

# Experimentally Analysing the Suitability of Waste Materials in Sustainable Concrete Construction

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**ABSTRACT:** In India, as the cost of construction material is expensive and labour cost is cheap, the favourable choice of construction is concrete, rather than the steel structures which is fast, simple and requiring few labours. Now-a-days, the natural resources are depleting day by day. The generation of waste materials is increasing at rapid phase on another hand. These arose a need of optimized and enhanced usage of available waste materials as a resource in the ingredient of concrete. The main focus is on the reduction of waste and sustainable resource usage, which minimizes the impact of waste on environment. This can be achieved by implementing enhanced technology by Reuse, Recycle, and Reduce (3R) principle. In this study, eight different waste materials viz coconut shell, steel slag, demolished construction, marble, glass, ceramic tile, fly ash, and artificial stone dust were collected from different industries in the country and were experimentally investigated for their suitability as both fine and coarse aggregate in concrete construction. In this paper, various properties such as crushing strength, impact strength, sieve analysis, water absorption, and specific gravity of waste materials are compared with the conventional fine and coarse aggregate along with Indian Standards. Concrete mix of M20 grade is designed as per Indian standard code IS 10262. The water absorption of fine steel slag and fine ceramic waste is almost similar to conventional aggregates. The particle size distribution of steel slag and ceramic waste is compared with conventional mix. The waste materials such as steel slag and broken ceramic tile are partially replaced for fine and coarse aggregate up to 50%, in intervals of 10%. The workability and compressive strength of new concrete is compared with the conventional concrete. The workability of concrete increases with the increase in replacement by ceramic waste, whereas for the steel slag replacement, it decreases. The optimum percentage of replacement is 30% for coarse aggregate replaced by coarse steel slag, 30% fine aggregate by fine steel slag and 10% fine aggregate by fine ceramic waste. Thus the suitability of waste material for concrete construction is found and is suggested for sustainable construction.

**KEYWORDS:** Waste material, Steel slag, Ceramic tile, Compressive strength, Workability, Property.

## I. INTRODUCTION

Concrete is prepared by mixing, fine aggregate, coarse aggregate, binder and water. In this paper cement is used as a binding material, river sand as fine aggregate, broken stone as coarse aggregate. The different waste materials such as Steel Slag(SS), Ceramic Tile(CT) waste, Construction & Demolished(C&D) waste, Coconut Shell(CS), Glass(G), Stone Dust(SD), Fly Ash(FA), Marbles(M) were collected from various industries. The total annual production of different waste materials in India are 12 million tons (MT) of Steel Slag, 119 MT of Ceramic waste, 3000 MT of Construction & Demolished waste, 200 MT of Fly Ash, 10 MT of Marbles waste, 500 MT of Glass waste, 10 MT of Coconut Shell, 50 MT of Stone dust. The current concrete construction is unsustainable because it consumes large amount of broken stone, river sand and cement which it leads to the scarcity of natural materials and hence sustainability is becoming an important issue. Moreover these waste materials create environmental pollution. Therefore steps are taken to reduce the consumption of natural materials. Special concrete is made by replacing natural material with the ultimate goal of preparing concrete with eco-friendly components and to make high strength and sustainable concrete.

