on mechanical properties of concrete will be studied.*

***Key Words*: Steel fiber, Cupola slag , Hooked end steel fibers**

1. INTRODUCTION

1.1 General

At present, development in India is mainly by implementation of infrastructure projects. Due to that construction projects are executed at very rapid rate. In the developing country like India, availability of natural resources is also an influencing factor apart from finding due to this rapid infrastructural growth it requires large amount of construction materials like cement, aggregates, wood etc. Concrete is a flexible engineering material used in most of the civil engineering structures. Since the availability of natural resources of concrete is limited as we get it from natural deposits at present, there is a need to develop a new material that that can effectively replace with conventional without compromising with strength and durability properties of concrete. So there is need to replace these natural materials by alternative options which are obtained to industrial by product like cupola slag. The cheapest and the easiest way of getting substitute for natural aggregate is by crushing cupola slag to get artificial aggregate of desired size and grade. Industry produced a large amount of byproduct material during casting process. It also has an environmental issue in disposal of these byproducts since it cannot be used anywhere except the land filling. So by there is a need to replace natural aggregate by cupola slag to solve concrete as well as environmental and industry problem. Concrete has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. At the same instant concrete is brittle and weak in tension. The two main deficiencies of plain concrete are low tensile strength and a low strain at fracture. These shortcomings are generally overcome by the addition of steel fiber into the concrete.

2. LITERATURE REVIEW

A.M. Shende et.al., (2012) "Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade" The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cemetitious material, aggregate and water and by adding some special ingredients. The presence of micro cracks in the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of fibres in the mixture. Different types of fibers, such as those used in traditional composite materials can be introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. The fibres help to transfer loads at the internal micro cracks. Such a concrete is called fibre-reinforced concrete (FRC). It is observed that compressive strength increases from 11 to 24% with addition of steel fibres, flexural strength increases from 12 to 49% with addition of steel fibres and split tensile strength increases from 3 to 41% with addition of steel fibres.

Abdul Ghaffar et.al., (2014) The purpose of this research is based on the investigation of the use of steel fibers in structural concrete to enhance the mechanical properties of concrete. The objective of the study was to determine and compare the differences in properties of concrete containing without fibers and concrete with fibers. This investigation was carried out using several tests, compressive test and flexural test. A total of eleven mix batches of concrete containing 0% to 5% with an interval of 0.5% by wt. of

cement. 'Hooked' steel fibers were tested to determine the enhancement of mechanical properties of concrete. The workability of concrete significantly reduced as the fiber dosage rate increases. In general, the satisfactory improvement in various strengths is observed with the inclusion of Steel fibers in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fiber content. The optimum fiber content to impart maximum gain in various strengths varies with type of the strengths. Ductility of concrete is found to increase with inclusion of fibers at higher fiber content. The width of cracks is found to be less in SFRC than that in plain cement concrete beam.

Bagal Shreyash Vinayak and Shete Gunderao N.(2017) Concrete is mostly wide construction material in the world due to its ability it can be mould and shape. However concrete has some deficiencies as listed below, Low tensile strength, Low post cracking capacity, Brittleness and low ductility, Low impact strength. These properties can be improved by the use of steel fiber reinforced concrete. The addition of fibers improves the post cracking response of the concrete, i.e., it improves its energy absorption capacity and apparent ductility, and also provides crack resistance and crack control. In this paper, an attempt has been made to study the strength properties of concrete with different percentages of hooked end steel fibers and fly ash. The concrete mixture design is done for M30 grade of concrete with water cement ratio 0.45. The steel fiber reinforced concrete containing fibers of 0.5%, 1.0% and 1.5% volume fraction of hooked end steel fibers of 60 aspect ratio were used. The cement in concrete is replaced with percentage of 10%, 15% and 20% by weight of fly ash. The cube size is 150mm x150mm x150 mm for testing the compressive strength of concrete. Flexural strength is checked by testing beams of size 700 mm x 150 mm x 150 mm beneath two points loading. From experiment, it was concluded that the most optimum fiber and fly ash content that gives maximum compressive strength and flexural strength was 1.5% and 10% respectively. The reduction in workability due to fiber addition can be compensated by addition of fly ash.

D. A. Aderibigbe and A. E. Ojobo (1982) Investigations conducted on the pozzolanic properties of a cupola slag revealed that on the basis of chemical constituents alone, the cupola slag could be considered a pozzolana. Physical tests, however, showed that the slag exhibited little pozzolanic activity. An improvement in physical properties was obtained by calcining the slag at 700°C for 5 hr. Without sacrificing appreciable strength (e.g. a 13.5% reduction in strength), up to 20% replacement of Portland cement by cupola slag is possible in the preparation of cement mortar. This results in appreciable cost savings in areas where cement is expensive and cupola slag is considered a waste product.

