High Strength Rice Husk- Ash Concrete Incorporating Quarry Dust As Partial Substitute For Sand

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Abstract- *Various civil engineering construction with reinforced concrete or plain concrete are multi-storied buildings, bridges, chimneys, water tanks, hydraulic structures like dam etc .Each structure has its own intended purpose and hence the corresponding requirement related with concrete say for example, multi-storied buildings require concrete of high compressive strength.*

The RHA is varied from 5% to 20% at an interval of 5% by weight of cement. Various strengths considered for investigations are compressive strength, flexural strength, split tensile strength and bond strength. Cube of size 150 mm x 150 mm x 150 mm for compressive strength, beams of size 500 mm x 100 mm x 100 mm for flexural strength, cylinders of size 100mm diameter and 200 mm height for split tensile strength, and cubes of size 150mm x 150mm x 150 mm with a bar of diameter 10 mm for pull out strength are used. All the specimens were water cured up to 7 and 28 days and tested subsequently. The workability is measured with the slump cone. The wet and dry density at 7 and 28 days is calculated. Relation between compressive strength and all other strengths are developed. A comparison of results of MRHAC (Modified Rice Husk Ash Concrete) with that of normal concrete, showed significant improvements in the results of various strengths.

I. INTRODUCTION

Change in living standard of people, environmental concerns and economy has made to search for substitutes for basic constituents of concrete. Along with durability and serviceability of the structures, person also wants aesthetic view and fast erection of the structure. To cater to these requirements- new technologies, new construction practices and new concrete making materials are being used. In today's world, various kinds of civil engineering structures are coming into picture, placing greater demand on material performance, the need for more fundamental information on the behavior of concrete under different types of loads is of prime importance.[1]

The production of ordinary portland cement is not only costly and energy intensive, but it also produce large amount of carbon emissions. The production of one ton of ordinary portland cement produces maximum CO2 in the atmosphere. Limestone (CaCO3) which is a raw material available in nature and it is a primary need for the production of cement material. [2]

The use of manufactured sand as a partial replacement for fine aggregate and rice husk ash as partial replacement to cement reduces greenhouse gas emission proportionally and result in a more "green concrete", through reduction of energy consumptions. The main moto behind this research is explained below.[3]

To investigate the behavior of modified rice husk ash concrete (MRHAC) composite with various volume fractions of RHA.

1. To investigate the strength properties of MRHAC composite with various volume fractions of RHA.
2. To investigate other properties such as workability, density and elastic constants.
3. To compare the properties of these special concretes with that of normal concrete.
4. To determine the properties of hardened concrete, such as compressive strength, split tensile strength, flexural strength and pull out strength.[4]

II. LITERATURE SURVEY

It is observed from the literature survey that the use of sugarcane bagasse ash concrete is more advantageous as it provides the same mechanical properties as that of plain concrete in comparatively lesser cost. Thus, one can think of replacing some percentage of cement by rice husk ash in the concrete. It is also inferred from the available literature that use of M-sand enhances the mechanical properties of the cement concrete. It gives more enhanced results regarding workability, water retention capability, compressive and flexural strength.

Now a days all over the world, concrete is one of the most extensively used material in the construction industry. As concrete is such a popular and important construction material a lot of research is done and some still going on to improve the mechanical properties of concrete. A lot of research work has been done and is going on the use of steel slag and also bagasse ash as cement replacement in enhancing different properties of concrete. Research work done by different researchers is discussed here in brief.

Yashwanth M. K. et.al. [1] investigated experimentally the fresh and hardened properties of lightweight concrete using sugarcane bagasse ash as replacement for cement by weight at 0%, 5%, 10%, 15% and 20% and expanded polystyrene beads as 100% replacement for coarse aggregate respectively. They found that there is marginal increase in workability with bagasse ash content up to 10%.The compressive strength of lightweight concrete increases with bagasse ash content up to 15% and beyond in strength. This 15% bagasse ash replacement strength is slightly less than ordinary portland cement based lightweight concrete at 28 days.