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In terms of strength, workability and durability, no material plays the equal role of concrete therefore full replacement of ingredients is not possible [1]. Waste materials can be used as a partial replacement material in concrete production [2]. Strength and durability of concrete has improved when ceramic waste is used [3]. When the percentage of replacement increases, the compressive strength of ceramic concrete decreases this is because of the low specific gravity and high porosity. Cost saving is more when ceramic waste is used [4]. The compressive strength and split tensile strength of coconut shell concrete is lower than the conventional concrete [5]. Addition of coconut shell decreases workability and density of concrete. Workability of coconut shell concrete increases with the addition of flyash [6]. The macropore volume can be reduced when flyash is added to recycled concrete. Even though the strength is low for glass beads, the bond formation is better. But marbles are not good in bonding inspite of its good strength [7]. Using the waste glass as fine aggregate in concrete, there is a reduction in unit weight of concrete [8]. Up to reasonable percentage of replacement steel slag can be used to improve the properties of concrete [9]. Workability of recycled coarse aggregate from demolished waste and natural coarse aggregate is the same [10]. When coal bottom ash is used as replacement of fine aggregate, the workability decreases but the compressive strength at 28 days increases [11]. Due to the greater surface area of contact, smooth texture, spherical shape of waste marble powder, the workability and compressive strength of concrete increases. Cost of construction can be reduced when the waste materials are used in construction industry [12]. Cost reduction and social benefits can be obtained by the mass utilization of waste material in the construction field even when used partially [13]. By using industrial waste in construction, it becomes a lucrative option to the industry, as it is sustainable and durable [14]. Waste management strategies need to be planned and developed by reduce, reuse, recycle, which in turn will minimize the cost of construction [15]. This leads to the analysis of various waste materials which is being left unused, as a replacement material for the ingredients of concrete such as cement, river sand and broken stone, by comparing the properties and finding its suitability as replacement material in construction.

The work in this paper is divided in different stages such as collection of materials, testing their properties and comparing with the Indian standards, designing the mix for M20 grade concrete, manufacturing the concrete with best waste material, testing the fresh and hardened concrete properties for the workability and compressive strength to find its suitability in sustainable construction.

Paper is organized as follows. Section II describes the experimental work carried out and the designed mix for M20 grade concrete and with the test results, workability and compressive strength were represented as graph and the discussion is made in section III. Section IV presents the conclusion.

## II. RELATED WORK

### MATERIALS

The collected waste materials are converted to various forms such as powder, fine aggregate and coarse aggregate. In order to analyse the property of waste materials collected, the following tests were performed to compare with cement, conventional fine and coarse aggregate along with the Indian Standard. Crushing strength, Impact, Specific gravity and Water absorption were tested for coarse aggregate. Specific gravity and Water absorption are tested for fine aggregate. Fineness, Consistency and Specific Gravity tests were made for binder material. Particle size distribution curve is made to compare the gradation of waste aggregates with conventional.

### TEST ON AGGREGATES

The crushing strength and impact are determined for the coarse aggregate as per IS: 2386 (Part IV) – 1963 and IS: 383 – 1970. The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load. Specific gravity and water absorption is determined as per IS: 2386 (PART III ) -1963. The Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded

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compact aggregate. Generally, flat and elongated particles are avoided and are limited to about 15 % by weight of the total aggregate.

### TEST ON BINDER

The fineness of cement is determined by dry sieving as per IS: 4031 (Part 1) – 1996. The percentage of water for normal consistency for a given sample of cement is determined by vicat apparatus. Specific gravity of cement is determined by IS 2720- Part 3 using specific gravity bottle.

### CONCRETE

Properties such as workability and compressive strength were conducted for the concrete with waste material and compared with the conventional concrete. The various percentage of replacement of fine and coarse aggregate is 0% to 50% in steps of 10%. Workability test is done to determine the relative consistency of freshly mixed concrete by using slump as per IS: 7320 – 1974, IS: 1199-1959 and SP: 23-1982.

### MIX DESIGN

Mix designed as per IS 10262- 1982 for M20 grade of concrete with the design stipulations as 20mm size of aggregate, 0.9 compaction factor, good degree of workability and mild exposure. The mix proportion obtained is 1: 1.425: 3.10 with the water cement ratio of 0.5.

## III. RESULT AND DISCUSSION

### MATERIALS

The following are the test results of the various waste materials tested for coarse aggregate, fine aggregate and binder as per the Indian standards procedure along with the standard value, which is shown in table 1- 3.

