

Effect of Percentage Variation of Silica Fume and Different Mixing Approach on Recycled Aggregate Concrete

Rina Kumari¹, N. Kisku², Dr. V. Pandey³

M.Tech. Final Year Student, Department of Civil Engineering, B.I.T Sindri, Dhanbad, India¹

Assistant Professor, Department of Civil Engineering, B.I.T Sindri, Dhanbad, India²

Professor & HOD, Department of Civil Engineering, B.I.T Sindri, Dhanbad, India³

ABSTRACT: The present paper work explores the efficiency of recycled coarse aggregates in the production of concrete in detail. It was observed from the preliminary investigation that the strength property of recycled aggregate concrete is lower than the natural aggregate concrete. In the present investigation, recycled coarse aggregate has used which obtained from a laboratory as a waste in addition to silica fume partially replaces in percentage 0%, 5%, 10% and 15% of cement by weight. Its Compressive strength, split tensile strength and flexural strength test results for M30 grade of concrete prepared through recycled coarse aggregate and silica fume by using two different types of mixing approach called “Normal Mixing Approach (NMA)” and “Pre-soaked slurry Two Stage Mixing Approach (TSMA_{SC})” then compared their results. Strength of concrete increased on use of silica fume in both mixing approach, but the rate of gain of strength is more in pre-soaked slurry two stage mixing approach. From the complete investigation, results indicate that one of the way to utilized recycled aggregate in structural concrete by incorporating 5% silica fume in RAC in pre-soaked slurry two stage mixing approach.

KEYWORDS: Silica Fume, Recycled Aggregate, Recycled Aggregate Concrete.

I. INTRODUCTION

The aggregate obtained from recycling of construction and demolition waste is termed as ‘Recycled Aggregate’. Recycled aggregate is defined as an aggregates resulting from the processing of material previously used in construction industries. Rapidly increased construction industry throughout the world caused large scale depletion of natural aggregate which contributes large amount of construction and demolition waste. The increased amount of construction & demolition waste going to landfill sites are causing significant damage to the environment. The utilization and recycling of C&D waste in new construction industry become more important, due to the greater awareness of environmental protection, continue depletion of NA, scarcity of land for disposal of C&D waste and increased disposal cost of waste material. In construction work, aggregates and water are nature dependent material. Scarcity of these natural occurring materials needs to find other alternative sources. One of the alternatives of coarse aggregate is recycled concrete aggregate obtained from construction works. As we know, concrete is a composite and leading construction material for more than a century. Neville et al. [2003] reported that the estimated global production of concrete is at an annual rate of 1 m³ (approximately 2.5 tones) per capita. According to Tsung et al. [2006] the global consumption of natural aggregate will be in the range of 8-12 billion tones after 2010.

In-spite of various advantages the use of RCA is limited because of their low properties. RCA mainly differ from NA in that they are composed of two different materials: NA and cement mortar attached. Cement mortar is the reason of the worse properties of RCA. G.C Lee et al. [2013] showed that RA is highly heterogeneous and porous, as well as contained a high content of impurities. The heterogeneity affects the characteristics of RA and these properties have a negative influence on RAC quality such as reduction of the compressive strength, tensile strength due to the porosity of

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

concrete and a weak aggregate matrix interfacial bond. In this project, various laboratory waste used and silica fume will be used further for increasing the strength of RA in concrete.

Silica fume is a highly reactive pozzolanic material composed of silicon dioxide (SiO_2) in non-crystalline form. It is light to dark grey or bluish green-grey colour powder produced by an electric arc furnace drying the manufacture of silicon or ferrosilicon alloy. It has a spherical like fly ash, but it is 100 times smaller, with an average size diameter $0.1\mu\text{m}$. It is a byproduct of the smelting process in the silicon and ferrosilicon industry. The reduction of high-purity quartz to silicon at temperatures up to $2,000^\circ\text{C}$ produces SiO_2 vapors, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica. Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent.

