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Experimental Work on Structural Elements of Concrete by the Replacement of Copper Slag with Fine Aggregate

J.Ushakranti, K.Srinivasu, T.Chandrasekhar Rao, P.Ch.Sanjeeva Rao

Abstract*:*In this study fine aggregate is replaced with copper slag in different proportions in different grades of concrete and tests were evaluated on concrete members. The replacement of fine aggregate ranges from 0 to 100 percent is studied. Different concrete mixtures were prepared with different proportions of copper slag ranging from 0 to 100 percent. Different strength tests were conducted and the results obtained are compared with the nominal mix. For the above replacement an experimental study has been conducted on the design of RCC slab. For this work, simply supported slabs were prepared and static loads are applied on slabs, the load – deflection patterns were studied and plotted and the obtained results are compared with the control mix. the design of two way slab was done by using Staad Pro software and the results are presented.

Index Terms: concrete, copper slag, durability, fine aggregate, replacement, and slab.

I. INTRODUCTION

Present days, development of facilities has increased demand for natural sand, which makes it greater expensive and leads to environmental imbalances. The utilization of suitable sustainable choice materials proves that it is the most efficacious choice to traditional concrete materials and can take care of the surrounding environment. Copper slag is an industrial byproduct of copper production. Copper slag is a high-gravity glassy granular material. Sivagamasundari.R, Kumaran.G[1] worked on Experimental study on the behaviour of concrete one way slabs reinforced with GFRP reinforcements under constant and variable amplitude repeated loadings, concluded that, at ultimate load, GFRP reinforced slabs experience concrete crushing followed by the rupture of GFRP reinforcements. As the ultimate load carrying capacity of GFRP reinforced slabs is increased, the corresponding deflections, strains and crack width are reduced by increasing the thickness, grade of concrete, reinforcement ratio of the slabs. GFRP reinforced concrete slabs experiences better performance under cyclic loading than those slabs reinforced with steel. S.Deepa Shri, R.Thenmozhi[2] work done on, An experimental investigation on the flexural behavior of SCC Ferrocement slabs incorporating fibers and given that flexural tests have been conducted on all the slabs by varying the parameters. It is observed that the load carrying capacities, energy absorption, deformation at ultimate load are high in the case of SCC ferrocement hybrid polypropylene fibers. Further, it was observed that there is reduction in crack width and increase in number of cracks in the case of SCC ferrocement hybrid, polypropylene fibers, indicates delay in crack growth. P.Vasanthi[3] researched on Flexural behavior of reinforced concrete slabs using Steel slag as coarse aggregate replacement and concluded that, the use of steel slag as replacement of coarse aggregate in concrete is beneficial for the better workability and strength it imparts up to 60% replacement level. Akshay A. Thakare, Kalyani V. Kothavade, P P. D. Dhake, P. D. Jadhao[4], investigated on Comparative experimental study on flexural behavior of composite slab and RCC slab and concluded that six composite slabs are split into two groups of three slabs and tested under static and cyclic loading to get 'm-k' values and RCC slab is tested under static loading for flexural. As a result composite slab proved to be more efficient than R.C.C. slab for small scale use. Vojtech Buchta, Roman Fojtik, Jan Hurta[5], investigated on Experimental load tests of reinforced concrete slab, presented that, from extensive research of foundation slab tests will be used to numerical modeling interaction between foundation structure and subsoil and then used to improving existing models. N. Jayaramappa, Kiran.T, Dr.A.Krishna, Rajesha.R.N.[6], studied on Experimental investigation on behaviour of RC slabs under Static load, given that slabs are analyzed to investigate the flexural behavior of reinforced concrete slabs with and without SBR LATEX AND CHICKEN MESH. RC slabs with above mentioned composite materials have been tested up to failure with varying reinforcement ratio, the rebar diameter and the rebar spacing. The ultimate load increased with increase in percentage of steel reinforcement. The RCC+SBR Slabs showed higher ultimate load when compared to the normal RCC Slabs respectively. Rajeshwaran R, Yamini V, Nivedha DGS and Madhu Bala AM[7], researched on Experimental evaluation of Concrete Slab using hollow steel pipes. Load bearing capacity and deflection of conventional concrete slab is compared with concrete slab using hollow steel pipes and observed that the composite section is best for the maximum load performance than the normal RC slab. The change in diameter does not affect the performance of specimen.

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* Correspondence Author
J.UshaKranti*, Research Scholar, Department Of Civil Engineering, Acharya Nagarjuna University, Guntur-522510, AP, India.
Dr.K.Srinivasu, Professor, Department Of Civil Engineering R.V.R&J.C. College Of Engineering, Guntur-522019, A.P, India.
Dr.T.Chandrasekhar Rao, Department Of Civil Engineering, Bapatla Engineering College, Bapatla, India.
Dr.P.Ch.Sanjeeva Rao, Department Of Civil Engineering R.V.R&J.C. College Of Engineering, Guntur-522019, A.P, India.

