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STRENGTH PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN,SILICA FUME AND ALSO PARTIAL REPLACEMENT OF FINE AGGREGATEWITH STEELSLAG

T.Yeswanth kumar[1] and Dr.E.Arunakanthi[2]

[1]*P.G. Student, Dept. of Civil Engineering, JNTUA College of Engineering , Anantapuramu, 515002, Andhra Pradesh, India*

[2]*Associate Professor, Dept. of Civil Engineering, JNTUA College of Engineering, Anantapuramu, 515002,Andhra Pradesh,India*

Abstract-- In present day to day life the infrastructure development of structure has been increasing, In construction one of main material is natural fine aggregates, has lead to a decrease of available natural resources, on the other hand a high volume of steel slag production has generated a considerable amount of waste material. Steel slag[2] is generated in a 1600^o C (3000^o F) furnace, organic, semi-volatile, or volatile compounds are not present in steel slag. Chemically steel slag consists primarily of oxides of calcium, iron, silicon, aluminum, magnesium and manganese in complexes of calcium silicates, aluminosilicates and aluminoferrite (primarily with BOF and EAF slag). These compounds are generally similar to those found in the natural environment.

In this present work the properties of concrete with partial replacement of fine aggregates by steel slag fine form using steel slag waste as a substitute rather than natural fine aggregates along with metakaolin[4], silicafume[3]substitute of cement were studied for M_{30} grade concrete. The properties of the various ingredients of the concrete and steel slag aggregates were experimentally determined and mix design has been prepared for concrete for various proportions of steel slag aggregates in fine form.

Fresh concrete properties such as workability, air content and density were determined for all the replacement proportions. Mechanical properties such as compressive strength, tensile strength and flexural strength for various replacement proportions of fine aggregates with steel slag fine aggregates were found out and from that optimum replacement proportion was determined separately. The present investigation, 25% fine aggregate replacement by steel slag provide optimum strength.

Key words: steel slag, metakaolin, silicafume, compressive strength, Split tensile strength.

I. INTRODUCTION

India is expected to post the fastest growth in cement demand of any major national market, advancing 8.0% per year through 2019. Many other developing countries in the Asia/Pacific region will post similarly strong growth, including Vietnam, Indonesia, and Pakistan. The pace of gains in China will slow considerably from that of recent years, and growth in cement demand will actually trail the global average. Concrete is the largest synthesized material which has a per capita consumption of 1.5 tons per annum in India, says S.K.Manjrekar, former president of the Indian chapter of American Concrete Institute. Due to the increased use of concrete in almost all types of construction works, the demand of natural or river sand has been increased For the producer, the benefits of recycling industrial wastes are economical and environmental for the user additional technical benefits may be attained from recycling. It is independent of where it is recycled. But the economical benefit is determined on the demand for the waste by different user. This fact has forced the Government to lay down restrictions on sand quarrying process resulting in the scarcity and significant increase in its cost.

This research work determines the effect of partial substitution of fine aggregates by steel slag on the mechanical properties of concrete. The use of metakaolin ,silicafume[5] increased both the mechanical strength and the modulus of the elasticity of concrete. Use of these steel slag is not very usual though it has no behavioural problem and there has been little research work done on the steel slag. Steel slag is an unavoidable by-product in Steel making, it is essentially a mixture of metal oxides and silicon dioxide i.e. silicate. However, Steel Slag [1] is nonmetallic in nature and does not contain hazardous materials. Slag is an alternative construction material with superior environment friendly qualities and better product features. Current production of steel slag is around 12 million tonnes per annum. However, with steel production on the rise, slag production is also expected to increase manifold. In contrast with other nations, most slag produced in India, especially steel slag, is discarded, however, this is increasingly becoming a problem due to paucity of land; utilization of slag is in the trial phase. Right now, there is no statutory regulation or norm for controlling the slag generation or for utilization of slag. Environmental scientists and toxicologists completed an industry-wide "Human Health and Ecological Risk Assessment (HERA)". Based on worst case exposure assumptions the HERA demonstrated that iron and steel slag poses no meaningful threat to human health or the environment when used in a variety of residential, agricultural, industrial and construction applications. Consequently, the metals in the slag matrix are not readily available for uptake by humans, other animals or plants, do not bioaccumulate in the food web and are not expected to bioconcentrate in plant tissue. Today industry's disposal of steel slag is one of the environmental problems around the world; a large quantity of steel slag is generated during separation of the molten steel from impurities in steel-making furnaces. Current production of steel slag is around 12 million tonnes per annum. However, with steel production on the rise, slag production is also expected to increase manifold. In contrast with other nations, most slag produced in India, especially steel slag, is discarded, however, this is increasingly becoming a problem due to paucity of land; utilization of slag is in the trial phase. The waste is dumped in nearby pits and vacant spaces. This leads to serious environmental pollution an occupation of vast area of land. So it poses a severe threat on the environment, eco-system and the health of the people. This huge unattended mass of marble is too high and is used in concrete as partial replacement of natural fine aggregate in construction industry. In modern way of construction, aggregate in bituminous mix such as pavements surface, basaes, surface treatments, sealcoats, slurry Coates and cold patch. The optimum is taken by previous study Metakaolin(15%), silicafume(10%) used as Cementous materials in the present study.