TABLE 1. TEST FOR COARSE AGGREGATE

Tests	Steel slag	Ceramic waste	Glass	Construction and Demolished waste	Coconut shell	Marble	Broken stone	Standard value
Impact %	25.26	17.5	61.95	60.42	82.6	67.79	9.03	<45
Crushing %	62.03	21.8	51.68	52.59	96.22	49.74	36.52	<45
Specific gravity	3.84	2.33	0	2.27	1.06	1.04	2.80	2.5- 2.7
Water absorption %	5	2.8	0	7.85	4.64	3.98	0.5	0.1 – 2.0

TABLE 2. TEST FOR FINE AGGREGATE

Tests	Steel slag	Ceramic waste	Construction and Demolished waste	Stone dust	River sand	Standard value
Specific gravity	3.00	2.35	2.27	2.63	2.74	2.5- 2.7
Water absorption %	1.32	0.71	16.33	13.77	1.00	0.1- 2.0

TABLE 3. TEST FOR BINDER

Tests	Cement	Flyash
Fineness %	5	4
Specific gravity	29	27
Consistency %	3.15	2.8

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Aggregates to be used for wearing course, the impact value should not exceed 30%. For bituminous Macadam the maximum permissible value is 35%. For water bound macadam base courses the maximum permissible value defined by Indian Road Congress is 40%. Therefore, the waste materials like glass, construction & demolished waste, coconut shell, marble waste cannot used for road work ceramic waste can be used for road work. The crushing strength of ceramic waste is wit in the standard limit, whereas all other waste materials is not in the limits prescribed by Indian standards. Therefore ceramic waste can be used in making roads. The specific gravity of an aggregate is considered to be a measure of strength or quality of material. The effect of specific gravity on aggregate varies the weight of concrete cubes. Weight of cube plays an important role in determining the quality of concrete and compressive strength. Only the specific gravity of steel slag is greater than the standard value where as the specific gravity of ceramic waste and construction demolished wastes are almost similar to that of standard, which can be used in the field of construction. Water absorption gives an idea of strength of aggregate. An aggregate having more water absorption are more porous in nature. The less pores we have, the good is the bonding between each element. Less pores means less breathing space for concrete. In coarse aggregate form, except broken stones all other waste material have high water absorption, as porosity is nil for glass, water absorption is zero. Ceramic waste has closer value to standards. By adding some admixtures or alternating property of ceramic waste, it can be used in construction. The specific gravity of stone dust is similar to river sand and also falls within the limit of standard value by Indian Standards, whereas, the other waste materials falls outside the range, but the deviation is not much higher. The fly ash is available in powder form; it can be used as a replacement material for cement due to its pozzolanic nature. Fly ash can also be used as an admixture, whose fineness, specific gravity and consistency are shown in table 3.

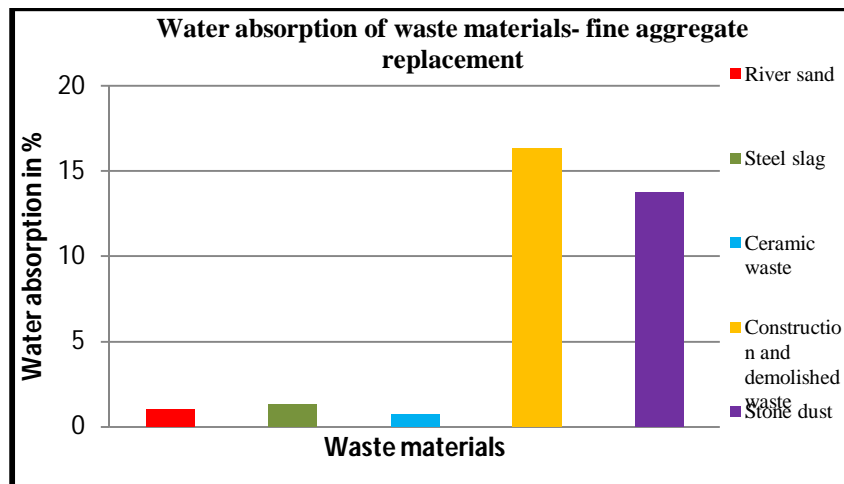


Fig 1. Water absorption for waste materials (fine aggregate)

The water absorption of all the waste materials in fine aggregate form is shown in figure 1. The water absorption of ceramic waste and steel slag as fine aggregate falls under the standard value and almost similar to conventional river sand. Therefore they can be used as a replacement material for river sand. But the other waste materials such as construction and demolished waste and stone dust has very high water absorption of about 16% increase than the conventional river sand, therefore they are not suitable for construction.

