Experiment Studies by Replacing Sand with Granulated Blast Furnace Slag in Combination of Fly Ash and MetaKaolin, on Fresh and Durability Properties

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Abstract - The utilization of river sand has a drastic and ecological balance in environment. The main study relates to sand as a basic material for the preparation of concrete. The growth of over population and continuous excavation of river sand has resulted the natural calamity and environmental hazard. River sand is obtained from the river beds for the construction of buildings and gigantic infrastructures to meet the demands of the population growth. The advent of globalization and sophisticated Technology needed to fulfill the demands of national and international global market has become a major problem to preserve the river sand used as a fine aggregate in the production of concrete. The research on river sand to replace with industrial by-product as GBFS, Fly ash, rice husk ash and MetaKaolin (MK) as substitutes of industrial waste materials have given a great challenge to solve different ways to dump the materials in a systematic manner. The Experimental work on a large scale is carried out to check this problem to recycle the waste materials in place of river sand and cement to bring an amicable and friendly ecological balance creating a clean and green environment.

The latest trend of practical work was carried out to analyze the durability and mechanical properties by the use of cementitous material replacing cement with 0.38% of Fly ash,0%,10% MetaKaolin and rivers and replaced with (0%,40%) of GBFS. The results have clearly indicated that the combination of Fly ash, MetaKaolin with GBFS have better resistance properties to acid and sulphate attack to enhance the durability of concrete.

Key words: GBFS, Fly ash, MetaKaolin, Self compacting concrete, Chloride Durability

I. INTRODUCTION

The advent of Technology and globalization with the expansion of population has resulted in the depletion of building materials to meet the demands of global market. River sand is the basic ingredient used as a fine aggregate in concrete production. The growing demand of competitive market demands construction material on a large scale directed to the over utilization of river sand which has a severe detrimental effect like the raise in river bed depth, lowering of the water table and increase in saline content of river. The prolonged life of durability of construction and infrastructure has indirect effect on national economy in terms of maintenance, service and economic imbalance. Durability is the defined as the measure of the resistance calculated quantatively as freezing and thawing. The ingredient mixed in certain ratio of concrete is not fully resistant to acids such as oxalic and phosphoric acids present in acid solutions disintegrate the cement particles. The ground water contains acid solutions such as oxalic and phosphoric acids which disintegrate cement concrete. The process of hydration of cement leads to calcium hydroxide ($Ca(0H)_2$) and hydrated C_3A will form calcium sulphate and calcium sulpho aluminate and increase porosity of concrete. The lowering of C_3A sulphate attack can be reduced. The mixed proportion of water cement ratio plays a vital role to enhance the durability properties. The sulphate attack is a clear indication of whitish color traced by the marks of concrete. The phrase sulphate attack represents the escalation volume of cement paste in concrete or mortar as a result of chemical reaction between the hydration of cement and sulphate solution. The initial fading effect begins at the surface and corners and finally injects into the concrete to scaling and spalling effect due to expansion and cracking of the concrete structures.

II. LITERATURE REVIEW

A rising demand and consumption of river sand in the construction industries an alternative material to river sand becomes vital [1].several experimental works carried out to reuse of the waste industrial by product [2,3]. The industrial by products are GGBS, Fly ash, Rice husk ash, GBFS, fire waste [8] can be used as ingredients of concrete [8,7]. These waste industrial by product could improve workability and hardened properties of concrete [4, 5]. The research work carried out easily available and cheap industrial waste material to river sand. [Jadhava and Kulkarni 2012]. Khajura and siddique[2014] proved that when river sand replaced as a GBFS in the concrete had increased strength [6,1]. Granulated blast furnace slag reduces $c0_2$ and it is free from silt and clay [8, 9]. The use of Fly ash with GBFS in concrete showed improved durability and other structural properties [9, 10] .

