Effect of different types of fine aggregates on mechanical properties of concrete - A review

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Concrete has been widely used as a construction material in buildings, tall structures and other industrial structures etc. Numerous research works has been carried out to assess the mechanical properties of concrete like compressive strength, flexural strength, and tensile strength. This review paper shows the results obtained from experimental results by various researchers on the effects of different types of fine aggregate on mechanical properties of concrete. The review of these papers has shown that the performance of manufactured sand and copper slag as fine aggregate in concrete is better when replaced with natural river sand. The percentage of replacement of natural sand by fly ash up to 40% in concrete subjected to elevated temperature of 200°C has shown increase in tensile strength.

INTRODUCTION

Conventionally concrete is mixture of cement, sand and aggregate. The properties of aggregate affect the durability and performance of concrete, so fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river sand. The global consumption of natural sand is very high, due to the extensive use of concrete. In general, the demand of natural sand is quite high in developing countries to satisfy the rapid infrastructural growth, in this situation developing country like India facing shortage in good quality of natural sand. In recent times with a boost in construction activities, there is a significant increase in the consumption of concrete causing the dwindling of natural sand. This has led to several environmental issues thereby government imposing a ban on the unrestricted use of natural sand. This has resulted in the scarcity and significant rise in the cost of natural sand. Therefore, an alternative to river sand has become the need of the hour. The promotional use of manufactured sand will conserve the natural resources for the sustainable development of the concrete in construction industry. Manufactured sands are made by crushing aggregate to sizes appropriate for use as a fine aggregate. During the crushing process the manufactured sand have irregular shapes. Due to irregular shape of the aggregates there is a better packing among the particles thereby reducing the voids in concrete [1].

COMPRESSIVE STRENGTH

From the Figure 1, it has been observed that workability of concrete increases with the addition of copper slag in the concrete mixes. This increase in the workability with the copper slag is attributed to the low water absorption characteristics of copper slag. The highest compressive

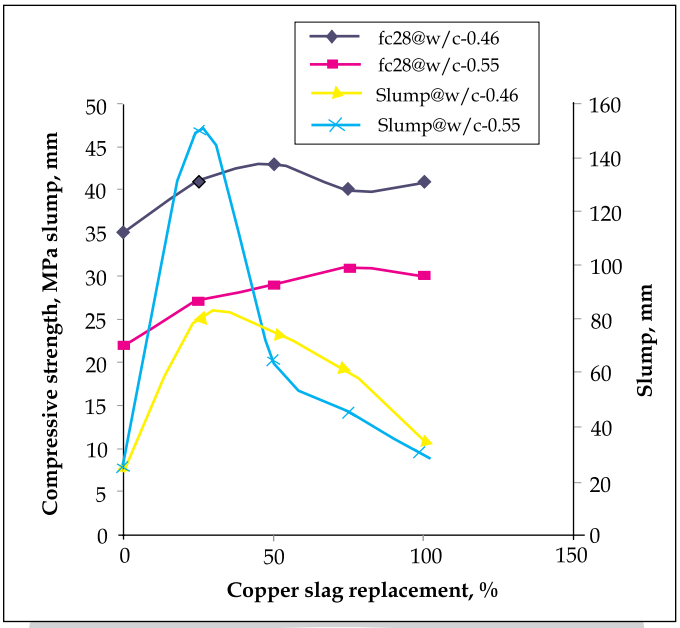

Figure 1. Relationship between workability and strength of concrete [2]