R. Srinivasan et.al. [2] In this paper, Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased.

A. Bahurudeen et.al. [3] carried out tests on sugarcane bagasse ash based portland pozzolana cement. They found that various supplementary cementitious materials significantly influences fresh and hardened properties of concrete. Interaction of pozzolanic material with cement and chemical admixtures produces diverse effects in the fresh properties of blended cement concrete. Their experiment aims to ascertain the effect of different bagasse ash replacements of cement on the compatibility with superplasticizers in cement paste. Sugarcane bagasse ash based portland pozzolana cements were produced with three different levels of replacement-10%,15%,and 20%. By referring their research work, it was also observed that polycarboxylic ether based superplasticizer was more compatible with bagasse ash blended cement than sulphonated naphthalene based superplasticizer.

Biruk Hailu and Abebe Dinku [4] used sugarcane bagasse ash as a partial cement replacement material. The study examined the potential use of sugarcane bagasse ash as a partial cement replacement material. For their investigation, bagasse ash sample was collected from Wonji sugar factory and its chemical properties were investigated. The bagasse ash was then ground until the particles posing the 63µm sieve size reach about 85% and the specific surface area about 4716 cm^2/gm. Ordinary portland cement and portland pozzolana cement were replaced by ground bagasse ash at different percentage ratios. Normal consistency and setting time of the pastes containing ordinary portland cement and bagasse ash from 5% to 30% replacement were investigated. The compressive strengths of different mortars with bagasse ash addition were also investigated. Four different C-35 concrete mixes with bagasse ash replacements of 0%, 5%, 15%, and 25% of the ordinary portland cement were prepared with water to cement ratio of 0.55 and cement content of 350 kg/cm^3 for the control mix. The test results indicated that upto 10% replacement of cement by bagasse ash results in better concrete properties.

K. Ganesan et. al. [5] found that the utilization of waste materials in concrete manufacture provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of blended cements. In this study, the effects of bagasse ash content as partial replacement of cement on physical and mechanical properties of hardened concrete are reported. The properties of concrete investigated include compressive strength, splitting tensile strength, water absorption, permeability characteristics, chloride diffusion and resistance to chloride ion penetration. The test results indicated that bagasse ash is an effective mineral admixture, with 20% as optimum replacement ratio of cement.

Ajay Goyal et.al. [6] reported that sugarcane bagasse (SCB) which is a voluminous by-product in the sugar mills when juice is extracted from the cane. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. The ash, therefore, becomes an industrial waste and poses disposal problems. For obtaining amorphous and reactive sugarcane bagasse ash (SCBA), several trials were conducted to define optimum burning time and temperatures. SCBA used in their study was obtained by burning SCB at 600o C for 5 hours under controlled conditions and its physical, chemical, and mineralogical characterization was done to evaluate the possibility of its use as binder partially replacing cement in the mortar applications.

V. Syam Prakash [7] investigated on ready mixed concrete using manufactured sand as fine aggregate. His study says, concrete is the most widely used composite construction material. Ready mixed concrete can enhance the speed of construction and improve the quality of concrete components. The constituent materials of Ready Mixed Concrete (RMC), especially the fine aggregate, play a very important role for imparting better properties of concrete in its fresh and hardened state. In Kerala, river sand was used as fine aggregate for construction. Due to the continuous mining of sand from river led to the depletion of river sand and it became a scarce material. Also, since sand mining from river caused a lot of environmental issues. Hence the Government has banned mining of the same. As a substitute to river sand, Manufactured sand (M-sand) has been produced by crushing stone. His paper presents the physical and mechanical properties of M-sand and ready mixed concrete prepared using M-sand. Experimental results shows that the quality of M-sand is better than the river sand in many respects, such as cleanliness, grading, strength, angularity, flakiness, elongation etc. Design of RMC and its experimental investigation reveals that the use of M-sand in RMC imparts better properties for RMC in its fresh state and hardened state. Test results on RMC in its fresh and hardened state are also presented in this paper. The study concludes that M-sand is a suitable and viable substitute to river sand and could be effectively used in RMC which provides adequate strength and durability for the concrete.