II. RELATED WORK

Regarding shape and texture Ravindrarajah and Tam et al. [2005] reported that, the particle shape of recycled aggregate is angular and surface texture is more rough and porous. Malhotra et al. [2005] has made observations contrary to the above indicating a more rounded shape and smooth texture for recycled aggregate. Zega et al. [2010] studied the influence of different types of coarse aggregate and w/c ratio on the properties of recycled aggregate and grading of RCA does not depend on the w/c ratio of the concrete from which the recycled aggregate derived and the shape and texture of parent concrete aggregate. Gonzalez-Fontebao and Martinz-Abella et al. [2008] was reported that 4 – 12 mm and 10 – 25 mm size of recycled aggregate having density 11.4% and 10.1% lower than the natural aggregate. Yang et al. [2008] observed that water absorption and adhere cement paste on the surface of the aggregate is directly proportional to each other.

Poon et al. [2007] observed that recycled aggregate concrete made with air dried recycled aggregates resulted in higher initial slump and longer period to come to zero slump when compared to normal concrete. Ozgur cakir, Omer Ozkan Sofyanli et al. [2014] observed that compressive strength decreased with increase in silica fume content, but compressive strength loss of concretes containing recycled aggregate was less than the concrete containing natural aggregate at early age due to silica fume usage and continuous and significant improvement in tensile splitting strength of recycled aggregate with time.

Padmini et al. [2009] examined that at a given compressive strength, the tensile strength of RAC made with RCA was lower than of normal concrete. This difference was lower when compressive strength of concrete is low. Tabsh and Abdelfatah et al. [2009] observed that in his study that the tensile strength of RAC depends on the strength of concrete from which the RCA was derived and it was more significant in case of lower strength concrete.

Sato et al. [2007] studied the flexural behavior of reinforced beams made with recycled aggregate under static and sustained loadings. Yang et al. [2008] demonstrated that with the increase in relative water absorption capacity of recycled aggregates flexural strength of RAC also decreased.

Tam, V.W.Y, Gao, X.F. et al. [2005] introduced two stage mixing approach for the improvement of ITZ between aggregate and mortar in concrete, in which thin layer of cement fills the cracks and pores as a result of which ITZ becomes dense and strong and improved mechanical properties of concrete. Tam et al. [2005] in their study, proposed a two stage mixing approach for the improvement of ITZ between aggregate and mortar in RAC. In this approach, the first stage mixing water was used to form a thin layer of cement on the surface of the recycled aggregate, which penetrates in to the old pores and cracks and gets filled the voids and cracks thereby the ITZ becomes dense and strong which improve the mechanical properties of RAC.

Silica fume is one of the supplementary cementitious materials used for high strength concrete. Its addition to concrete mixtures results in lower permeability, bleeding, and porosity, because their silicon dioxides (SiO_2) react and consume calcium hydroxide which is produced by the hydration of cement. Basic advantages behind silica fume reaction are: lime consuming activity, smaller pore size distribution, and lower heat of hydration.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

III. MATERIAL AND THEIR TESTS

Material used:

A) CEMENT & SILICA FUME - Portland Slag Cement (PSC) (IS: 455) was used in the entire experimental work. The cement used in test is manufactured by Lafarge Concrete Co., India. The cement was stored in bags and kept minimum exposure from humidity. The cement was uniform in colour i.e light grey colour and was free from any hard lumps and chemically analyzed from laboratory. Densified fused silica fume dark grey in colour, used in this work collected from Krishna Udyog, Kolkata - West Bengal. The chemical composition of cement and silica fume tabulated in Table 1.

Table 1: Chemical composition of cement and silica fume

Ingredients	% content in cement	% content in silica fume
SiO ₂	28.17	85.725
AL ₂ O ₃	14.10	6.92
Fe ₂ O ₃	1.64	0.535
CaO	43.43	2.81
MgO	5.93	0.825
P ₂ O ₅	0.03	1.29
SO ₃	0.67	0.21
Na ₂ O ₃	0.43	0.0
TiO ₂	0.72	0.235

B) NATURAL FINE AGGREGATE - The sand used for experimental programme was procured from Barakar River, Dhanbad and conformed to grading zone II as per IS: 383-1970. The sand was sieved through 4.75 mm sieve to remove any particle greater than 4.75 mm. Fig. 1 given below shows maximum and minimum of natural aggregate limits according to IS:383-1970 and NF shows the gradation of natural aggregate used in this experiment. Fig. 1 shows a graph between maximum, minimum limits of natural fine aggregate and NF used in this experiment according to IS:383-1970.

