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Research Paper

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Strength and Flexural Behavior of Concrete Made With Metakaolin, Copper Slag and Waste Glass Powder

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***Abstract*—** In construction industry, consumption of cement and sand is increasing day by day as well as cost is also increasing. So to reduce the consumption of cement and sand, there is a need to replace a part of cement by some pozzolanic material to reduce the consumption of cement and replace apart sand by some silica based materials to control the environmental pollution to some extent. The main focus of this project has been studied that flexural behaviour of concrete made with 15% metakaolin as replacement of cement,100% copper slag as replacement of fine aggregate and 100% waste glass as replacement as fine aggregate. In this project work, an attempt has been made to produce the strength using metakaolin as replacing materials and copper slag , waste glass are as alternate sand. The experimental work carried out and the results obtained are presented and discussed in this report.

Keywords—metakaolin,copper slag, pozzolanic, glass powder.

I. INTRODUCTION

All over the world growth is being witnessed in construction industry in many countries. Infrastructure sector is also a key driver for the India's economy improvement. Natural resources are being heavily exploited for the growth of infrastructure. In construction industry, consumption of cement and sand is increasing day by day as well as cost is increasing, So reduce the consumption of cement partial replacement with some alternative materials such as Metakaolin, Egg cell powder, Glass powder, Rice husk ash. These are in cementious properties. And reduce the consumption of sand partial replacement with some alternative materials such as copper slag, glass powder etc. These are in silica properties and does not harm humans as well as animals, if not dealt carefully and it is less friendly to environment because these are non-biodegradable and these are chemical diverties including sodalime silicate, calcium, alumina etc. Here study strength and flexural behavior of concrete made with metakaolin, copper slag and waste glass powder.

A. MIX COMPOSITION

The general procedure of testing of composites mostly follows the economic criteria (cost minimization) with respect to simplicity of technology and possible applicability in practice, which would contribute to the building sustainability. The design can be based only on determination of the density of the compressive strength, split tensile strength and flexural strength using by alternate fine aggregated regardless to its saturation, and the remaining components can be just added.

- Alternate fine aggregate of wide grading curve,
- Constant-minimum amount of binder (cement),
- Weight of metakaolin according to the requirement of cementious properties,
- Amount of water according to required workability.

B.OBJECTIVE OF THE STUDY

The main objective of this investigation is to evaluate the mechanical properties of metakaolin, copper slag, waste glass powder on the compressive strength and other properties of concrete and to evaluate the possibility of using metakaolin, copper slag, waste glass powder in concrete without sacrificing the strength and this project is to study the flexural behavior of alternate fine aggregate such as 100% copper and waste glass concrete beam with alternate fine aggregates and15% of mtakaolin are added with this project. The followings were also considered.

- To study the compressive strength of concrete cubes at 28 days.
- To study the tensile strength of concrete cylinders at 28 days
- To study flexural behavior of reinforced concrete beams.
- To study the crack pattern and deflection

To determine the percentage of copper slag, waste glass powder which gives maximum strength when compared to control concrete.

II. REVIEW OF LITERATURE

Sivakumar. Tetal(2016) experimented that replacement of 0% (control specimen),30%,40% and 50% copper slag for fine aggregate with stand in each series.Concrete cubes,cylinders and RCC beams are cast and tested in labortaries for found the flexural strength.The optimum level of replacement of copper slag is found to be 40% and the results are better than that of control mix.

Mali.J.R.etal(2017) studied that the replacement of fine aggregates. M20 grade of concrete mix with water-cement ratio of 0.45 is used to determine the various mechanical properties. This research work mainly consist of substitution of natural sand partially by copper slag in concrete is done with replacement of 0%, 15%, 30%, 45%. In addition to this another material added to enhance mechanical strengths, polypropylene fiber is added in percentages of 0%, 0.1%, 0.3%.Study of result clearly present the effect of copper slag and polypropylene fiber on the flexural strength of concrete

Deepak.S etal(2017) has experimented that thereplacement of cement by waste glass powder such as 20%,25% and 30%.Quartz powder replacement of cement with 5%and steel fiber 1% of total coarse aggregate and the results was compared with conventional concrete.

