International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-2S2, January 2019

Mechanical Properties of Sustainable Concrete Incorporating Manufactured Sand and Rice Husk Ash

KG Rahul Varma, P. Jagadeesh

Abstract— ***Because of high constructional activities, use of concrete is very extensive and its ingredients, i.e. cement, sand and gravel becomes scarce. Many studies were carried out by researches for partial or optimal replacement of cement, sand and gravel by alternate materials. Cement production leads to global warming as CO_2 is released in atmosphere during its production, equal to seven percent of total CO_2 emission in world. Therefore cement is partially replaced by rice husk ash (RHA) as it is rich in silica. Large space in concrete (35%) is filled by sand. Natural sand may get exhausted in future because of its high demand. Digging of sand in huge quantity nearby rivers is hazardous to environment as it effects ground water level and causes soil erosion. Therefore natural sand is partially replaced by manufactured sand (MS) as MS is obtained on crushing of granite rocks which are easily available at nearby places. Use of MS reduces the transportation cost of carrying natural sand from far-off river beds. In the current study, cement is partially replaced by RHA by 10% and sand by MS by 25%, 50%, 75% and 100% to get desired strength concrete. Various tests like compressive strength, split tensile strength and flexural strength were conducted on specimens. Present study revealed that to get M20 concrete, 100 % sand replacement with MS is the optimum proportion for 10% replacement of cement with RHA.***

Keywords — Rice Husk Ash (RHA), Manufactured Sand (MS), Fly Ash (FA), Compressive strength(CS), Split tensile strength(ST), Flexural strength(FS).

I. INTRODUCTION

After water, the most used material by humans on the earth is concrete which is highly used in construction for its high strength and stability. If its consumption is done at the same rate, it may get exhausted in the coming future. Cement, sand and gravel are the ingredients used in concrete, so we have to find alternatives to replace these ingredients in concrete which will be easily available at all times at low cost to give good strength eco-friendly concrete. Production and consumption of cement as per International Cement Review (USGS Mineral Resources Report, Tech Sci Research) is shown in Figure 1 and Figure 2 respectively.

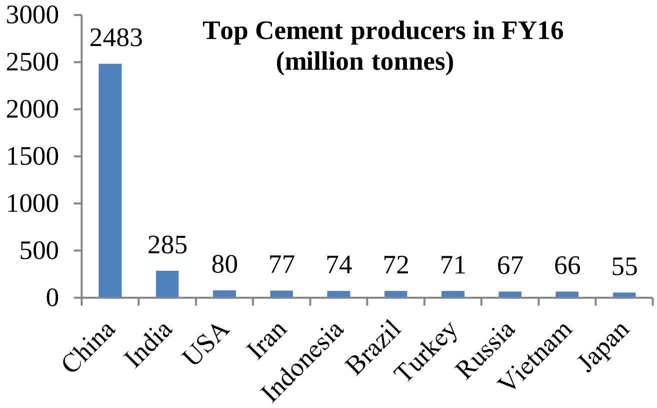

Figure 1. Top Cement producing countries in the world.