strength obtained was 43 MPa (50 % replacement), the corresponding strength for control concrete was 35 N/mm^2. The full replacement of sand by copper slag yielded higher compressive strength compared to that of the control mix. However, with different replacements the variation in strength was marginal [2]. According to Figure 2, it is observed that Concrete incorporating copper slag exhibits good mechanical properties and therefore up to 40% by weight of natural sand can be replaced by copper slag. The 28 days average compressive strength obtained for copper slag mix concrete shows 0.45% to 23.6% increase in compressive strength when compared to control mix concrete [3]. The 28 days compressive strength of concrete mix increases up to 40% of replacement of copper slag i.e., 56.3 N/mm^2 and decreases for 50 % replacement of copper slag with fine aggregate that is 45.13 N/mm^2 [4]. Fine aggregate (sand) was replaced with four different percentages (0%, 25%, 50% and 75%) of fly ash, copper slag and granite powder by weight. Compressive strength, split tensile strength were determined at 7, 14 and 28 days. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of above mentioned industrial waste as partial replacement of fine aggregate (sand) and it can be effectively used in structural concrete. The compressive strength of various mixes of Copper slag, Granite powder, and Fly ash fiber in concrete at 28 days will be 51.8 N/mm^2 [5]. By investigation, it has been observed that the percentage increase of compressive strength of concrete is 10.04 and 16.54% at the age of 7 days and 28 days by replacing 40% of cement with GGBS and 20% of sand with crusher sand [6]. Flow of mortar with copper slag for any compacting effort is less compared to mortar with natural sand designed for equal volume. When equal weight of copper slag is used, the flow is better even for 100% replacement due to more slurry (cement and water) for the given weight of copper slag. Use of copper slag at 20%-40% replacement level appears better for mortar [7]. The compressive strength of cement mortar with 50% replacement of natural sand by manufactured sand reveals higher strength as compared to reference mix [8]. The blending of mineral admixture with cement can enhance the resistance of cement towards high temperature. At 20% cement replacement by fly ash can enhance the compressive strength of concrete when exposed to high temperature [9]. It is observed that the target strength has been obtained from (10-30%) replacement ratio and an only gradual decrease is seen in higher replacement that is 36 to 30 N/mm^2. Hence both copper slag and quarry can be partially replace the use of natural sand without sacrificing strength and durability [10]. A compressive strength of concrete with natural sand increased by 7.72% after fully replacing by artificial sand at 7 days and 3.98% at 28 days. The indirect split tensile strength of concrete with river sand as fine aggregate found marginally higher than concrete with artificial sand as fine aggregate, it is 3.78 MPa and 3.71 MPa respectively. Split tensile strength for all specimens was more than 10% of compressive strength. The flexural strength of concrete with artificial sand as fine aggregate was recorded 2.81% more than concrete with natural river sand as fine aggregate [11]. The compressive strength were found to increase with increase in the percentage replacement of natural sand by fly ash upto 40% at elevated temperature of 200°C and thereafter decrease [12]. Higher fineness modulus, particles grading shape and texture have contributed to better workability of manufactured sand. Manufactured sand found to have good gradation and good finish which is lacking in Natural sand. For 75% of Robosand replacement we can get better compressive strength than that of normal concrete [13]. It is observed that for 40% sand, 40% marble sludge powder, 20% quarry rock dust had the best compressive strength that is 38.66 N/mm^2 which means a total of 60% sand can be replaced by 40% marble sludge powder and 20% quarry rock dust [14]. Figure 3 shows that 28 days compressive strength is increased by 4.8% that is 34.7 N/mm^2 for the 40% replacement of sand by quarry dust as compared to referral concrete [15].

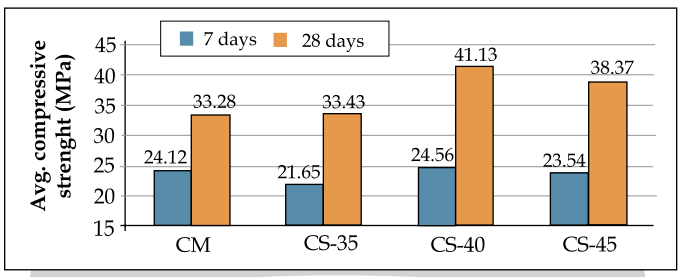

Figure 2. Compressive strength variation with different proportion of copper slag for 7 & 28 days [3]

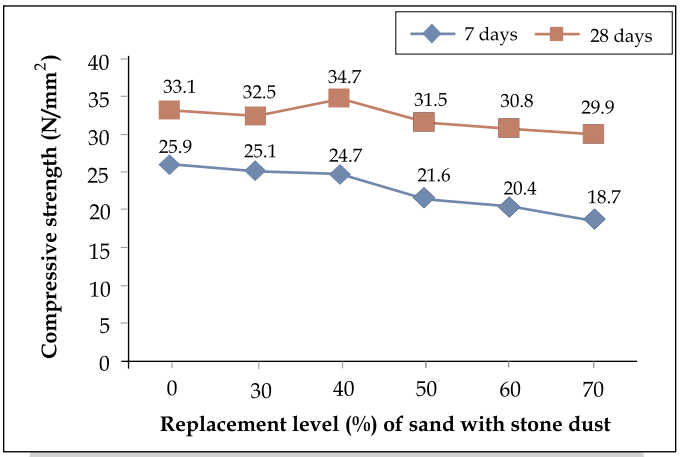

Figure 3. Variation of compressive strength with stone dust [15]

SPLIT TENSILE STRENGTH

Figure 4 shows that the 28 days average split tensile strength obtained for copper slag mix concrete shows 16.61% to 34.98% increase in split tensile strength when compared to control mix concrete [3]. It has been observed that the tensile strength at 25% replacement of cement with fly ash, GGBS, granite powder decreases by days of curing [5]. The split tensile strength of concrete with 60% replacement of natural sand by manufactured sand reveals higher strength as compared to reference mix [8]. According to experiment, it is observed that the split tensile strength of the concrete is seen high in 10-30% replacement ratio in both copper slag and quarry dust concrete mixes i.e., 3.55 to 3.32 N/mm^2 and 3.55 to 3.43 N/mm^2 [10]. The tensile strength were found to increase with increase in the percentage replacement of natural sand by fly ash upto 40% at elevated temperature of 200°C and thereafter decrease [12]. According to investigations for 50% quarry rock dust and 50% marble sludge powder had the best value of split tensile strength is 3.15 N/mm^2 [14].