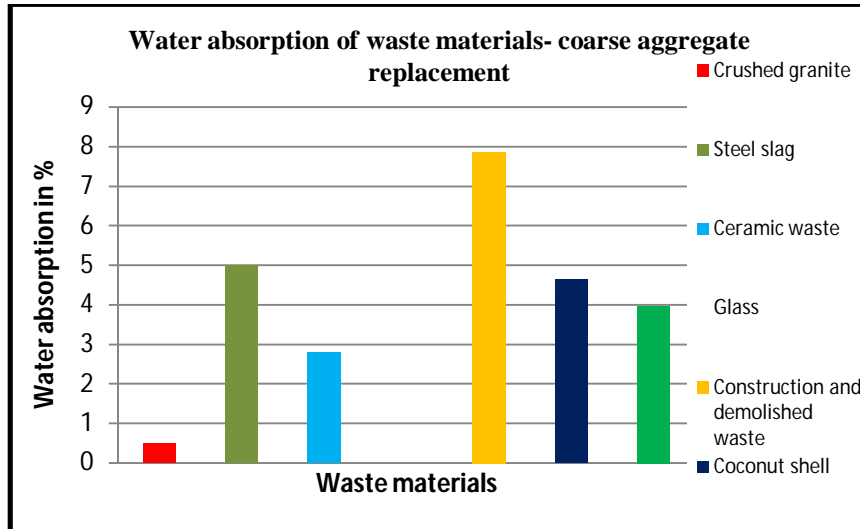


Fig 2. Water absorption for waste materials (coarse aggregate)

The water absorption of all the waste materials in coarse aggregate form is shown in figure 2. The water absorption of glass as fine aggregate is nil. Hence it can be used as a replacement material. The highest water absorption is observed for construction and demolished waste with 7% increase than the conventional crushed granite. The other waste materials with the difference in water absorption of about 4.5% can be used as replacement material for coarse aggregate with some admixtures.

### Gradation of aggregates

The particle size distribution of aggregates was found as per IS 2386 (part1) 1963. Conforming to code IS: 383, the fraction from 4.75 mm to 150  $\mu$  is used as fine aggregate. The fraction from 20 mm to 4.75 mm is used as coarse aggregate. Flakiness and Elongation indices are below 15%.

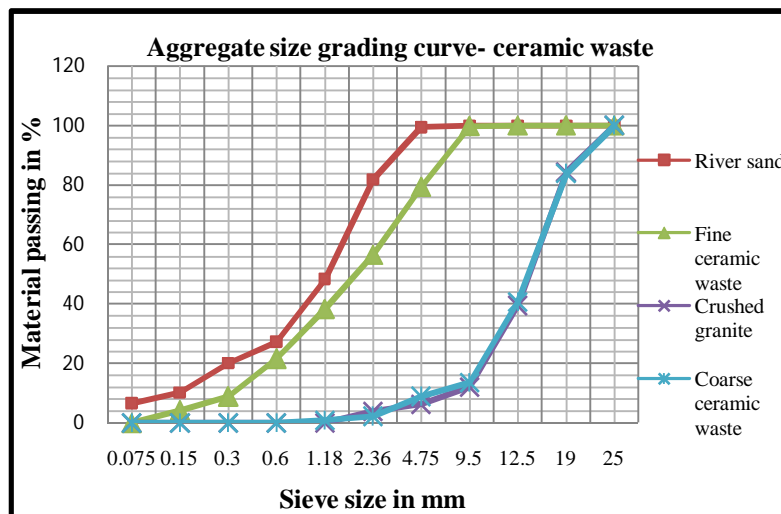


Fig 3. Particle size distribution of ceramic waste with natural aggregates

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Particle size distribution of the conventional fine aggregate (river sand), conventional coarse aggregate (broken stone), fine ceramic waste and coarse ceramic waste are shown in the figure 3. The particle size distribution of coarse ceramic waste and crushed granite are almost same. The fine ceramic waste has the S shaped curve. The material retained from 4.75 mm to 150 μ can be used as replacement material for fine aggregate.

