iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 2 **Issue:** VII **Month of publication:** July 2014

DOI:

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Utilization of Copper Slag as Fine Aggregates in Cement Concrete Pavements

Thongam Prantic Singh[#1], Dr.Rajashekhara.M.R[*2], Suhas R[#3]

[#]1 *M. Tech Student, Highway Technology, DSCE, Bangalore, India*

[#]2 *Professor, Department of Civil Engineering, DSCE, Bangalore, India*

[#]3 *Assistant Professor, Department of Construction Technology & Management, DSCE, Bangalore, India*

Abstract— This paper reports on an experimental investigations carried out to evaluate the effects of concrete mix properties prepared with partial replacement of fine aggregates by copper slag at levels of 10%, 20%, 30%, 40%, 50% and 60%. In this study, M30 grade concrete was considered to study the strength parameters, compressive and flexural strength development for concrete curing periods of 3, 7 and 28 days. It was found that all mixes yielded comparable or higher compressive and flexural strength than the control concrete for all curing periods. Compressive and flexural strength increases with respect to the percentage replacement of copper slag by the weight of fine aggregate up to 40% replacement. The compressive strength of cube and flexural strength of beam at 28 days curing period was increased by 31.6% to 54.87% and 10.87% to 26.62% respectively with replacement of copper slag. The quality of concrete mixes was found good from ultrasonic pulse velocity. Flexural fatigue analysis was carried out to predict fatigue life of concrete specimens where 40% of fine aggregate was replaced by copper slag and maximum strength is obtained; at three stress ratios (0.65, 0.70 and 0.75 of fatigue failure loads). From the data obtained S-N curves are developed using linear regression model considering log normal distribution as is being presently adopted. The number of repetitions to failure was compared with the IRC: 58 model and found that up to 0.75 stress ratio it shows more number of repetitions to failure than the suggested IRC-58 fatigue life and at higher stress ratio it fail earlier.

Keywords— Copper Slag, Compressive Strength, Flexural Strength, Ultrasonic Pulse Velocity, Flexural Fatigue, Stress Ratio

I. INTRODUCTION

Aggregate are considered one of the main constituents of concrete since they occupying more than 70% of concrete matrix. Natural material being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, hence it is inevitable either to search for another alternative material or partly replace it by some other material. Concerned about this artificially manufactured aggregate and some industrial by-products such as copper slag; that are either recycled or discarded as a waste can be used as an alternative material for conventional construction materials; thereby leading to global sustainable development and reducing pollution and disposal problems as well. Copper slag is a by-product obtained during the matte (molten copper sulphide) smelting and refining of copper [7]. Production of one tonne of copper generates approximately 2.2-3 tonnes of copper slag [2], [4], [6], [8], [9], [14]. Presently, world-wide, about 33 million tonnes of slag is generated annually with India contributing 6-6.5 million tonnes. Copper slag has number of favorable mechanical properties for aggregate use, including excellent soundness characteristics, good abrasion resistance and good stability [6]. A study carried out by Central Road Research Institute (CRRI), New Delhi has shown that copper slag can be used as a partial replacement for sand as fine aggregate in concrete up to 40% in pavement grade concrete without any loss of cohesiveness and the compressive and flexural strength of such concretes is about 20% higher than that of conventional cement concretes of the same grade [11]. Binod Kumar et al. [5] investigate the feasibility of using copper slag, as a partial replacement of sand in the preparation of pavement quality concrete (PQC) and dry lean concrete (DLC) mixes and concluded that a blend of stone dust with copper slag content up to 40% could be used as fine aggregate for PQC as well as DLC. Al-Jabri et al. [2] investigated the effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC) and found that the surface

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

water absorption decreased as copper slag quantity increases up to 40% replacement; beyond that level of replacement, the absorption rate increases rapidly. D.Brindha et al. [9] study effect of replacing fine aggregate by copper slag on the compressive strength and split tensile strength and concluded that percentage replacement of sand by copper slag shall be up to 40%. Wei Wu et al. [15] investigated the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate and concluded that less than 40% copper slag as sand substitution can achieve a high strength concrete that comparable or better to the control mix, beyond which however its behaviours decreased significantly.

II. MATERIAL USED

A. Cement

Ordinary Portland cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS: 4031-1996-Part II. If the 28 days strength is not less than 33N/mm^2, 43N/mm^2 and 53N/mm^2 it called 43 grade and 53 grade cement respectively. Birla Super 53 grade cement conforming to IS: 12269-1987 was used in the present investigation. The tests performed on this cement are summarized in Table 1.

