Studies on Mechanical Properties of SCC with Construction and Demolition Waste as Coarse and Fine Aggregates

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***Abstract* - India being a fast growing economy has caused a boost in the construction industry. Increase in construction activities has resulted in accumulation of construction and demolition waste. These waste materials like mortar, concrete, tiles, glass, wood etc being non-biodegradable lead to pollution and also waste of land resource when used as dumping yards. As a solution to this problem these waste generated must be reduced, reused and recycled. For this purpose the coarse and fine aggregate content in SCC is attempted to be replaced by crushed construction and demolition waste.**

The objective of the research project is to study the mechanical properties of SCC when the fine aggregates are replaced by C&D waste in different percentages and hence to find the optimum replacement. Two cases will be investigated with five different types of C&D waste ie concrete waste, mortar waste, crushed tiles and manufactured sand as fine aggregate and recycled concrete aggregate as coarse aggregate where in one only the fine aggregate will be replaced where as in the second both coarse and fine aggregate will be replaced simultaneously .

Keywords: Self-Compacting Concrete, C&D waste, Fresh Properties, Hardened Properties

I. INTRODUCTION

As construction activities increase, the demand for raw materials also increase and so does the waste generated. It has been estimated that the total solid waste produced in India is about 96 million tons out of which 14.5 million tons is construction waste alone. The estimated construction and demolition waste in the year 2010 was 24 million tons **[1]**. This construction and demolition waste can be characterized into major and minor components depending on its volume availability. Major components include cement, concrete, steel bricks, rubble, cement mortar and wood and minor components consist of pipes, electrical fixtures, tiles, panels, glass etc. **[2]**. Certain C&D waste when crushed to required size may have the potential to replace conventional construction materials like cement, coarse or fine aggregates. Keeping this in mind the present experimental investigation explores the use of a combination of different C&D waste as replacement for aggregates in different replacement levels in self-compacting concrete.

II. EXPERIMENTAL PROGRAMME

2.1 Materials

The materials used for this experimental investigation are all subject to the basic material tests for the purpose of their characterization. The cement used was OPC 43 grade with specific gravity of 3.28. Fly ash with specific gravity (SG) of 2.15 was used to partially replace cement. Natural River sand with SG 2.53 conforming to zone II and natural coarse aggregate of 20mm down size with SG 2.6 are used. The material used as replacement for fine aggregate M sand, mortar, concrete and ceramic waste are mixed together in equal proportions of 25% each and the mix then was subject to material tests. It was found to conform to zone II classification with SG of 2.54. Recycled concrete aggregate used as replacement for coarse aggregate was crushed to 20mm downsize and has a SG of 2.43. For ensuring good workability, flowability and segregation resistance super plasticizer Glenium B233 and viscosity modifying agent Glenium Stream 2 are used in this research work.

2.2 Mix Design

The mix calculations for SCC are done using Nan Su method. Three w/c are considered keeping the remaining quantities constant and the mix with optimum workability and compressive strength is chosen. The superplasticizer and VMA content was fixed based on trial and error. The same mix design was used for all replacements with only a variation in SP content for some replacement levels. The specimen calculations and trial mix details for M_{30} SCC are as shown in Table 2.1 and Table 2.2 respectively.

Table 2.1: Specimen calculations

Cement	214.28 kg/m^3
Fly ash	208.12 kg/m^3
FA	970.35 kg/m^3
CA	779.59 kg/m^3
Water	135.16 liters/m^3
HRWRA	1.3%
VMA	0.18%

Table 2.12: Details of trial mixes

Sl no	mix w/c	slump flow	T50cm	V funnel	L box	U box	Compressive strength 7days
1	0.3	687	4.8	6	0.91	12	23.41
2	0.32	710	4.2	4.8	0.93	5	22.96
3	0.35	730	3.9	4	0.9789	5	20.98