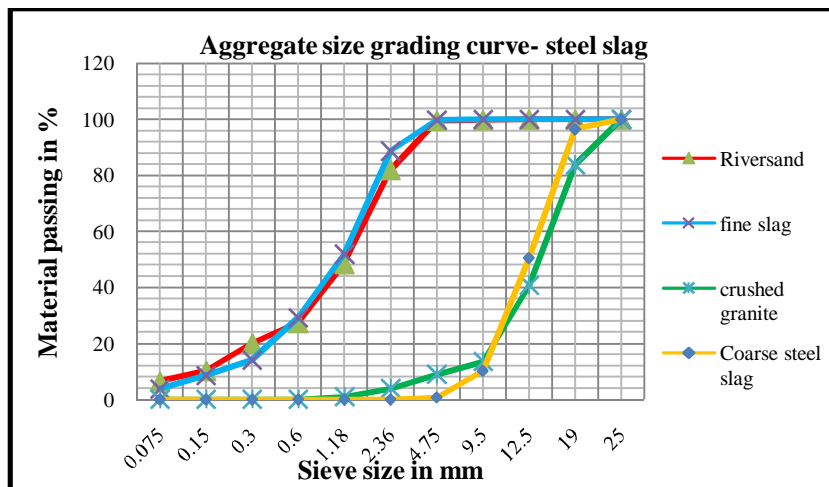


Fig 4. Particle size distribution of steel slag with natural aggregates

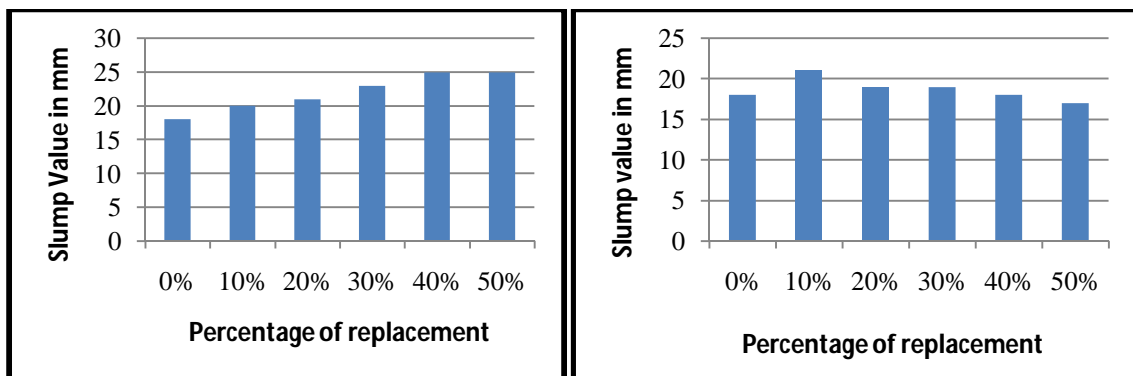
Particle size distribution of the conventional fine aggregate (river sand), conventional coarse aggregate (crushed granite), fine steel slag and coarse steel slag are shown in the figure 4. Fine steel slag follows the path of river sand and coarse steel slag follows the path of crushed granite in the gradation curve. Steel slag in both fine and coarse aggregate can be used as a replacement material in the field of construction.

## CONCRETE

### SLUMP

Figure 5 (a), (b), (c) and (d) shows the workability of concrete replaced by ceramic tile and steel slag for coarse aggregate and fine aggregate respectively.