III. METHODOLOGY

The specimens are subjected to loading separately up to the failure. The load carrying capacity, deflection and crack pattern of the concrete beams are studied. This chapter briefly explains the methodology adopted in this experimental work. In the first phase, the physical properties of ingredients of concrete and fresh concrete properties have been found and a mix design for M40 concrete was calculated. This chapter briefly explains the methodology adopted in this experimental work.

A.EXPERIMENTAL METHOD

The following methodology has been followed in this experimental investigation, Preliminary tests on metakaolin,copper slag and waste glass. M40 used (1:1.68:2.97). Mix proportion such as follows

- Conventional beam
- 15%Metakaolin + 100%Sand + 100%Coarse aggregates
- 15%Metakaolin + 100%Copper slag + 100%Coarse aggregates.
- 15%Metakaolin + 100%Waste glass + 100%Coarse aggregates.
- 15%Metakaolin + 50% Copper slag+50% Waste glass + 100%Coarse aggregate

Fig1. Mix ratio and material requirements

Mix Ratio M40								
Mi	**C**	**FA**	**Met**	**Copper Slag**	**Glass Powder**	**CA**	**Water**	**SP**
CC	1	1.68	0	0	0	2.97	0.42	0.005
M1	0.85	1.68	0.15	0	0	2.97	0.42	0.005
M2	0.85	0	0.15	1.68	0	2.97	0.42	0.005
M3	0.85	0	0.15	0	1.68	2.97	0.42	0.005
M4	0.85	0	0.15	0.84	0.84	2.97	0.42	0.005
Cubes	**3**	**0.15**	**0.15**	**0.15**	**0.0101**	**m3**		
CC	4.00	6.73	0	0	0	11.91	1.97	0.20
M1	3.40	6.73	0.60	0	0	11.91	1.97	0.20
M2	3.40	0	0.60	6.73	0	11.91	1.97	0.20
M3	3.40	0	0.60	0	6.73	11.91	1.97	0.20
M4	3.40	0	0.60	3.37	3.37	11.91	1.97	0.20
	17.60	**13.47**	**2.40**	**10.10**	**10.10**	**59.54**	**9.85**	**1.00**
Cylinders	**1**	**0.15**	**0.3**	**0.0150**	**m3**			
CC	5.93	9.98	0	0	0	17.64	2.96	0.30
M1	5.04	9.98	0.89	0	0	17.64	2.96	0.30
M2	5.04	0	0.89	9.98	0	17.64	2.96	0.30
M3	5.04	0	0.89	0	9.98	17.64	2.96	0.30
M4	5.04	0	0.89	4.99	4.99	17.64	2.96	0.30
	26.07	**19.95**	**3.56**	**14.96**	**14.96**	**88.20**	**14.80**	**1.48**
Prisms	**1**	**0.5**	**0.1**	**0.1**	**0.0050**	**m3**		
CC	1.98	3.33	0.00	0.00	0.00	5.88	0.99	0.10
M1	1.68	3.33	0.30	0	0	5.88	0.99	0.10
M2	1.68	0	0.30	3.33	0	5.88	0.99	0.10
M3	1.68	0	0.30	0	3.33	5.88	0.99	0.10
M4	1.68	0	0.30	1.66	1.66	5.88	0.99	0.10
	8.69	**6.65**	**1.19**	**4.99**	**4.99**	**29.40**	**4.93**	**0.49**
Beam	**1**	**1.6**	**0.15**	**0.1**	**0.024**	**m3**		
CC	9.48	15.96	0	0	0	28.22	4.73	0.47
M1	8.06	15.96	1.42	0	0	28.22	4.73	0.47
M2	8.06	0	0.30	15.96	0	28.22	4.73	0.47
M3	8.06	0	0.30	0	15.96	28.22	4.73	0.47
M4	8.06	0	0.30	7.98	7.98	28.22	4.73	0.47
	41.71	**31.92**	**2.31**	**23.94**	**23.94**	**141.12**	**23.64**	**2.37**
TOTAL	**94.07**	**71.99**	**9.45**	**53.99**	**53.99**	**318.26**	**53.22**	**5.34**

IV. RESULTS AND DISCUSSION

The results of the experimental investigation on cube specimens, prism specimens and five beam specimens are presented in this chapter. The behavior of beam specimen in terms of crack development, failure mode and ultimate loads were observed during the test.