2.3 Test Specimens and Testing

For the present investigation C & D Waste namely M sand, concrete, mortar and ceramic waste was collected from locally available sites. They materials were manually crushed to required size using a rammer and sieved through a 4.75mm sieve for fine aggregate and 20mm sieve for coarse aggregates. The crushed fine waste namely concrete, mortar and ceramic waste and M sand were mixed in equal proportions and used in 0, 30, 50, 70 and 100% replacement levels for river sand along with no replacement for coarse aggregate for the first set. Analyzing the results obtained another set of investigations were conducted where coarse aggregate was replaced by recycled concrete aggregate by 30% along with 0, 30 and 50% replacement of river sand by four crushed C&D waste mixed in equal proportions along with a slight increase in the SP for better workability. To understand the mechanical properties of each of these replacements a total of 72 cubes, 24 cylinders and 24 prisms divided into 8 different series of 9 cubes, 3 cylinders and 3 prisms each were cast and tested at 3, 7 and 28 days of curing. The mix with no coarse or fine aggregate replacement was considered the reference or control mix to which comparisons were drawn.

The dry ingredients were first mixed thoroughly after which water was added in three sets of 70% water only, 20% water with SP and remaining 10% water with VMA. With each addition of water the concrete was thoroughly mixed. Tests on fresh properties of concrete were conducted immediately after mixing. Slump flow, V funnel, L box and U box test were carried out and results were tabulated. The concrete was then cast into cubes, cylinders and prisms and demoulded after 24 hours. The specimens were then cured for the required days before testing for compressive, split tensile and flexural strength.

III. RESULTS AND DISCUSSION

1.1 workability results

The results of the different workability tests conducted in comparison to the prescribed limits for all the specimens are tabulated below in Table 3.1

Table 3.1: Workability test results

Sl no.	Mix	Slump Flow (mm)	T_{50} (sec)	V funnel (sec)	L box (h2/h1)	U box (diff. in height)
1.	Prescribed limits	600-800	2-7	4-12	0.8-0.9	0-30
2.	CA 0% FA 0%	710	4.2	4.8	0.93	5
3.	CA 0% FA 30%	682	5.4	8.3	0.905	13
4.	CA 0% FA 50%	700	5	7.6	0.912	9
5.	CA 0% FA 70%	670	7.3	10.9	0.9048	12
6.	CA 0% FA 100%	680	7.6	13.1	0.8947	15
7.	CA 30% FA 0%	765	2	6.3	0.9789	8
8.	CA 30% FA 30%	740	5.24	10.2	0.9578	5
9.	CA 30% FA 50%	775	4.18	8.5	0.9789	18

From the workability results it was observed that all the mixes were well within the limits set for SCC. It was also observed that as the replacement level increased the workability decreased with an exception of FA 50% of the CA 0% series which had better workability than the rest of the replacement levels. The CA 30%serieswith increased SP of 1.5% also showed a similar trend with FA 50% exhibiting best workability.

1.2 compressive, split tensile and flexural strength test

The mechanical strength of different test specimens was conducted and the results are as shown in Table 3.2.

Table 3.2: Average strength test results for 0% and 30% CA replacement series

Mix	28day Compressive Strength (MPa)	Split Tensile Strength (MPa)	Flexural strength (MPa)
codal provisions	30	3.06	3.834
Control mix-0%	38.22	3.183	3.22
CA0% FA30%	34.96	3.29	3.99
CA0% FA50%	35.56	3.19	3.84
CA0% FA70%	30.22	3.29	3.82
CA0% FA100%	30.81	3.18	3.74
CA30% FA0%	36.59	3.71	4.71
CA30% FA30%	43.56	3.36	3.93
CA30% FA50%	40.03	3.25	3.85

It was observed that the compressive strength of all the replacement levels of the CA 0% series was lower than that of the control mix. The strength was observed to reduce with increase in replacement levels with an exception of FA 50% of the CA 0% series which was the most optimum mix for that series. It was also observed that the mixes with both coarse and fine aggregate replaced exhibited better strength when compared to the mixes with only fine aggregate replacement and maximum strength was observed for CA 30% with FA 50% replacement. For all the replacement levels of the CA 0% series the split tensile and flexural strength obtained are lower than that of the control mix but in case of CA 30% series they are higher.