FLEXURAL STRENGTH

According to Figure 5, the 28 days average flexural strength obtained for copper slag mix concrete shows 27.78% to 38.89% increase in flexural strength when compared to control mix concrete [3]. The flexural strength is more for all the proportions (30%, 40%, & 50%) of concrete mix that is 6.12, 6.11 and 6.58 N/mm^2 and this may be due to toughness of copper slag [4]. The flexural strength were found to increase with increase in the percentage replacement of natural sand by fly ash upto 40% at elevated temperature of 200°C and thereafter decrease [12]. Figure 6 shows that the maximum gain in flexural strength of 28 days is 6.80 N/mm^2 at 70% replacement level of sand by stone dust as compared to the control mix concrete [15].

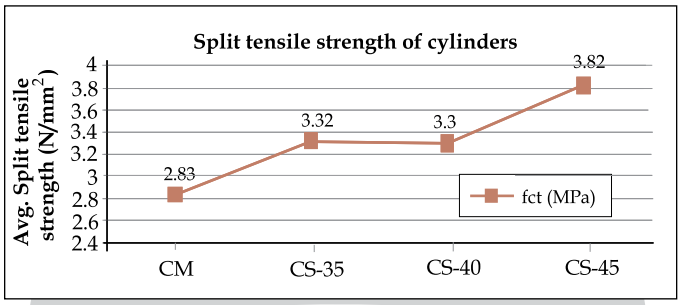

Figure 4. Split Tensile strength variation with different proportion of copper slag [3]

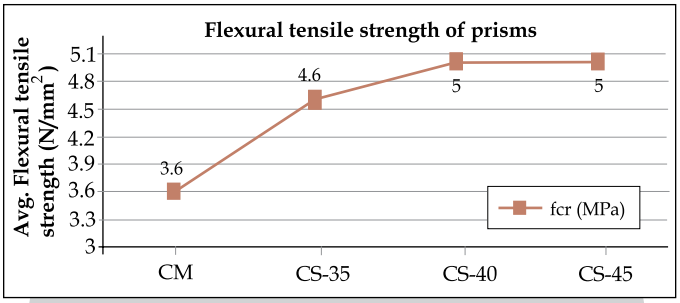

Figure 5. Flexural strength variation with different proportion of copper slag [3]

DISCUSSIONS

From the literature review, it can be observed that much research work has been carried out on concrete replacing fine aggregate by alternative sands. The experiments has been conducted on the mechanical properties of concrete for various percentage replacement of fine aggregates by alternative sands.

Limited information is available on concrete with different types of aggregate subjected to sustained elevated temperatures.

There may be chances of structures which may be subjected to accidental fire which may also affect the durability of the structures. Manufactured sand is been used extensively due to the non-availability of natural fine aggregates. The literature review does not provide sufficient information on concrete structures with M-sand subjected to elevated temperature. Hence much research work is needed to understand the effect on manufactured sand in concrete when exposed to elevated temperatures.

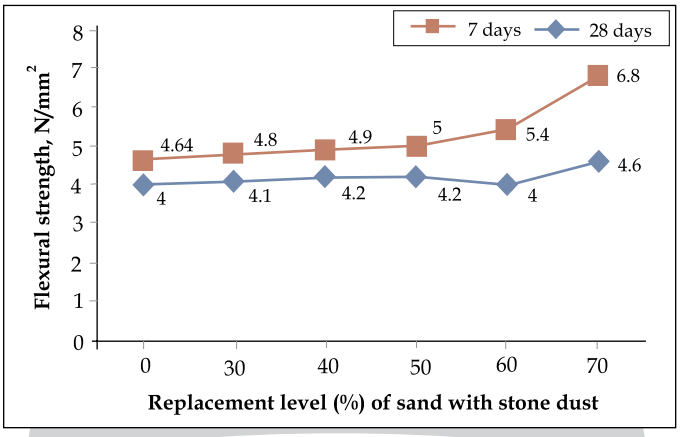

Figure 6. Variation of flexural strength with Stone Dust [15]

CONCLUSIONS

Based on the literature survey, the following conclusions can be made:

1. The compressive strength of cement mortar with 50% replacement of natural sand by manufactured sand reveals higher strength as compared to reference mix.
2. The compressive strength of various mixes of Copper slag, Granite powder, and Fly ash fiber in concrete at 28 days will be 51.8 N/mm^2.
3. The maximum gain in flexural strength of 28 days is 6.80 N/mm^2 at 70% replacement level of sand by stone dust as compared to the referral.
4. The flexural strength were found to increase with increase in the percentage replacement of natural sand by fly ash up to 40% at elevated temperature of 200°C and thereafter decrease.
5. The split tensile strength of the concrete is high in 10-30% replacement ratio in both copper slag and quarry dust concrete mixes at 28 days will be 3.55 to 3.32 N/mm^2 and 3.55 to 3.43 N/mm^2.