A.COMPRESSIVE STRENGTH OF CUBES

The Compressive Strength Results of Concrete cube Specimens for 7 and 28 days are presented in the Table and the comparisons of the results are shown in Figure. However, valid colored photographs can also be published.

Table 1-compressive strength

Name	**Cube. No.**	**Crusing Load in Kn/Mm^2**	**Compressive Strength in N/Mm^2**	**Average**
conventional	C_{11}	1035	46.00	46.15
	C_{12}	1040	46.22	
	C_{13}	1039	46.18	
15% Metokaolin	C_{21}	1058	47.02	47.00
	C_{22}	1056	46.93	
	C_{23}	1059	47.07	
Copper slag	C_{31}	1084	48.18	48.24
	C_{32}	1085	48.22	

	C_{33}	1087	48.31	
Waste glass	C_{41}	1145	50.89	50.65
	C_{42}	1147	50.98	
	C_{43}	1149	51.07	
Copper slag + Waste glass	C_{51}	1144	50.84	50.89
	C_{52}	1147	50.98	
	C_{53}	1145	50.89	

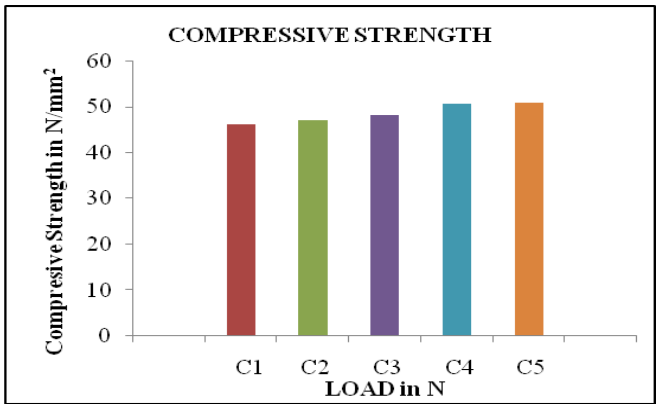

Fig 2-compressive strength

i.Replacing of 15% metakaolin as cement made with concrete compressive strength had 40%is excess over the conventional concrete. Hence 15% of metakaolin may be used to make concrete as cement.

ii.Concrete made with 100% copper slag as fin aggregate concretecompressive strength had 25%is excess over the conventional concrete. Hence copper slag may be used to make concrete as fine aggregate.

iii.Concrete made with 100%waste glass as fine aggregate concretecompressive strength is 12% excess over to the conventional concrete. Hence waste glass aggregate may be used to make concrete as fine aggregate.

iv.Concrete made with 50%waste glass and 50% copper slag as fine aggregate concretecompressive strength had 10%N/mm2 is excess over the conventional concrete. Hence waste glass aggregatemay be used to make concrete as fine aggregate.

B.SPLIT TENSILE STRENGTH OF CYLINDERS

The Split Tensile Strength Results of Concrete Cylinder Specimens for 28 days are presented in the Table and comparisons of results are shown in Figure.

Table2- split tensile strength

Name of Mix	**No.**	**Crusing Load in Kn/Mm^2**	**Strength in N/Mm^2**	**Average**
Conventional specimen	CY_1	274	3.88	3.93
	CY_{11}	280	3.96	
	CY_{12}	279	3.95	
15% Metokaolin	CY_{21}	300	4.25	4.32
	CY_{22}	307	4.35	
	CY_{23}	309	4.37	
100% Copper slag	CY_{31}	279	4.01	4.05
	CY_{32}	289	4.08	
	CY_{33}	286	4.05	
100%Waste glass	CY_{41}	289	4.77	4.16
	CY_{42}	268	3.79	
	CY_{43}	278	3.93	
50%Copper slag + 50%Waste glass	CY_{51}	295	4.18	4.22
	CY_{52}	299	4.23	
	CY_{53}	300	4.25	