II. EXPERIMENTAL PROGRAM

Material used and their properties

A. Cement: Ordinary Portland Cement (OPC) ACC 53 grade available in local market of standard brand was used in investigation. OPC 53 grade confirming with IS 12269 – 1987 is used. The cement is kept in an airtight container and is stored in humidity controlled room to prevent cement from being exposed to moisture. The Cement is tested for its various proportions as per IS 4031 - 1996.

B. Coarse Aggregate: Machine Crushed angular granite metal of less than 20 mm size from a local source was used as coarse aggregate. It is necessary to know the density, specific gravity and water absorption of aggregates in order to determine the mix proportions of concrete to be produced. Tests have been carried out as per the procedure given in IS 2386 (Part 3) – 1963.

C. Fine Aggregate: The locally available river sand was used as fine aggregate in present investigation. The sand is free from clayey matter, salt and organic impurities. The sand is tested for its various properties like Specific Gravity, Fineness modulus, Bulk Density etc in accordance with IS 2386 (Part 3) – 1963. Fine aggregate passing through 4.75 mm IS sieve was used. It confirms to grading zone II of IS 383 – 1970. The specific gravity and fineness modulus are found to be 2.61

D. Water: The quality of water is important because its contaminants can adversely affect the strength of concrete and cause corrosion of the steel reinforcement. Water used for producing and curing concrete should be reasonably clean an d free from deleterious substances such as oil, acid, alkali, salt, sugar, silt, organic matter and other elements which are detrimental to concrete or steel. I f the water is drinkable, it is considered to be suitable for concrete making. Hence, potable tap water confirming to I S 456 – 2000 was used in this study for mixing and curing.

E. Steel slag: Steel slag is obtained from TADIPATRI MILL Jambulapadu(v) Tadipatri Mandal, Ananthpur District Andhra Pradesh, Pin - 515411, India and its specific gravity in fine form was found to be 2.95. The slag was collected from the open stocking yard of the industry where the slag was exposed to atmosphere over a period of more than 1.5 years. The chemical composition of steel slag is expressed in terms of simple oxides calculated from elemental analysis. Determined by Le-Chatlier Method (IS: 228, 1987). The chemical compounds present in steel slag from a typical basic oxygen furnace and the chemical composition satisfies ACI 233 R-03, 2003.

F. Metakaolin: MetaCem 85C – High Reactivity Metakaolin obtained from Astra Chemicles,Chennai is used. The specific gravity of Metakaolin is 2.6. The Metakaoline is in conformity with the general requirement of Pozzolona.

G. Silica fume: Silica Fume (Grade 920 D): Obtained from Astra Chemicles,Chennai – micro silica 920 D conforming to ASTM C1240.

H. Mix proportion: Based on the ingredient properties of concrete, M30 concrete mix design as per IS 10262-2009 was prepared and its proportion was 0.45: 1: 1.53: 2.58 (W: C: FA: CA) by weight.