Joseph O. Afolayan and Stephan A. Alabi (2013) The compressive strength of the concrete designed using blast cupola furnace slag and granulated cupola slag as a coarse aggregate and partial replacement for cement was investigated. A series of experimental studies were conducted involve concrete production in two stages. The first stage comprised of normal aggregate concrete (NAC) produced with normal aggregates and 100% ordinary Portland cement (OPC). Meanwhile, the second stage involved production of concrete comprising of cupola furnace slag an aggregates with 100% ordinary Portland cement (OPC) and subsequently with 2%, 4%, 6%, 8% and 10% cementitious replacement with granulated cupola furnace slag that had been grounded and milled to less than 75 μm diameter. The outcomes of compressive strength test conducted on the slag aggregate concrete (SAC) with and without granulated slag cementitious replacement were satisfactory compared to normal aggregate concretes (NAC).

Mekala Prathap Reddy and Dr. K. Chandrasekhar Reddy (2015) This paper investigation on M-30 grade of concrete with water cement ratio 0.45 to study the compressive strength, and tensile strength of steel fibers reinforced concrete (SFRC) containing fibers of an interval of 0.5%,1%,1.5% volume fraction of hook end steel fibers of aspect ratio 60 were used. The different percentage of one or more mineral admixtures with combination of steel fibers is used in this study. After curing this specimen were tested as per relevant codes of practice Bureau of Indian standard. A result data obtained has been analyzed as compared with a control specimen. A relationship between compressive strength VS days and flexural strength VS days respected graphically. Result data clearly shows percentage increase in 7, 28 & 54 days compressive strength for M-30 grade of concrete.

Mithun Sawant and Daksha Dhande (2017) Nowadays waste materials are used in the conventional concrete. In the present work the waste material cupola slag which is a by-product of cast iron manufacturing used for the preparation of Pervious concrete. Concrete made from cupola slag as partial replacement of cement will be studied for workability, compressive strength, permeability. We will use Cupola Slag as partial replacement of cement by different percentage. The percentage replacement of Cupola Slag will be 15%, 25%, 35% with cement. We will prepare cubes, finally slump test, compressive strength test, will be conducted to obtain the necessary results. A large no. of trial mixes are required to select the desired optimum replacement of cement by waste material Cupola Slag

R. Balaraman and Dr. N.S. Elangovan (2018) Investigations conducted on cupola slag as partial replacement with combination of fine and coarse aggregates. Fine and Coarse aggregate requirements in construction is more and there availability is less so there is a need to search a replacing material like cupola waste slag which is by-product of cast iron manufacturing. The disposal of cupola slag in open area causes environment pollution, it can be recycled for use in construction industry without producing any harm to human and environment. In this study a combined replacement of both fine and coarse aggregates were replaced. The design mix for M30 grade concrete were arrived and the target strength was found to be 20.960

N/mm2 at 7 days. Cupola slag was used in concrete as partial combined replacements for fine and coarse aggregates (20%, 30%, 40%) to ascertain applicability in concrete. Since the maximum compressive strength attained was 5.33 N/mm2 for 40%(20%F.A and 20%C.A) at 7 days..The concrete with cupola slag as partial combined replacement gives less strength.

R. Balaraman and S. Anne Ligoria (2015) Nowadays waste materials are utilized in the preparation of conventional concrete. In the present work the waste material considered is cupola slag which is by-product of cast iron manufacturing. The design mix for M20 and M25 grade concretes were arrived and the target strength was found to be 26.960 N/mm2 and 30.51 N/mm2 respectively. Cupola slag was used in concrete as partial replacements for fine and coarse aggregates (5%, 10%, 15%, 20%, 25%, 50% and 100%) to ascertain applicability in concrete. Since the disposal of cupola slag in open area causes environment pollution, it can be recycled for use in construction industry without producing any harm to human and environment. The maximum compressive strength attained was 33.778 N/mm2 and 38.222 N/mm2 at 15% for both M20 and M25 grades of concrete respectively at 28 days. Similarly the maximum split tensile strength atta0ined was 3.206 N/mm2 and 3.819 N/mm2 for M20 and M25 grades at 15% and 5% respectively. The concrete with cupola slag as partial replacement for coarse aggregates gives less strength when compared to fine aggregates.