TABLE 1: PROPERTIES OF CEMENT

Sl. No.	Properties	Results
1.	Normal Consistency (%)	34
2.	Setting Time (minutes)	
	i. Initial setting time	57
	ii. Final setting time	240
3.	Specific gravity	3.10

B. Coarse Aggregates

Coarse aggregates are inert particle materials that pass through the sieve size of 80 mm and retained on sieve size 4.75 mm. In the present study, locally available granite of size 20 mm and 10mm in the proportion 60% and 40% by volume respectively was used. The physical properties of coarse aggregates are given in Table 2.

TABLE 2: PROPERTIES OF COARSE AGGREGATES

Sl. No.	Properties	Results
1.	Abrasion Value, %	24.97
2.	Combined Elongation and Flakiness Indices, %	28.0
3.	Crushing Value, %	25.36
4.	Impact Value, %	21.10
5.	Specific gravity	2.63
6.	Water Absorption, %	0.45

C. Fine Aggregates

River sand available locally was used as fine aggregates and they conform to IS: 383-1970 (reaffirmed 1997). Sieve analysis was done using standard sieve analysis procedure and the sand conforms to Zone II. The physical properties and sieve analysis details are given in Table 3 and 4 respectively.

D. Copper Slag

Copper slag used in the present studies was procured from Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu, India. The physical properties and sieve analysis of Copper Slag are given in Table 3 and 4 respectively. Fig. 2 shows particle distribution curve of sand and copper slag.

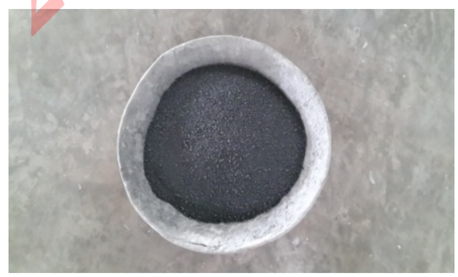


Fig. 1 Copper slag

TABLE 3: PROPERTIES OF FINE AGGREGATES AND COPPER SLAG

Properties	Fine Aggregates	Copper Slag
Specific gravity	2.53	3.57
Water absorption, %	0.80	0.14
Moisture content, %	0.50	0.10
Fineness modulus	2.55	2.68
Bulk density, g/cc	1.67	0.14
Grading zone	Zone II	Zone II

TABLE 4: SIEVE ANALYSIS OF RIVER SAND AND COPPER SLAG

IS Sieve	Percentage Passing		Grading for Zone II as
	Sand	Copper slag	

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

(mm)			Per IS:383-1970
4.75	100.00	100.00	90-100
2.36	97.10	97.80	75-100
1.18	79.30	79.40	55-90
0.60	56.70	44.10	35-59
0.30	9.90	8.40	8-30
0.15	2.00	2.40	0-10
0.075	0.20	0.90	-
Pan	0.00	0.00	-

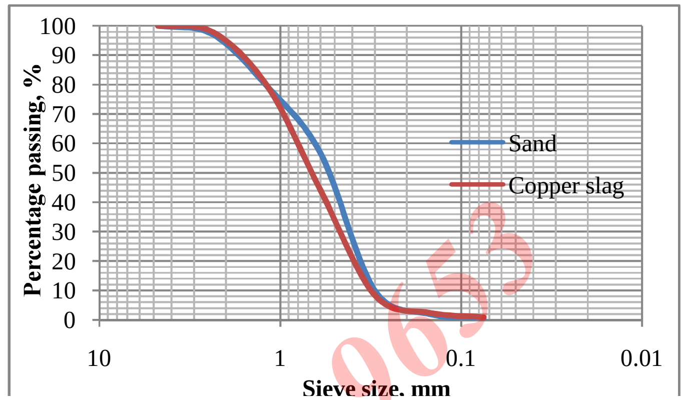


Fig. 2 Particle size distribution curve of sand and Copper slag

E. Water

Water is the most important constituent of a concrete mass which enables bonding between cementitious materials and the aggregates and also helps in the hydration of cement which is the most important phenomenon in gaining strength. Potable water which is free from salts and impurities was used for mixing and also curing purposes.