I. Procedure: This study was carried out by taking Metakaolin as 15% and silicafume as 10% by weight of cement. 6 Standard cubes of 150mm x 150mm x150mm are cast and are cured in water for each mixture. In the first series S1, S2, S3, S4, and S5 mixes are prepared with partial replacement of cement as 10%, 15%, 20%, 25%, 30% & 35% respectively along with replacement of cement with Metakaolin as 15% and silicafume as 10% with cement replacement. After curing of these specimens, these are tested for compressive strength [6], Split tensile strength [7], flexure strength.

III. EXPERIMENTAL RESULTS

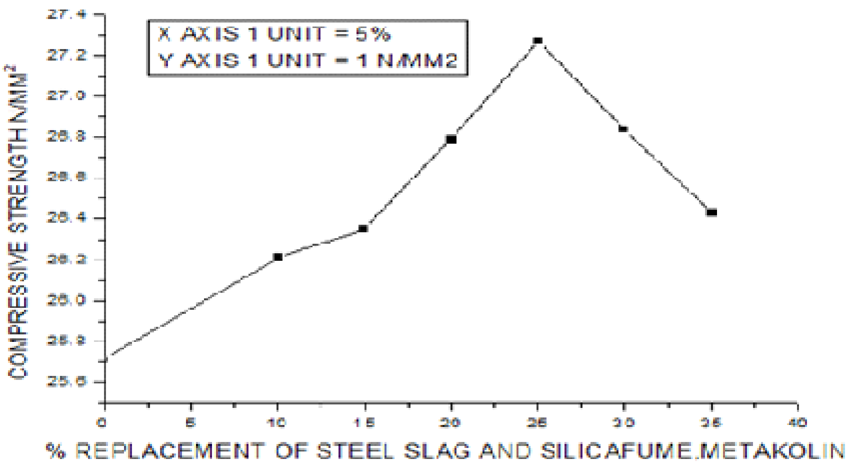

Fig 1: 7 day's Compressive strength in N/mm² of cubes

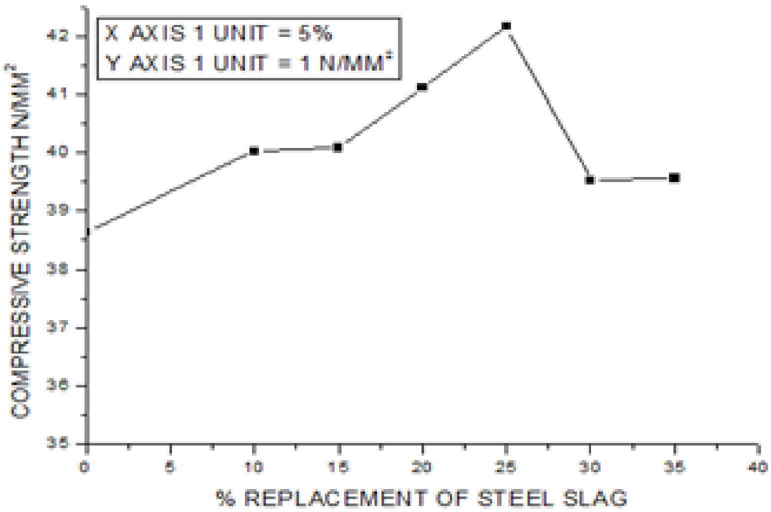

Fig 2: 28 day's Compressive strength in N/mm² of cubes

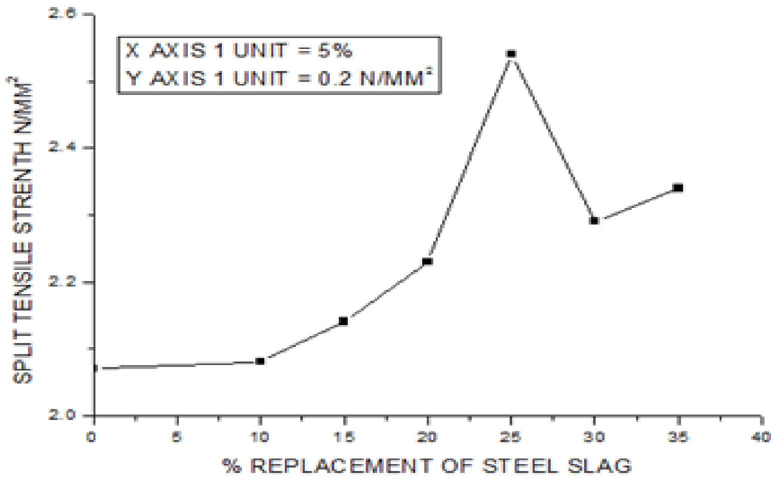

Fig 3: 7 day's Split tensile strength in N/mm² of cylinders

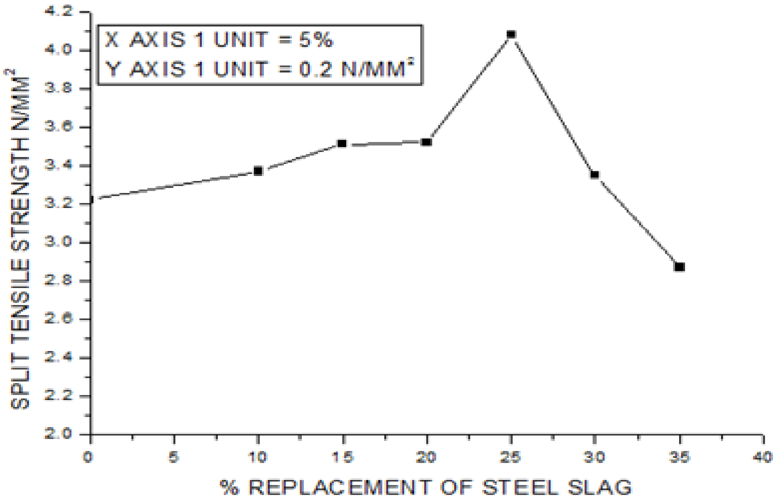

Fig 4: 28 day's Split tensile strength in N/mm2 of cylinders

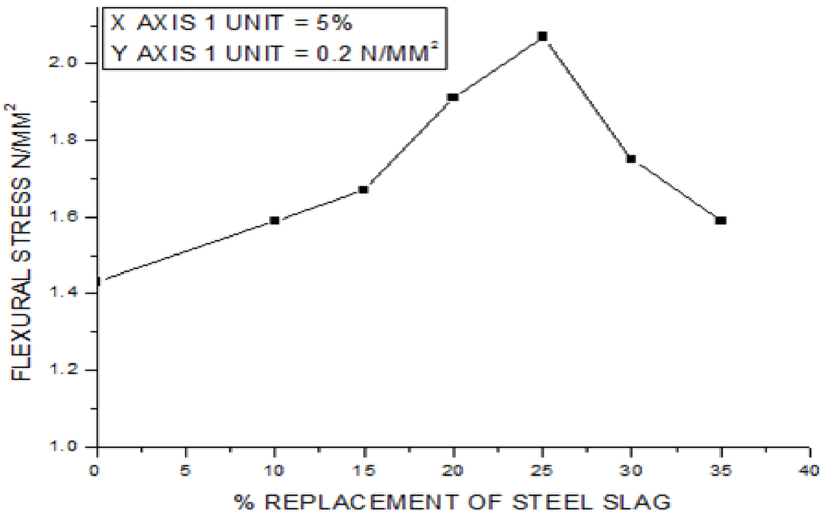

Fig 5: 7 day's flexure strength in N/mm2 of beams

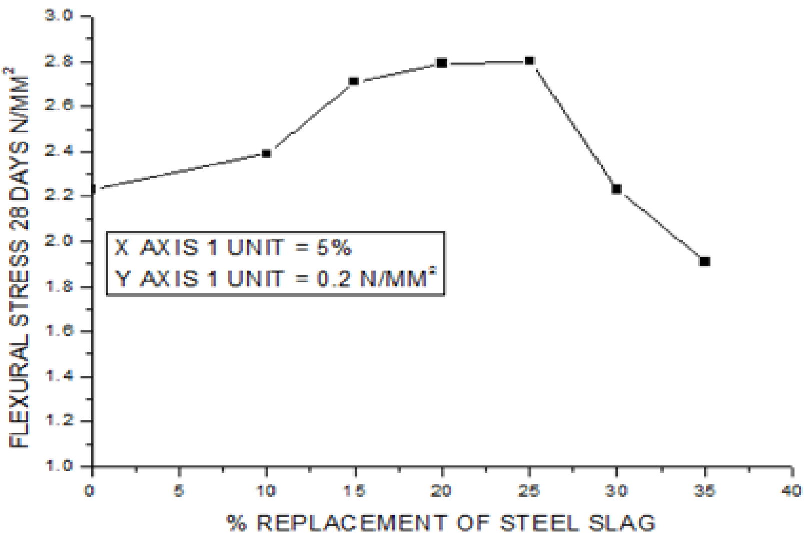