Abdolkarim Abbasi et.al. [8] studied use of the industrial and agricultural wastages in concrete partly as cement replacement. In their research the moisture percent and the method of burning bagasse, physical characteristics, chemical combination, crystal fixtures and specific area of bagasse ash were investigated and compared with cement. Replacing cement by 10% of bagasse ash by fine grade (specific area of 9000cm/gm), the workability and flowbility is optimized and compressive strength at 28 days is increased by 25% in comparison with normal concrete. Using bagasse ash has no effect on the setting time and absorbing water.

V. Subathra Devi et.al. [9] studied the effect of partial replacement of coarse and fine aggregates by steel slag (SS), on the various strength and durability properties of concrete, by using the mix design of M20 grade. The optimum percentage of replacement of fine and coarse aggregate by steel slag is found. Workability of concrete gradually decreases, as the percentage of replacement increases, which is found using slump test. Compressive strength, tensile strength, flexural strength and durability tests such as acid resistance and rapid chloride penetration, were experimentally investigated. The results indicated that for conventional concrete, the partial replacement of fine and coarse aggregates by steel slag improves the compressive, tensile and flexural strength. The mass loss in cubes after immersion in acids is found to be very low. Deflection in the RCC beams gradually increased, as the load on the beam increased, for both the replacements.

B.V.Venkatarama Reddy [10] studied the suitability of M-sand as fine aggregate in mortars and concrete. Sand is used as fine aggregate in mortars and concrete. Natural river sand is the most preferred choice as a fine aggregate material. River sand is a product of natural weathering of rocks over a period of millions of years. It is mined from the river beds and sand mining has disastrous environmental consequences. River sand is becoming a scarce commodity and hence exploring alternatives to it has become imminent. Rock crushed to the required grain size distribution is termed as manufactured sand (M-sand). In order to arrive at the required grain size distribution the coarser stone aggregates are crushed in a special rock crusher and some of the crushed material is washed to remove fines. His investigation was an attempt toevaluate the characteristics of mortars and concrete using M-sand as fine aggregate. For the purposes of comparison characteristics of mortar and concrete with river sand has also been explored.

N.Vijayaraghavan and A.S. Wayal [11] found that the volume of concrete consumed by the construction industry is very large. In India, conventional concrete contains natural sand obtained from riverbeds as fine aggregates. 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. Here various durability tests were conducted for concrete. From the test results, it is observed that with increasing proportion of manufactured sand the penetration of water into concrete decreases.

Tap Ji,et.al.[12] The mix proportion of manufactured sand concrete(MSC) was designed based on a minimum paste theory, where microfines was added to replace part of cement. The effect of microfines content on the workability and mechanical properties of MSC was investigated. The study reveals the microfines can be used as an ingredient of MSC and the moderate amount of microfines can improve the workability of MSC. The compressive strength, axial compressive strength, splitting tensile strength and elasticity modulus of MSC increase gradually with the increasing of microfines. However, too much amount of microfines makes the mechanical properties of MSC decrease. Mixing microfines in MSC can reduce the dosage of cement, carbon emission, concrete cost and benefit from environment protection. The use of minimum paste theory in the mix proportion design of MSC is expected to improve the volume stability and cracking-resistant performance of MSC.

M. C. Nataraja, A. S. Manu and G. Girish [13] This paper reports the results of some experimental studies on the use of different types of manufactured sand in cement mortar. Granulated Blast Furnace Slag (GBFS) sand which is a ferrous slag and Crushed Granite sand (CGS) obtained from vertical cone crusher were considered. In this investigation, cement mortar mix 1:3 and the replacement of Natural Sand (NS) by GBFs and CGS at various percentage is considered at different water cement ratios namely 0.4, 0.5, 0.6. With the addition of manufactured sand the workability of mortar in terms of flow decreases gradually as the replacement level increases. This is mainly due to irregular features of the surface characteristics and also due to higher water absorption capacity. The manufactured sand exhibited better strength due to good bond characteristics. The reduction in flow varies over a wide range depending on the type and percentage of replacement levels. This loss in flow can be adjusted by adding suitable dosage of super plasticizer. From this study it is observed that the manufactured sand is a good alternative for the natural river sand in mortar provided the workability is compensated by adding suitable dosage of plasticizer. In spite of this, manufactured sand is quite economical.