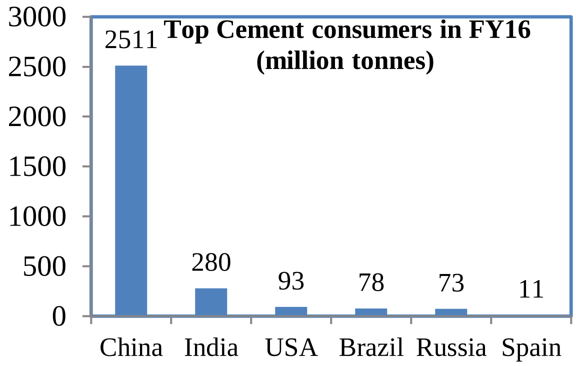

Figure 2. Top cement consumers in 2016

Cement is a chief ingredient in concrete production. Huge quantity of raw materials and energy is consumed in cement production. Cement production leads to global warming as CO_2 is released in atmosphere during its production, equal to seven percent of total CO_2 emission in world as mentioned by Vinita [6]. Therefore there is a need of finding alternative for cement to meet its future demand. Using industrial and agricultural by products as partial replacement for cement can save cost, energy and environment. Reduction of cement use will reduce CO_2 emission. Human activities produce wastes over 2500 MT per year from industries, agriculture and from rural and urban areas. It has been proved from research that many useful products can be produced using these solid wastes as organic and inorganic resources. Fly ash (FA), blast furnace slag (BFS), rice husk ash (RHA), silica fume (SF) and demolished construction materials are the most used solid wastes.

Manuscript published on 30 January 2019.
* Correspondence Author (s)
KG Rahul Varma, Research scholar, School of Civil Engineering,Vellore institute of Technology, Vellore, Tamil Nadu, India (koli448844@gmail.com)
Dr. P. Jagadeesh, Professor, School of Civil Engineering,Vellore institute of Technology, Vellore, Tamil Nadu, India (p.jagadeesh@vit.ac.in)

These solid wastes which pollute the nature can be disposed by using them as partial replacement for cement. Demand of cement is fulfilled to some extent, on use of these supplementary cementious materials. Ha Thanh le [5] reported that cement can be partially replaced with rice husk ash as it has high silica in it which is helpful for bonding in concrete. India is one of the largest rice cultivation country in the world and about twenty million tons of RHA is generated every year. RHA is generated by burning of rice husk at certain temperature. Bharadwaj A [9] stated that huge quantity of ash is produced during burning of rice husk although it has low density. About 75% organic volatile matter in rice husk burns up and remaining 25% is converted into ash on burning, which is called as RHA. RHA pollutes the land in which it is disposed. Therefore alternatives are being looked for dumping RHA. Cement will be partially replaced by RHA in the present investigation. RHA has high silica content and large surface area as studied by Mehta [7]. Partial replacement of cement with RHA in concrete reduces the CO_2 emissions from concrete industry. RHA acts as an ideal filler in concrete. It fills the voids in concrete which increases the strength and reduces porosity in concrete. RHA forms C-S-H gel in concrete, which is less porous and highly dense thereby avoiding any cracks or corrosion in concrete. RHA acts as pozzolanic material which increases the strength and durability of concrete according to Mahmud [8]. Increase in compressive strength has been observed upto 20% replacement of RHA by cement in research done by Ganesan K [10]. Appropriate percentage replacement of cement with RHA in concrete gives concrete of good strength which can be used in making structures. Large space in concrete (35%) is filled by sand. Natural sand may get exhausted in future because of its high demand. Digging of sand in huge quantity nearby rivers is hazardous to environment as it effects ground water level and causes soil erosion. Now, good natural sand is not easily available and is getting exhausted very fast. So there arises need of finding a replacement for natural sand to make concrete. Natural sand can be replaced by MS, slag, bottom ash, recycled aggregate etc. according to Tao Ji and Jian-Feng Chen [3]. In aforesaid replacements, MS is the most substitute replacement material as on today for sand according to Huajian Li [1]. MS is the green and most economical replacement for natural sands in concrete as mentioned by C. Jialong [11]. MS can be a better replacement for natural sand if it is manufactured using proper machines. MS which is properly graded will have less voids and it will be economical as the quantity of cement required will be less. Concrete made of natural sand is less durable as natural sand is not properly graded and it has high silt and organic impurities which influence the concrete durability, whereas concrete made of MS is durable as MS has zero silt or organic impurities. Demand for manufactured sand is growing as Natural sand is not able to fulfill the present construction demand. MS concrete had higher compressive strength compared to natural sand concrete as found by B.X. Li [12]. Research done by Cai JW [13] showed that use of MS with high microfine content in concrete gives good quality concrete. The allowable limit of MS fines (passing75 µm) as per ASTMC 33 is 7% [14] and the limit for M-sand fines (passing 150 µm) as per the IS is 20% [15]. According to Dilek U [21], M sand contain large quantity of fines. It impacts the water demand and workability of mortar [16]. Gonclaves JP [16] and Donza H [17] reported considerable improvement in durable and mechanical properties of the concrete using M sand. The rough surface, irregular particle shape and angular edges of MS effects the properties of concrete like workability and durability as mentioned by Xinxin Ding [2]. The sharp edges in MS gives better bonding with cement than natural sand according to Mahendra R [21]. MS is dust free and can be crushed in any required size. Since MS is obtained on crushing of granite rocks, it is easily available nearby. Thereby transportation cost is reduced in carrying natural sand from far-off river bed. M-sand is also 15-25 % cheaper than river sand [21].