Fig 6: 28 day's flexure strength in N/mm2 of beams

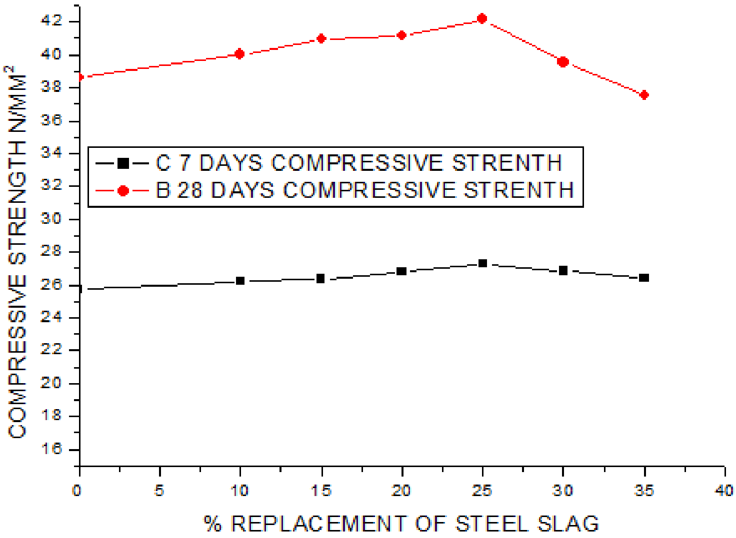

Fig 7: Compressive strength of cubes for 7 days and 28 day

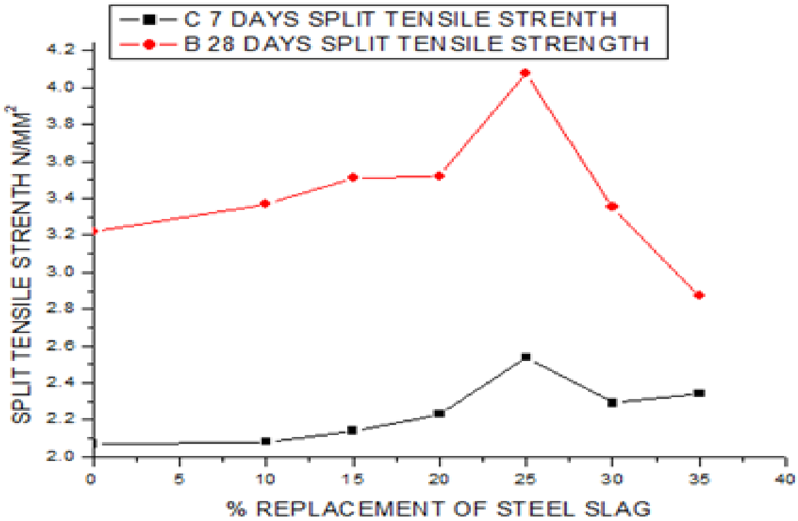

Fig 8: split tensile strength of cylinders for 7 day and 28 days

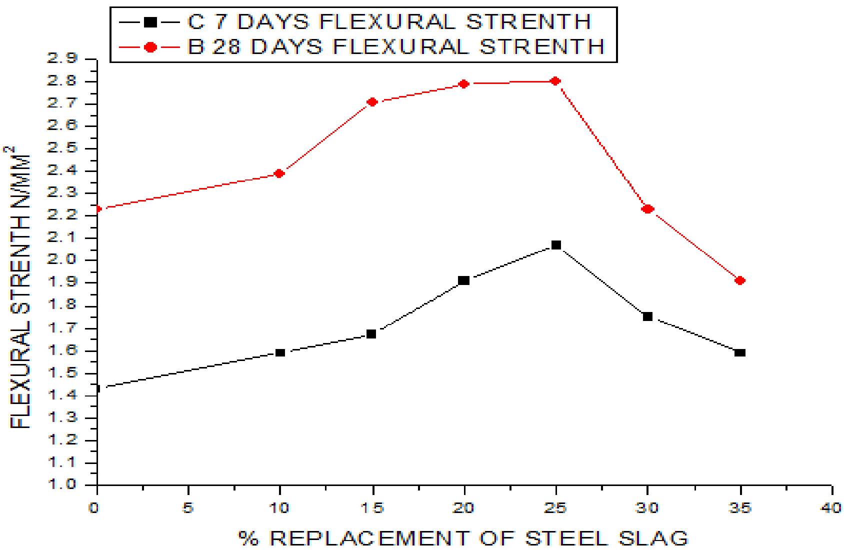

Fig9:flexural strength of beams for 7days and 28 day

TABLE I

COMPRESSIVE STRENGTH OF CUBES WITH STEEL SLAG REPLACEMENT

Percentage of natural sand	**Percentage of steel slag**	**Metakaolin**	**silica fume**	**Compressive strength** (N/mm^2)		Percentage variation in compressive strength at 28 days
				7 days	**28 days**	
100%	0%	---	---	25.71	38.63	----
90%	10%	15%	10%	26.21	40.03	3.62
85%	15%	15%	10%	26.35	40.97	6.05
80%	20%	15%	10%	26.79	41.12	6.44
75%	25%	15%	10%	27.27	42.17	9.16
70%	30%	15%	10%	26.84	39.53	2.32
65%	35%	15%	10%	26.43	37.56	-2.76

TABLE 2

SPLIT TENSILE STRENGTH OF CYLINDERS WITH STEEL SLAG REPLACEMENT

Percentage of natural sand	**Percentage of steel slag**	**Metakaolin**	**Silica fume**	**Split tensile strength** (N/mm^2)		Percentage variation in compressive strength at 28 days