II. OBJECTIVE OF WORK

The aim of this work is to study the strength characteristics of concrete and flexural behavior of slabs. In this research work, for M30 and M40 grade of concrete, casting of slabs was done for various proportion of copper slag replacement of sand with 0%, 20%, 40%, 60% and 100%. The load – deflection patterns were studied and plotted and the obtained results are compared with nominal concrete.

III EXPERIMENTAL INVESTIGATION

A Materials Used

Ordinary Portland cement, 53 Grade [9] was used. Locally available river sand [8] conforming to grading zone II was selected and locally available crushed stone aggregate of 12.5 mm nominal size was used.

Potable water was used for the preparation of the specimens and for curing purpose, conforming to IS code [11]

Copper slag is an industrial by-product material produced from the process of manufacturing copper. In this work, grade2 copper slag was taken.

The physical and chemical properties of copper slag are given in table 1&2.

Table1. Physical properties of copper slag

Property	Typical Values
Colour	Black, glassy
Grain Shape	Angular, Multifaceted
Hardness	7Moh
Specific Gravity at 25^0C	3.61
Bulk Density at 25^0C	1750 kg/m^3
pH	7.0
Conductivity at 25^0C	4mho/m
Weight loss on ignition	4%
Moisture content	<0.1%

Table2. Chemical properties of copper slag

Constituent	Percentage
Silica (SiO_2)	25-35
Free Silica	<0.5
Alumina (Al_2O_3)	2-9
Iron Oxide (Fe_2O_3)	45.55
Calcium Oxide (CaO)	2-9
Magnesium Oxide (MgO)	1-5
Copper Oxide (CuO)	0.7
Sulphates (SO_3)	0.2
Chlorides (Cl)	0.003

A High Yield Strength Deformed (HYSD) bar of 8 mm diameter is used as a main bar and 6 mm diameter bar is used as distribution bars. Tension test was performed on this material in the laboratory conforming to IS code [16].

B Mix Design

The mix design for both M30 and M40 grade of concrete, in this project Indian Standards Recommended guidelines was followed [11]

C Casting of Test Specimens

Slab of size 1200mm x 600mm and thickness 70mm was taken. Wooden moulds of required size were prepared using plywood boards. The moulds were coated initially with oil so as to enable easy removal of the moulds.

For above grade of concrete, number of reinforced concrete slab specimens are prepared, casted and cured.

The moulds were casted and cured on an even surface (fig.1 to 4(b)).

Fig.1. Cutting of steel rods

Fig.2. Mould and reinforcement arrangement before casting

Fig.3. Casting of concrete

Fig.4 (a). Curing of concrete

Fig. 4(b). Curing of concrete

IV SPECIMEN DESIGN

Simply supported two way RCC slab specimen w designed by limit state method as per IS code [13, 14].

A. Test Set-up

All the specimens were tested under two point loading and are placed under UTM (2000kN capacity). A concentrated load was applied on these slabs have been tested up to failure. The experimental setup was shown (fig.5 to 7).

Fig.5 (a) Test setup

Fig.5 (b) Test setup

Fig.5 (c) Test setup

Fig.6. Failure of specimen

Fig.7. crack pattern of specimen

The maximum force and the compressive strength were determined for different percentage replacements of sand by copper slag.

V RESULTS

The values obtained from the test results are tabulated below

Table3. M30 grade slab test

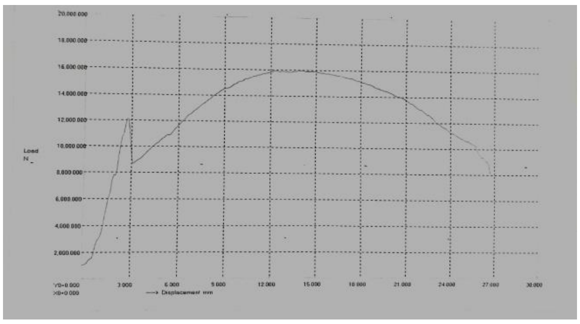
S.No	% replace ment	Weight of slab (kg)	Max.force (kN)	Compression strength (N/mm^2)
1	0	125	15.95	0.177
2	20	135	16.30	1.020
3	40	155	17.05	1.250
4	60	140	13.05	1.312
5	100	142	6.10	0.165