Nguyen Van Tuan et.al. [14] studied the use of rice husk ash to produce ultra-high performance concrete. According to them, the limited available resource and the high cost of silica fume (SF) in producing ultra-high performance concrete (UHPC) give the motivation for searching for the substitution by other materials with similar functions, especially in developing countries. Rice husk ash (RHA), an agricultural waste, is classified as “a highly active pozzolan” because it possesses a very high amount of amorphous SiO_2 and a large surface area. The possibility of using RHA to produce UHPC was investigated in their study. The result shows that the compressive strength of UHPC incorporating RHA, with the mean size between 3.6 µm and 9 µm, can be achieved in excess of 150 MPa with normal curing regime. The interesting point is that the effect of RHA on the development of compressive strength of UHPC is larger than that of SF. Besides, the sample incorporating the ternary blend of cement with 10% RHA and 10% SF showed better compressive strength than that of the control sample without RHA or SF. This blend proved to be the optimum combination for achieving maximum synergic effect.

M. Jamil et.al. [15] studied the pozzolanic contribution of rice husk ash in cementitious system. Rice husk ash (RHA) is an established supplementary cementitious material (SCM). Extensive research has been carried out to incorporate RHA as a SCM in casting concrete and mortar. RHA contributes in two fold of effects in concrete or mortar; i.e. filler effect and pozzolanic effect. Replacement percentages of RHA used in various previous studies were chosen arbitrarily like 5%, 10%, 20% and so on to determine the total effect of RHA. But the unique filler effect or pozzolanic effect of RHA in cementitious system is yet to be investigated comprehensively by the scientific community. Investigation was carried out to find the maximum pozzolanic (chemical) contribution of RHA in cementitious system in terms of replacement percentage. The determination is analytical and based on the hydration reaction of cement and the pozzolanic reaction of RHA with the hydration product. The obtained result was also verified with the experimental results available from published literatures.

Nihat Kabay, et. al. [16] studied the properties of concrete with pumice powder and fly ash as cement replacement materials. They found that, Turkey is rich in natural pozzolan and pumice is abundantly found in several regions of the country. In their study, pumice powder (PP) and fly ash (FA) were used as cement replacement materials and the effect of partial replacement of PP, FA and their blends by cement on physical, mechanical and durability properties of concrete was investigated. Test results showed both PP and FA addition resulted in lower mechanical strength at early ages, but comparable strength at later ages compared to the reference concrete. Replacement of cement with PP, FA and their blends resulted in concrete with decreased water absorption, sorptivity and void content and higher magnesium sulfate resistance compared to the reference concrete. Since pumice is abundantly found in Turkey, this material might be used as an additive in concrete applications or as a precaution against magnesium sulfate attack.

III.. PERFORMANCE ANALYSIS

3.1 Experimental Analysis

The tests on hardened concrete are carried out according to relevant standards wherever applicable. Results of various strengths are computed according to the strength of material theory. Various tables presented in this chapter shows the results obtained from the test on wet and hardened concrete Results of hardened QDC and MRHAC are discussed in comparison with those of normal concrete.

3.1.1 Workability and density

Workability of concrete with and without RHA is determined with the help of slump cone test. The density is obtained by measuring the weight and volume of cube moulds respectively. Results of these properties are shown in Table 4.1.