Comparing values obtained experimentally to codal standards it can be observed that compressive and split tensile strength obtained for all replacement levels was higher than the compressive and split tensile strength specified for M30 grade concrete in the code. A similar trend was observed for the flexural strength results except for in the case flexural strength of 70 and 100% FA replacement levels for the CA 0% series who's values are 0.365 and 2.45% lower than that of those prescribed in codal provisions.

From the studied literature we can observe that, **Hemalatha B.R et al. [2]** have found that the optimum percentage replacement of construction and demolition waste is 50% which was found to be similar to the results obtained in the present investigation. In the paper by **A Seeni et al [5]** they have found that for replacement of coarse aggregate upto 30% the strength results are better than concrete strength with 0% coarse aggregate replacement which is again similar to the results obtained from the present investigation. **V. A. Dakwale [3]** in his paper has found that replacement of river sand by ceramic waste by 30% and in the paper by **P Suganthy et al [12]** they have found that replacement of sand by crushed fire bricks by 25% replacement levels gives best results whereas in the present investigation optimum results are obtained at 50% replacement levels when compared to the rest of the replacements. **Prashanth O Modani [9]** in his paper has found that sand when completely replaced by glass powder and **S Keerthinarayana [14]** found that complete replacement of sand by stone dust exhibited better results when compared to that of the control specimen, but in the present investigation all replacement levels exhibited lower strength when compared to control specimen.

A comparison of the strength gain for different replacement specimens of the CA 0% series was shown in the Figure 3.1, it was observed that for all the replacement levels around 40-50% and 50-60% of the strength at 28 days was attained by 3 and 7 days respectively. In case of 70% replacement the initial strength gain was higher than the other replacements being 62.3 and 73.6% of the 28 day strength attained at 3 and 7 days respectively. But it was lower at 28 days.

A comparison of the strength gain for different replacement specimens of the CA 30% series is shown in the Figure 3.2, it was observed that for all the replacement levels around 50-60% and 60-70% of the strength at 28 days was attained by 3 and 7 days respectively. In case of 50% replacement the initial strength gain at 3 and 7 days is higher compared to the other but lower at 28 days.

A comparison of the 28 day compressive strength for all the replacement levels of the CA 0 and 30% series are shown in Figures 3.3 and 3.4 respectively. It is observed that in the CA 0% series maximum strength was obtained for the control mix and 50% FA replacement was found to be optimum. whereas for the CA 30% series 50% replacement was found to be maximum and also greater than that of the control mix.