The emission of co_2 coupled with production of cement and the same is accounted for environmental pollution. To solve these problems many experimental work carried out by replacing cement with Fly ash and MetaKaolin in normal concrete [11]. The research work showed that replacement of cement with fly ash and MetaKaolin effects early and long term strength [12,13]. The use of fly ash and MetaKaolin showed enhancement in durability and strength [14].

Replacing cement by Fly ash and MetaKaolin this ternary powder improves the structural properties of concrete [15,16].

The present experimental results of carried out to evaluate durability and mechanical properties by the use of cementitous material replacing sand by (0%, 40%) with GBFS and cement by (0%, 10%) with MetaKaolin for constant 38%here the work carried for M_{40}grade sec of fly ash and constant water cement ratio 0.37.

III. TEST PROCEDURE

Acid and sulphate resistance 100mm×100mm×100mm size of cubical specimen were immersed in water for 28 days of curing. After 28 days of curing, cubical specimen were taken out and kept for drying. Its weight and compressive strength were calculated before keeping in acid and sulphate solution. Then, these cubes were immersed separately in 5% of HCL, 5% of H_2SO_4 and 5% of H_2SO_4 to measure the degree of sulphate and acids resistance.

These tests were conducted at different ages of 28, 56, 90 and 180 days to evaluate the percentile (%) loss of weight and percentile(%) loss of strength due to acids and sulphate solution.

IV. DURABILITY FACTOR OF M40 GRADE OF SELF COMPACTING CONCRETE

100mm×100mm×100mm size of cubical specimen were immersed in water for 28 days of curing. These specimens were dried before immersing in 5% of HCL, 5% of H2SO4 and 5% of Na2SO4. Four specimens were removed from each group and cleaned with soft nylon brush. The specimens were tested for durability factors at 28, 56, 90 and 180 days for compressive strength.

$$\text{Durability factor} = (S_r \times N)/M$$

Where, Sr = % of relative strength at N days

N = No.of days at which durability factor is required

M = No.of days at which the exposure is terminated (M=100)

V. RESULTS AND DISCUSSIONS

Table No: 1 represents quantities of materials required for 1 m^3 by a constant 38% of fly ash and water/cement ratio of 0.37 at 0% replacement of sand by GBFS; 40% replacement of sand by GBFS; 40% replacement of sand by GBFS and 10% replacement of cement by MetaKaolin.

Mix replacement	Cement Kg/ m^3	Metakaolin Kg/ m^3	Fly Ash Kg/ m^3	Sand Kg/ m^3	GBFS Kg/ m^3	Course Aggregate Kg/ m^3	Water Lt/ m^3r
0%	317	-	212	876	-	726	195
40%	317	-	212	525	351	726	195
40% + 10%	285	-	212	525	351	726	195

Table 1: Quantities of the materials required for 1 m^3 of M40 grade

Table No: 2 represents the fresh properties of M20 grade of self compacting concrete. It is observed that the workability increases in combination of fly ash, metakaolin with GBFS.

Mix	0% replacement of sand by GBFS	40% replacement of sand by GBFS	40% replacement of sand by GBFS+10%MK
Slump Flow	630×630mm	600×600mm	640×640mm
V funnel	7 sec	12 sec	6 sec
L box	0.85	0.8	0.87
V funnel at T=5min	13 sec	15 sec	11sec

Table 2: Fresh properties of M40 grade of SCC

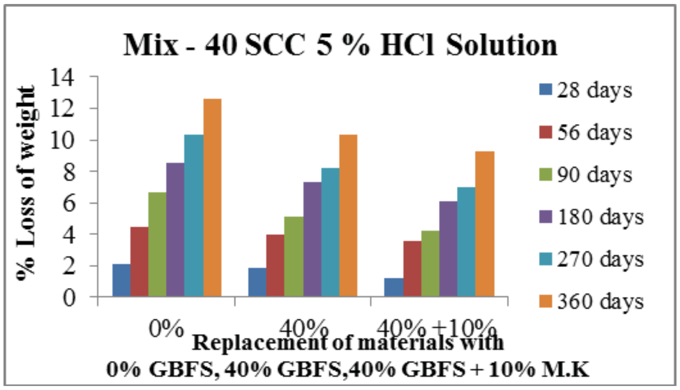
M40 - % Loss of weight immersed in 5% HCl solution:

Table No: 3(a) represents % loss of weight for different replacement at different stages. The % of loss of weight goes on increasing from 2.1% for 28 days to 12.6% for 360 days for 0% replacement of sand by GBFS. But it is increasing from 1.89% to 10.3% for 40% replacement of sand by GBFS and again increasing from 1.21% to 9.3% for 40% replacement of sand by GBFS and 10% replacement by metakaolin.

The above result shows that % loss of weight goes on decreasing 2.1% to 1.21% for 28 days and 12.6% to 9.3% for 360 days. Hence acid resistance is more for replacement of 40% GBFS and 10% of metakaolin as compared to 0% replacement of sand.

S.NO	% GBFS	28 days	56 days	90 days	180 days	270 days	360 days
1	0%	2.1	4.5	6.67	8.5	10.3	12.6
2	40%	1.89	3.96	5.1	7.3	8.2	10.3
3	40% +10%	1.21	3.6	4.2	6.1	7	9.3

Table 3 (a) Mix - 40 SCC 5% HCl solution



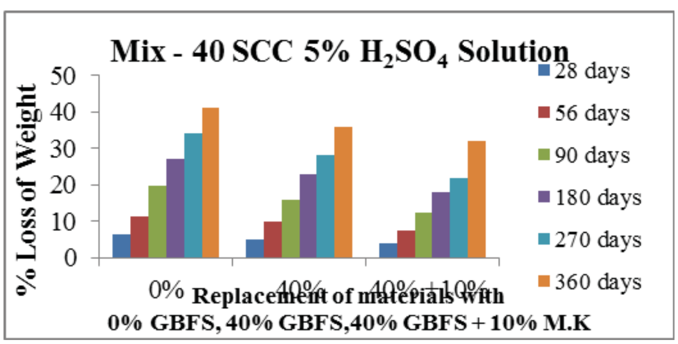
M40 - % Loss of weight immersed in 5% H_2SO_4 Solution:

Table No: 3(b) represents % loss of weight for different replacement at different stages. The % of loss of weight goes on increasing from 6.3% for 28 days to 41% for 360 days for 0% replacement of sand by GBFS. But it is increasing from 5.2% to 3.6% for 40% replacement of sand by GBFS and again increasing from 4.1% to 32% for 40% replacement of sand by GBFS and 10% replacement by metakaolin.

The above result shows that % loss of weight goes on decreasing 6.3% to 4.1% for 28 days and 41% to 36% for 360 days. Hence acid resistance is more for replacement of 40% GBFS and 10% of metakaolin as compared to 0% replacement of sand.

S.NO	% GBFS	28 days	56 days	90 days	180 days	270 days	360 days
1	0% GBFS	6.3	11.34	19.8	27	34	41
2	40% GBFS	5.2	9.9	15.8	23	28	36
3	40% GBFS+10% M.K	4.1	7.34	12.4	18	22	32

Table 3 (b) Mix - 40 SCC 5% H_2SO_4 solution



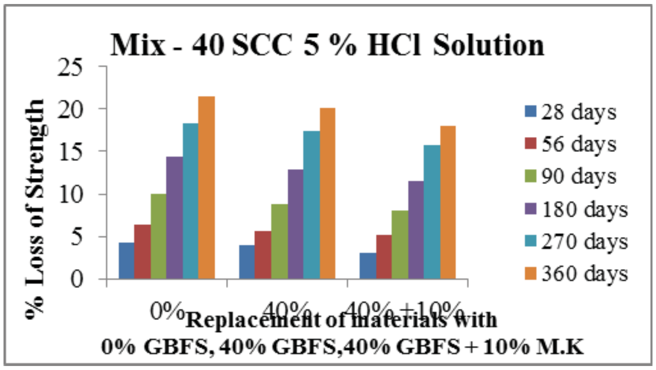
M40 - 5% of HCl solution of loss of strength:

Table No: 4(a) represents % loss of strength for different replacement at different stages. The % of loss of strength goes on increasing from 4.25% for 28 days to 21.4% for 360 days for 0% replacement of sand by GBFS. But it is increasing from 3.98% to 20.1% for 40% replacement of sand by GBFS and again increasing from 3.1% to 18% for 40% replacement of sand by GBFS and 10% replacement by metakaolin.

The above result shows that % loss of strength goes on decreasing 4.25% to 3.1% for 28 days and 21.4% to 18% for 360 days. Hence acid resistance is more for replacement of 40% GBFS and 10% of metakaolin as compared to 0% replacement of sand.

S.NO	% GBFS	28 days	56 days	90 days	180 days	270 days	360 days
1	0%	4.25	6.38	9.95	14.45	18.3	21.4
2	40%	3.98	5.6	8.8	12.9	17.44	20.1
3	40% +10%	3.1	5.2	8.1	11.5	15.7	18

Table 4 (a) Mix - 40 SCC 5% HCl solution



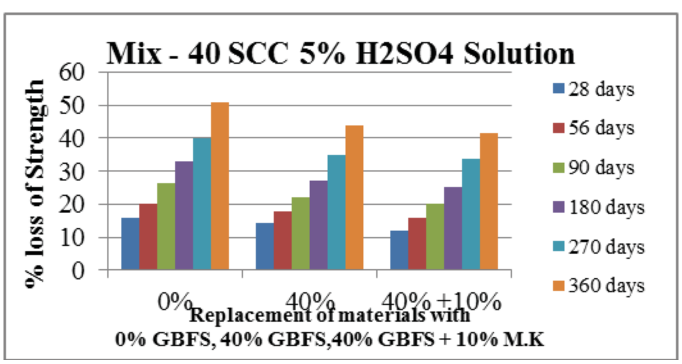
M40 - 5% of H_2SO_4 solution of loss of strength:

Table No: 4(b) represents % loss of strength for different replacement at different stages. The % of loss of strength goes on increasing from 15.95% for 28 days to 51% for 360 days for 0% replacement of sand by GBFS. But it is increasing from 14.4% to 44% for 40% replacement of sand by GBFS and again increasing from 11.9% to 41.4% for 40% replacement of sand by GBFS and 10% replacement by MetaKaolin.

The above result shows that % loss of strength goes on decreasing 15.95% to 11.9% for 28 days and 51% to 41.4% for 360 days. Hence acid resistance is more for replacement of 40% GBFS and 10% of metakaolin as compared to 0% replacement of sand.

S.NO	% GBFS	28 days	56 days	90 days	180 days	270 days	360 days
1	0% GBFS	15.95	20.1	26.3	32.8	39.8	51
2	40% GBFS	14.4	17.9	21.9	27	35	44
3	40% GBFS+10% M.K	11.9	15.7	20.2	25.1	33.8	41.4

Table 4 (b) Mix - 40 SCC 5% H2SO4 solution



S.NO	% GBFS	28 days	56 days	90 days	180 days	270 days	360 days
1	0% GBFS	0	0	0	0	0	0
2	40% GBFS	0	0	0	0	0	0
3	40% GBFS+10% M.K	0	0	0	0	0	0