TABLE 5: MIX PROPORTIONS DETAILS (in kg/m^3) CONSIDERED IN THE PRESENT STUDIES

Mix Materials	CC	Mix-1	Mix-2	Mix-3	Mix-4	Mix-5
Cement	414	414	414	414	414	414
Coarse aggregates	1129	1129	1129	1129	1129	1129
Fine aggregates	638	574	510	446	382	319
Copper slag	0	90	180	270	360	450
Water	186	186	186	186	186	186

III. MIX PROPORTIONS

Control Concrete grade have been chosen as M30. For proportioning of mixes, IRC method of mix design has been followed as per IRC: 44-2008. Concrete mixtures were prepared with different percentage replacement of Copper slag by weight of fine aggregates in proportions of 0% (for control concrete), 10%, 20%, 30%, 40%, 50% and 60%. All the mixes were proportioned by the method of absolute volumes considering the specific gravity of the constituent materials. Mix proportions of all the type of mixes considered in the present studies are given in Table 5.

IV. EXPERIMENTAL WORK

The results of fresh properties of concrete such as slump and compaction factor are determined and hardened properties such as compressive strength, flexural strength, ultrasonic pulse velocity and fatigue analysis are presented.

A. Rheology of Concrete

Fresh concrete or plastic concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of cement, aggregate and water mixed together to control the properties of concrete in the wet state as well as in

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

the hardened state. Tests adopted for measurement of workability in the present investigation are:

1. Slump test
2. Compaction factor test

TABLE 6: MEASUREMENT OF WORKABILITY

Mix Designation	Slump (mm)	Compaction factor
CC (control concrete)	33	0.91
Mix-1 (10% CS)	35	0.91
Mix-2 (20% CS)	47	0.89
Mix-3 (30% CS)	54	0.88
Mix-4 (40% CS)	61	0.88
Mix-5 (50% CS)	72	0.88
Mix-6 (60% CS)	75	0.85

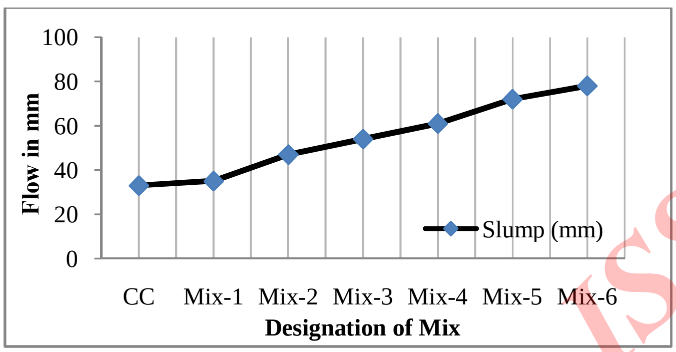


Fig. 3 Slump at values for different mixes

Slump values ranges from 33 mm to 75 mm and compaction factor ranges from 0.85 to 0.91. Mix-6 of 60% copper slag replacement yielded maximum slump values of 75 mm which shows good workability than the other mixes.

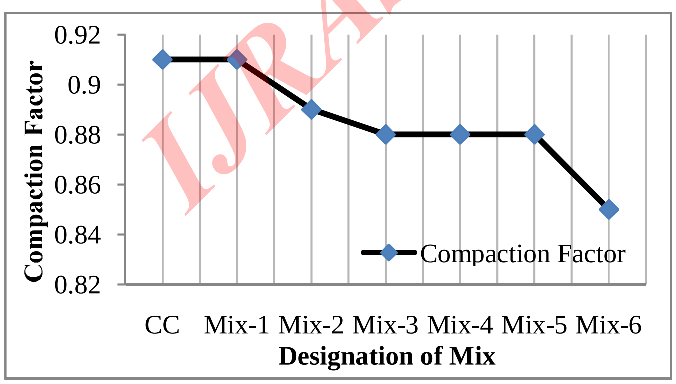


Fig. 4 Compaction factor for different mixes

B. Compressive Strength

A total number of 63 concrete cube specimens of standard dimension 150x150x150 mm were cast as per mix design and compressive strength test were conducted to evaluate the strength development of concrete mix containing copper slag of different proportions at curing periods of 3, 7 and 28 days in a compressive testing machine, as per IS: 516-1976. The cube compressive test results of various mixes considered in comparisons is given in Table 7.

TABLE 7: COMPRESSIVE STRENGTH TEST RESULTS

Mix Designation	Avg. Compressive Strength in N/mm^2 at Curing Period of			Percentage Strength Gain at 28days
	3days	7days	28days	
CC	17.44	27.61	35.23	-
Mix-1	19.77	30.16	46.36	31.60
Mix-2	23.25	30.66	47.12	33.75
Mix-3	25.29	32.77	48.77	38.43
Mix-4	26.81	34.95	54.56	54.87
Mix-5	24.56	30.23	51.63	46.55

C. Flexural Strength

To find the flexural strength of concrete, beam specimens of standard dimension 500x100x100 mm were cast with 10%, 20%, 30%, 40%, 50% and 60% replacement of fine aggregate by copper slag and for control concrete. The flexural strength of concrete beam specimens was determined using third point loading method. The specimens was loaded and tested in accordance with the ASTM Test Method C78. The flexural strength results of various mixes considered in comparisons is given in Table 8.

