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UTILIZATION OF CERAMIC WASTE AS A REPLACEMENT OF AGGREGATES AND ITS EFFECT ON VARIATION OF EXPENDITURE

ACHSAH ELIZABETH JACOB[1], Er. AKASH AGGARWAL[2], YOGENGRA KUMAR KUSHWAHA[3]
[1]Student of M.Tech in Construction Engineering and Management, SHUATS-Allahabad
[2,3]Assistant Professor, Dept. of Civil Engineering, SHUATS- Allahabad

ABSTRACT

India is marked as a developing country; new developments can be seen widely in the field of constructions. With the increase in population, the developments have increased leading to more constructions for our own needs. Construction industry needs construction materials in a huge demand which includes cement, sand and aggregates (coarse and fine). Also these materials are from nonrenewable natural resources and expensive. Use of natural resources emerges to the concern for protecting environment. And to preserve these resources like aggregates, alternative materials should be used which are rejected as waste. Construction Industry has its own merits and demerits, one among the most serious demerit is disposal of waste and a solution to this problem can be obtained by finding a way to reuse these wastes in the most effective manner keeping in mind to economize expenditure. Construction and Demolition (C&D) wastes adds to the maximum proportion of wastes generated worldwide i.e. about 75%. Moreover, ceramic materials add the maximum proportion of wastes in the C & D wastes i.e. about 54%. Ceramic waste includes brick wall (debris), ceramic tiles and ceramic waste of utensils. Present practice of disposal of these ceramic wastes is only landfill. It is because of the lack of knowledge and experience, unavailability of measures and risk avoidance. It is predicted that 30% of the total ceramic material brought daily to the site changes to waste because of the improper handling of the materials and this turns to be a huge amount when calculated for a project. These wastes cannot be recycled in any way and hence causes disposal problem and loss to the industry. This waste is hard, durable and resistant to all type of declining forces and these properties make them an alternative for the replacements which has to be done for the concrete production. Use of ceramic waste in concrete makes it economical and also solves the disposal issues. In this research, we have casted concrete blocks with partial replacement of aggregates (both fine and coarse) with ceramic waste material and observed the variation in expenditure keeping in view the basic characteristics of concrete.

Keywords: Replacements, Ceramic wastes, Economical, Utilization of waste, Compressive strength, Strength of the concrete.

INTRODUCTION

Aggregates (coarse and fine) and cement are the most essential ingredients used in the production of the concrete in the field of construction. The over utilization of these natural resources is having an adverse effect on the environment and climatic conditions. Preservation of these natural resources such as aggregates; is a need to the society and its wellbeing and can be preserved by using suitable substitute that are rejected and are considered as waste.

In recent decades, we have witnessed increasing social concern over the waste management generally the waste from the construction industry which includes C&D waste, broken tiles, sanitary ware waste, ceramic waste etc. These wastes are just dumped as landfills but there have been researches in which these waste can be used for the production of concrete by replacing certain percentage of the construction ingredients with the ceramic waste. Thus the use of ceramic waste in concrete makes it economical and also solves the disposal issues. In addition, to the preservation of the environment, use of these ceramic waste yields a series of advantages such as reduction in the use of the raw materials which furthers contributes to enhancement of the natural resources (*Juan and Medina, 2010)*.

The History of Aggregates in the field of Construction

For thousands of years, Sand and stones were used by the people for the foundation work. During the period of the Roman Empire, aggregates were produced and used for the first time for the construction of aqueducts and road networks. The discovery of concrete, which was an important construction material created an instantaneous and unfluctuating demand for the construction aggregates. The invention of modern methods like blasting has empowered the expansion of quarries, which is now used worldwide, where there bedrock sediments of aggregates exists. Natural sand and gravels are earthed as aggregates where limestone, stone bedrock sediments do not exist. There are many places where both of these are not available, construction requirement is hence fulfilled by transporting these aggregates by trucks, rail etc. demand can be partially met by using slag or recycled concrete.

Modern Production: The invention of modern methods like blasting has empowered the expansion of quarries, which is now used worldwide, where there bedrock sediments of aggregates exists. Natural sand and gravels are earthed as aggregates where limestone, stone bedrock sediments do not exist. There are many places where both of these are not available, construction requirement is hence fulfilled by transporting these aggregates by trucks, rail etc. demand can be partially met by using slag or recycled concrete.

Currently, the total demand of aggregate (in US) by final market sector was 30% to 50% for non-residential buildings (offices, hotels, stores, manufacturing plants, government and institutional buildings) and for housing it is 25%

The American Society for Testing and Materials published an exhaustive listing of specifications which includes ASTM D 692 and ASTM D 1073 for various construction aggregate products, which, by their individual design, are suitable for specific construction purposes. These products include specific types of aggregates (coarse and fine) designed for such uses as additives to asphalt and concrete mixes, as well as other construction uses.