Table 4 (c) Mix - 40 SCC 5% H_2SO_4 solution

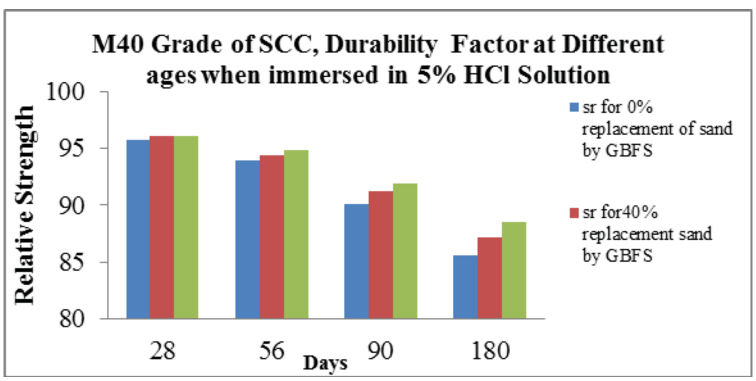
M40 grade of SCC, Durability factors at different ages when immersed in 5% HCl solution:

Table No: 5(a) represents durability factor changes from 14.89% for 28 days to 85.55% for 180 days for 0% replacement of sand by GBFS. But it is increasing from 14.94% to 87.1% for 40% replacement of sand with GBFS. But again it is increasing from 15.07% to 88.5% for 40% replacement of sand by GBFS and 10% replacement of cement by MetaKaolin.

The above result shows that % of durability factor goes on increasing 14.89% for 28 days to 85.55% for 180 days. Hence acid resistance is more for replacement of 40% GBFS and 10% of MetaKaolin as compared to 0% replacement of sand

Days	0% replacement of sand by GBFS		40% replacement of sand by GBFS		40% replacement of sand by GBFS and 10% by M.K	
	Relative strength	Durability factor	Relative strength	Durability factor	Relative strength	Durability factor
28	95.75	14.89	96.02	14.94	96.02	15.07
56	93.92	29.13	94.4	29.37	94.8	29.5
90	90.05	45.03	91.2	45.6	91.9	45.95
180	85.55	85.55	87.1	87.1	88.5	88.5

Table 5 (a) M40 Grade of SCC, Durability Factor at Different ages when immersed in 5% HCl Solution



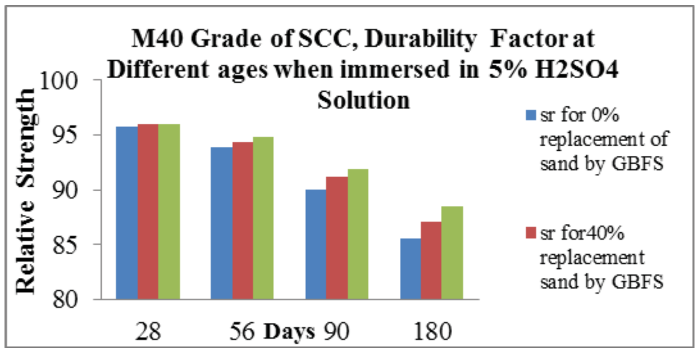
M40 grade of SCC, Durability factors at different ages when immersed in 5% H2SO4 Solution:

Table No: 5(b) represents durability factor changes from 13.07% for 28 days to 67.2% for 180 days for 0% replacement of sand by GBFS. But it is increasing from 13.32% to 73% for 40% replacement of sand with GBFS. But again it is increasing from 13.7% to 74.9% for 40% replacement of sand by GBFS and 10% replacement of cement by metakaolin.

The above result shows that % of durability factor goes on increasing 13.07% for 28 days to 67.2% for 180 days. Hence acid resistance is more for replacement of 40% GBFS and 10% of metakaolin as compared to 0% replacement of sand.

Days	0% replacement of sand by GBFS		40% replacement of sand by GBFS		40% replacement of sand by GBFS and 10% by M.K	
	Relative strength	**Durability factor**	**Relative strength**	**Durability factor**	**Relative strength**	**Durability factor**
28	84.05	13.07	85.6	13.32	88.1	13.7
56	79.9	24.86	82.1	25.54	84.3	26.22
90	73.7	36.85	78.1	39.05	79.8	39.9
180	67.2	67.2	73	73	74.9	74.9

Table 5 (b) M40 Grade of SCC, Durability Factor at Different ages when immersed in 5% H_2SO_4 Solution