S.P Singh and S.K Kaushik (2001) The paper presents results of an investigation carried out to study the fatigue strength of steel fiber-reinforced concrete (SFRC). An extensive experimental investigation was planned in which 127 SFRC beam specimens 100 x 100 x 500 mm in size were tested under four-point flexural fatigue loading in an MTS closed loop electrohydraulic universal testing machine. The specimen incorporated three different volume fractions (that is, 0.5, 1.0, and 1.5%) of corrugated steel fibers 0.6 x 2.0 x 30 mm in size. One hundred and eight specimens were also tested under static flexure to obtain the static flexural strength of different batches of concrete prior to fatigue testing. The test data are used to generate the S-N curves and regression analysis is used to propose an equation to predict the flexural fatigue strength of SFRC. A probabilistic approach is used to predict the fatigue reliability of SFRC. The fatigue-life distributions of SFRC at a given stress level is shown to approximately follow the two-parameter Weibull distribution. The S-N relationships have been used to obtain the parameters of the Weibull distribution. Design fatigue lives have been obtained for different stress levels for SFRC corresponding to different probabilities of failure.

Vikrant S. Vairagada and Kavita S. Kene (2012) Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc.. Fiber reinforced concrete has been successfully used in slabs on grade, shotcrete, architectural panels, precast products, offshore structures, structures in seismic regions, thin and thick repairs, crash barriers, footings, hydraulic structures and many other applications. This review study is a trial of giving some highlights for inclusion of steel fibers especially in terms of using them with new types of concrete. The study on the introduction of effect of steel fibers can be still promising as steel fiber reinforced concrete is used for sustainable and long-lasting concrete structures. This review study tried to focus on the most significant effects of addition of steel fibers to the concrete mixes. The steel fibers are mostly used fiber for fiber reinforced concrete out of available fibers in market. According to many researchers, the addition of steel fiber into concrete creates low workable or inadequate workability to the concrete, therefore to solve this problem of superplasticizer without affecting other properties of concrete may introduce.

Vishwash K. Mistry et.al., (2016) Main source of getting natural aggregates is through extraction from rocks. The excavation of rocks from valley produce worst environmental impacts of cutting and screening out coarse aggregate make concrete costlier. Even only natural resources of Coarse aggregate can't fulfill the requirements of constructions so there is a need to search a replacing material like cupola waste in this study efforts are made to replace the natural aggregate with cupola slag aggregates in varying percentage of replacement from 0 to 100 percent for intervals of 10 percent for M20 grade concrete with 0.5 constant W/C ratio under accelerated concrete curing condition for 3 days at 85 degree temperature. Efforts are made to carry out impact on compressive strength of concrete.

3. PROPERTIES AND MATERIAL USED

3.1 Cement

ISI marked OPC 53 Grade cement was used in this work with specific gravity of 3.15 and standard consistency 26%.

3.2 Fine aggregate

Sand used in his work confirming to Zone-III, with fineness modulus of 2.75 and specific gravity 2.6.

3.3 Coarse aggregate

Crushed stone with a maximum size of 10mm and uniform quality having specific gravity 2.74, conforming to IS 383-1970.

3.4 Cupola Slag

Table 3.1- Physical properties of cupola slag

Properties	Value
Specific gravity	3.5
Impact value	6.1%
Crushing strength	35.5%
Water absorption	0.4%

Table 3.2 –Chemical properties of cupola slag

Properties	Value
SiO_2	48.7%
Al_2O_3	11.8%
Fe_2O_3	11.1%
CaO	21.2%
MgO	1.3%
K_2O	1.4%

3.5 Steel Fiber

Table 3.3 – Physical properties of Steel fiber

Properties	Value
Diameter	0.75mm
Length of fibre	60mm
Appearance	Bright in clean wire
Average aspect ratio	80
Deformation	Hooked at both ends
Tensile strength	1050 MPa
Modulus of Elasticity	200 MPa
Specific Gravity	7.8

4. MIX DESIGN

4.1 Mix Proportion

Cement = 594.3 Kg
Fine aggregate = 736.87 Kg
Coarse aggregate = 875.67 Kg
Water cement ratio = 0.35

Mix proportion in M_{30} = 1:1.2:1.5

5. CONCLUSION

Different aspects of various authors on steel fiber reinforced concrete and partial replacement by cupola slag have been discussed. This gives the theoretical knowledge about the utilization of cupola slag and steel fibers into the conventional concrete. From the literatures it is understood that the partial replacement of coarse aggregate by cupola slag shows good mechanical properties. The cupola slag addition increases the fire resistance and reduces the cost and environmental issues. By the addition of steel fiber the flexural strength and tensile strength increases. When proportion of steel fiber increases then density of concrete will be more. Therefore based on the literature study, the major conclusion is that cupola slag can be used in partial replacement of coarse aggregate in steel fiber reinforced concrete.

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