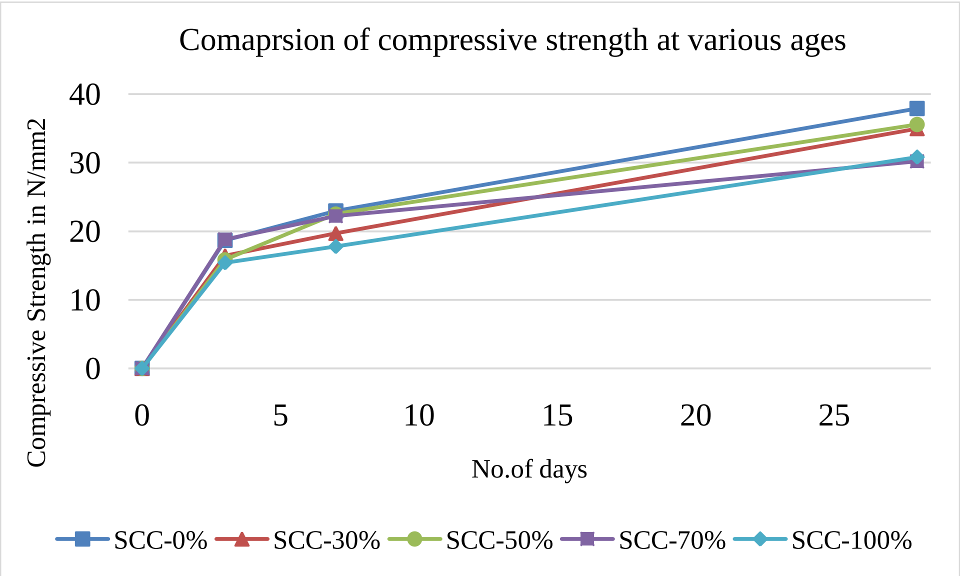

Figure 3.1: Graph showing strength gain over time

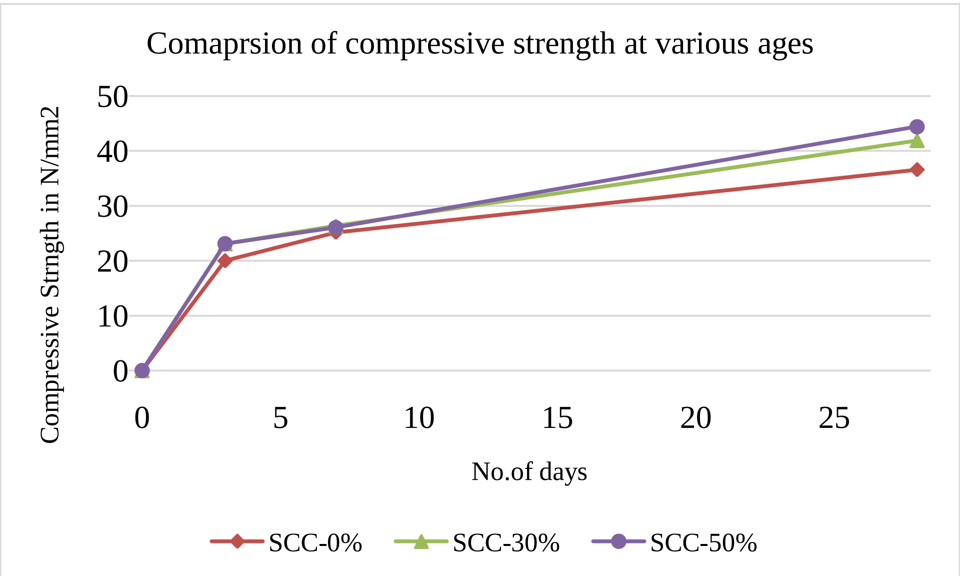

Figure 3.2: Graph showing strength gain over time

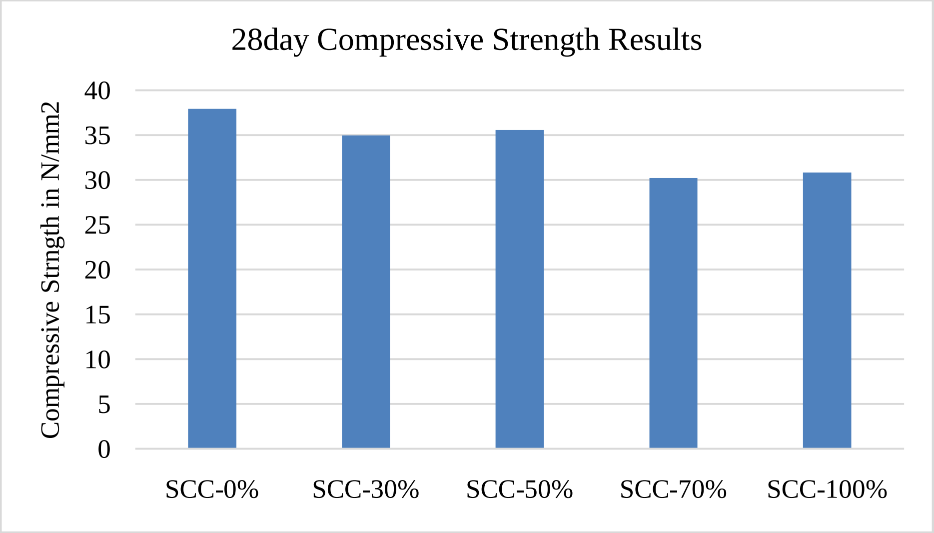

Figure 3.3: 28 day compressive strength results for CA 0% series

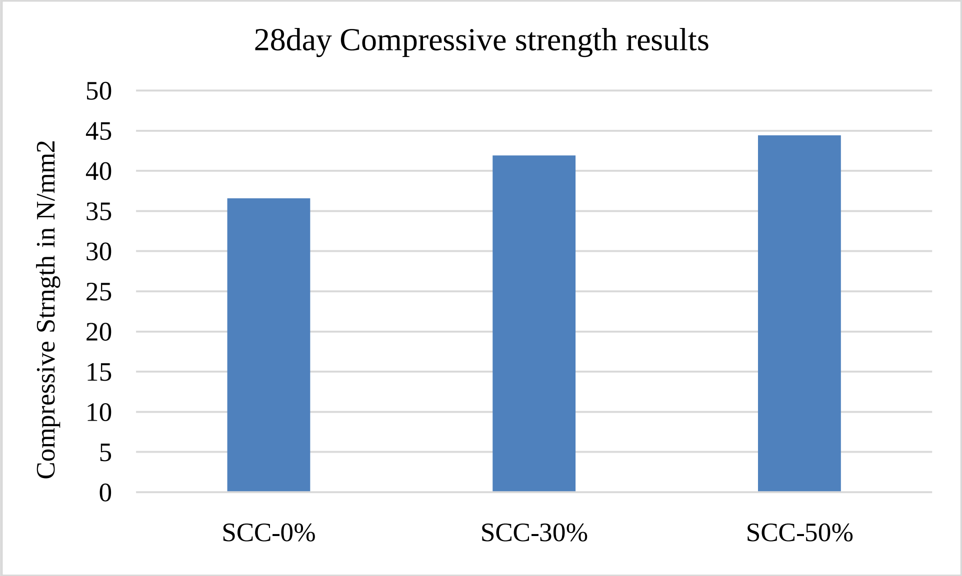

Figure 6.17: 28 day compressive strength results for CA 30% series

IV. CONCLUSIONS

The current experimental investigation was carried out to understand the effect of replacement of coarse and fine aggregates by waste material on the fresh and hardened properties of SCC. This attempt was made in order to understand the potential reuse of waste materials thus reducing the need of disposing C&D waste. Based on the experiments conducted and the observations made during the present investigation the following conclusions were drawn,

1. Characterization of material properties of the C&D waste to be used as replacement have been done and results obtained are compared to the natural materials to be replaced.
2. The specific gravity of the aggregates was expected in the range 2.5 to 3.
3. The specific gravity of natural sand was observed to be 2.53 with zone II gradation.
4. Natural coarse aggregate used has a specific gravity of 2.606 whereas the specific gravity of recycled coarse aggregate is 2.43 which was slightly below the expected limit.
5. In case of mortar waste the calculated specific gravity was 2.73 which is within the range and it was observed to conform to zone II gradation except for the 150µ size which is 30% higher than the zone II upper limit for that particular sieve size.
6. The specific gravity of M sand is 2.55 which was within the range and it is observed to conform to zone II gradation except for the 150µ sieve size which is 72% higher than the zone II upper limit for that size.
7. In case of ceramic waste the calculated specific gravity was 2.46 which was slightly lower than expected value and it is observed to conform to zone II gradation except for the 1.18mm size which is 24.36% lower than the zone II lower limit for that sieve size.
8. In case of concrete waste the calculated specific gravity was 2.74 which was within the range and it was observed to conform to zone II gradation except for the 1.18mm size which is 21.45% lower than the zone II lower limit for that size.
9. When all the materials to be used as replacement for river sand are mixed together in equal proportions the specific gravity of the mix obtained is 2.54 which was within the expected range for specific gravity for aggregates.
10. It is observed that by mixing the wastes in equal proportions (25% each) Zone II characterization was obtained which is same as that of river sand.