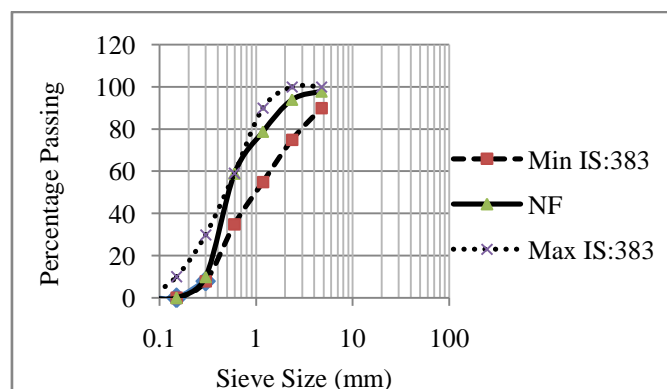


Fig. 1 Gradation of natural fine aggregate

C) RECYCLED COARSE AGGREGATE - The quality of recycled aggregate obtained from waste concrete is different from the natural coarse aggregate due to adhere mortar on recycled coarse aggregate, which has used in entire test. The maximum size of coarse aggregates 20mm, were used in the work which obtained from sieving through 20mm, 10mm, 4.75mm sieve and removed all aggregate passing through 4.75mm sieve as per IS: 383-1970 without

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

providing any type of surface treatment recycled coarse aggregate were used in testing purpose. Physical and mechanical properties of recycled coarse aggregate are tabulated in Table 2.

Table 2: Properties of recycled coarse aggregate

TEST PERFORM	RESULT
Sieve Analysis	20 mm size
Fineness Modulus	6.92
Specific Gravity (SSD)	2.66
Moisture Content	1.24%
Water Absorption (SSD)	2.8%
Impact Value	22.37%
Crushing Strength	27.11%
Bulking of Aggregate in loose state	1.24 gm/cm ³
Bulking of Aggregate in dense state	1.44 gm/cm
Flakiness Index	15%

Fig. 2 shows a graph between maximum, minimum limits of natural coarse aggregate and RCA used in this experiment according to IS:383-1970.

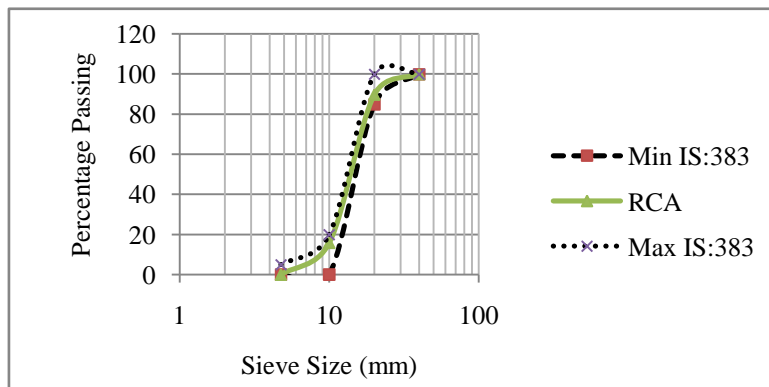


Fig. 2 Gradation of recycled coarse aggregate

IV. RESULT AND DISCUSSION

For each concrete mixture, three 150 mm cubes, 150x300 mm cylinders and 100x500 mm beams were casted. The cubes, cylinders and beams were used to determine the compressive, split tensile and flexural strength. Compressive, tensile and flexural tests were carried out for all concrete mixtures and details of results were shown below with bar charts. 100% of RCA were checked for only 0%, 5%, 10%, 15% silica fume replacement in “Normal Mixing Approach (NMA)” and “Pre-soaked Slurry Two Stage Mixing Approach (TSMA_{SC})” for M30 grade of concrete. The result were analyzed and systematically represents the influence of silica fume on properties of recycled aggregate concrete using constant w/c ratio of 0.43 throughout the experiment and results are shown here in the form of bar chart.



Fig. 3(a) Flow chart of normal mixing approach

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Flow chart given in Fig. 3(a) gives the procedure used for making of concrete by normal mixing approach. It is most common approach and widely used in construction industries.