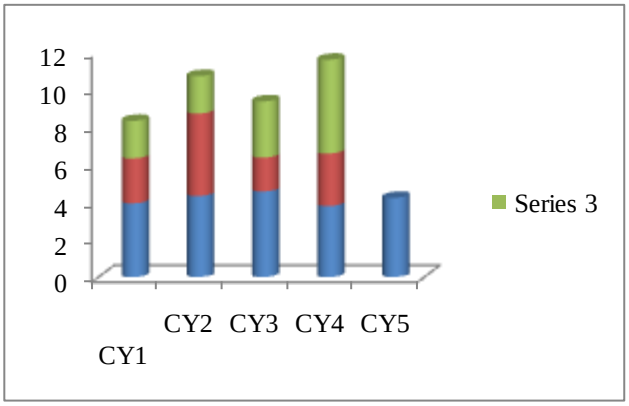

Fig 3- split tensile strength

i. Replacing of 15% metakaolin as cement made with concrete split tensile strengthhad 10%is excess over the conventional concrete. Hence 15% of metakaolin may be used to make concrete as cement.

ii. Concrete made with 100% copper slag as fin aggregate concretesplit tensile strength had 14%is excess over the conventional concrete. Hence copper slag may be used to make concrete as fine aggregate.

iii. Concrete made with 100%waste glass as fine aggregate concrete split tensile strength is 17% excess over to the conventional concrete. Hence waste glass aggregate may be used to make concrete as fine aggregate.

iv.Concrete made with 50% waste glass and 50% copper slag as fine aggregate concretesplit tensile strength had 13% is excess over the conventional concrete. Hence waste glass aggregate may be used make concrete as fine aggregate.

C.FLEXURAL STRENGTH OF PRISIM

The Flexural Test Results for the PRISIM Specimens are presented in the Table

Table 3- prism strength

Name Of Mix	Prisim	Crusing Load in KN/mm^2	Strength in N/mm^2	Average
Conventional specimen	P_{11}	12.50	6.25	6.31
	P_{12}	12.72	6.36	
	P_{13}	12.66	6.33	
15% Metokaolin	P_{21}	12.55	6.28	6.33
	P_{22}	12.69	6.35	
	P_{23}	12.73	6.37	
Copper slag	P_{31}	12.70	6.35	6.43
	P_{32}	13.10	6.55	
	P_{33}	12.80	6.40	
Waste glass	P_{41}	12.75	6.40	6.43
	P_{42}	12.97	6.49	
	P_{43}	12.89	6.50	
Copper slag + Waste glass	P_{51}	12.71	6.3	6.37
	P_{52}	12.73	6.37	
	P_{53}	12.90	6.45	

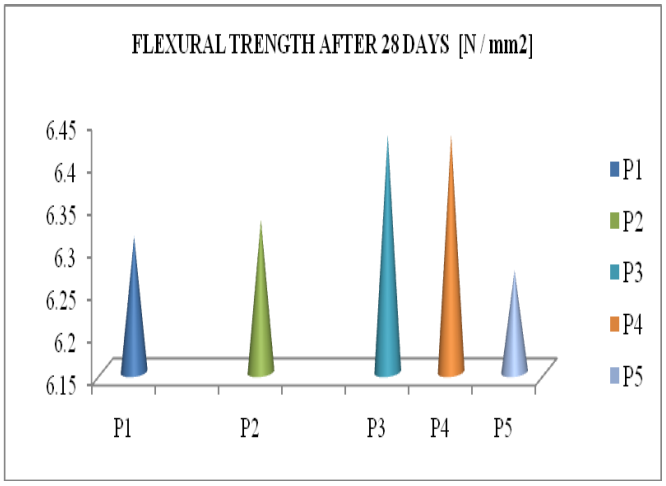

Fig 4- prism strength

i. Replacing of 15% metakaolin as cement made with concrete flexural strengthhad 30% excess over to the conventional concrete. Hence 15% of metakaolin may be used to make concrete as cement.

ii. Concrete made with 100% waste glass as fine aggregate concreteflexural strength is 53%excess over to the conventional concrete. Hence waste glass aggregate may be used to make concrete as fine aggregate.

iii. Concrete made with 50% waste glass and 50% copper slag as fine aggregate concreteflexural strength 10% excess over to the conventional concrete. Hence waste glass aggregate may be used to make concrete as fine aggregate.

