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A review on utilization of ceramic waste and foundry sand in concrete

KEYWORDS: waste utilization, ceramic waste powder, waste foundry sand, Physical and mechanical Properties.

Shyam Makwana	Prof. Yashwantsinh zala
Civil Engineering Department, Marwadi education foundation group of institutions (Rajkot) , Gujarat Technological University	Civil Engineering Department, Marwadi education foundation group of institutions (Rajkot) , Gujarat Technological University

ABSTRACT This paper deals with a state of art review on utilization of ceramic waste and foundry sand in civil engineering practice. In the world, there are a large amounts of calcined-clay wastes and waste foundry sand to generate from the industry each year. So, these wastes are used in landfills. Reusing these wastes in concrete could be a very beneficial situation for society. Therefore, at one side, we can solve the problems of industries and at the other side, we can make more sustainable concrete by reducing non renewable resources like cement and aggregates and also solve environmental problems related to land filled wastes. This paper shows the conclusions from different research papers with using these wastages in concrete. So it has good expectation that it behave well in construction industry.

I. INTRODUCTION

Many researchers have made attempts to use the waste materials to reduce the disposal problems and to improve the physical and mechanical properties of concrete. Fly ash, silica fume, Pozzocrete, Quartz Sand, egg shell powder etc.are some of the waste materials used for making concrete more

durable. Indian ceramic production is 100 Million ton per year. In ceramic industry, about 15%-30% waste material generated from the total production. This waste is not recycled in any form at present. The Ceramic industries are dumping the waste in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry. There are about 50,909 foundries in the world from which 6 – 10 million tons of foundry sand is totally discarded on to the ground. The Indian Metal Casting (Foundry Industry) is well established & producing estimated 9.344 MT (Million Tons) of various grades of Castings as per International standards. There are approximately 4500 foundry units out of which 85% can be classified as Small Scale units & 10% as Medium & 5% as Large Scale units. So, these wastages generate environmental and disposal problems.

TABLE 1 : Physical properties of ceramic waste (Hiroshi Higashiyama, Elsevier, Construction and Building Materials 26 (2012) 96–101)

Physical properties	Ceramic waste
Maximum size (mm)	5.0
Specific gravity	2.30
Water absorption (%)	0.47
Finess modulus	3.74

TABLE 2 : Chemical properties of ceramic waste (Amitkumar D. Raval, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-2, July 2013)

Materials	Ceramic Powder (%)
SiO_2	63.29
Al_2O_3	18.29
Fe_2O_3	4.32
CaO	4.46
MgO	0.72
P_2O_5	0.16
K_2O	2.18

Table 3: Physical Properties of Spent Green Foundry Sand (R. Siddique, Waste Materials and By-Products in Concrete, Springer-2008)

Property	Results
Specific Gravity	2.39-2.55
Bulk Relative Density, kg/m^3	2589
Absorption, %	0.45
Moisture Content, %	0.1-10.1
Clay Lumps and Friable Particles	1-44
Coefficient of Permeability (cm/sec)	10^{-3}-10^{-6}
Plastic Limit / Plastic Index	Non plastic

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

Table 4: Chemical properties of foundry sand ®. Siddique, Waste Materials and By-Products in Concrete, Springer-2008)

Constituents	Value (%)
SiO_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
SO_3	0.09
Na_2O_3	0.19
K_2O	0.25

In the ceramic waste, the proportion of SiO2 is about 60-70% and in foundry sand is 80-90% which is responsible to improve the strength and durability of concrete. So, it can be used in concrete to improve the properties of concrete and reduce disposal problems on land and environmental problem.

I. LITERATURE REVIEW

The literature review showed there is a lack of information regarding the influence of the incorporation of recycled ceramic waste and foundry sand on the mechanical behaviour of concrete.

The general features of a few selected experimental researches concerning the properties of concrete with these wastages analysed in the present article are briefly described next.

A) UTILIZATION OF CERAMIC WASTE IN CONCRETE

1) Eva Vejmelkova, Martin Keppert & Robert C erny present in their research work to do experimental work regarding the basic physical characteristics, mechanical and fracture-mechanics properties, durability characteristics, hydric and thermal properties of high performance concrete (HPC) with up to 60% of Portland cement replaced by fine-ground ceramics.

In this research, they concluded that up to 60% replacement of OPC cement with fine ground ceramic i)The compressive strength decreased very fast after replacement levels higher than 20%. ii) The bulk density of HPC mixes decreased with increase with fine ground ceramic. iii) The frost resistance of HPC mixes concrete is excellent up to 40% replacement levels.