The present work involves replacement of sand by MS and cement by RHA to develop concrete of desired strength.

II. MATERIALS AND METHODOLOGY

In general the materials used for designing concrete are cement, sand and gravel. As shortage of cement and sand may arise in future because of its large use and high demand. There is a need of finding replacements for cement and sand to meet the future demand. In the present research, cement is partially replaced by RHA and natural sand by MS. In rice mills, rice husk is obtained during separation of rice from paddy. Obtained rice husk is burned at specified controlled temperatures, which results in formation of RHA. As India is the largest rice cultivating country, RHA can be produced in any quantity. MS is produced by crushing of locally available granite rocks into required size. It is dust free. Table 1 and Table 2 given below shows the general chemical composition of cement and RHA.

Table 1. Chemical composition of cement

Compound	Mass (%)
Lime (Cao)	60-65%
Silica (SiO_2)	20-25%
Aluminium Oxide (Al_2O_3)	4-8%
Iron Oxide (Fe_2O_3)	2-4%
Magnesium Oxide (MgO)	1-3%
Gypsum ($CaSO_4$. $2H_20$)	1-4%

Table 2. Chemical composition of RHA

Compound	Mass (%)
SiO_2	93.4
Al_2O_3	0.05
Fe_2O_3	0.06
CaO	0.31
MgO	0.35
K_2O	1.4
Na_2O	0.1

Ordinary Portland cement (OPC) of grade 43 is used conforming to IS 12269:1987. Manufactured sand is used as fine aggregate and crushed granite stones of size 20 mm and 12 mm were used as coarse aggregate.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-2S2, January 2019

The physical properties of coarse and fine aggregates are shown in Table 3. Specific gravity of cement and RHA are 3.15 and 2.3 respectively and fineness of cement and RHA are 311.5 m^2/Kg and 285.7 m^2/Kg respectively.

Table 3. Physical properties of aggregates

Physical properties	Coarse aggregate	Fine aggregate
Specific gravity	2.65	2.58
Water absorption	0.5%	1%
Fineness modulus	7.69	2.61

The main objective of this research is to study the suitability of RHA and MS as replacement materials for cement and river sand respectively. M20 mix design is done and mix is prepared as per IS 10262:2009. Concrete mix is prepared using RHA and M-Sand as replacement materials. Partial replacements of cement and sand is done by RHA and MS at various percentages: 10% replacement of cement is done by RHA and 25%, 50%, 75%, 100% replacement of sand is done by MS. Different combinations of replacement percentages of cement by RHA and sand by MS are mixed, placed in cubes, cured and tested. Tests like compressive strength (CS), split tensile strength (ST) and flexural strength (FT) are conducted on concrete specimens. The main objective is to find the mechanical properties of concrete made by partial replacements of cement by RHA and sand by MS. Then comparing it with properties of normal concrete. All these properties are analyzed in this paper by discussing the obtained results.

