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An Experimental Study on Compressive Strength of Sustainable Concrete using Ceramic Waste as Partial Replacement of Cement

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ABSTRACT

The transformation from a conventional consumption based society to a sustainable society is urgently required due to the pollution of the natural environment, the exhaustion of the natural resources and the decreasing capacity of the final waste disposal facilities. One of the ways to solve this problem is to use ceramic waste (CW) concrete as partial replacement with cement in structural concrete. Also to develop a sustainable concrete using new supplementary cementitious material (SCM) like ceramic waste powder which is produced from ceramic tiles at the manufacturing process and dismantled tiles, broken pieces of tiles and it was partially replaced with Ordinary Portland cement (OPC).Concrete mixtures were produced, tested and compared in terms of compressive strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7 and 28 days. As a result, the compressive strength achieved up to 30% replacing cement with ceramic waste. This research work is concerned with the experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing cement via 0%, 10%, 20%, 30%, 40% and 50% of ceramic waste. Keeping all this view, the aim of the investigation is to study the behavior of concrete while replacing the ceramic waste with different proportions in concrete.

Highlights

1.Usage of ceramic waste in profitable manner.
2. Minimizing cement production
3. Reducing toxic gasses emissions
4.Producing less cost sustainable concrete

1. Introduction

While the developed, industrialized countries are called upon to reduce pollution of the environment and their share of the usage of the world's resources, including energy, the developing countries need to avoid the mistakes of the past. This problem is particularly acute, since cement production as well as fly ash generation in developing countries are expected to increase significantly in the next few decades. There is an increasing demand for concrete worldwide, estimated to double within the next 30 years. This demand can be met without a corresponding increase in greenhouse gases by using supplementary cementitious materials to replace a maximum amount of the cement in concrete; we can reduce energy and resource consumption, reduce CO_2 emissions, and reduce the negative environmental impact. Now a days in many developing countries, sustainability is the major issue. Which involves to build our communities in such a way that we can all live comfortably without consuming all of our resources, we make an impact on the environment through how we survive our lives. In fact, it is open fact that concrete executes outstanding responsibilities for the construction of modern infrastructures, industrialization and urbanization for the growing population in the globe. Besides, it is relevant to mention that the concrete industry today is the largest consumer of natural resources for manufacturing cement.

Energy plays a crucial role in the growth of developing countries. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for building materials like cement, the importance of using industrial waste is very important. Ordinary Portland cement (OPC) plays a major role in constructions. To manufacture one ton of Ordinary Portland cement, the same amount of carbon dioxide is released to the atmosphere which leads to greenhouse effect [1]. Therefore, to save environment from global warming there should be replacement in cement with different binders having cementious properties like ceramic waste, hypo sludge, fly ash, silica fume GGBS, Metakoline and other industrial by products. To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. In this respect ceramic waste is one of the sustainable technique. Ceramic waste In Now a days using of ceramic wastes in research areas become active that encompass a number of disciplines including civil engineering and constructional materials. Globally ceramic production is 100 million ton/year. In Ceramic industry about 15-30% waste material generated from total production. This waste is could not be recycled in any manner. With the chemical and physical properties, Ceramic waste, it can be said that it is a durable hard and highly resistant to biological, chemical & physical degradation forces[2]. The advancement of concrete technology can reduce the consumption of natural resources. The use of replacement materials offer cost reduction, energy savings and few hazards in the environment.

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The principle waste coming from ceramic industry is ceramic powder and shown in **Figure1**. Ceramic waste are generated as a waste during the process of dressing & polishing. It is estimated that 15-30% waste produced from raw materials and some portion of this waste is used on site such as for excavation, pit refill. The disposals of these materials acquire large land areas. Ceramic waste can be used to improve its strength and other durability factors. **. [2]** Concluded that Ceramic powder with Replacement in Cement of 0% to 50% for M 20 Grade of Concrete and Compressive strength with 30% C.W replacement is optimum then decreases. **[3]** D.Raval, Indrajit N.Patel in his research he experimentally proved Ceramic powder with Replacement in Cement of 0% to 50% for M 25 Grade of Concrete and Compressive strength with 30% C.W replacement is optimum then decreases.

Figure: 1. Ceramic waste powder

2.0 Materials

2.1 Cement

Cement used in this research attempt was 53 Grade Ordinary Portland cement. The specific gravity of cement was 3.15 and specific surface area of 225 m^2/kg having initial setting time of 35 min and final setting is 600 min respectively.

2.2 Fine Aggregate

The fine aggregate used in this investigation is conforming to Zone-2. The fine aggregate specific gravity is found to be 2.6

2.3 Coarse Aggregate

Crushed granite is used as coarse aggregate. The coarse aggregate is obtained from a local crushing passing from 20mm sieve well graded aggregate. The specific gravity of coarse aggregate is found to be 2.80.

2.4 Super plasticizer

To improve the workability of concrete, 0.5% of cement weight of CONPLAST SP430 is used as chemical admixture.

2.5 Ceramic Waste

In this research an attempt is made to produce sustainable based concrete constituting ceramic powder as alternative material for cement. The ceramic powder used in the experiment is locally available areas and land fill in Muscat, Oman.

The chemical composition of cement and ceramic powder is presented in Table.1

Table 1. Chemical Composition of ceramic powder and cement.