11. Nan-Su method used for calculation of mix design was simple and material quantities can be easily calculated. Packing factor being key for the calculation was found to be 1.14 by trial and error for 53% fine to all in aggregates ratio.
12. SP and VMA dosage were fixed based on workability requirement which were 1.3 and 0.18% respectively for the 0% CA replacement range and 1.5 and 0.18% for the 30% CA replacement range.
13. In case of SCC the design mix was fixed based on both workability and compressive strength results which in this case was obtained from the 0.32 w/c set.
14. It is observed that both SP and VMA are to be added to the mix after mixing them with water separately and each has to be mixed for a considerable amount of time to ensure uniform mixing.
15. As the replacement levels increased the workability of the mix were observed to reduce.
16. Workability results for 50% replacement levels for fine aggregates of the 0% CA series are observed to be best among all other replacements in that series.
17. Observing the workability results of 0% CA with 0, 30, 50, 70 and 100% FA replacement levels the SP dosage was increased to 1.5% from 1.3%.
18. Mixes with 30% CA replacement exhibited good workability with maximum workability for the 50% FA replacement mix.
19. SCC cubes were to be demoulded after 48 hours of setting.
20. It was observed that initially 0% CA with 70% FA replacement exhibited highest results, 1.01% higher than that of the control mix.
21. From the 28 day compressive strength results it was observed that 50% replacement of fines with 0% CA replacement gave best result when compared to the other replacement levels of the 0% CA series but was still lower that the control mix by 6.2%.
22. For mixes with 30% CA replacement the compressive strength was greater than all the replacement levels with 0% CA replacement. In case of the FA0% it was slightly lower than the control mix by 3.5% but the other two mixes with FA 30 and 50% the strength was observed to be higher than that of the control mix. The mix with 30% CA and 50% FA exhibited best results being around 17.19% greater than the control mix.
23. It was observed that the mixes with CA0% for all replacement level the split tensile and flexural strength was lower than that of the control mix.
24. It was observed that the specimens with replaced coarse and fine aggregates exhibited better split tensile and flexural strength when compared to that of the control mix.
25. The compressive, split tensile and flexural strength values of the different replacement levels are found to be lower that the specimen without replacement but the values are still found to be within the prescribed limit.
26. Based on the results obtained it can be concluded that waste materials can be successfully used as replacements for natural aggregates without causing much reduction in properties of both fresh and hardened concrete, hence reducing quantity of waste to be disposed.