III. MIX DESIGN

The design of M20 grade concrete is done by using IS 10262 – 2009 code method and is shown in Table 4 and Table 5 as follows:

Table 4. Mix ratio of concrete

Materials	Quantity(kg/m^3)	Ratio
Cement	350	1
Fine aggregate	693	1.98
Coarse aggregate	1161	3.3
Water	182	0.52

Table 5. Mix proportions of RHA and M-Sand

S.no	Mix name	% of RHA	% of M-Sand
1	M0	0	0
2	M1	10	25
3	M2	10	50
4	M3	10	75
5	M4	10	100

IV. RESULTS AND DISCUSSIONS

A. Compressive strength test

The compressive strength test was conducted on casted cubical specimens after 7, 14 and 28 days curing period respectively. The test results are tabulated in Table 6 and plotted in Figure 3.

The compressive strength (N/mm^2) = Failure load/cross sectional area.

Table 6. Compressive strength test results

S.No	Mix name	Compressive strength (N/mm^2)		
		7 days	14 days	28 days
1	M0	19.12	22.64	27.23
2	M1	18.18	21.55	26.71
3	M2	19.43	23.46	27.67
4	M3	20.34	24.51	28.19
5	M4	21.08	25.72	29.13

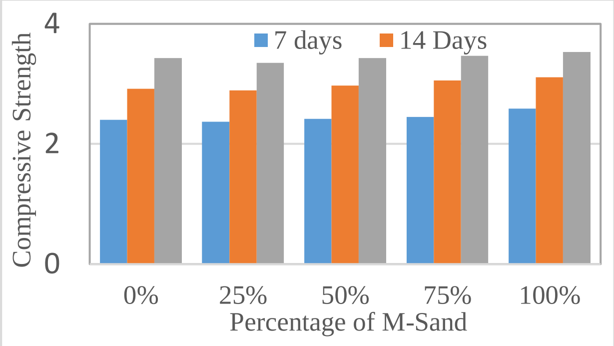

Figure 3. Compressive strength versus age of concrete

From the above results, It has been observed that for 10% cement replacement with RHA and with increase in percentage replacement of natural sand with MS by 25%, 50%, 75% and 100%, the compressive strength of RHA-MS concrete increases.There is increase in Compressive strength of concrete with increase in MS as MS is rough and angular in shape which helps in excellent bonding between aggregate particles. Presence of silica in small content in MS and in high amount in RHA contributes to the development of strength in concrete. RHA acts as an pozzolanic material and ideal filler in concrete.

The maximum compressive strength is obtained for M4 mix in which river sand is fully replaced with M-Sand and cement with 10% RHA. Compressive strength of M4 mix (10% RHA and 100% MS) increased by 7% when compared to M0 mix (0% RHA and 0 % MS).

B. Split tensile strength test

The split tensile strength test was conducted on casted cylindrical specimens of size 150 mm x 300 mm after 7, 14 and 28 days curing period respectively. The test results are tabulated in Table 7 and plotted in Figure 4. The split tensile strength (N/mm^2) = (2P) / (πDL)

Table 7. Split tensile strength test results

S.no	Mix name	Split tensile strength (N/mm^2)		
		7 days	14 days	28 days
1	M0	1.62	2.12	2.60
2	M1	1.58	2.10	2.56
3	M2	1.63	2.18	2.62
4	M3	1.67	2.21	2.65
5	M4	1.76	2.29	2.74

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

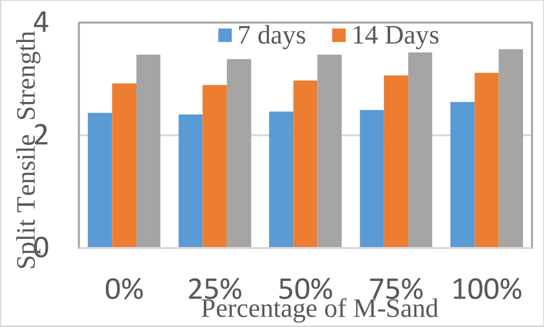

Figure 4. Split tensile strength versus age of concrete

From the above results, It has been observed that for 10% cement replacement with RHA and with increase in percentage replacement of natural sand with MS by 25%, 50%, 75% and 100%, the split tensile strength of RHA-MS concrete increases. Split tensile strength is increasing with increase in MS as MS is rough and angular in shape which helps in excellent bonding between aggregate particles. Presence of silica in small content in MS and in high amount in RHA contributes to the development of strength in concrete. RHA acts as an pozzolanic material and ideal filler in concrete.