Table 3.1 Physical properties of concrete

Sr. No.	Mix designation	% of QD	% of RHA	Wet Density in kg/m³	Dry Density in kg/m³ at 7 days	Dry Density in kg/m³ at 28 days	Workability in mm
1	M0	0	0	2642.41	2522.45	2512.30	93
2	M1	5	0	2658.63	2566.86	2528.70	90
3	M2	10	0	2675.71	2572.73	2542.85	85
4	M3	15	0	2699.15	2575.12	2553.30	72
5	M4	20	0	2712.78	2588.77	2572.42	65
6	M5	10	5	2668.43	2549.47	2536.74	87
7	M6	10	10	2661.33	2538.24	2533.95	79
8	M7	10	15	2657.45	2531.45	2521.41	78
9	M8	10	20	2612.20	2524.86	2505.00	69

Sr. No	QD Volume fraction V_s (%)	RHA Volume fraction V_h (%)	Slump (mm)	Slump Loss using as per eq. 1
1.	0	0	95	0.00
2.	5	0	89	6.31
3.	10	0	85	10.52
4.	15	0	72	24.21
5.	20	0	68	28.42
6.	10	5	83	12.63
7.	10	10	79	16.84
8.	10	15	76	20.00
9.	10	20	70	26.32

Workability is measured in terms of slump. Results from Ta proportion but increase in QD and RHA content workability is reduced.

3.1.2 Slump loss

Slump loss has a great effect on the concrete workability and it parameter.

Table 3.2 Slump loss

From the values of slump loss it can be seen that as QD and RHA content increases the workability decreases and slump loss increases. The graph is plotted for slump loss versus QD content and RHA content respectively as shown in fig 4.1 and fig 4.2

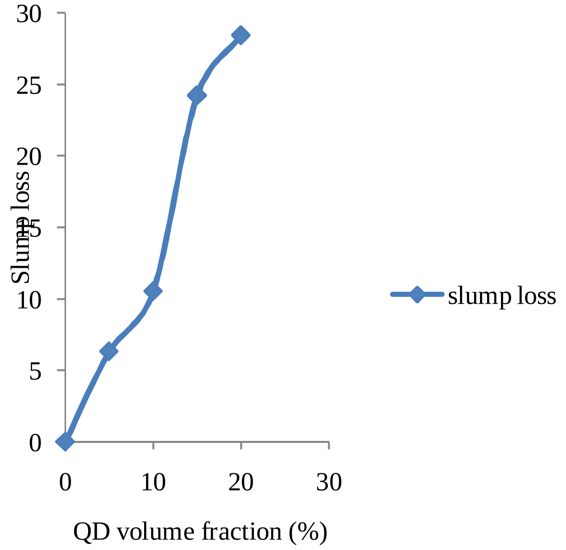

Fig.3.1 Variation of slump loss with respective to MS

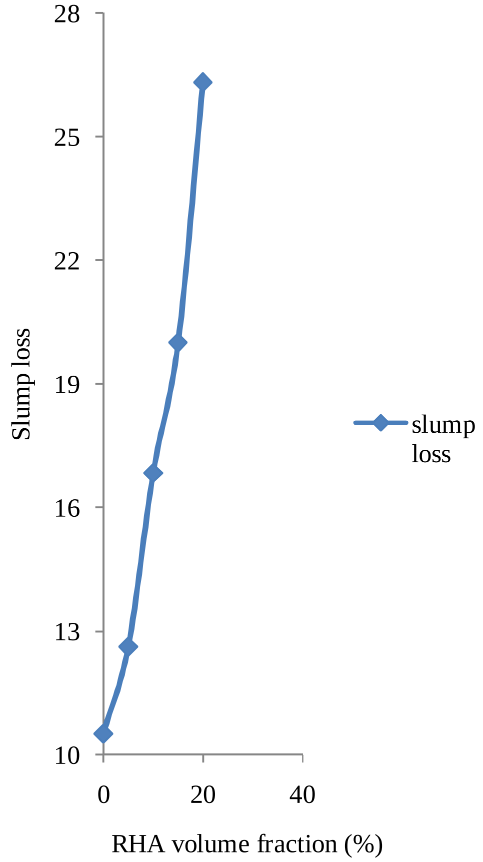

Fig.3.2 Variation of slump loss with respective to RHA

3.1.3 Compressive strength test

The results of compressive strength are obtained using Eq.2 and presented in Table 3.3 and Table 3.4.