V. REFERENCES

1. Roshan S. Shetty, "*Construction and demolition waste – An overview of the Indian construction industry*", International journal of chemical, environmental and biological sciences (IJCEBS) Volume 1, Issue 4 (2013), ISSN 2320- 4079, EISSN 2320- 4087
2. Hemalatha B.R, Nagendra Prasad and B. V. VenkataSubramanya, "*Construction and demolition waste recycling for sustainable growth and development*", Journal of Environmental research and development, Vol. 2, No. 4, June 2008.
3. A. Dakwale and R. V. Ralegaonkar, "*Development of sustainable construction material using construction and demolition waste*", Indian journal of Engineering and Materials Sciences, Vol 21, August 2014, pp. 451 – 457.
4. Akshay C. Sankh, Praveen M. Biradar, Prof. S. J. Naghathan and Manjunath B. Ishwargol, "*Recent trends in replacement of natural sand with different alternatives*", IOSR Journal of Mechanical and Civil Engineering (IOSR -JMCE), e- ISSN:2278-1684, p-ISSN: 2320- 334X, PP 59- 66.
5. A Seeni, Dr. C. Selvamony, S. U. Kannan and M. S. Ravikumar, "*Experimental study of partial replacement of fine aggregate with waste material from china clay industry*", International Journal of Computational Engineering Research, Vol. 2, Issue 8.
6. Sherif A. Khafaga, "*Production of High Strength Self compacting concrete using recycled aggregate as fine and/or coarse aggregates*", World applied sciences journal 29 (4): 465 – 474, 2014, ISSN 1818- 4952
7. M Seethapathi, S. R. R. Senthilkumar and K. Chinnaraju, "*Experimental study in high performance self-compacting concrete using recycled aggregate*", Journal of Theoretical and Applied information technology, 10th September 2014, Vol. 67 No. 1.
8. I POP and T. Onet, "*Usage of recycled aggregate for the production of self-compacting concrete*", BuletinŞtiinŃific al UniversitătŃii de Nord Baia Mare, Seria D, ExploatăriMiniere, Prepararea SMU, MetalurgieNeferoasă, GeologieşiIngineriaMediului, vol.XXIV, Nr. 2, 2010.
9. Prashanth O Modani and Vinod M. Mohitkar, "*Recycled aggregate self-compacting concrete: A sustainable concrete for structural use*", International Journal of engineering research and technology (IJERT), ISSN 2278- 0181, Vol. 4, Issue 1, January 2015.
10. Prashanth O Modani and Vinod M. Mohitkar, "*Self- compacting concrete with recycled aggregate: A solution for sustainable development*", International Journal of civil and structural engineering, Vol 4, No. 3, 2014.
11. Perkins, G. D. (2008) 'Development of concrete containing waste glass'. inPlassmann, P. and Roach, P. (eds.) Proceedings of the 3rd Research Student Workshop. Pontypridd: University of Glamorgan, pp. 78-80
12. P. Suganthy, Dinesh Chandrashekar and Satish Kumar P. K., "*Utilization of pulverized plastic in cement concrete as fine aggregate*", IJRET, ISSN: 2319-1163, volume 02, Issue 06, June 2013.
13. SachinBalakrishnaKandekar, AmolJagannathMehetre and Vijayshree A. Auti, "*Strength of concrete with different types of fine aggregate*", International Journal of Scientific and Engineering Research Volume 3,Issue 9, September 2012, ISSN 2229-5518.
14. S Keerthinarayana and R. Srinivasan, "*Study on Strength and Durability of Concrete by Partial Replacement of Fine Aggregate using Crushed Spent Fire Bricks*",BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI, Publicat de, UniversitateaTehnică „Gheorghe Asachi" din Iași, Tomul LVI (LX), Fasc. 2, 2010, Secția, CONSTRUCȚII. ĂRHITECTURĂ.
15. Manguriu G. N., Karugu C. K., Oyawa W. O., Abuodha U. O. and Mulu P. U., "*Partial Replacement of Natural River Sand with Crushed Rock Sand in Concrete Production*", Global Engineers and Technologists Review, Vol. 3, No. 4, 2013.
16. Veera Reddy .M, "*Investigation on Stone Dust and Ceramic Scrap as Aggregate Replacement in Concrete*", International Journal of Civil and Structural Engineering, Volume 1, No. 3, 2010. ISSN 0976-4399.
17. Sija K Sam, DeepthyVarkey and Dr. Elson John, "*Self-Compacting Concrete with Recycled Coarse Aggregate*", IJERT, ISSN 2278-0181, Volume 3, Issue 9, September 2014.
18. N. K. Deshpande, Dr. S. S. Kulkarni and H. Panchpande, "*Strength Characteristics of Concrete with Recycled Aggregates and Artificial Sand*", International Journal of Engineering Research and Applications, ISSN 2248-9622, Vol. 2, Issue 5, September- October 2012, pp.038-042.
19. Nansu, Kung chung Hsu and His-Wen Chai, *" A simple mix design method of self-compacting concrete"*, Cement and Concrete Research, 2001, vol 31, pp. 1799-1807.
20. IS 456:2000, [Reaffirmed 2005], "*Plain and Reinforced Concrete – Code of Practice*", Fourth Revision, Bureau of Indian Standards, New Delhi, India.
21. IS 10262:2009, "*Standards Concrete Mix Proportioning Guidelines*", First Revision, Bureau of Indian Standards, New Delhi, India.
22. IS 383:1970, [Reaffirmed in 2002], "*Specifications for Coarse & Fine Aggregates from Natural Sources for Concrete*", Bureau of Indian Standards, New Delhi, India.
23. IS 2386 (Part I):1963, [Reaffirmed in 2011], "*Methods of Tests for Aggregates for Concrete*", Bureau of Indian Standards, New Delhi, India.
24. IS 516:1959, [Reaffirmed 1999], Edition 1.2, "*Methods of Tests for Strength of Concrete*", Bureau of Indian Standards, New Delhi, India.
25. Specification and Guidelines of Self-compacting concrete, EFNARC, February 2002.