Aggregates today: Construction aggregates are also known as aggregates, which are broadly classified as coarse and fine aggregates, including gravels, crushed stones, sand, slag, recycled concrete etc. Aggregates are said to be the most unearthed material in the world and is used in drainage applications such as foundation, septic drains fields, retaining wall drains, and roadside edge drains. These serve as a reinforcement to increase strength and durability to the concrete. Aggregates are basically granular, inert and inorganic materials which consist of stone-like solids. Aggregates can be either as road bases, fillings or can be used with cementing materials such as Portland or asphalt cement. Among these the most popular use of aggregates is to produce Portland cement concrete (P.C.C). About three-fourth of the total volume of P.C.C is occupied by aggregate. It is an assured fact that the components occupying such a large percentage of the mass should have an important outcome on the properties of both the fresh and hardened products. In addition to this, aggregates are used in asphalt cement concrete in which they utilize 90% or more of the total volume. Aggregates are the materials used for the manufacture of construction outcomes i.e. RMC which constitutes of 80% of aggregates, pre-cast, lime, cement and asphalt which is made of 95% of aggregates. These aggregates are used to resist compressive strength. Aggregates are cheaper than cement and provide durability and stability to concrete. Aggregates are one among the most important ingredients. These aggregates help in reduction of shrinkage and also effects economy. Earlier aggregates were considered to be chemical inert substance but now it has been found that some of them are chemically active and also shows the bond between the aggregates and the paste. Aggregates helps in filling the voids, provides rust protection to the pipe, in water filtration and also used in sewage treatment processes. Production of these aggregates are from the natural resources and are extracted from the quarries, gravel pits and also from the sea which are known as marine aggregates. From other industrial processes, like blast furnace slag, china clay residues, we obtain by-products, these are the secondary aggregates.

Environmental and social issues of aggregate manufacturing industry: There are two stages in aggregate processing i.e. quarrying and processing raw materials and delivery of aggregates to the concrete production plant. There are major environmental impacts caused due to these processes such as at the stage of quarrying and processing the landscape is scarred, dust and noise pollution, some of these sources are in the areas of outstanding natural beauty which is affected, los of agricultural land(or removal from use for many years), energy consumption, carbon dioxide emissions etc and at the stage of delivery of these aggregates many problems are faced such as transportation issues, fuel consumption, traffic related issues etc.

Ceramic waste: One of the greatest obstacles of the biota or the environment is connected to the deportation of waste and using it. Bulks of wastes are generated annually in all the countries. C&D wastes add to the maximum ratio of wastes generated worldwide i.e. about 75%.Moreover, ceramic materials add the maximum proportion of wastes in the C & D wastes i.e. about 54%. The worldwide manufacture of ceramic tiles during 2011-12 was around 11,200 million square meters. China, the leading ceramic tiles manufacturer (5,200 million square meters) which is 47% of world fabrication as well as customer (4,300 million square meters) which is 39% of world ingestion. India ranks third with an account of about700 millionsq.metres i.e. 6.5% of the world manufacture. This huge production has made tile to be the most commonly used material in the world. Usually, broken pieces of tile, ceramic and sanitary ware are generated in altered forms, some of which are formed in companies in the course of and after making process due to faults in either production or human actions, and also unsuitable raw ingredients. Some others are formed in transportation and distribution procedures and finally, the most bulk of them are created as a result of destroying constructions. It is projected that around 30% of daily fabrication of ceramic materials in India changes to wastes and this amount reaches to millions ton per year. These wastes are not recycled presently in any form. Consequently, they are unusable in practiced and cause environmental and disposal problems. Though, the ceramic wastes are highly resistant to chemical, biological and physical degradation forces and are durable and hard. The properties of these materials make them a good and suitable choice that can be used in concrete. The usage of waste ceramic tiles in concrete effects the characteristics of green and hardened concrete, and makes it cost-effective and also solves some of the disposal problems. (Daniya *and Ahmad, 2015*)

Ceramic wastes classifications: These are classified as non-recyclable wastes except for the purpose of using it as filing material. Established on the researches regarding usage of these C&D wastes, ceramic wastes are likely to be used in the production of concrete. However there are no protocol and specifications for using these wastes in the concrete. In addition to this, the local industry doesn't have expertise to utilize this material. Clay is abundantly used in the making of ceramics, and it is not a pozzolanic material. It is because of the absence of silicate property which when reacts with water to form calcium hydroxide in the concrete production. The reformation of clay to develop into pozzolanic starts during the dehydration process which is initiated when clay is heated around 500 C , and thus amorphous and active aluminium oxide is separated.