Table 4.3 Compressive strength of QDC

Sr. No.	QD (%)	Compressive Strength in N/mm^2 from Eq. 2		% Variation in Compressive Strength Over Control Concrete		% increase in 28 Days compressive Strength Over
		7 Days	28 Days	7 Days	28 Days	7 Days
1	0	27.5	53.15	0.0	0.0	93.27
2	5	33.99	56.25	23.6	5.8	65.49
3	10	37.48	59.40	36.3	11.8	58.48
4	15	30.11	50.93	9.5	-4.2	69.15
5	20	22.74	41.49	-17.3	-21.9	82.45

From the above table, the optimum percentage of QD in QDC is found out to be 10%. In the remaining experimental investigation, the QDC content is kept constant, i.e.10%.

Table 3.4 Compressive strength of MRHAC

Sr. No	Rice Husk ash (%)	% Variation in compressive strength	
		7 days(N/mm^2)	28 days(N/mm^2)
1	0	37.48	58.25
2	5	37.78	60.15
3	10	40.89	60.35
4	15	35.40	48.50
5	20	28.00	40.55

The results obtained for various strength of concrete are expressed analytically by various mathematical expressions to model the behaviour of modified steel slag concrete. The results predicted in the present work by the regression analysis are in excellent agreement with that of experimental value.

IV.CONCLUSIONS

4.1Conclusion

The following conclusions are drawn from the test result and discussion of this investigation.

1. The maximum compressive strength, flexural strength, split tensile and bond strengths achieved are 60.35, 14.49, 3.00and 10.85 MPa at 10% of RHA volume fractions respectively.
2. Elastic constants of QDC and MRHAC are obtained by various methods. Empirical expressions for modulus of elasticity i.e. static and dynamic have been developed in terms of QD and RHA volume fraction and cube compressive strength of QD and MRHAC. Predicted values of modulus of elasticity are excellent agreement with those of expression derived from the graph plotted.
3. In general, the significant improvement in various strengths is observed with the inclusion of QD and RHA in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of RHA content. The optimum RHA content is 10% to impart maximum gain in strength.
4. Satisfactory workability was maintained with addition of super plasticizer of given dosage.
5. It is observed that the equivalent compressive strength of MRHAC decreases as % of RHA increases after 10% of RHA addition.
6. Flexural strength of MRHAC is increased with increasing percentage of RHA
7. The split tensile strength at 7 days and 28 days of curing observed to be increasing marginally.
8. The bond strength is increased with increase in RHA content.

4.2 Scope for future work

The present work has good scope for future research. Some of the research areas are as follows:

1. Study of the behavior of MRHAC at elevated temperatures.
2. Study of MRHAC in high-strength, high-performance concrete.
3. Study of impact resistance, abrasion resistance and permeability of MRHAC.
4. Study of behavior of MRHAC after incorporation of fibers.

REFERENCES

[1] Yashwanth. M.K, Dr.B.G.Nareshkumar, "An Experimental Study on Bagasse ash as Replacement for Cement in LightweightConcrete", International Journal of Latest Trends in Engineering and Technology (IJLTET), pp.

[2] R.Srinivasan, K.Sathiya, "Experimental Study on Bagasse Ash in Concrete",International Journal for Service

Learning in Engineering Vol. 5, No. 2, pp. 60-66, 2010ISSN 1555-9033.

[3] A. Bahurudeen, A.V. Marckson, Arun Kishore, Manu Santhanam "Development of sugarcane bagasse ash based Portland pozzolana cement and evaluation of compatibility with superplasticizers", Construction and Building materials, Vol.68, October 15, 2014, pp.

[4] Biruk Hailu and Abebe Dinku "Application of sugarcane bagasse ash as a partial cement replacement material", African Journals Online, Zede Journal, Vol.29, 2012,pp.

[5] K. Ganesan, K. Rajagopala and K. Thangavel, "Evaluation of bagasse ash as supplementary cementitious material", Cement and concrete composites, Volume 29, Issue 6, pp.515-524.