The maximum split tensile strength is obtained for M4 mix in which river sand is fully replaced with M-Sand and cement with 10% RHA. Split tensile strength of M4 mix (10% RHA and 100% MS) increased by 5.4 % when compared to M0 mix (0% RHA and 0 % MS).

C. Flexure Strength Test

The flexural strength test was conducted on casted rectangular specimens of size 500 mm x 100 mm x 100 mm after 7, 14 and 28 days curing period respectively. Flexural strength of both Conventional concrete and RHA-MS based concrete mixes were studied at different curing periods.

The flexural strength (N/mm^2) = (Pl) / (bd^2)

The flexural strength test results are tabulated in Table 8 and plotted in Figure 5.

Table 8. Flexure Test results

S.No	Mix name	Flexure strength in N/mm^2		
		7 Days	14 Days	28 Days
1	M0	2.40	2.92	3.43
2	M1	2.37	2.89	3.35
3	M2	2.42	2.97	3.43
4	M3	2.45	3.06	3.47
5	M4	2.59	3.11	3.54

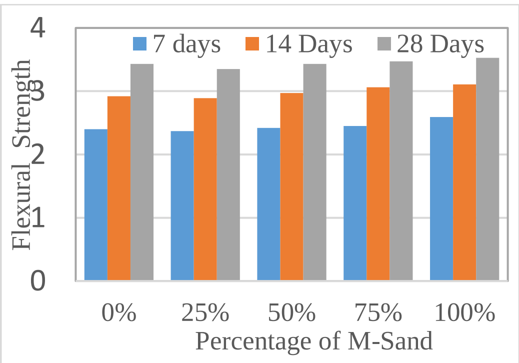

Fig 5. Flexure strength versus age of concrete

From the above results, It has been observed that for 10% cement replacement with RHA and with increase in percentage replacement of natural sand with manufactured sand by 25%, 50%, 75% and 100%, the flexural strength of RHA-MS concrete increases. There is increase in flexural strength with increase in MS as MS is rough and angular in shape which helps in excellent bonding between aggregate particles. Presence of silica in small content in MS and in high amount in RHA contributes to the improvement of strength in concrete. RHA acts as an pozzolanic material and ideal filler in concrete.

The maximum Flexural strength is obtained for M4 mix in which river sand is fully replaced with M-Sand and cement with 10% RHA. Flexural strength of M4 mix (10% RHA and 100% MS) increased by 3.2 % when compared to M0 mix (0% RHA and 0 % MS).

V. CONCLUSION

From the current research, it can be said that, replacement of cement by 10 % RHA and river sand with 100% manufactured sand is the optimum proportion to develop M20 Concrete.

From the obtained results of this current research, the following conclusions below can be drawn:

- The Compressive strength, Split tensile strength and Flexural strength are maximum for M4 mix (10% of RHA and 100% of M-Sand) compared to other mixes (M0, M1, M2, M3 and M4 mix).
- Compressive strength of M4 mix (10% RHA and 100% MS) increased by 7% when compared to M0 mix (0% RHA and 0 % MS).
- Split tensile strength of M4 mix (10% RHA and 100% MS) increased by 5.4 % when compared to M0 mix (0% RHA and 0 % MS).
- Flexural strength of M4 mix (10% RHA and 100% MS) increased by 3.2 % when compared to M0 mix (0% RHA and 0 % MS).
- Compressive, split tensile and flexural strength is increasing with increase of MS as MS is rough and angular in shape which helps in excellent bonding between aggregate particles.
- Presence of silica in small content in MS and in high amount in RHA contributes to the improvement of strength in concrete. RHA acts as an pozzolanic material and ideal filler in concrete.