Fig 5. Workability of concrete with the replacement



(a) Coarse aggregate by ceramic waste

(b) Fine aggregate by ceramic waste

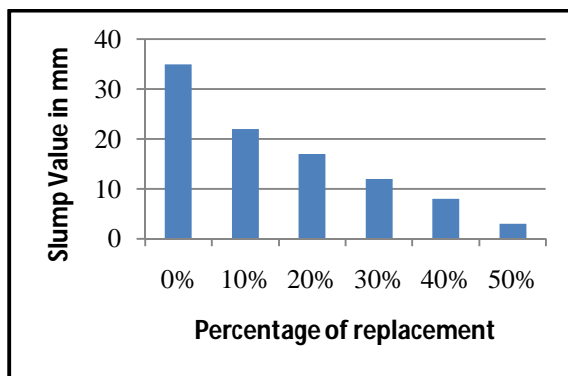
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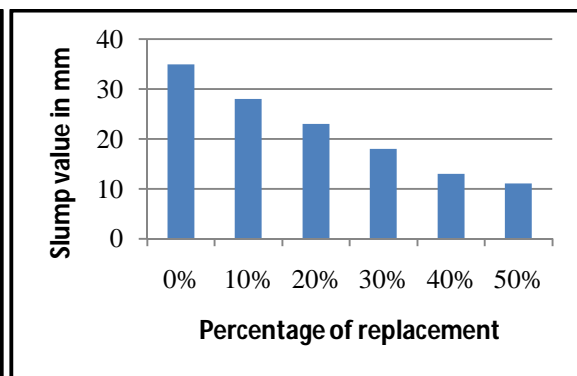
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As the percentage of replacement increases, the workability increases for coarse aggregate replacement by ceramic waste but decreases for fine aggregate replacement this is because, more water is absorbed by fine ceramic waste. The optimum percentage of replacement for fine ceramic waste is 10%. As the percentage of replacement increases, the workability decreases for both fine and coarse steel slag replacement. So, admixture can be used to increase the workability. Steel slag should be cured well before using for concrete work. So that all the water used for concrete mixing will be used for hydration of cement.



(c) Coarse aggregate by steel slag

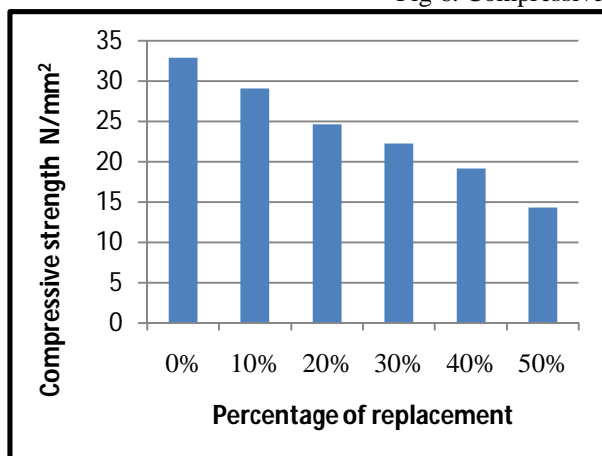


(d) Fine aggregate by steel slag

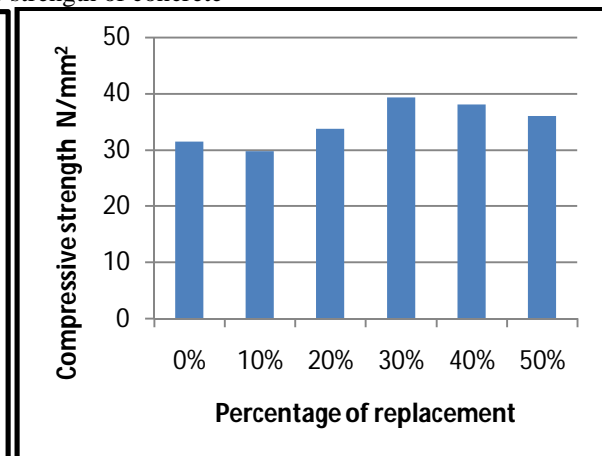
### COMPRESSIVE STRENGTH

Compressive strength of concrete specimens are determined as per IS: 516 – 1956, IS: 1199 – 1959, SP: 23-1982, IS: 10086 – 1982 and is shown in figure 6 (a), (b), (c) and (d). It consists of applying a compressive axial load to moulded cubes at a rate which is within a prescribed range until failure occurs. Tests shall be made at recognized ages of the specimens, the most usual being 28 days.