TABLE 8: FLEXURAL STRENGTH TEST RESULTS

Mix Designation	Avg. Flexural Strength in N/mm^2 at Curing Period of			Percentage Strength Gain at 28days
	3days	7days	28days	
CC	4.69	6.08	8.00	-
Mix-1	4.60	6.73	8.93	11.62
Mix-2	5.33	6.87	10.07	25.87
Mix-3	5.33	6.93	10.13	26.62
Mix-4	5.47	7.00	11.07	25.87
Mix-5	4.87	6.93	9.00	12.50

ISSN: 2321-9653
INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Mix-6	4.73	6.53	8.87	10.87

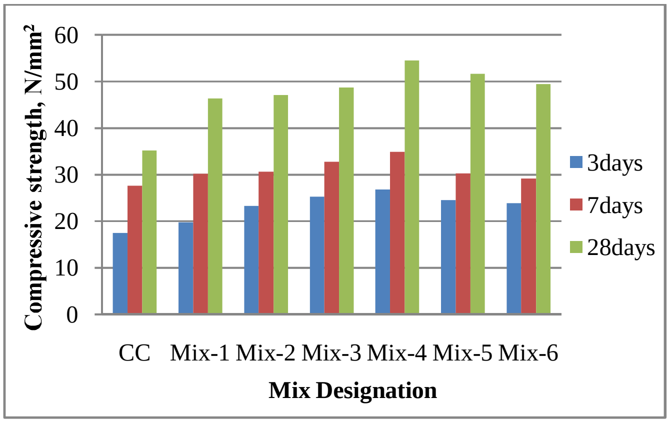


Fig. 5 Comparison of compressive strength of various mixes

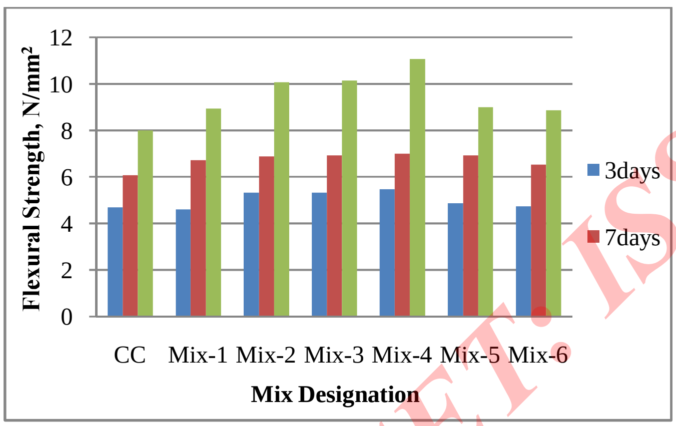


Fig. 6 Comparison of flexural strength of various mixes

D. Ultrasonic Pulse Velocity

The ultrasonic pulse velocity of concrete is mainly related to its density and modulus of elasticity. This in turn, depends upon the materials and mix proportions used in making concrete as well as the method of placing, compaction and curing of concrete. UPV test was conducted for seven concrete mixtures named as CC, Mix-1, Mix-2¸ Mix-3, Mix-4, Mix-5 and Mix-6 at curing period of 28 days. The quality of concrete was assessed using the guidelines given in Table 2 of IS: 13311(Part 1)-1992. Table 9 gives the results of UPV test for various concrete mixes. The Basic formula for estimating the pulse velocity is given by

Pulse velocity = (Path length/Travel time)

TABLE 9: UPV TEST RESULTS

Mix Designation	Pulse Velocity (km/s)	Quality of Concrete
CC	4.18	Good
Mix-1	4.32	Good
Mix-2	4.39	Good
Mix-3	4.42	Good
Mix-4	4.47	Good
Mix-5	4.40	Good
Mix-6	4.36	Good

1) Evaluation of Modulus of Elasticity from UPV Data

The dynamic Young's Modulus of Elasticity (E) may be determined from pulse velocity and dynamic Poisson's Ratio (μ) from the following equation obtained from IS: 13311(Part I)-1992.

$$E = [\rho\ (1+ \mu)\ (1-2\mu)\ /\ (1- \mu)]*V^2$$

Where, E = Young's Modulus in N/mm^2
ρ = Density of Concrete in kg/m^3
μ = Poisson's Ratio = 0.24
V = Pulse Velocity in m/s