Table5: Properties of fresh mixtures

Material	Slump (mm)	Bulk density (kg m_3)
CR	180	2410
Cb10	210	2400
CB20	210	2380
CB40	180	2394
CB60	150	2370

CR-Control Concrete, CB10, CB20, CB40, CB60 - 10%,20%,40%,60% replacement of cement with fine ground ceramic waste

Table 6 : Compressive strength (MPa)

Material	7 days	28 days
CR	63.3	62.0
CB10	65.2	65.7
CB20	47.8	60.2
CB40	37.9	42.6
CB60	21.3	22.5

Therefore, fine-ground ceramics at lower Portland cement replacement levels may be considered a viable alternative to metakaolin as supplementary cementitious material in concrete.

2) C. Medina studied in their research work to explores whether substituting 20% and 25% recycled sanitary ware for gravel in coarse aggregate affects structural recycled concrete resistance to water.

In this study, The maximum depth of water penetration is not exceeds than 30mm in recycled concrete by using 20% and 25% sanitary ware waste replaced with coarse aggregates than natural concrete.

i) At the 28-day compressive and tensile splitting strength values for the concretes studied. The use of recycled aggregate in CC-25 was found to improve compressive and tensile splitting strength by 12% and 26%, respectively, compared to the reference concrete. ii) The effective porosity values obtained were 38%, 41% and 42% of total RC, CC-20 and CC-25 total porosity, respectively. The value for CC-25 was 15% greater than for RC. iii) the total water absorption values found to increase over RC was 36% for CC-20 and 46% for CC-25. iv) Sorptivity values for CC-20 and CC-25 were 11% and 38% higher than in conventional concrete, respectively.

In light of these findings, the replacement of natural aggregate with recycled sanitary ware industry waste is feasible from the standpoint of its resistance to water permeation.

3) Amitkumar D. Raval studied in this research to replace OPC cement with ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-25 grade concrete.

He concluded that the Compressive Strength of M25 grade concrete increases when the replacement of cement with ceramic waste up to 30% by weight of cement and further replacement of cement with ceramic powder decreases the compressive strength.

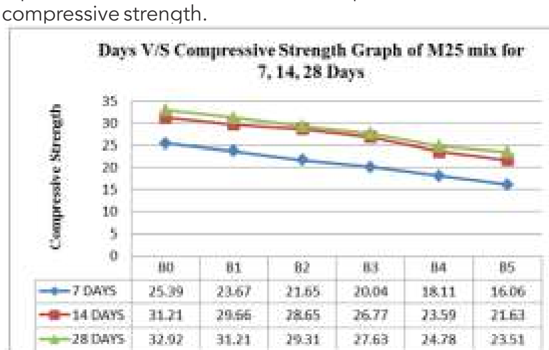

Figure: 1 Percentage Replacement of Ceramic waste V/S Compressive Strength (N/mm2) of Concrete for M25 mix at 7, 14 and 28 days

Concrete on 30% replacement of cement with ceramic waste, compressive strength obtained is 26.77 N/mm2 and vice-versa the cost of the concrete is reduced up to 13.27% in M25 grade and hence it becomes more economical without compromising concrete strength than the standard concrete.

4) Lalji Prajapati presents in this research work that ceramic slurry waste powder is replaced by cement in concrete. Concrete grade M25 was made by replacing by 0% to 30% of Ordinary Portland 53 grade cement with ceramic slurry waste powder passing through 90 microns. Compressive strength, flexural strength, water absorption and sorptivity are determined with water cement ratio 0.48.

As compare to convention concrete addition of ceramic waste powder, its characteristic strength is decreased compare to conventional concrete. Compressive strength of cylinder using ceramic waste powder is been replaced by up to 30 % without affecting its characteristic strength of M25 grade concrete.

Compare to conventional concrete flexural strength insignificantly decreased at replacement of ceramic waste powder. Water absorption and sorptivity increased at replacement of cement compare to conventional concrete, but then after 10% interval its increase very less.

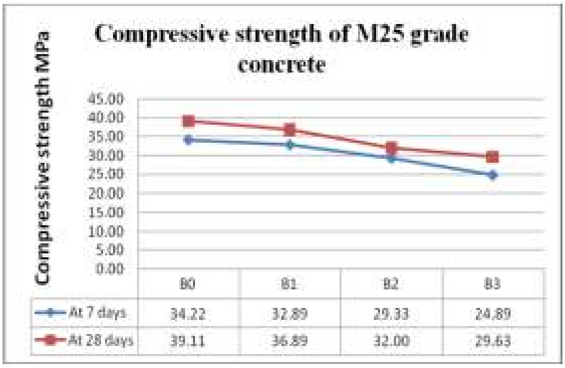

Figure: 2 Day V/S Compressive strength of cube at 7 and 28 days

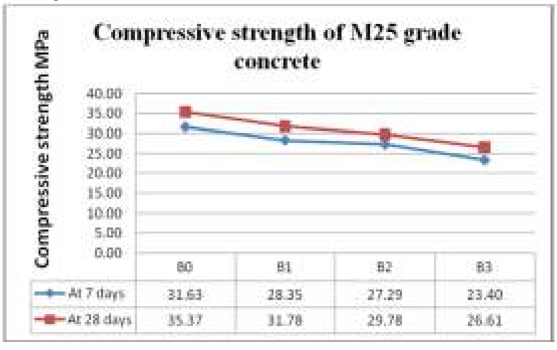

Figure: 3 Day V/S Compressive strength of cylinder at 7 and 28 days

So, up to 30% replacement of cement by ceramic waste slurry powder is technically and economically feasible and viable.