Fig 6. Compressive strength of concrete



(a) Coarse aggregate replaced by ceramic waste



(b) Coarse aggregate replaced by steel slag

For the concrete up to 20% replacement of fine aggregate by ceramic waste, the compressive strength is more than the conventional concrete beyond which the strength decreases but the compressive strength decreases for all the percentage of replacement for coarse aggregate replacement by ceramic waste than the conventional concrete.



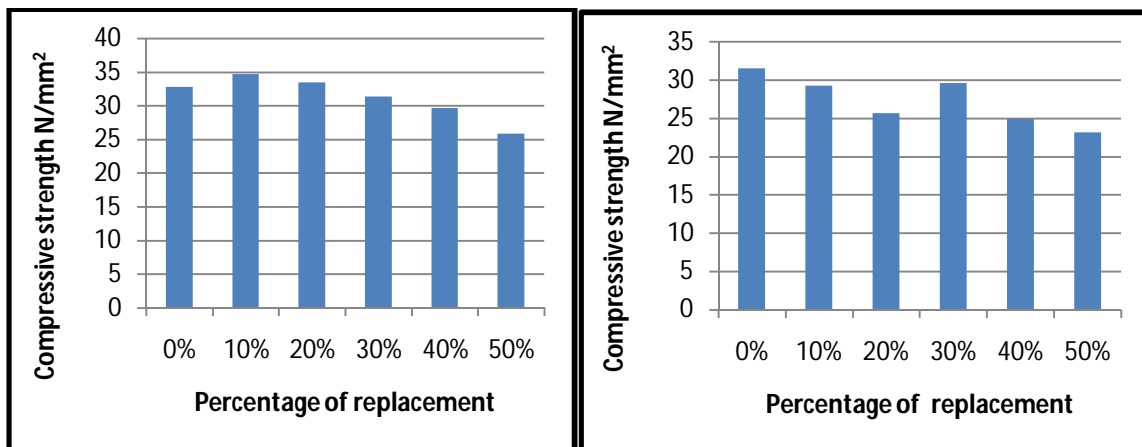
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Therefore the optimum percentage of replacement of ceramic waste in fine form is 20%. As the percentage of replacement increases, the compressive strength decreases up to 20% and then it increases for 30% replacement of fine aggregate steel slag. Also the decreased compressive strength has not much deviated from the compressive strength of conventional concrete. Except for 10% of replacement of coarse aggregate by coarse steel slag, all the percentage of replacement shows better compressive strength than the conventional concrete. Steel slag in coarse aggregate gives better compressive strength.



(c) Fine aggregate replaced by ceramic waste

(d) Fine aggregate replaced by steel slag

#### IV. CONCLUSION

From the test results observed, by analysing the properties of waste materials like construction and demolished waste, stone dust, marble waste, ceramic waste, steel slag, glass waste, fly ash, coconut shell the following conclusions were made.

- The Impact value of steel slag and ceramic waste falls under the standard value defined by IRC, therefore it can be used for road works.
- The crushing strength of ceramic waste is within the limits prescribed by Indian standard and hence coarse ceramic waste can be used for road works.
- The water absorption value of ceramic waste as coarse aggregate has a closer value to that of standard. By adding some admixtures and by altering the property of ceramic waste, it can be used in construction.
- The specific gravity of stone dust and water absorption of ceramic waste and steel slag as fine aggregate falls under the standard value. Therefore they can be used as a replacement material for river sand.
- As per the consistency and fineness value of fly ash, it can be used as a replacement material for cement due to its pozzolanic nature.

Therefore steel slag and ceramic waste is used as replacement material and its workability and compressive strength were analysed.