Chemical composition	Ceramic Powder	Cement (in %)
Lime(Ca O)	4.46	62
Silica(SiO_2)	63.29	22
Alumina	18.29	05
Magnesium	0.72	01
Calcium sulphate	4.05	04

3.0 Experimental Program

In this research work an attempt is made to produce sustainable concrete using ceramic powder as partial replacement of cement. The percentage of ceramic powder replaced as 10%, 20%, 30%, 40% and 50% with OPC and found out compressive strength. In this case ordinary Portland cement content is taken as 250kg/m3 to find the better properties of ceramic powder. In order to improve the workability of concrete chemical admixture (CONPLAST SP430) is added. The mix proportion is presented in Table.3

In the laboratory, all the required materials are mixed in rotary mixing machine with addition of Water for 3-5 minutes specimens casted. The concrete is poured into the moulds. Make sure top surface is well finished and the sizes of the specimens like cube moulds (150mm x 150mm x 150mm), The casted specimens are demoulded after 24 hours and are kept in different curing regimes. The specimens cured in water for 7 and 28 days.

3.1 Tests done on constituents of concrete

It includes the various tests on constituents of concrete and shown in Table 2

(1)Aggregate

(i)Sieve analysis

(ii)Specific gravity of aggregate

(iii)Mechanical properties of aggregate

(2) Cement

(i) Specific gravity of cement

(ii)Fineness of cement

(iii)Normal consistency of cement

(iv) Initial final setting time of cement

(v)Compressive strength of cement

(vi) Slump test

Table 2. Properties of Constituents of concrete.

Materials	Specific Gravity
Cement	3.15
Ceramic Powder	3.1
Fine Aggregate	2.6
Coarse Aggregate	2.8
Super Plasticizer	1.5

3.2 Mix design

The mix design is prepared for M 25 grade of concrete according to recommendation of IS 456-2000. As in case of ordinary Portland cement concrete, the cement content is taken as 250kg/m3 because to find the properties of ceramic powder and more focused on ceramic powder properties, the coarse aggregates and fine aggregates occupy about75%-80% mass of concrete. The mix proportion for M25 grade of concrete is presented in Table.3

Table 3. Mix Proportion.

Particulars	Normal concrete	Sustainable Concrete (10%)	Sustainable Concrete (20%)	Sustainable Concrete (30%)	Sustainable Concrete (40%)	Sustainable Concrete (50%)
Cement (Kg/m^3)	250	225	200	175	150	125
Ceramic Powder (Kg/m^3)	-	25	50	75	100	125
Coarse Aggregate (Kg/m^3)	1420	1420	1420	1420	1420	1420
Fine Aggregate (Kg/m^3)	711	711	711	711	711	711
Water (Kg/m^3)	125	125	125	125	125	125
Admixture (Kg/m^3)	1.25	1.25	1.25	1.25	1.25	1.25

3.3 Mixing and casting of sludge based Concrete-

In the laboratory, cement with and without ceramic powder ranging from 0%, 10%, 20% 30% 40% and 50% and the aggregates are mixed for 3-5minutes in a rotary mixing machine with addition of Water and admixture to the dry mix and three samples cubes for each proportion were casted. The concrete is poured into the moulds and compacted with the help of vibrating table machine. The top surface is well finished. The sizes of the cube moulds used are (150mm x 150mm x 150mm. The cast specimens are demoulded after 24 hours of casting and are kept in different curing regimes. The specimens cured in water for 7 and 28 days.

4 Test Results and Discussion

4.1 Compressive Strength

Concrete specimens with and without sludge are prepared and cured for 7 and 28 days in water then tested for compressive strength. The sustainable concrete specimens are prepared for five different replacements from 0%, 10%, 20%, 30%, 40%, 50% and tested at the age of 7 and 28 days. It was noticed from the results that there is steep increase in compressive strength with addition of ceramic powder. This increase in strength parameter because of silica content present in ceramic powder. Beyond 30% replacement there is decrease in strength. This is may be due to taking less cement content. Based on this statement it can be concluded that 30% replacement is optimum. The results are shown in Figure 2

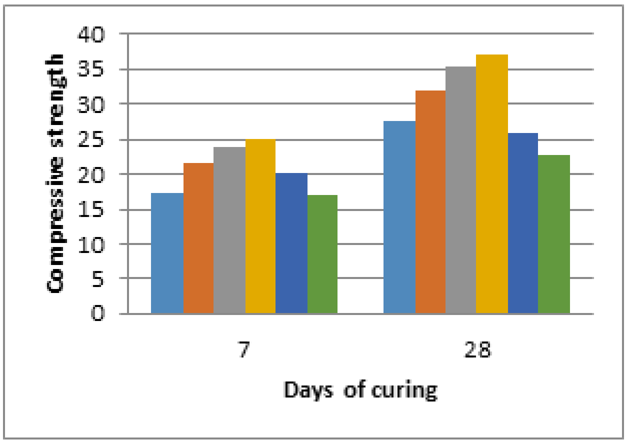

Figure 2. Graph on compressive strength for 7 and 28 days.

5. Conclusion

Based on experimental investigations on the compressive strength of sustainable concrete, it was noticed that:

1. 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.
2. Sustainable concrete with ceramic waste shows better performance in strength properties compared to conventional concrete
3. It was noticed that sustainable concrete with ceramic powder is economical and eco friendly
4. Utilization of ceramic waste and its application are used for the development of the construction industry
5. Land fill can be minimized by using Ceramic waste in profitable manner

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