Justification: The study conducted here is an endeavour to examine the usage of ceramic waste as a replacement of aggregates for the making of concrete blocks. The current study is a part of a detailed program where experimental investigations have been carried out to access the result of replacing the usual material by reasonable alternative or backup i.e. Ceramic waste on the strength concrete, weight of concrete and the manufacturing cost. For this study 72 cubes were cast by substituting coarse aggregate by ceramic waste. The compressive strength of this concrete were observed and compared with those of conventional concrete. To achieve this comparative study cubes were cast replacing coarse aggregate by 10%, 15%, 20%, 25% 30% 40% and 50%. These cubes were tested after 7, 14 and 28 days. To identify compressive strength, weight and cost of volume mix in the ratio 1:2:4 (where 1 is proportion cement, 2 is for fine aggregate of size less than 4.75mm and 4 is for coarse aggregate of size between 12.5mm and4.75mm size aggregate) were used during the investigations at water cement ratio of 0.55.

REVIEW OF LITERATURE

This chapter deals with the review of literature on major areas that include the use of ceramic in the concrete.

2.1 Ceramic wastes

- ***Torgal and Jalali* (2010)** examined the feasibility of using ceramic wastes in concrete and their results show that concrete with 20% cement replacement although has a minor strength loss but possess increased durability performance, while when concrete mixes with ceramic aggregates show better results than the control concrete mixtures concerning compressive strength, capillary water absorption, oxygen permeability and chlorine diffusion thus leading to more durable concrete structures.
- ***Juan et al.* (2010)** investigated the re-use of ceramic wastes in construction industry and demonstrated that the introduction of recycled ceramic aggregates has no negative effects on cement hydration, and can thus be considered an inert material and that waste from the ceramic sanitary ware industry can be used to partially substitute natural coarse aggregates, and indeed confers the recycled concrete with positive characteristics as regards mechanical behavior. The recycled concrete obtained can be used for structural purposes, since its characteristic compressive strength exceeds 25 N/mm2, the minimum strength requires for structural concrete.
- ***Raval et al.*(2013)** reported the use of ceramic waste powder as partial replacement of cement in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-25 grade concrete. The wastes employed came from ceramic industry which had been deemed unfit for sale due to a variety of reasons, including dimensional or mechanical defects, or defects in the firing process. The results demonstrated that the use of ceramic masonry rubble as active addition endows cement with positive characteristics as major mechanical strength and the economic advantages. Reuse of this kind of waste has advantages economic and environmental, reduction in the number of natural spaces employed as refuse dumps. Indirectly, all the above contributes to a better quality of life for citizens and to introduce the concept of sustainability in the construction sector.
- ***Rajamannan et al.* (2013)** investigated the effect of addition of ceramic waste to clay materials and concluded from chemical, mineralogical and morphological analyses, that water absorption and compressive strength tests show that ceramic waste can be added to the clay material with no detrimental effect on the properties of the sintered fire-clay products. The test results indicate that the ceramic waste could be used as filler in ceramic bricks, thus enhancing the possibility of its reuse in a safe and sustainable way.
- ***Da Silva et al.* (2014)** performed a study to evaluate the physical and mechanical properties of solid bricks made with soil-cement mixtures uniaxially pressed with the addition of construction waste, having hydrated lime and CPII F-32 Portland cement as binding agents to be used in formulations. Raw materials were characterized by particle size analysis, Atterberg limits, XRF and XRD. Solid bricks were made with soil-cement mixtures and Ceramic Wastes, which were cured for 7, 28 and 56 days and submitted to compressive strength, water absorption and modified durability tests. The best results

obtained were for percentages of 12% cement and 4% incorporated Ceramic Wastes.

- ***Zimbili et al.* (2014)** investigated the usage of ceramic waste in construction and the results proved that the temperatures used in the manufacturing of ceramic tiles (about 900 degree centigrade) are sufficient to activate pozzolanic properties of clay. They also showed that, after optimization (11-14% substitution); the cement blend performs better, with no morphological difference between the cement blended with ceramic waste, and that blended with other pozzolanic materials. Sanitary ware and electrical insulator porcelain wastes are some wastes investigated for usage as aggregates in concrete production. When optimized, both produced good results, better than when natural aggregates are used
- ***Daniyal and Ahmad* (2015)** investigated the effect of addition of crushed waste ceramic tiles as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution and analyzed that, the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5was determined as about 30%. The compressive and flexural strength of optimal concrete was found 5.43% and 32.2% higher than reference concrete respectively. The findings revealed that using waste ceramic tile lead to enhancing the properties of concrete.

MATERIALS AND METHODOLOGY

Cement: In this experimental study, Pozzolana Portland Cement (P.P.C) of Prism brand obtained from single batches throughout the investigation was used. The two basic ingredients of Portland cement are namely argillaceous and calcareous material. Cement of uniform colour (i.e. grey with a light greenish shade) and free from lumps was used in this experimental work.