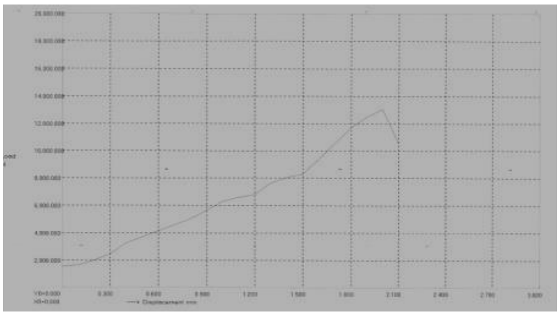
Table4. M40 grade slab test

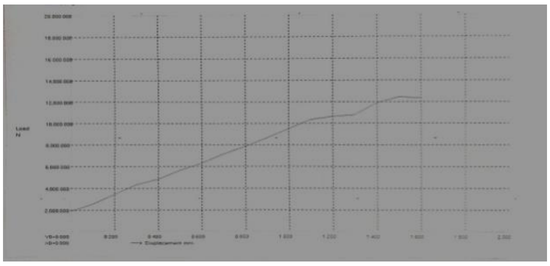
S.No	% replace ment	Weight of slab (kg)	Max.force (kN)	Compression strength (N/mm^2)
1	0	132	13.00	1.043
2	20	140	12.75	1.532
3	40	144	12.45	1.956
4	60	150	13.50	2.031
5	100	155	11.60	1.823

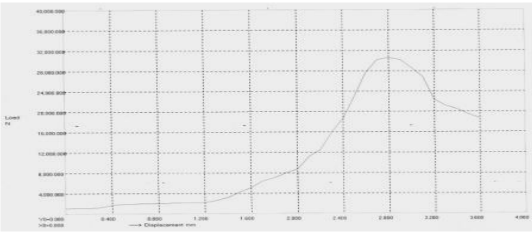
VI LOAD-DISPLACEMENT CURVES

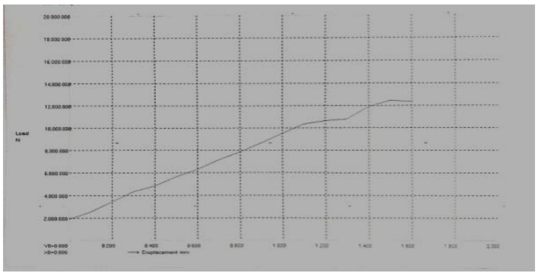
The following graphs shows the Load- deflection behavior











VII ANALYTICAL STUDY

In this study, by using Staad Pro software (Structural Analysis and Designing Program), we designed two way slab, the input data and results are included**.** This software is most used Software for Civil Engineering designing,

STAAD PRO DESIGN RESULTS

A Input Pages Report

Geometry Data

Item	Value	Unit
Length along shorter direction	0.6	m
Length along longer direction	1	m
Panel Type	Four edges discontinuous	
Criteria for Depth	User-Defined Depth	
User Defined Depth	0.07	m

Material Data

Item	Value
Grade of Concrete	M30
Grade of Steel	Fe415
Unit weight of concrete	2500kg/m^3

Loads

Item	Value	Unit
Include self-weight	Yes	
Superimposed dead load	3.5	kN/m^2
Live load	1	kN/m^2
Other load	1	kN/m^2

Reinforcement Data

Item	Value
Bar size along shorter direction(mm)	6
Bar size along longer direction.(mm)	8
Clear Cover(mm)	15
Shear Consideration	Increase Steel Percentage
Steel % along X-direction at top	0.12
Steel % along Y-direction at top	0.12

B Calculation Sheet Report

Design Data

Clear Length of shorter span of the slab, L_x= 600.000 mm
Clear Length of longer span of the slab, L_y= 1000.000 mm
Panel Type is Four Edge Discontinuous
Uniformly Distributed Live Load, W_l= 0.00100 N/sq. mm
Characteristic Strength of concrete, F_{ck}= 30.000 N/sq. mm
Characteristic Strength of steel, F_y= 415.000 N/sq. mm
Unit Weight of Concrete, g_c= 0.0000245 N/cubic mm
Bar size for reinforcement in shorter Direction, f_x= 6.000mm
Bar size for reinforcement in longer Direction, f_y= 8.000 mm
Clear Cover to the outermost Reinforcement Bar of the slab, d' = 15.000 mm.