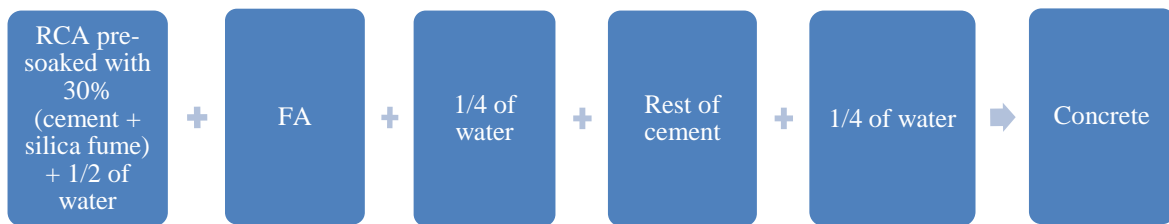


Fig. 3(b) Flow chart of pre-soaked slurry two stage mixing approach

Fig. 3(b) shows a flow chart of pre-soaked slurry two stage mixing approach for making of concrete. This is the new technique for concrete making and research work on this approach is still in progress.

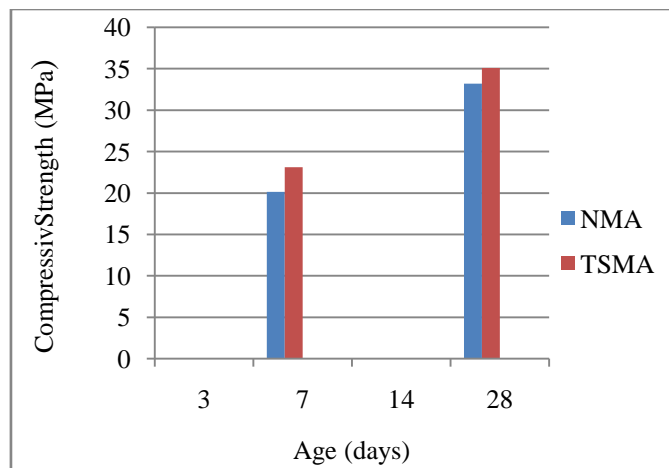
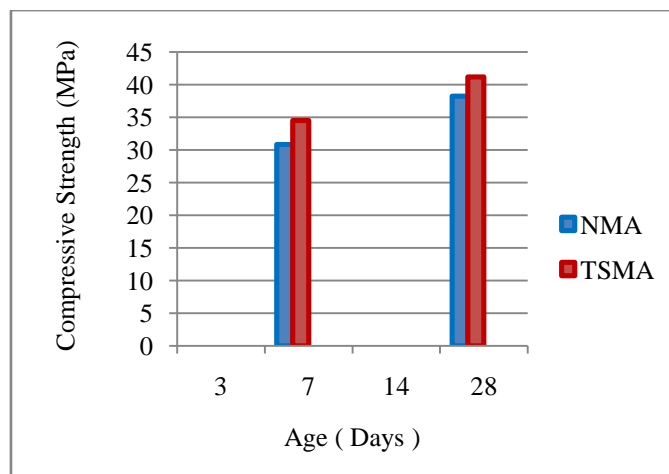


Fig. 4(a) Compressive strength of concrete without using SF in NMA and pre-soaked slurry TSMAC



International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Fig. 4(b) Compressive Strength of concrete using 5% SF in NMA and pre-soaked slurry TSMAsc

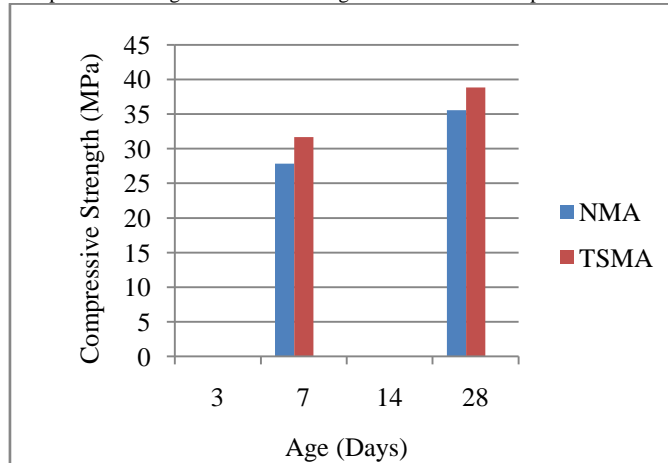


Fig. 4(c) Compressive strength of concrete using 10% SF in NMA and pre-soaked slurry TSMAsc