				7 days	**28 days**	
100%	0%	---	---	2.07	3.22	----
90%	10%	15%	10%	2.08	3.37	4.65
85%	15%	15%	10%	2.14	3.51	9.01
80%	20%	15%	10%	2.23	3.52	9.31
75%	25%	15%	10%	2.54	4.08	26.70
70%	30%	15%	10%	2.29	3.35	4.03
65%	35%	15%	10%	2.34	2.87	-10.86

TABLE 3

FLEXURE STRENGTH OF BEAMS WITH STEEL SLAG REPLACEMENT

Percentage of natural sand	**Percentage of steel slag**	**Metakaolin**	**Silica fume**	**flexure strength** (N/mm^2)		Percentage variation in compressive strength at 28 days
				7 days	**28 days**	
100%	0%	---	---	1.43	2.23	----
90%	10%	15%	10%	1.59	2.39	7.17
85%	15%	15%	10%	1.67	2.71	21.52
80%	20%	15%	10%	1.91	2.79	25.11
75%	25%	15%	10%	2.07	2.8	25.56
70%	30%	15%	10%	1.75	2.23	0
65%	35%	15%	10%	1.59	1.91	-14.34

IV. CONCLUSION

Based on the above results of the investigation conducted on concrete with partial replacement of steel slag fine aggregate up to 25% by weight of fine aggregate, Metakaolin as 15% and silicafume as 10% by weight of cement respectively, the following conclusions can be drawn:

1. Compressive strength of concrete is increased with the replacement of steel slag with natural aggregate up to 25% and the strengths decreased with the replacement of steel slag with natural aggregate more than 25%. Hence 25% Cement replacement by steel slag is taken as optimum.
2. Split tensile strength of concrete is increased with the replacement of steel slag with natural aggregate up to 25% and the strengths decreased with the replacement of steel slag with natural aggregate more than 25%. Hence 25% Cement replacement by steel slag is taken as optimum.
3. Flexural strength of concrete is increased with the replacement of steel slag with natural aggregate up to 25% and the strengths decreased with the replacement of steel slag with natural aggregate more than 25%. Hence 25% Cement replacement by steel slag is taken as optimum
4. From above results it is noticed that though there is no significant increase in Compressive strength but there are significate increase in split tensile strength and flexural strength, the above replacements are acceptable and economical, since not available of natural fine aggregate is more in cities.

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