The E-values calculated using the above equation are given in Table 10

TABLE 10: E-VALUE OBTAINED FROM UPV TEST RESULTS

Mix Designation	Pulse Velocity (m/s)	E-Value (N/mm^2)
CC	4180	350882.94
Mix-1	4320	378897.40
Mix-2	4390	395527.19
Mix-3	4420	405261.03
Mix-4	4470	418889.26
Mix-5	4400	410307.28
Mix-6	4360	407074.38

E. Accelerated Fatigue Load Testing

Beam specimens of size 500x100x100 mm were cast using the mix proportion determined for Mix-4 where 40% of fine aggregate is replaced by copper slag and maximum strength is obtained and the specimens were cured for 28 days. The beam specimens are marked in the same way as for the static flexure test. The load cell was brought in contact with the loading frame placed on the specimen. The computer system and other instrumentations are kept ready. The support points at 400 mm apart from the bottom and 133.33 mm

Vol. 2 Issue VII, July 2014
ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

from the top. The load was then applied on the frame by giving data entries in the computer. The specimens were subjected to accelerated half sine wave form of cyclic loading tests at three stress levels 65%, 70% and 75% of static flexure failure load results got by the static flexural strength with a rest period of 1s and frequency of load application being 2 Hz i.e., two cycles per second and the number of repetitions to failure under each stress level was recorded. The flexural static failure load is obtained as average flexural strength of three specimens and the values are given in Table 11.

TABLE 11: FATIGUE LOADS AT DIFFERENT STRESS RATIOS

Mix Designation	**Flexural Load**	**SR = 0.65**	**SR = 0.70**	**SR = 0.75**
Mix-4	26.67 KN	17.33 KN	18.67 KN	20.00 KN

The number of repetitions to failure of Mix-4 concrete at different stress levels is given in Table 12. For convenience in the development of fatigue models the results have been arranged in an ascending order.

TABLE 12: FATIGUE TESTING RESULTS FOR MIX-4

Sl. No.	**No. of Repetitions to Failure (N)**		
	SR = 0.65	**SR = 0.65**	**SR = 0.65**
1.	164	164	164
2.	625	625	625
3.	1028	1028	1028
4.	7865	7865	7865
5.	13457	13457	13457
6.	18763	18763	18763
7.	22989	22989	22989
8.	28663	28663	28663
9.	29861	29861	29861

F. Fatigue Analysis

The data in Table 12 was used to analyse for predicting the fatigue life of the concrete Mix-4. Log Normal Distribution Model is considered in the present studies.

1) Log Normal Distribution Model :

Various approaches have been used in the fatigue life assessment of structural elements. A widely accepted approach for engineering practice is based on empirically derived S-N diagrams, also known as Wohler curves. From the fatigue data obtained for Mix-4 specimens under investigation S-N curves are developed using linear regression model, considering Log Normal Distribution. The linear regression model is of the form (y = ax + b) in which stress ratio (SR) is taken on Y-axis and Log (N) values are taken on X-axis. The scatter diagram and the linear relationship obtained of test results for Mix-4 specimens are shown in Fig. 7. The linear regression model considering all the values along with R^2 are given in equation 1.

$$y = -0.0184x + 0.761 \ldots\ldots\ldots\ldots\ldots (1)$$

With, R^2 = 0.1576, R^2 being the regression coefficient

In this case, y = S, the stress ratio and x = Log N. Then the equation becomes

$$\text{Log}_{10}\,N = \frac{0.7613 - SR}{0.0184}$$

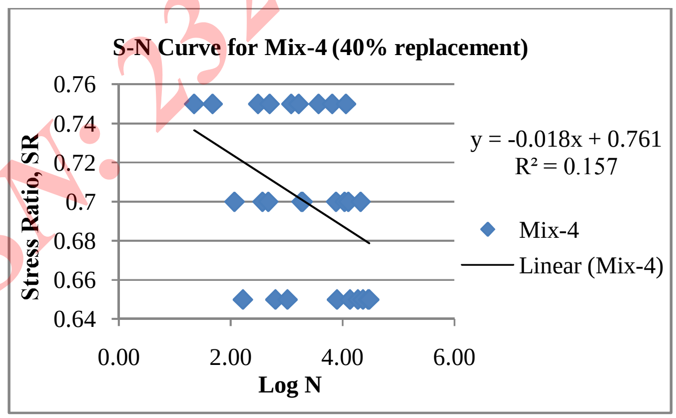


Fig. 7 Relationship between stress ratio (SR) and Log N

From the results obtained for 9 specimens in the linear regression model shown above, the R^2 value obtained is 0.1576 which clearly shows that there is a lot of scatter among the number of repetitions. Applying the correction by omitting lowest values, linear regression model considering 6 specimens per stress ratio is developed. The corrected model is shown in equation 2 and the relation is shown in Fig. 8.