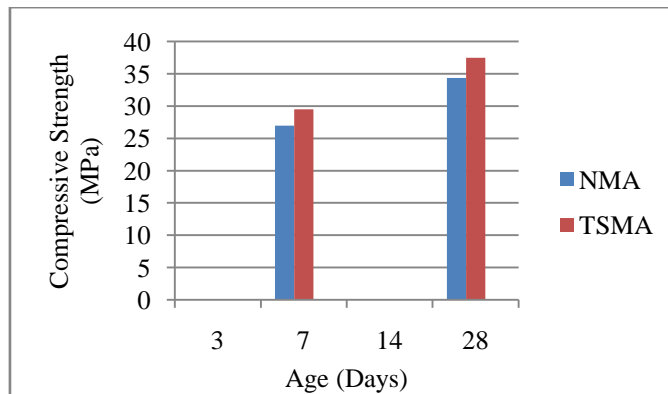


Fig. 4(d) Compressive strength of concrete using 15% SF in NMA and pre-soaked slurry TSMAsc

Fig. 4(a), fig. 4(b), fig. 4(c), fig. 4(d) shows the compressive strength of concrete at 7 days and 28 days in both mixing approach. Fig. 4(a) shows compressive strength of concrete without using silica fume as a partial replacement of cement in both mixing approach. Similarly fig. 4(b), fig. 4(c), fig. 4(d) compare the compressive strength of concrete at 7 and 28 days using 5%, 10% and 15% of silica fume as a partial replacement of cement in both mixing approach.

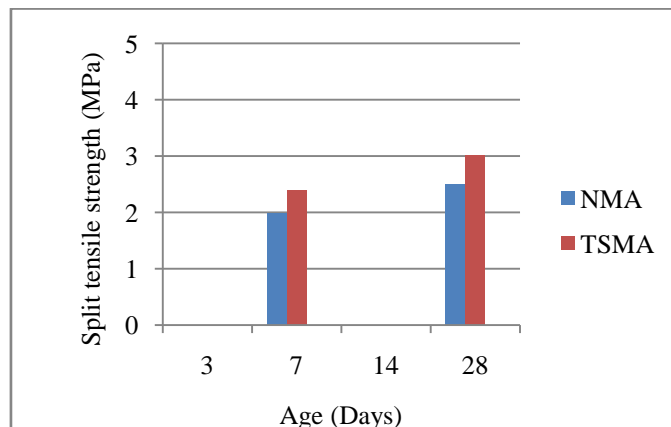


Fig. 5(a) Tensile strength of RAC using 0% SF in NMA and pre-soaked slurry TSMAsc

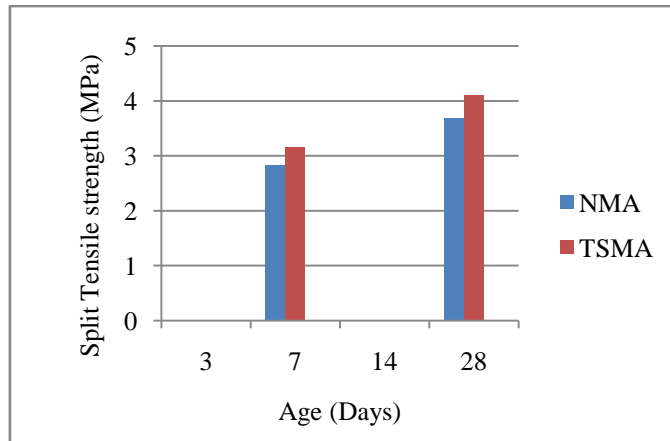


Fig. 5(b) Split tensile strength of RAC using 5% SF in NMA and pre-soaked slurry TSMA_{sc}