References

1. Nimitha, Vijayraghavan and A.S. Wayal, "Effect of Manufactured sand on Durability Properties of Concrete", *American Journal of Engineering Research*, Vol.02, Issue 12, pp.437-440, 2013.
2. C. K. Madheswaran, P. S. Ambily, J. K. Dattatreya , N. P. Rajamane, "Studies on use of Copper Slag as Replacement Material for River Sand in Building Constructions" *J. Inst. Eng. India Ser. A* (July–September 2014) 95(3), pp.169–177.
3. Deepak Gowda B., H.B.Balakrishna, "Experimental Study on Flexural Behavior of Reinforced Concrete Beams by Replacing Copper Slag as Fine Aggregate", *International Journal of Civil and Structural Engineering Research*, Vol.02, pp.97-103, 2014.
4. K.Sabarishri,V.Saichaitanya,S.Raguvaran,K.Sarathkumar,M. Mohankuamar,"Experimental Study on Strength Properties of High performance Concrete Using Copper Slag as a Partial Replacement of Fine Aggregate, *Journal of Chemical and Pharmaceutical Sciences*, Issue.8, pp.52-56, 2015.
5. K.Kayathri, C.Vignesh Kumar, M.Gohila Rani, K.Karthik, "Effect of Copper Slag, Fly Ash and Granite Powder as a Partial Replacement in Fine Aggregate", *International Journal of Innovative Research in science, Engineering and Technology*, Vol.3,No.5pp.439-443, 2014.
6. Mahesh Patel, P.S.Rao and T.N.Patel, "Experimental Investigation on Strength of High Performance Concrete with GGBS and Crusher Sand", *Indian Journal of Research*, Vol.3 No.4, pp.114-116, 2013.
7. M. C. Nataraja, G. N. Chandan and T. J Rajeeth, "Flow Properties of Cement Mortar Using Copper Slag as Fine Aggregate", *Journal of Civil Engineering Technology and Research*, Vol.02, No.01, pp.23-31, 2014.
8. Priyanka A.Jadhav, Dilip K.Kulkarni, "Effect of replacement of natural sand by manufactured sand on the properties of cement mortar", *International Journal of Civil and Structural Engineering*, Vol.03, Issue 03, pp.621-628, 2013.
9. Shweta Patil and K.B.Prakash, "Effect of Mineral Admixtures on the Resistance of Concrete Subjected to Elevated Temperatures-A Review", *International Journal of Advanced Technology in Engineering and Science*, Vol.02, Issue 12, pp.122-130, 2014.
10. P. Pradeep, Rama Mohan Rao. P, "Studies on influence of copper slag and quarry dust as fine aggregate replacement in concrete", *Singaporean Journal of Scientific Research*, Vol.06, Issue 02, pp. 89-94,2014.
11. Wakchaure M. R., Er. Shaikh A.P., Gite B.E. "Effect of Types of Fine Aggregate on Mechanical Properties of Cement Concrete", *International Journal of Modern Engineering Research*, Vol.02, Issue 05, pp.3723-3726, 2012.
12. Parvati V. K, Prakash K.B., "Feasibility Study of Fly Ash as a Replacement for Fine Aggregate in Concrete and its Behaviour under Sustained Elevated Temperature", *International Journal Of Scientific & Engineering Research*, Vol.04, Issue 05, pp.87-90, 2013.
13. Rachana MN and E.Ramesh Babu, "Experimental Investigation on Rob Sand as Replacement Material of Fine Aggregate in Normal Concrete", *International Journal of Advanced Technology in Engineering and Science*, Vol.02, No.07, pp.269-274, 2014.
14. RonakMalpani, Sachith Kumar Jegarkal, Rashmi Shepur, Ravi Kiran H. N, Veena Kumara Adi, "Effect of Marble Sludge Powder and Quarry Rock Dust as Partial Replacement for Fine Aggregates on Properties of Concrete", *International Journal of Innovative Technology and Exploring Engineering*, Vol.04, No.01 pp.39-42, 2014.
15. Sandeep Kumar Singh, Vikas Srivastava, V.C. Agarwal, Rakesh Kumar and P.K. Mehta, "An Experimental Investigation on Stone Dust as Partial Replacement of Fine Aggregate in Concrete", *Journal of Academia and Industrial Research*, Vol.03, No.05, pp.229-232, 2014.

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