$$y = -0.0547x + 0.9092 \ldots\ldots\ldots\ldots\ldots (2)$$

With R^2 = 0.4709

$$\text{Log}_{10}\,N = \frac{0.9092 - SR}{0.0547}$$

From the analysis on the corrected results, it is evident that R^2 value has increased to 0.4709.

Vol. 2 Issue VII, July 2014
ISSN: 2321-9653
INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

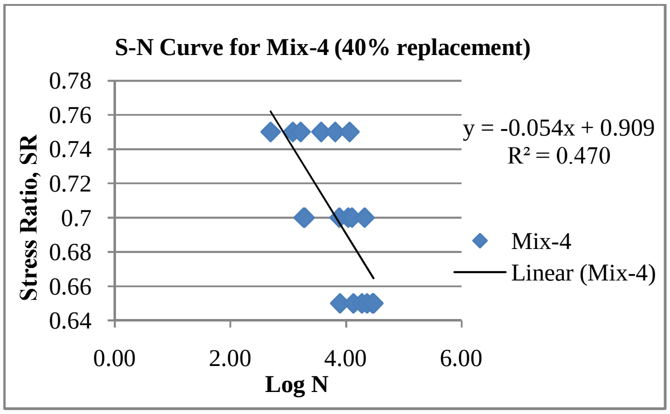


Fig. 8 Relationship between stress ratio (SR) and Log N after omitted value

2) Comparison of Fatigue Life Values

The fatigue equation given by IRC: 58-2011 code was used to compare with the developed linear regression model for Mix-4 concrete. IRC: 58-2011- Guidelines for the design of plain jointed rigid pavements for highways is the procedure that is presently being used in India for the design of rigid pavements.

The models suggest by IRC: 58 are given below

N = Unlimited For SR < 0.45

$$N = \left[\frac{4.2577}{SR - 0.4325}\right]^{3.268} \quad \text{When } 0.45 \leq SR \leq 0.55$$

$$\text{Log}_{10}N = \frac{0.9718 - SR}{0.0828} \quad \text{For } SR > 0.55$$

Similarly for Mix-4 with SR being > 0.55, the equation becomes

$$\text{Log}_{10} N = \frac{0.9092 - SR}{0.0547}$$

All test data for Mix-4 specimens are used to compare fatigue life with IR: 58 model. The comparison is shown in Table 13 and Fig. 9.

TABLE 13: COMPARISON OF FATIGUE LIFE

Stress Ratio "SR"	Number of Repetitions to Failure, N	
	IRC: 58	Mix-4 (40% Replacement)
0.55	124222	4447830
0.60	30927	527500
0.65	7700	62560
0.70	1917	7419
0.75	477	880
0.80	119	104
0.85	30	12