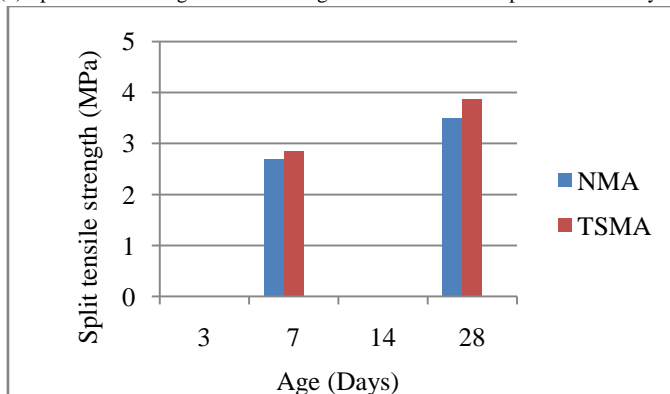


Fig. 5(c) Split tensile strength of RAC using 10% SF in NMA and pre-soaked slurry TSMA_{sc}

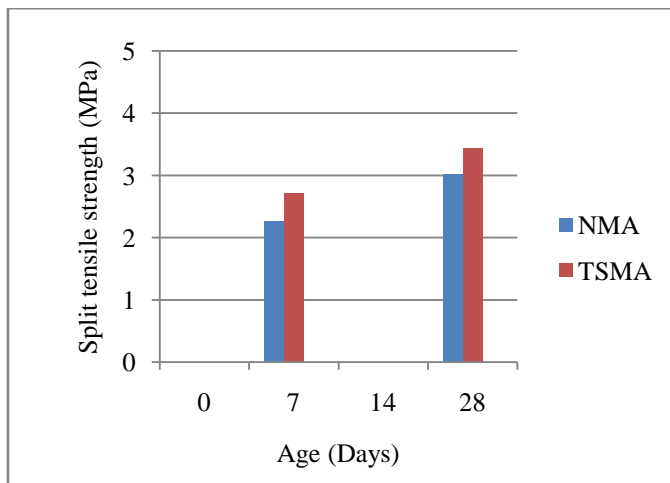


Fig. 5(d) Split tensile strength of RAC using 15% SF in NMA and pre-soaked slurry TSMA_{sc}

Fig. 5(a), fig. 5(b), fig. 5(c), fig. 5(d) shows the split tensile strength of concrete at 7 days and 28 days in both mixing approach. Fig. 4(a) shows split tensile strength of concrete without using silica fume as a partial replacement of cement in both mixing approach. Similarly fig. 4(b), fig. 4(c), fig. 4(d) compare the split tensile strength of concrete at 7 and 28 days using 5%, 10% and 15% of silica fume as a partial replacement of cement in both mixing approach.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

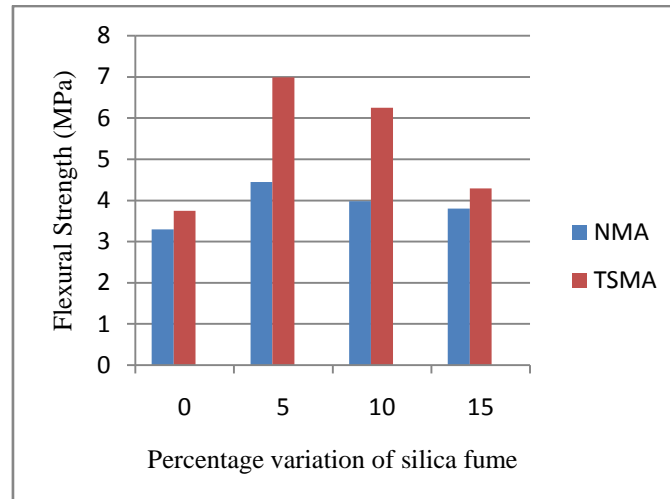


Fig. 6 Flexural strength of concrete with percentage variation of silica fume in both mixing approach

Fig. 6 shows the flexural strength of concrete at 28 days in both mixing approach. Fig.6 also compare the flexural strength of concrete with and without using silica fume as a partial replacement of cement.

V. CONCLUSION

In this experimental work detailed and systematic procedure is carried out for different properties of RCA which is obtained from the laboratory as a waste. The influence of different percentage of silica fume with 100% recycled coarse aggregates are investigated by normal and pre-soaked slurry two stage mixing approach on the properties of fresh and hardened RAC. The following conclusions may be drawn on the basis of the test results are given below.