VI. CONCLUSION

1) For M40 grade of SCC made with 38% Fly ash, 10% MetaKaolin with constant water cement ratio (w/c: 0.37)
2) Replacement 40% of GBFS for fine sand gave better result of workability
3) Using 40% GBFS and 10% MetaKaolin combination , % Loss of weight and % Loss of Strength are gradually decreasing in the Acids (HCl & H_2SO_4)
4) In the case of Na_2SO_4 the % Loss of weight and % Loss of Strength is comparatively nil (these indicates that it helps in curing of concrete)
5) A better Durability of the concrete when the sand is replaced by 40% GBFS and 10% MetaKaolin.
6) Loss of weight and strength is Nil in NA_2SO_4 Solution

REFERENCES

[1] Isa Yuksel, Omer Ozkan, and Turhan Bilir, "Use of Granular Blast – Furnace Slag in Concrete as Fine Aggegarte", ACI Materials Journal, V. 103, No. 3, May – June 2006
[2] Ismail Z.Z., AL-Hashmi E.A. (2007). "Reuse of waste iron as a partial replacement of sand in concrete."Waste Management Vol. 28 pp 2048-2053.
[3] Gartner, E., 2004. Industrially interesting approaches to low-CO2 cements. Cement and Concrete Research, 34, 1489-1498.
[4] Ameri M., Kazemzadehazad.S. (2012) "Evalution of the use of steel slag in concrete". 25th ARRB Conference – Shaping the future: Linking policy, research and outcomes, Perth, Australia.
[5] D. K. Singha Roy, "Performance of Blast Furnace Slag Concrete with Partial Replacement of Sand by Fly Ash", International Journal of Earth Sciences and Engineering, Volume 04, Octo 2011, pp. 949-952.
[6] Binici H., Temiz H.S., Kose M.M. (2006). "The effect of fineness on the properties of the blended cements incorporating ground granulated blast furnace slag and ground basaltic pumice." Construction and Building Material Vol. 21 pp 1122-1128.
[7] Bakhareva T., Sanjayana J.G., Cheng Y.B. (2001) "Sulfate attack on alkali-activated slag concrete." Cement and Concrete Vol. 32 pp 211-216.
[8] Singh, S.P. and Murmu, M. "Eco-friendly concrete using by-products of Steel industry".
[9] Taylor, M., Gielen, D., 2006. Energy efficiency and CO2 emissions from the global cement industry. International Energy Agency.
[10] L. Zeghichi, "The effect of replacement of naturals Aggregates by slag products on the strength of Concrete", Asian journal of civil engineering vol. 7, (2006), Pages 27 -35.
[11] Li Yijin, Zhou Shiqiong, Yin Jian, and Gao Yingli, "The effect of fly ash on the fluidity of Cement paste, mortar, and concrete".
[12] J.T. Ding, and Z. Li, "Effects of metakaolin and silica fume on properties of concrete", *ACI Materials journal*, Vol. 9(4), 2002, pp. 393 – 398.

[13] J.M. Khatib, and J.J. Hibbert, "Selected Engineering properties of concrete incorporating slag and metakaolin", *Construction and Building Materials*, Vol. 19(6), 2005, pp. 460-472.
[14] H.-S. Kim, S-H. Lee, and H-Y. Moon.,"Strength properties and durability aspect of high strength concrete using Korean Metakaolin", Construction and Building Materials, Vol. 21(6), 2007, pp .1229-1237.
[15] A.M. Fadzil, M.J. Megat Azmi, A.B. Badrol Hisyam, M.A. Khairun Azizi., Engineering Properties of Ternary Blended Cement Containing Rice Husk Ash and Fly Ash as Partial Cement Replacement Materials, International Conference on Construction and Building Technology, **A - (10)** – 2008, pp. 125 – 134.
[16] Al-Akhras N.M, (2006). "Durability of metakaolin concrete to sulfate attack." Cement and Concrete Research Vol. 36 pp 1727-1734.