- As the percentage of replacement increases, the workability increases for coarse aggregate replacement by ceramic waste. But the optimum percentage of replacement for fine ceramic waste is 10%, beyond which the workability decreases.
- As the percentage of replacement increases, the workability decreases for both fine and coarse steel slag replacement. So, admixtures can be used to increase the workability.
- For steel slag replacement, the compressive strength up to 20% of replacement of fine aggregate by fine steel slag decreases beyond which it increases for 30% of replacement. Hence the optimum percentage of replacement for fine steel slag is 30%. For the Coarse aggregate replacement by steel slag 30% is the



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optimum.

- For the fine ceramic waste replacement, 10% is the optimum percentage of replacement.

## REFERENCES

- [1] Dinesh. A., Borkar, Patel. Y.J., 2015, "Recycled aggregate concrete", International Journal for scientific research and development, Vol.3, pp. 547- 549.
- [2] Ankit J Patel, Sandip P. Patel, Daxesh Prajapathi, Harsh Patel, 2014, " Literature review on different waste materials use in concrete", Journal of emerging technologies and Innovative Research, Vol.1, pp. 899-902.
- [3] Hitesh Kumar Mandavi, Vikas Srivastava, Agarwal.V.C., 2015, "Durability of concrete with ceramic waste as fine aggregate replacement", International Journal of Engineering and Technical Research, Vol.3, pp. 196- 199.
- [4] Parminder Singh, Rakesh Kumar Singla ., 2015, "Utilization of Waste Ceramic tile as coarse aggregate in concrete", Journal of Multidisciplinary Engineering Science and Technology, Vol.2, pp. 3294-3300.
- [5] Amarnath Yerramala, Ramanchandrudu C, 2012, "Properties of concrete with coconut shells as aggregate replacement", International Journal of Engineering Inventions, Vol.1, pp. 21- 31.
- [6] Damodhara Reddy. B, Aruna Jyothy. S, Fawaz Shaik., 2014, "Experimental Analysis of the Use of Coconut shell as Coarse Aggregate", Journal of Mechanical and Civil Engineering, Vol.10, pp. 06-13.
- [7] Serniabat.T.S, Khan. M.N.N., S, Zain.M.F.M., 2014, "Use of waste glass as coarse aggregate in concrete: A possibility towards sustainable building construction", International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, Vol.8, pp. 1075-1078.
- [8] Tomas U. Ganiron Jr, 2013, " Use of recycled glass bottles as Fine aggregates in concrete mixture", International Journal of advanced science and technology, Vol.61, pp. 17-28.
- [9] Murthi. P, Alan. S, Chakkaravarthi. C, Raguraman. N, Seenivasan.P, 2015, "Sustainable replacement of steel slag as coarse aggregate in concrete", International Journal of Applied Engineering Research, Vol.10, pp. 314-345.
- [10] Chetna M Vyas, Darshana R Bhatt, 2013, "Concept of Green concrete using construction demolished waste as recycled coarse aggregate", International Journal of Engineering trends and technology, Vol.4, pp. 3160-3165.
- [11] Remya Raju, Mathews M. Paul, Aboobacker. K. A., 2014, "Strength performance of concrete using bottom ash as fine aggregate", International Journal of Research in Engineering and Technology, Vol.2, pp. 111- 122.
- [12] Latha G,Suchithreddy A, Mounika K, 2015, "Experimental investigation on strength characteristics of concrete using waste marble powder as cementitious material", International Journal of Innovative Research in Science, Engineering and Technology, Vol.4, pp.12691-12698.
- [13] Kothai PS, Malathy R, 2014, "Utilization of steel slag in concrete as a partial replacement material for fine aggregate", International Journal of Innovative Research in Science, Engineering and Technology, Vol.3, pp. 11585-11592.
- [14] Manaswini C, Vasu Deva, 2015, "Fibre reinforced concrete from industrial waste- a review", International Journal of Innovative Research in Science, Engineering and Technology, Vol.4, pp.11751-11758.
- [15] Yakkaluru peddavenkatesu, Harish Naik B, 2016, "Waste minimization in construction industry", International Journal of Innovative Research in Science, Engineering and Technology, Vol.5, pp.18023-18030.