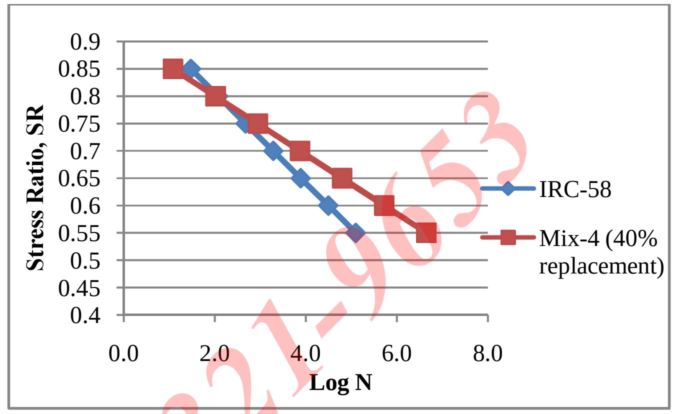


Fig. 9 Comparison of fatigue life between Mix-4 model and IRC: 58 model

V. RESULTS AND DISCUSSION

The test results indicated that all mixtures yielded comparable or higher compressive and flexural strengths than the control mixture for all curing periods. Furthermore, as copper slag content increases the compressive and flexural strength increases up to 40% replacement. Beyond that, the strength decreased with an increase in copper slag content. The reduction in compressive strength for concrete mixtures with higher copper slag content may be due to increase in the free water content that results from the low water absorption characteristics of copper slag in comparison with sand. This causes a considerable increase in the workability of concrete and thus reduces concrete strength with a reduction in cohesion. Mix-4 specimens yielded the highest average 28 days compressive strength of 54.56 N/mm^2, almost 55% higher compared with 35.23 N/mm^2 for the control mix. An increase of 56% of compressive strength was obtained at 28 days for Mix-4 specimens, compared to 7 days strength. But for control specimens, the increase in strength was only 28% compared to 7 days strength. Also Mix-4 specimens yielded the highest average 28 days flexural strength of 11.06 N/mm^2, almost 27% higher compared with 8.00 N/mm^2 for the control mix. An increase of 58% of flexural strength was obtained at 28 days for Mix-4 specimens, compared to 7 days strength. But for control specimens, the increase in strength was only 32% compared to 7 days strength. For control mixes, travel time of ultrasonic waves in concrete is greater and hence pulse velocity in control mix

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

is relatively less when compared to copper slag incorporated mixes.

VI. CONCLUSION

The workability of concrete increases significantly with the increase of copper slag content in concrete mixes. The inclusions of copper slag have considerably enhanced the strength characteristics of pavement quality concrete. The results of cube compressive, static flexural strength test have indicated that the strength increases with respect to the percentage replacement of copper slag by the weight of fine aggregate was up to 40% replacement. The compressive strength of cube and flexural strength of beam at 28 days curing period was increased by 31.6% to 54.87% and 10.87% to 26.62% respectively with replacement of copper slag. The highest compressive and flexural strength obtained was 54.56 N/mm^2 and 11.07 N/mm^2 respectively at 40% replacement. The comparison of fatigue life have indicated that the number of repetitions to failure of Mix-4 specimens was more up to 0.75 stress ratio than the allowable number of repetitions to failure suggested by IRC: 58. Therefore, it is recommended that copper slag admixed concrete up to 40% can be advantageously used for pavements carrying lower traffic loads.

REFERENCES

[1] Akihiko, Y. and Takashi, Y. “Study of utilisation of copper slag as fine aggregate for concrete”, Ashikaya Kogyo Daigaku Kenkyu Shuroku, Vol. 23, pages 79-85, 1996.

[2] Al-Jabri, K.S. and Makoto Hisada “Copper slag as sand replacement for high performance concrete”, Cement and Concrete Composites, Vol. 31, pages 483- 488, 2009.

[3] Al-Jabri, K.S., Abdullah, H. Al-Saidy and Ramzi Taha. “Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete”, Construction and Building Materials, Vol. 25, pages 933-938, 2011.

[4] Arivalagan.S, "Experimental study on the flexural behavior of reinforced concrete beams as replacement of copper slag as fine aggregate", Journal of Civil Engineering and Urbanism, Vol. 3, pages 176-182, 2013.

[5] Binod Kumar "Properties of pavement quality concrete and dry lean concrete with copper slag as fine aggregate", International Journal of Pavement Engineering Vol. 14, No.8, pages 746-751, 2013.

[6] Bipra Gorai, R.K. Jana and Premchand, “Characteristics and utilisation of copper slag-a review”, Resources, Conservation and Recycling, Vol. 39, No. 4, pages 299-313, 2002.

[7] Biswas, A.K. and Davenport, W.G. "Extractive metallurgy of copper", first edition Pergamon Press, Oxford, 1976.

[8] Caijun Shi, Christian Meyer, and Ali Behnood, “Utilization of copper slag in cement and concrete”, Resources Conservation and Recycling, Vol. 52, pages 1115-1120, 2008.

[9] D. Brindha and S. Nagan, "Utilization of copper slag as a partial replacement of fine aggregate in concrete", International Journal of Earth Sciences and Engineering, Vol. 3, No. 4, pages 579-585, 2010.

[10] Hwang, C.L and Laiw, J.C. “Properties of concrete using copper slag as a substitute for fine Aggregate”, Proceedings of the 3rd International Conference on Fly Ash, Silica Fume, Slag, and Natural Pozzolans In Concrete, SP-114-82, pages 1677-1696, 1989.