1. Care should be taken by manual crushing of recycled coarse aggregate otherwise appropriate grading of aggregate not achieved and may lead to greater or finer particles.
2. Porous and rough nature of surfaces generated due to the presence of adhere mortar on recycled coarse aggregate help in developing better bond although water requirement is more than the natural aggregate for achieving requisite workability. Due to the adherence of mortar the specific gravity and bulk density of RCA also reduced in comparison to natural aggregate.
3. In recycled aggregate concrete, workability is less than the natural aggregate concrete. The reason behind it is due to porous and rough surface texture of recycled coarse aggregate.
4. Workability of recycled aggregate concrete is reduced rapidly when concrete prepared by using silica fume, due to finer particle size of silica fume.
5. It is observed that use of recycled aggregate without any surface treatment shows lower performance level in terms of loads but addition of silica fume increased the performance of RAC.
6. The rate of gaining strength in both mixing approach is higher in earlier days than the rate of gaining of strength in 28 days.
7. Recycled aggregate concrete have lower value of compressive, tensile and flexural strength but after addition of silica fume, it enhance all mechanical properties of concrete in both mixing approach.
8. During preparation of concrete high water consumption was found out with recycle coarse aggregates due to surface texture and adhere mortar which further increased when silica fume is used as a partial replacement of cement.
9. Flakiness index is little higher than natural coarse aggregate.
10. 5% SF, as a partial replacement and 100% RCA gives better result among all the combinations in both mixing approach.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

REFERENCES

- [1] Bureau of Indian Standards, Indian Standard methods of test for aggregates for concrete part I, III and IV. IS: 2386, New Delhi, 1963.
- [2] Bureau of Indian Standards, India Standard specification for coarse and fine aggregates from natural sources for concrete. IS: 383, New Delhi, 1970.
- [3] Bureau of Indian Standards, Indian Standards recommended guide line for concrete Mix Design. IS: 10262, New Delhi, 2009.
- [4] Tsung, Y.T., Yuen Y. & Chen L.H. " Properties of HPC with recycled aggregates" in Cement and Concrete Research journal, 36(5) pp. 943-950, 2006.
- [5] Ravindrarajah, R. Sri, and C. T. Tam. "Properties of concrete made with crushed concrete as coarse aggregate." Magazine of Concrete Research 37.130 (2005): 29-38, 2005.
- [6] Malhotra V. M. "Recycled Concrete – A New Aggregate", Canadian Journal of Civil Engineering – 5, pp42 – 52, 2005.
- [7] Zega, C. J., Villagran-Zaccardi, Y. A., & Di Maio, A. A. "Effect of natural coarse aggregate type on the physical and mechanical properties of recycled coarse aggregates" in Materials and structures journal, 43(1-2), 195-202, 2010.
- [8] González-Fontebao, B., & Martínez-Abella, F. "Concretes with aggregates from demolition waste and silica fume materials and mechanical properties" in Building and Environment journal, 43(4), 429-437, 2008.
- [9] Yang, K. H., Chung, H. S., & Ashour, A. F. "Influence of type and replacement level of recycled aggregates on concrete properties". ACI Materials Journal, 105(3), 2008.
- [10] Poon, C. S., Kou, S. C., & Lam, L. "Influence of recycled aggregate on slump and bleeding of fresh concrete" in Materials and Structures journal, 40(9), 981-988, 2007.
- [11] Sato, R., Maruyama, I., Sogabe, T., & Sogo, M. "Flexural behavior of reinforced recycled concrete beams". Journal of Advanced Concrete Technology, 5(1), 43-61.
- [12] Padmini, A. K., Ramamurthy, K., & Mathews, M. S. "Influence of parent concrete on the properties of recycled aggregate concrete". Construction and Building Materials journal, 23(2), 829-836, 2009.
- [13] Tabsh, S. W., & Abdelfatah, A. S. "Influence of recycled concrete aggregates on strength properties of concrete". Construction and Building Materials journal, 23(2), 1163-1167, 2009.
- [14] Tam, V. W., Gao, X. F., & Tam, C. M. "Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach". Cement and Concrete Research journal, 35(6), 1195-1203, 2005.
- [15] Tam, V. Y., Gao, X. F., & Tam, C. M. "Comparing performance of modified two-stage mixing approach for producing recycled aggregate concrete". Magazine of Concrete Research, 58(7), 477-484, 2006.
- [16] Çakır, Ö., & Sofyanlı, Ö. Ö. "Influence of silica fume on mechanical and physical properties of recycled aggregate concrete". HBRC Journal, 2014.