REFERENCES

1 HuajianLi, Fali Huang, "Effect of granite dust on mechanical and some durability properties of manufactured sand concrete," Construction and Building materials, 109, 41-46, 2016.

2 Xinxin Ding, Chang yong Li, "Experimental study on long-term compressive strength of concrete with manufactured sand," Construction and Building materials, 108, 67-73,2016.

3 Tao Ji, Cai-Yi Chen, "A mix proportion design method of manufactured sand concrete based on minimum paste theory," Construction and Building materials, 44, 422-426, 2013.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

4 Rafat Siddique, Karambir Singh, "Properties of bacterial rice husk ash concrete," Construction and Building materials, 121, 112-119, 2016.
5 Ha Thanh Le, Horst-Michael Ludwig, "Effect of rice husk ash on properties of self-compacting high performance concrete," Materials & Design, 89, 156-166, 2016.
6 Vinita Vishwakarma, D. Ramachandran, "Studies of rice husk ash nanoparticles on the mechanical and microstructural properties of the concrete," Materials Today, 3, 1999-2007, 2016.
7 Mehta PK, "Rice husk ash as a mineral admixture in concrete," 2nd international seminar on durability of concrete, Gothenburg, Sweden, 131-6, 1989.
8 Mahmud, Hilmi, "Absorption and permeability performance of Selangor rice husk ash blended grade 30 concrete," Journal of engineering science and technology, 5.1, 1-16, 2011.
9 Bharadwaj A, Wang Y, Sridhar S, Arunachalam VS, "Pyrolysis of rice husk," Cur Sci, 87, 981-6, 2004.
10 Ganesan K, Rajagopal k, Thangavel K, "Rice husk ash blended cement: assessment of optimal level of replacement for strength and permeability properties of concrete," Constr Build Mater, 22 (8),1675-83, 2008.
11 C. Jialong, F. Yuanxing, "Present situation and problems of concrete aggregates in China," Archit, Technol, 1 (2005) 005, 2005.
12 J. Goncalves, L. Tavares, R. Toledo Filho, E. Fairbairn, E. Cunha, "Comparison of natural and manufactured fine aggregates in cement mortars," Cem. Concr. Res. 37 (6) 924-932, 2007.
13 Cai JW, Li BX Zhou MK, Hu XM, "Effects of crusher dust on properties of low/medium strength concrete with manufactured sand,"J Wuhan Univ Technol, 28(4), 27-30, 2006.
14 ASTM C33, "Standard specification for concrete aggregates," American Society of Testing and Materials Standards, 2003.
15 IS 383, "Specification for coarse and fine aggregates from natural sources for concrete," Bureau of Indian Standards, 2002.
16 Goncalves JP, Tavares LM, Toledo Filho RD, Fairbairn EMR, Cunha ER, "Comparison of natural and manufactured fine aggregates in cement mortars," Cem Concr Res, 37(6), 924-32, 2007.
17 Donza H, Cabrera O, Irassar EF, "High strength concrete with different fine aggregate," Cem Concr Res, 32(11), 1755-61, 2002.
18 Ch. Bala Rama Krishna, P Jagadeesh, "Compressive strength evaluation of eco-friendly concrete replacing sand partially with High impact polystyrene," International journal of civil engineering and technology, 9(1), pp. 865-870, 2018.
19 Rahul KG, Jagadeesh P, "Development of sustainable concrete using agro-waste and manufactured sand- A review," International journal of civil engineering and technology, 8(8), 92-100, 2017.
20 Saravanan S.S, Jagadeesh P, "Study on performance of manufactured sand as fine aggregates in high strength concrete constructions," International journal of civil engineering and technology, 8(6), 3014-3020, 2017.
21 Mahendra R. Chitlange, Prakash S. Pajgade, "Strength appraisal of artificial sand as fine aggregate in SFRC," J. Eng. Appl. Sci. 5(10), 2010.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)