

An Experimental Study on Partial Replacement of Cement with Ceramic Waste Powder

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ABSTRACT

Concrete is a construction material composed of cement, aggregates (fine and coarse aggregates), water and admixtures. Today many researches are ongoing into the use of Portland cement replacements, using many waste materials like, pulverized fly ash, ground granulated blast furnace slag, waste glass powder .A ceramic powder is also used as a binder with partial replacement of cement which takes some part of reaction at the time of hydration, and also it acts as a filler material. In this study, waste ceramic powder was used as a replacement to the concrete ingredient i.e. cement and the mechanical properties like compressive strength are measured and the size effect of ceramic waste powder on strength of concrete. For checking strength effect of replacement of cement by ceramic waste powder, the cement is replaced at 10%, 20%, 30%, 40% and 50%. For study of size effect of ceramic waste powder the powder is divided in to two grades one is ceramic waste powder having size less than 90 micron and another is ceramic waste powder having particle size ranges from 90 micron to 150 microns. For this study, concrete mixtures were prepared, for low grade M20 and medium grade M40. Strength studies like compressive strength, split tensile strength and flexural strength were conducted and comparisons have to be made with the conventional concrete.

INTRODUCTION

This research analyzed the impact of the use of ceramic powder, procured as residue from the ceramics industry, on the mechanical properties of conventional concrete. The councils of large-and medium-sized towns have for years been increasingly concerned with the collection,

storage and more recently treatment of domestic waste. Parallel to this, there has been a growing social and political awareness of environmental issues, particularly where this relates to the deterioration of the environment [1].

Ceramic waste from factories producing construction industry materials has been accumulating on frequently illegal rubbish tips, creating increasingly large piles. Although they are usually chemically inert, the rubbish tips where this waste accumulates, given their size and the scant environmental control exercised, have a significant visual impact that destroys the intrinsic quality of the landscape The reduction of natural and energy sources with increasing the advancement of concrete technology[3]. They have forced to focus on improvement, reuse of natural resources and find other substitutes.

Presently large amounts of Ceramic waste are generated in ceramic industries with an important impact on the environment and humans. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment. The industrial and economic growth witnessed in recent decades has brought with it an increase in the generation of different types of waste (urban, industrial, construction, etc.) despite the waste management policies which have been adopted nationally and internationally [5-7].

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The practice of dumping and/or the inadequate management of waste from the various manufacturing sectors have had a notable impact on the receiving environment, leading to water, soil, air and noise pollution, amongst other complications, and adding to existing environmental problems. At the same time, these practices represent an economic cost.

Recycling of ceramic:

The pollution of ground and surface waters began as soon as industry began producing manufactured goods and wasting liquids and solid matter simultaneously. In the 1930s, industries began to be aware of the eventual danger of their wastes when sent untreated into waterways [9]. It was natural for industry at that time to follow the lead of municipalities in using similar treatments to attempt to resolve their pollution problems. In the World War II there is an accelerated industrial production activity (Numerous, 2006), and two developments in the post-World War II era led to significant escalation in the problems of managing waste. First, a new phenomenon called "consumerism" emerged.

A long period of prosperity, combined with improvements in manufacturing methods led to rapid growth in the number and variety of consumer goods. In addition, new marketing and production practices were introduced, such as planned obsolescence and "throw-away" products [11]. The growth of advertising, along with the electronic media, played an important role in the evolution to our society's current level of overconsumption. The end result was a dramatic increase in the amount and variety of consumer goods—and, hence, wastes (The waste crisis). The second development was the birth of the "chemical age," which resulted in a dramatic change in the composition of the waste stream.

The petrochemical industry has grown explosively since that time, yielding a vast array of new synthetic organic compounds, a kind of pollution that had never existed before entered the environment, exhibiting toxicity as

well as non-biodegradability (Tammemagi, 1999; Nemerow, 2006). Radioactivity, petrochemical, and synthetic organic chemicals were largely developed and surfaced in the environment in the 1940s and 1950s. During this period, major environmental problems surfaced with rapid and serious consequences. Hence was born the advent of what was to become the pollution problems of the twentieth century (Nemerow, 2006). Historically, waste was simply dumped in depressions, ravines, and other handy locales that were close to the population centers producing the waste. Even though recycling was commonly practiced by all households during pre-industrial ages, large-scale recycling programs did not arise until the twentieth century.

The first organized programs were created in the 1930s and 1940s, when a worldwide depression limited people's ability to purchase new goods and the outbreak of World War II dramatically increased demands for certain materials [13].

Throughout the war, goods such as nylon, rubber, and various metals were recycled and reused to produce weapons and other materials needed to support the war effort. However, after the War there was a drastically decrease in the recycling efforts (Miller, 2010). It was not until the environmental movement of the 1960s and 1970s that recycling once again emerged as a popular idea.

This movement began in 1962 with the publication of Rachel Carson's book *Silent Spring*, detailing the toxic effects of the chemical DDT [15] on birds and their habitats. The book raised the consciousness of many people about the dangers to the environment from chemicals and other toxins produced by modern industries (Miller, 2010). Thereafter, the increase in the environmental awareness and consciousness required industry to meet tighter environmental standards on a global basis. In many countries, such requirements generally cannot be met by using conventional disposal of residual solid wastes in landfills (Wang et al., 2010).

Accordingly, much more emphasis has to be placed on waste reduction and recycling technologies as a necessary first step to reduce to a minimum the extent of the waste treatments to be provided. In recent years there has been growing concern about the negative impacts that industry and its products are having on both society and the environment in which we live. The concept of sustainability and the need to behave in a more sustainable manner has therefore received increasing attention. With the world's population growing rapidly the consumption of materials, energy and other resources has been accelerating in a way that cannot be sustained (Hester, R. E. & Harrison, 2009). In this scenario, solid waste management has moved to the forefront of the environmental agenda, with the amount of related activities and concern by citizens and governments worldwide reaching unprecedented levels [16].

TYPES OF CERAMIC TO RECYCLE:

Kyocera has a wide range of advanced ceramic materials to offer. Each one with its own unique characteristics designed to meet the requirements of many diverse applications. Some of the more widely used materials are described below.

ALUMINA

Alumina is the most widely used advanced ceramic material. It offers very good performance in terms of wear resistance, corrosion resistance and strength at a reasonable price. Its high dielectric properties are beneficial in electronic products.

Applications include armor, semiconductor processing equipment parts, faucet disc valves, seals, electronic substrates and industrial machine components.

SILICON NITRIDE

Silicon nitride exceeds other ceramic materials in thermal shock resistance. It also offers an excellent combination of low density, high strength, low thermal expansion and good corrosion resistance and fracture toughness [14].

Applications include various aerospace and automotive engine components, papermaking machine wear surfaces, armor, burner nozzles and molten metal processing parts.

SILICON CARBIDE

Silicon carbide has the highest corrosion resistance of all the advanced ceramic materials. It also retains its strength at temperatures as high as 1400°C and offers excellent wear resistance and thermal shock resistance. Applications include armor, mechanical seals, nozzles, silicon wafer polishing plates and pump parts.

ZIRCONIA

Zirconia has the highest strength and toughness at room temperature of all the advanced ceramic materials. The fine grain size allows for extremely smooth surfaces and sharp edges. Applications include scissors, knives, slitters, pump shafts, metal-forming tools, fixtures, tweezers, wire drawing rings, bearing sleeves and valves [12].

ENVIRONMENTAL APPLICATIONS:

At the very core of these technologies are selected materials from a number of classes ranging from purely organic- and inorganic-based matrices to the precious metals and alloys that all ought to meet well defined operation-relevant conditions and efficiencies.

Depending on the targeted application, each material foreseen as a base for component development has to be evaluated individually and its properties have to be modified in terms of corresponding application requirements. In order to elaborate tailored ceramic materials for gas separation and ion/electron transport at the relevant operating conditions and stability ranges, improved electrical or ionic conductivities and permeation rates are required. That can be achieved by doping and substitution which are actors on a nano-scale that usually lead to macroscopic impacts [10]

This chapter is dedicated to the fascinating world of tailoring ceramic material for energy and environmental

applications. Selected approaches to tune ceramics will be discussed to illustrate the versatile effects that compositional variation can have on the macroscopic properties, e.g. the conductivity of protons, oxygen ions and or electronic carriers, stability, etc. The present chapter will therefore consider the structural features of selected material classes, as well as the principles of transport in bulk and micro porous solids. It will furthermore illustrate and discuss the effects of selected additives and substituent's on sinter ability, electrical electrochemical properties and stability of selected ceramic materials for energy and environmental applications. The material variety will cover ceramic materials with different crystal structures like fluorites, perovskites, pyrochlores, fergusonites, as well as selected zeolite structures [8].

CONSTITUENT MATERIALS:

A ceramic-powder polymer composite, making use of a relaxer ferroelectric polymer that has a high room-temperature dielectric constant as the matrix, is developed. The experimental data show that the dielectric constant of the composites with $Pb(Mg_{1/3}Nb_{2/3})O_3-PbTiO_3$ powders can reach more than 250 with weak temperature dependence. In addition, the composites under a proper preparation procedure exhibit a high breakdown field strength (>120 MV/m), leading to a maximum energy storage density of more than $15 J/cm^3$.

Experimental results also indicate that the high electron irradiation does not have much effect on the dielectric behavior of $Pb(Mg_{1/3}Nb_{2/3})O_3-PbTiO_3$ powders, possibly due to the relaxer nature of the ceramic [6].

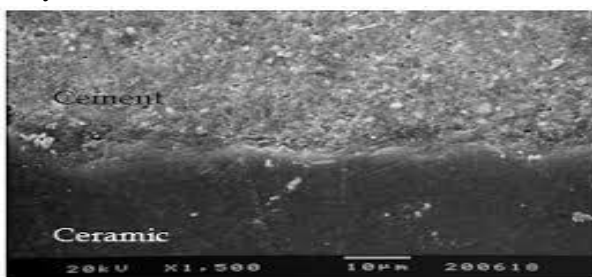


Fig: scanning electronic micrograph of a ceramic powder particles in cement paste

CASTING AND CURING:

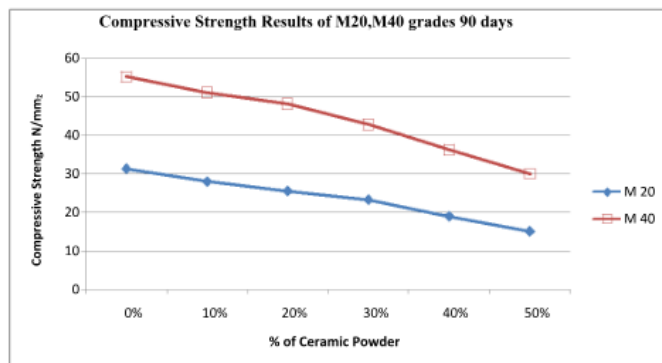
For casting, all the moulds were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage out of slurry. Careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams.

The concrete mixture was prepared by hand mixing on a watertight platform. On the watertight platform, the coarse and fine aggregates were mixed thoroughly. To this mixture, the cement was added. These were mixed to uniform colour then water was added carefully so that no water was lost during mixing. Clean and oiled moulds for each category were then placed on the vibrating table respectively and filled in three layers. Vibrations were stopped as soon as the cement slurry appeared on the top surface of the mould [4].

The specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition. After that these were de-moulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing. After de-moulding the specimen by loosening the screws of the steel moulds, the cubes, cylinders and beams were allowed to dry for one day before placing them in the temperature controlled curing tank for a period of 7 days, 14 days, 28 days [2].

Table: Compressive Strength (MPa) Results of Cubes of M20, M40 grades for 90-150µ for 90 days

% of Ceramic Powder	M20	M40
0%	31.33	55.24
10%	28.06	51.24
20%	25.55	48.24
30%	23.33	42.89
40%	19.04	36.22
50%	15.11	30.14



GRAPH: Compressive strength (MPa) results of Ceramic waste powder concrete cured in normal water

CONCLUSION

In accordance with the experimental phase carried out in this study, the following conclusions are drawn:

1. The Compressive strength of M20 grade concrete little decreases when the replacement of cement with ceramic powder (of size < 90 microns and 90-150 microns) up to 30% by weight of cement and further replacement of cement with ceramic powder decreases the compressive strength.
2. Concrete on 30% replacement of cement with ceramic powder, compressive strength loss obtained is 18.15% from L0 to LA 30 and Concrete on 30% replacement of cement with ceramic powder, compressive strength loss obtained is 23.85% from L0 to LB 30.
3. The Split tensile strength of M20 grade concrete little decreases when the replacement of cement with ceramic powder of size < 90 microns up to 30% and ceramic powder of size for 90-150 microns up to 20% by weight of cement and further replacement of cement with ceramic powder decreases the split tensile strength.
4. The Flexural strength of M20 grade concrete little decreases when the replacement of cement with ceramic powder of size < 90 microns up to 30% and ceramic powder of size for 90-150 microns up to 20% by weight of cement and further replacement of cement with ceramic powder decreases the flexural strength.
5. The Compressive strength of M40 grade concrete little decreases when the replacement of cement with ceramic powder (of size < 90 microns and 90-150 microns) up to 20% by weight of cement and further

replacement of cement with ceramic powder decreases the compressive strength.

6. Concrete on 20% replacement of cement with ceramic powder, compressive strength loss obtained is 14.46% from M0 to MA 20 and Concrete on 20% replacement of cement with ceramic powder, compressive strength loss obtained is 14.85% from M0 to MB 20.

7. The split tensile strength of M40 grade concrete little decreases when the replacement of cement with ceramic powder (of size < 90 microns and 90-150 microns) up to 20% by weight of cement and further replacement of cement with ceramic powder decreases the split tensile strength.

8. The flexural strength of M40 grade concrete little decreases when the replacement of cement with ceramic powder (of size < 90 microns and 90-150 microns) up to 10% by weight of cement and further replacement of cement with ceramic powder decreases the flexural strength.

With the increase of grades the percentage of replacement of ceramic waste is decreased. The observations made during the present investigation are in agreement with the results reported by earlier investigators. The experimental study has helped to investigate the various properties of Ceramic waste concrete as partial replacement of cement with ceramic waste in the production of Structural concrete. In view of the other advantages such as conservation of natural resources, free the ceramic waste material from landfills and elimination of disposal problems, the ceramic waste Concrete can be considered as a potential and suitable alternative material with a bright future.

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