[6] Ajay Goyal, Hatori Kunio, Ogata Hidehiko and Mandula "Properties and Reactivity of Sugarcane Bagasse Ash", Transactions of the Japanese Society of Irrigation, Drainage and Rural Engineering, Issue 3, pp. 243-251, (2010).

[7] V. Syam Prakash, "Ready mixed concrete using manufactured sand as fine aggregate", 32nd Conference on OUR WORLD IN CONCRETE & STRUCTURES, 2007.

[8] Abdolkarim Abbasi and Amin Zargar, "Using Baggase Ash in Concrete as Pozzolan", Middle-East Journal of Scientific Research 13 (6): 2013 ISSN 1990-9233© IDOSI Publications, 2013 DOI: 10.5829/idosi.mejsr.2013.13.6.2562, pp.716-719

[9] V. Subathra Devi and B. K. Gnanavel, "Properties of Concrete Manufactured using Steel Slag", 12th Global Congress on Manufacturing and Management, GCMM 2014, pp.

[10] B. V. Venkatarama Reddy, "Suitability of manufactured sand (M-Sand) as fine aggregate in mortars and concrete", CSIC project: CP 6597/0505/11-330, July 2011.

[11] Nimitha Vijayaraghavan, A.S. Wayal, "Effect of Manufactured Sand on Durability Properties of Concrete", American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-02, Issue-12, pp-437-440, 2013.

[12] Tap Ji, Cai-Yi Chen, Yi-Zhou Zhuang, Jian-Feng Chen, "A mix proportion design method of manufactured sand concrete based on minimum paste theory", Construction and Building Materials, Volume 44, pp-422-426, July 2013.

[13] M. C. Nataraja, A. S. Manu and G. Girish, " Use of Granulated blast furnace slag as fine aggregate in cement mortar", ISSN 2319-6009, NO. 2, May 2013, pp. 311-323

[14] Nguyen Van Tuan, Guang Ye, Klaas van Breugel , Alex L. A. Fraaij and Bui Danh Dai, "The study of using rice husk ash to produce ultra-high performance concrete", Construction and building materials, issue 4, pp. 2030-2035, April 2011.

[15] M. Jamil, A.B.M.A. Kaish, S.N. Raman and M.F.M Zain, "Pozzolanic contribution of rice husk ash in cementitious system", Construction and Building materials, pp. 588-593, October 2013.

[16] Nihat Kabay, M. Mansur Tufekci, Ahmet B. Kizhikanat, Didem Oktay, "Properties of concrete with pumice powder and fly ash as cement replacement materials", Construction and Building materials, volume 85, 15 june 2015, pages1-8

[17] I.S.12269- 1987, "Specification for 53 Grade Ordinary Portland Cement", Bureau of Indian Standard, New Delhi, 1988.

[18] I.S.456-2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete, (fourth Revision)", Bureau of Indian Standard, New Delhi, 2000.

[19] I.S.10262-2009, "Indian Standard Recommended Guidelines for Concrete Mix Design", Bureau of Indian Standard, New Delhi, 2010.

[20] I.S.383-1970, "Code of Practice for Plain and Reinforced Concrete, (Third Revision)", Bureau of Indian Standard, New Delhi, 1970.

[21] I.S.516-1975, "Method of Tests for Strength of Concrete", Bureau of Indian Standard, New Delhi.

[22] Neville A.M., "Properties of Concrete", ELBS Edition of 3rd Edition, Longman Group, U.K. Ltd., 1981.

[23] Shetty M.S., "Concrete Technology, Theory and Practice", S. Chand and company Ltd., New Delhi, 2003.

[24] BS 8110:1985 (part 2), "Structural use of concrete. Code of practice for special circumstances", British Standards Institution, 1985.

[25] ASTM standard C 234-91a," Standard test method for comparing concretes on the basis of the bond developed with reinforcing steel".

[26] Lydon and Balendran, "Some observations on elastic properties of plain concrete", Cement and concrete research-CEM Concrete Research, Vol.16, No.3, 1986.

[27] IS: 10086-1982, "Specification for moulds for use in tests of cement and concrete".