D.DEFLECTION OF BEAM

Table 4- flexural strength of beam

S. No.	Load in KN	Deflection at L/2 in mm	Remarks
1	0	0	
2	1	0	
3	2	0	
4	3	0	
5	4	0.37	
6	5	0.89	
7	10	0.89	
8	11	0.97	
9	15	1.75	
10	20	3.57	
11	25	3.93	
12	30	5.31	
13	34	7.28	
14	35	9.97	
15	37	11.36	Initial crack
15	40	12.38	
16	42.21	14.11	
17	44.00	14.88	
18	44.73	15.68	
19	46.33	15.56	Ultimate

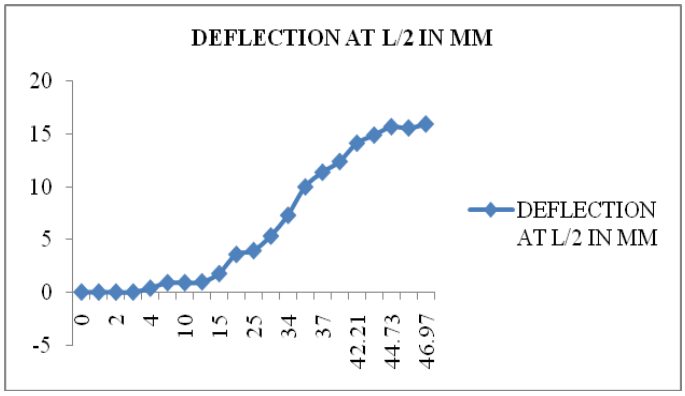

Fig 5- deflection diagram

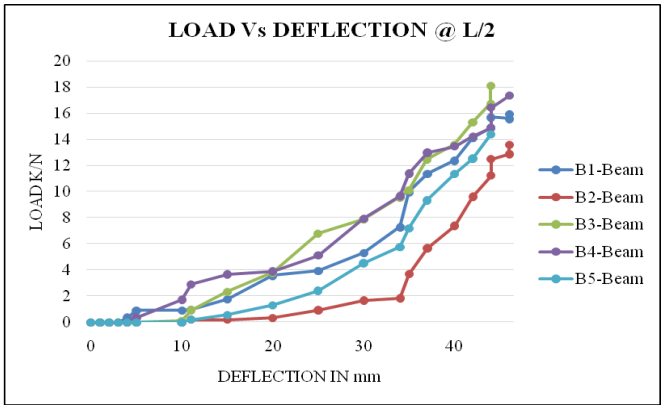

Fig 6- deflection graph for various beams

Fig 7-tested beam picture

V. CONCLUSION

In this project Industrial by product and recycling materials are used to minimize the cost and to ensure sustainable development and also the Industrial by product material and recycling by product materials are alternate fin aggregate used as natural sand. This will suggest a suitable recycling methodology for above waste materials. Also some tests were conducted in this project and materials were like river sand, coarse aggregate and cement are cement having all the results within acceptable limit as per IS code. Also addition of copper slag, waste glass and metakaolin as improved the flexural strength of concrete. While replacement of copper slag in concrete increases the density of concrete. Flexural strength of concrete with replacement of metakaolin as cement, copper slag and waste glass gives the satisfactory result.

•The compressive strength of concrete reaches the maximum value ofat a replacement level of 15% of metakaolin as cement,100%copper slag, 100% waste glass and both of 50% copper slag and 50% waste glass.
•The split tensile strength of concrete reaches the maximum value at 15% of metakaolin as cement,100%copper slag, 100% waste glass and both of 50% copper slag and 50% waste glass.
•The flexural strength of concrete prisim attains max value a 15% of metakaolin as cement,100%copper slag, 100% waste glass and both of 50% copper slag and 50% waste glass.

Hence it is concluded that recycled building waste can be effectively used as a fully replacement for natural aggregate comparatively higher than the results of conventional concrete results.It gives the results more than 20to 35% increased with the conventional concrete results.

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