A) UTILIZATION OF FOUNDRY SAND IN CONCRETE

1) Dushyant R. Bhimani presented in this research paper to replace fine aggregate with foundry sand accordingly in the range of 0%, 10%, 20%, 30% by weight for M-20 grade concrete.

Table 7: COMPRESSIVE STRENGTH (MPA) OF CONCRETE WITH FOUNDRY SAND

Foundry Sand	Avg.Compressive Strength, (MPa)	
	28 days	56 days
M1	28.50	32.80
M2	29.70	33.13
M3	30.00	34.50
M4	31.30	37.50

So, we can say that up to 30% foundry sand utilized for economical and sustainable development of concrete.

2) Khuram Rashid studied that to evaluate the compressive strength of concrete by utilizing three types of used foundry sand; with bentonite clay, with sodium silicate & with phenolic resin as partial replacement of fine aggregates. To accomplish the research an experimental program was conducted in which ten concrete mixtures were casted, by keeping all other parameters for concrete proportioning as constant and only change made was in the amount of fine aggregates. Ten, Twenty and Thirty percent replacement level of river sand by used foundry sands was maintained in this study. All fine aggregates were selected after achieving desired physical and chemical tests. Workability, compressive strength and modulus of elasticity were measured and compared with the conventional concrete termed as control mixture.

He concluded from this study that Concrete specimen with UFS exhibited higher workability than conventional concrete. The increase in workability may be attributed to the presence of finer Used Foundry Sand (UFS). In all cases rapid increase in workability has been observed when replacement level varied from 20% to 30%.

At age of 7 days, about 15 to 20 % reduction in strength was noticed when NS replaced by 10% UFS and further decrease in strength occurred when replacement level was increased. Similar results have been observed at 28 days but reduction in strength reduced to 8% when NS was replaced by 10% FBC and 25 to 33 % reduction in strength were observed at 30% replacement level. FPR showed better strength at age of 63 days, the compressive strength of control mixture and FBC up to 20% replacement level were almost same.

Consistent with the values of compressive strength, the Modulus of Elasticity (E) of UFS-concrete mixtures was smaller than that of control mixture.

3) Eknath P.Salokhe studied that to evaluate the comparative study of the properties of fresh & hardened concrete containing ferrous & non-ferrous foundry waste sand as fine aggregate replacement. Fine aggregates were replaced with four percentages of foundry sand. The percentages of replacements were 0, 10, 20, & 30% by weight of fine aggregate & tests were performed for all replacement levels of foundry sand for M20 grade concrete at different curing periods (7 & 28 days).

He concluded that compressive strength of concrete

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

mixtures with 10%, 20% and 30 % of foundry sand as sand replacement was higher than the control mixture (M-1) at 7 days age and the strength was maximum at 20% replacement level for both types of sands. Compressive strength results of concrete mixtures with and without FWS sand at the age of 28 days shown that concrete mixtures made with ferrous FWS exhibited lower compressive strength than control concrete for 10% & 20% replacement level and it was almost equal to that of control mix for 30% replacement level. Whereas Compressive strength of concrete mixtures made with non ferrous FWS exhibited almost equal value as that of control concrete for 10% replacement level and goes on reducing for 20% and 30% replacement level.

Splitting tensile strength of control mixture M-1 (0% FWS) was 3.3 MPa at 28 days. There was decrease in strength to 1.87 MPa for M-2 (10% Ferrous FWS), 2.85 for for M-3 (20% Ferrous FWS), 2.71 for M-4 (30% Ferrous FWS) and 2.08 for M-5 (10% Non-Ferrous FWS), 2.64 for M-6 (20% Non-Ferrous FWS) and 2.08 for M-7 (30% Non-Ferrous FWS) respectively. Higher value of splitting tensile strength was observed at 20% ferrous WFS and at 20% non ferrous FWS. So it is evident that both the foundry waste sands gives maximum splitting tensile strength at 20% replacement level.

Inclusion of both ferrous & non ferrous FWS gives dense concrete at 20% addition. Water absorption is minimum with 20% ferrous FWS & with 10% non ferrous FWS. Whereas mixture with 10% non ferrous FWS gives least water absorption value. Both ferrous & non ferrous FWS can be suitably used in making structural grade concrete.

III. CONCLUSION

From the above research papers, Conclusion are made that up to 20 to 30% replacement of ceramic waste and foundry sand in concrete improved the physical and mechanical properties of concrete with compare to conventional concrete.

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