Calculation of Reinforcement

Overall Depth of the Slab, D = 70.000 mm
Dead Load of Slab, W_d= D * g_c= 0.00171 N/sq. mm
Effective Depth of the Slab, d = D - d' - f_x/2 = 52.000 mm
Effective Thickness Of the Slab along X-Direction, d_x= d = 52.000 mm
Effective Thickness Of the Slab along Y-Direction, d_y= d - f_x/2 - f_y/2 = 45.000 mm
Effective Length of shorter span of the slab, L_{ex}= L_x + d = 652.000 mm
Effective Length of longer span of the slab, L_{ey}= L_y + d_y= 1045.000 mm
Ratio of longer to shorter span, r = L_y/L_x= 1.603
Max. Factored Load among all combination, W = 0.00521 N/sq. mm
Moment Co-efficient in shorter dir. at span, a_x= 0.09352
Moment Co-efficient in shorter dir. at edge, a'_x= 0.00000
Moment Co-efficient in longer dir. at span, a_y= 0.05600
Moment Co-efficient in longer dir. at edge, a'_y= 0.00000
Factored Moment at,
Span in shorter direction,

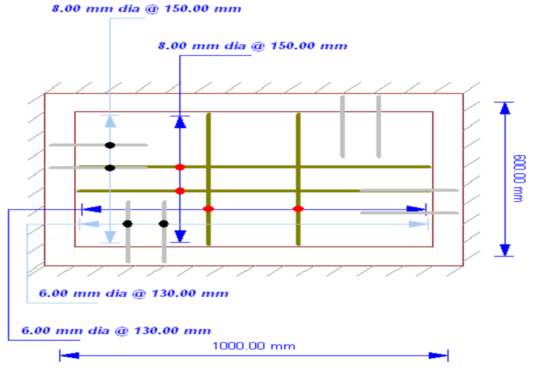
$M_{ux}= a_x * W * L_x^2= 207.23256$ N-mm
Span in longer direction,
$M_{uy}= a_y * W * L_x^2= 124.08940$ N-mm
Support in shorter direction,
$M'_{ux}= a'_x * W * L_x^2= 0.00000$ N-mm
Support in longer direction,
$M'_{uy}= a'_y * W * L_x^2= 0.00000$ N-mm
Width of the Slab, b = 1 mm

Limiting Moment of resistance of section

Along X-Direction, $M_{u,lim-x}= 11191.60056$ N-mm
Along Y-Direction, $M_{u,lim-y}= 8381.28370$ N-mm
Area of steel reinforcement in X-Direction at span bottom, $A_{stx}= 0.08400$ sq. mm
Area of steel reinforcement in Y- Direction at span bottom, $A_{sty}= 0.08400$ sq. mm
Area of steel reinforcement in X- Direction at support top, $A'_{stx}= 0.06240$ sq. mm
Area of steel reinforcement in Y- Direction at support top, $A'_{sty}= 0.05400$ sq. mm
Minimum Area of steel reinforcement in X-Direction, $A_{stx-min}= 0.08400$ sq. mm
Minimum Area of steel reinforcement in Y- Direction, $A_{sty-min}= 0.08400$ sq. mm
Cross-sectional Area of steel in X- Direction,
$Af_x= p * f_x^2/4 = 28.27431$ sq. mm
Cross-sectional Area of steel in Y- Direction,
$Af_y= p * f_y^2/4 = 50.26544$ sq. mm
Spacing in shorter Direction at span, $S_x= 150.000$ mm
Spacing in longer Direction at span, $S_y= 130.000$ mm
Maximum Spacing in shorter Direction, $S_{x-max}= 150.000$ mm
Maximum Spacing in longer Direction, $S_{y-max}= 130.000$ mm
Spacing in shorter direction at edge, $S'_x= 150.000$ mm
Spacing in longer direction at edge, $S'_y= 130.000$ mm

Calculation of Shear

Factored shear force in shorter direction, $V_{ux}= 1.51193$ N
Factored shear force in longer direction, $V_{uy}= 1.13286$ N
Shear stress developed at shorter span,
$t_{cx,dev}= V_{ux}/ (b + d_x) = 0.02908$ MPa
Shear stress developed at longer span,
$t_{cy,dev}= V_{uy}/ (b + d_y) = 0.02517$ MPa
Percentage of steel reinforcement in shorter direction at top, $P'_{tx}= 0.12000$
Permissible shear stress at the section along Y-axis, $t_{cx}=$ 0.26512 MPa
Percentage of steel reinforcement in longer direction at top, $P'_{ty}= 0.12000$
Permissible shear stress at the section along X-axis, $t_{cy}=$ 0.26512 MPa



V CONCLUSION

From test results, as partial replacement of sand with copper slag, it was found that

- For M30 grade concrete, the maximum compression strength at 40% replacement of copper slag was observed.
- The maximum compression strength at 60% replacement of copper slag was noticed for M40 grade concrete,
- By applying concentrated loads to the surface of copper slag based slabs, we find that as the loading speed increases, the slab failure mode changes and the maximum strength of slab increases.
- Staad Pro is a faster method of designing the structure and shows accuracy in results.

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