Fine Aggregate: The fine aggregate was locally available river sand which is passed through 4.75 mm sieve.

Coarse Aggregate : The coarse aggregate was locally available quarry, passing through 12.5mm sieve and retaining on 4.75mm sieve.

Super-plasticizer : 2% of super plasticizer of Conplast brand is used.

Water: Water that is fit for drinking (potable) is used for mixing and curing. The water cement ratio (w/c) of 0.55 for volumetric ratio 1:2:4

Ceramic Waste Aggregate: In this experimental study ceramic waste is provided by a local vendor from Allahabad, who sells ceramic tiles of different brands and discards the damaged or broken tiles. This sample had different sizes so it was broken into smaller pieces and thus is made to pass through 12.5mm sieve and retains on 4.75mm sieve.

Concrete

Volumetric concrete mix is prepared in the ratio 1:2:4 Good stone aggregate and Natural River sand of Zone-II were used as coarse and fine aggregate respectively. Maximum size of coarse aggregate was 12.5 mm, and maximum size of fine aggregate was 4.75mm.

Result and Conclusion

The compressive strength of conventional concrete as well as ceramic waste concrete at 7, 14, 28 days are given in table 1.

Table 1: Compressive strength of ceramic waste concrete (W/C=0.55)

S.N.	Cube designation	Compressive strength(kN/mm^2)				% age of ceramic waste	% increase in strength
		7 days	14 days	28 days	Avg. at 28 days		
1	V1	12.93	15.7	15.83	17.31	0%	-
		11.8	14.42	18.2			
		13.5	15.8	17.9			
2	V2	11.56	16	18.67	20.19	10%	16.64%
		8.89	13.78	20.13			
		11.28	13.15	21.78			
3	V3	7.56	18.22	25.33	27.42	15%	58.41%
		9.91	19.37	27.78			
		9.33	17.33	29.16			
4	V4	4.18	9.42	24.58	20.5	20%	18.42%
		16.09	11.2	21.11			
		11.2	13.78	15.82			
5	V5	11.24	15.56	23.24	21.43	25%	23.80%
		16.09	15.2	19.2			
		12.44	16.09	21.87			
6	V6	9.96	18.76	23.56	25.78	30%	48.93%
		12.13	17.42	27.47			
		11.11	19.38	26.31			
7	V7	7.73	12	19.02	19.14	40%	10.57%
		8.4	12.71	20.09			
		7.11	14.13	18.31			
8	V8	9.33	13.56	18.6	17.46	50%	0.87%
		8.53	12.9	16.31			
		10.49	12.62	17.47			

Workability: The workability of the replaced concrete is same as that of the referral concrete. Replacement of coarse aggregate by the ceramic waste does not affect the workability. The values are given in table 2.

Table2: workability of the replaced concrete

Percentage of	Workabilty

ceramic waste	
10%	25mm
15%	15mm
20%	17mm
25%	12mm
30%	12mm
40%	10mm
50%	10mm

COST ANALYSIS:

In the present study the cost of 10 m^3 referral concrete (M-15 with PPC). The cost of material is calculated below according to market rate (march-april 2017).

CEMENT CONCRETE OF 1: 2: 4 (for 10 cum)

Dry volume of 10 cum = 1.52 * 10 = 15.2 cum

Therefore the percentage reduction in cost for the percentage replacement of the ceramic waste concrete is shown in the table 5.

Table5: Cost analysed for the percentage replacements

Percentage Replacement	Percentage reduction in cost (approx)
10%	3.7%
15%	5.65%
20%	7.53%
25%	9.42%
30%	11.31%
40%	15.07%
50%	18.85%

Conclusion

From the above study following conclusions are drawn-

- With increase in the percentage replacement of ceramic waste, the compressive strength increases as compared to that of conventional concrete up-to a replacement level of 40%. At 50% replacement the strength is almost the same (increases by 0.87%)
- At 10% replacement, the compressive strength increases by 17%,
  At 15% replacement, the compressive strength increases by 58%
  At 20% replacement, the compressive strength increases by 18%,
  At 25% replacement, the compressive strength increases by 24%,
  At 30% replacement, the compressive strength increases by 49%,
  At 40% replacement, the compressive strength increases by 11%,
  At 50% replacement, the compressive strength increases by 1%,
- Percentage change in cost is increasing with increase in the percentage of replaced ceramic waste. (maximum reduction is of 18.85% at 50% replacement level of coarse aggregate)
- Weight or the dead load of the concrete decrease with increase in the percentage of ceramic waste.
- Usage of ceramic helps in reducing the degradation of the environment both by using waste materials as well as by reducing the usage of the natural resources available

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