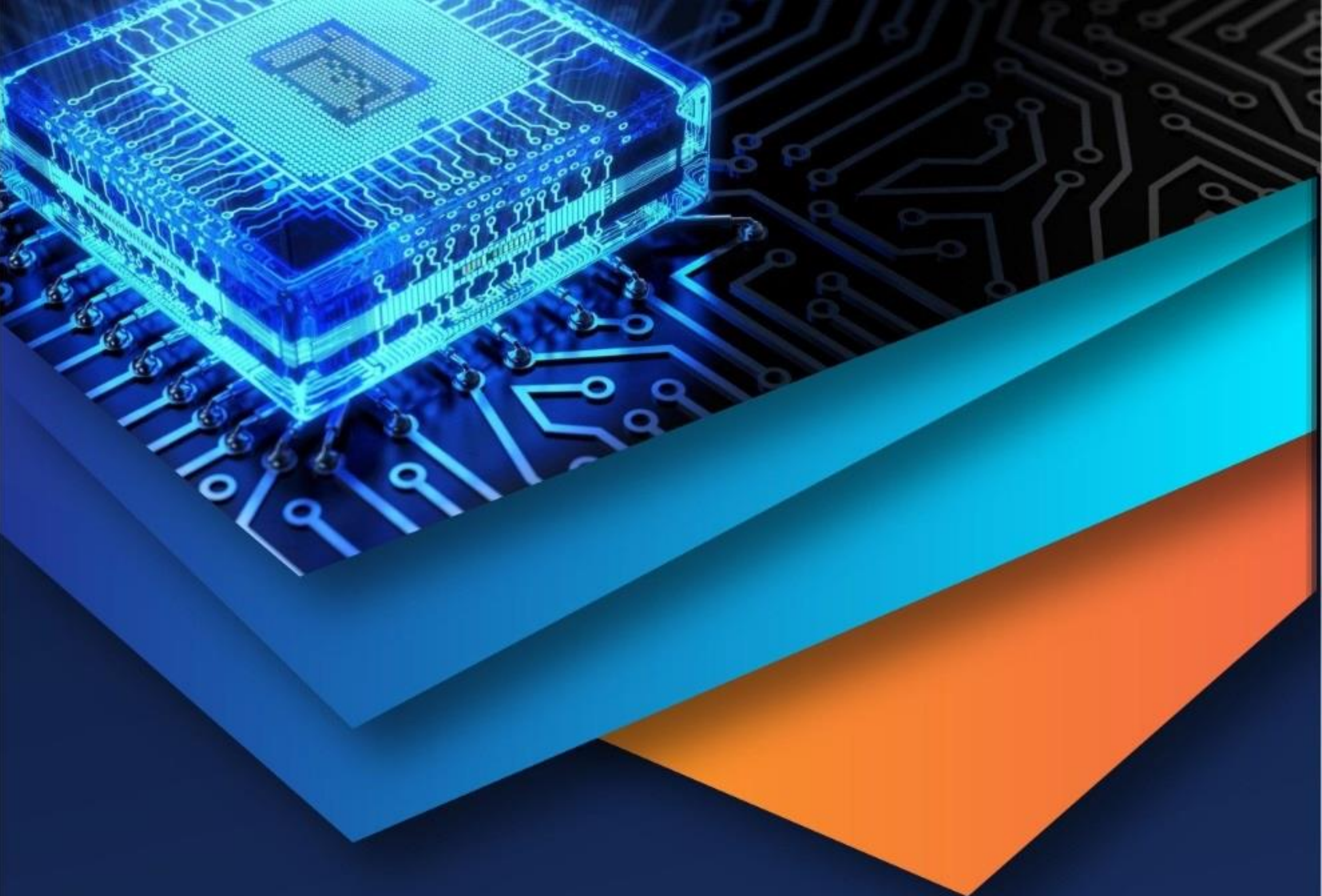
[11] IS: 1905-1987, “Code of Practice for Structural use of U nreinforced Masonry”, Bureau of Indian Standard, New Delhi.

[12] K. P. Nagaraja, "Flexural Fatigue Strength of HVFA Concrete", International Conference on Construction and Building Technology, C (38) pages 415-424, 2008.

[13] Suresh Kumar K.S., Kamalakara G.K., Sagar Kamble, Amarnath M.S., "Fatigue Analysis of High Performance Cement Concrete for Pavements using the Probabilistic Approach", International Journal of Emerging Technology and Advanced Engineering, Vol. 2, No. 11, pages 640-644, 2012.

[14] T.Ayano and K.Sakata, “Durability of concrete with copper slag fine aggregate”, Proceedings of the Fifth ACI International Conference on Durability of Concrete, Vol. 192, pages 141-158, 2000.

[15] Wu, W., Zhang, W. and Ma, G. “Mechanical properties of copper slag reinforced concrete under dynamic compression”, Construction and Building Materials, Vol. 24, No. 6, pages 910-917, 2010.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

SJIFactor TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY