REPLACEMENT OF COARSE AGGREGATES WITH SILICA FUME AND CERAMIC TILES

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Transforming Education Transforming India

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CERTIFICATE

Certified that this project report entitled ***"REPLACEMENT OF COARSE AGGREGATE WITH SILICA FUME AND CERAMIC TILES"*** *submitted by* ***RASHIDUL ISLAM,*** *Registration Number* ***11309156,*** *respectively student of School of Civil Engineering,*

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ABSTRACT

This report is all about to generate a study on concrete which incorporate Over silica fume and ceramic tiles partially due to their abundance.

Analysis of incorporated concrete was done in fresh state as well in hardened state to evaluate different properties of concrete i.e. slump, compaction factor test, unit weight, and compressive strength are evaluated. From all the results and experimental approach, it is concluded that Concrete formed with over silica fume and ceramic tiles aggregate showed beneficial performance as compared with the concrete made up of natural aggregate obtained from local resources. It reduces the cost of concrete by reducing the aggregate cost and produces economical infrastructure system. It has been observed that the use of waste materials results in the formation of light weight concrete. Uses of such waste materials will not only cut down the cost of construction, but will also contribute in safe disposal of waste materials. Apart from the environmental benefits, the addition of such wastes, also improves certain properties of resultant concrete. Cubes of concrete were prepared and tested to study the compressive strength. The results were compared with concrete made with river wash gravel as coarse aggregates which at present is the only coarse aggregate. It can be

strength of crushed over bricks - sand concrete and gravel - sand concrete increase by more than 30%. Use of broken over burnt bricks as coarse aggregate for structural concrete is recommended when natural aggregate is not easily available, high strength of concrete is not required and the bearing capacity of the soil is low.

Keywords: Experimental, Investigation, Concrete Waste, Coarse Aggregate.

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CHAPTER 1 INRODUCTION

1.1 INTRODUCTION TO PROJECT

The use of waste material as aggregates in civil engineering applications is beneficial because it reduces the environmental impact and economic cost of quarrying operations, processing, and transport. Reuse of construction and demolition waste is becoming increasingly desirable due to rising hauling costs and tipping fees for putting this material into landfills. In recent years, sustainable construction initiatives have also made reuse of construction and demolition debris (as aggregates and otherwise) an appealing option when considering d

esign alternatives for many types of structures. Incorporating these aggregates into cementitious materials is practical, as cementitious materials are non-homogeneous composites that allow material of different sizes and compositions to be bound in a cementitious matrix.

1.2 PRINCIPAL OF CONCRETE

Concrete is the most important building material used in the construction industry globally. Concrete production has become expensive over the years due to increased demand of construction. This has led to an increase in the rates of the materials used to make concrete i.e. aggregates and cement. One of the development goals of India’s vision 2020 is to provide affordable housing to all citizens especially those in the slums and shanties. This may be accomplished by provision of quality alternative building materials such as Brick ballast and ceramic tiles aggregates. Thus from economical point of view, a research on the production of cost effective concrete to meet demand is the most important step in the right direction in concrete technology. Therefore, the provision of locally available aggregates from the utilization of brick ballast and ceramic tiles to be used in concrete production will help in lowering the cost of construction of housing units (low cost housing) for human dwelling.Design of concrete mixes involves determination of the proportions of the given constituents, namely, cement, water, coarse and fine aggregates and admixtures, if any, which would produce concrete possessing specified properties both in the fresh and hardened states with the maximum overall economy. Workability is specified as the important property of concrete in the fresh state; for hardened state compressive strength and durability are important. The mix design is, therefore, generally carried out for a particular compressive strength of concrete with adequate workability so that fresh concrete can be properly placed and compacted, and to achieve the required durability.

The key objective of this work was to develop concrete mixtures, using silica fume and ceramic tiles as a partial replacement for normal aggregates, which exhibit acceptable properties comparable to that of structural coarse aggregates.

Specific objectives

1) To design concrete mixes using Brick ballast and ceramic tiles as aggregates.

2) To establish the availability and economic feasibility of the silica fume and ceramic tiles as Aggregates.

1.3 NEED FOR THE STUDY

In concrete mix design, it is necessary to analyze experimentally and practically all the components of the concrete mix i.e. cement, aggregates, and water.The research will be majorly dealing with the analysis of the properties of silica fume and ceramic tiles to be used as coarse aggregates in concrete. The crushed clay waste was obtained from chimney and west management places. Prior to developing mix designs, grading was done to obtain the required particle size distribution and tests were performed to characterize the aggregate. The compressive strengths at 3, 14 and 28 days of curing of concrete cubes will be analyzed.

1.4 MATERIAL USED

1.4.1 Cement

A cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete, which is a combination of cement and an aggregate to form a strong building material.

Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.Hydraulic cements (e.g., Portland cement) set and become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack

1.4.2 Aggregate

Aggregates are inert granular materials such as sand, gravel or crushed stone that are an end product in their own right. They are also the raw materials that are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete.

Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into several distinct categories, and are either coarse or fine:

1.4.3 Coarse aggregates

aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources. Primary, or 'virgin', aggregates are either Land- or Marine-Won. Gravel is a coarse marine-won aggregate; land-won coarse aggregates include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. Secondary aggregates are Coarse materials which are the by-products of extractive operations and are derived from a very wide range of materials

Recycled concrete is a viable source of aggregate and has been satisfactorily used in granular subbases, soil-cement, and in new concrete. Recycled aggregates are classified in one of two ways, as:

1. Recycled Aggregate (RA), or as
2. Recycled Concrete Aggregate (RCA).

1.4.3 Ceramic Tiles

A tile is a manufactured piece of hard-wearing material such as ceramic, stone, metal, or even glass, generally used for covering roofs, floors, walls, showers, or other objects such as tabletops. Alternatively, tile can sometimes refer to similar units made from lightweight materials such as perlite, wood, and mineral wool, typically used for wall and ceiling applications.

Tiles are often used to form wall and floor coverings, and can range from simple square tiles to complex mosaics. Tiles are most often made of ceramic, typically glazed for internal uses and unglazed for roofing, but other materials are also commonly used, such as glass, cork, concrete and other composite materials, and stone. Tiling stone is typically marble, onyx, granite or slate. Thinner tiles can be used on walls than on floors, which require more durable surfaces that will resist impacts.

1.4.4 Fine aggregates

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.

1.5 AGGREGATE CRUSHING VALUE (ACV)

Objective

To determine the relative measure of the resistance of an aggregate to crushing under gradually applied compresspive load.

Apparatus

· An open ended steel cylinder of nominal 150mm internal diameter with plunger and base plate.

· Round ended steel tamping rod 16mm diameter and 600mm long.

· A weighing balance.

· Sieves of 14mm, 10mm and 2.36mm size.

· A compressive testing machine capable of applying 400KN, at a uniform loading rate.

· A cylindrical metal measure of internal dimensions; 115mm Ø by 180mm deep.

1.6 Procedure

The surface-dry aggregate was sieved through 14mm and 10mm sieves and the material retained on 10mm sieve adopted for test. The retained material was placed in the cylindrical measure and its weight determined and recorded as Wt (A).

The cylinder of the test apparatus was put in positi. on and the test sample placed in three layers each layer being subjected to 25 strokes of the tamping rod. The surface of the aggregate was then levelled and the plunger inserted and ensured it rested horizontally on the surface of the aggregates

CHAPTER 2 LITRATURE REVIEW

2.1 SILLICA FUME

Lucky Chandra AND Djwantoro Hardjito:(2011)

Pozzolanic materials and calcium carbonate can be used to partially replace the use of cement in making mortar or concrete without altering the rheological properties of the fresh mixture. This study focuses on the use of fly ash in the range of 0-30%, silica fume 0-10% and calcium carbonate 0-15% of the cement content, by mass. The workability of the fresh mortar was evaluated, and the compressive strength of hardened mortar were measured at the ages of 7, 14, 28 and 56 days. Test results show that increasing partial replacement of cement with fly ash increased the workability and compressive strength of mortar.

Reza Bani Ardalan, Alireza Joshaghani & R. Douglas Hooton :(2013)

This paper presents the results of an experimental study carried out to investigate the performance of self-compacting concrete (SCC) mixes, which produced using blended binders containing pumice powder in various proportions. As a volcanic material, pumice possesses pozzolanic properties and can effectively be added to the concrete mixture. The influence of pumice powder on the self-compactibility properties such as slump flow, V-funnel flow, U-box and J-ring flow and compressive strength was investigated. Also, in order to clearly understand the effect of pumice powder on the workability retention of concrete, the slumps were measured with elapsed time. The comparison has been made between SCC with pumice powder to other mixtures with fly ash and slag through tests on fresh and hardened concrete.

c. An investigation of CaSi silica fume characteristics and itspossible utilization in cement-based and alkali-activated materials: (2015)

This paper presents a comparison between Si silica fume (a by-product of silicon metal or ferrosilicon

alloys) used in civil engineering applications and CaSi silica fume (a by-product of calcium–silicon alloys).

Si silica fume has been recognized as being a by-product of more importance to the concrete industry. A

lot of studies have looked at its properties and at how it can contribute to the improvements in fresh and

hardened concrete. On the contrary, few papers have been published on CaSi silica fume. Chemical, mineralogical

and physical characteristics are analyzed here. Rheological and mechanical behaviors of

cement pastes and mortars composed of Si and CaSi silica fume are also studied in order to observe

the effect of CaSi silica fume as cement replacement. The results show that these two types of silica fume

do not affect in the same way the fresh and hardened properties of cementitious materials. Replacing a

part of cement by CaSi silica fume does not improve the compressive strength as Si silica fume does but a

good rheological behavior is maintained. To complete this work, the alkaline activation of 100%CaSi silica fume mortars is investigated. These preliminary results show that this by-product is worth to be studied

and lead us to believe that it could be used in construction materials.

A. Joshua Daniel, S. Sivakamasundari & A. Nishanth :

The utilization of Ordinary Portland Cement (OPC) cause hazar a use of the foams as promising insulating material d due to emission of CO_2 To avoid this, Pozzolanic material is used as a substituted for OPC. These are activated by alkaline to form a gel known as aluminosilicate which acts as a binder in concrete. In this study cement is partially replaced by Silica fume (SF). The torsional behaviour of the conventional concrete and SF based geo-polymer concrete is tested with varying percentage of longitudinal reinforcement. The results were compared in terms of torque, twist, stiffness degradation, curvature ductility, torsional toughness and crack width.

D. Porosity and insulating properties of silica-fume based Foams: (2009)

The synthesis of silica-fume based foams, with a multi-range macroporosity, was obtained by alkaline activation. Foams were obtained through an *in situ* foaming process exploiting the gaseous production of hydrogen caused by the oxidation, in alkaline medium, of metal silicon impurities contained in silica fume. Potassium or sodium alkaline solutions were selected and a temperature of 70 −C was sufficient to promote the development of hydrogen bubbles, the increase of the viscosity and the consolidation of the foams. The balance of these reactions allowed to entrap hydrogen bubbles inside the structures creating highly porous foams. The foams were characterized in term of macro- and microstructure, porosity distribution, infrared spectroscopy, thermal and acoustic properties achieved. The foams showed ultra-macroporous structures, with a total porosity of ≈ 80%. The average values of bulk density (0.5 g cm-3), thermal conductivity (0.16 W m-1 K-1), and the acoustic behaviors, highlighted

Waheeb A. AI-Khaja :(2010)

The study investigates the efficiency of silica fume in influencing the compressive strength, drying shrinkage and compressive creep of high-strength concrete at constant laboratory conditions. The silica fume and plain concrete mixes used in this investigation had the same workability and water to cement ratio achieved by using a superplasti-cizing admixture. The results indicate that the compressive strength of silica fume concrete is 18.3% higher than plain concrete at an age of about 1 month. Shrinkage and creep of plain concrete wereconsiderably reduced by using silica fume, given a 1 month reduction in strain of 34.9% and 18.5% for shrinkage and creep, respectively, leading. to a reduction in the total deformation of 20.8%. Thus, concrete made with silica fume as a part of the cementitious material is useful for various concrete structural applications, especially for prestress concrete members where prestress losses are mainly influenced by creep and shrinkage, and an increase in concrete strength at an early age is desirable

M. Rostami, K. Behfarnia :(2017)

this research was carried out to examine the effect of using silica fume on permeability of alkali activated slag concrete by substitution of three levels of silica fume including 5 wt%, 10 wt% and 15 wt% of slag. The effects of two types of curing conditions including water curing and curing under plastic cover were also examined. Short-term and final water absorption, penetration of chloride ion and depth of penetration of water were measured to examine the permeability. The effect of these factors on compressive strength was examined and the relation between compressive strength and passing electrical charges and depth of water penetration was also evaluated. To contrast the use of silica fume on internal characteristics of concrete, samples were observed by scanning electron microscopy (SEM)

S. Wild, B.B. Sabir, and J.M. Khatib :(2009)

Existing data on the relationships between temperature, pozzolanic activity and cement hydration are reviewed with particular emphasis on condensed silica fume (CSF)-ordinary Portland cement blends. CSF concrete with a range of fume contents has been cured at two temperatures (20°C and 50°C) for periods up to 91 days. Strength development and relative strength are considered in relation to temperature, cement hydration and pozzolanic action. The observed results establish that relative strength varies directly with CSF content and that the strength enhancement at early curing periods, which is achieved by increase in curing temperature, is a result of increased reaction rate between Ca(OH)2 and CSF.

2.2 CERAMIC TIES

Derrick J. Anderson, Scott T. Smith & Francis T.K. Au :(2011)

The importance of sustainability and recycling has become increasingly recognised and understood in academia and industry over the last several decades. Recycling construction and debris waste is one of many avenues that provide a great opportunity to prevent waste material from entering landfills and reduce the construction industry reliance on decreasing natural resource supplies. A coarse aggregate replacement scheme in concrete is investigated with three different waste ceramic tile materials in replacement ratios including 20%, 25%, 35%, 50%, 65%, 75%, 80% and 100%. Results show waste ceramic as a possible practicable natural coarse aggregate replacement material with minimal changes in mechanical properties.

Zahide Bayer Ozturk &Elif Eren Gultekin :(2013)

the samples with waste show high strength due to the amount of crystalline phases and a low thermal expansion value. The experiment reveals that the addition of 33% BFS in ceramic wall tiles results in about a 25% increase in strength. The results also indicate that blast furnace slag is a potential secondary raw material for the production of wall tiles.

The effects of blast furnace slag have been studied by measuring the linear shrinkage, water absorption, dried strength, fired strength, thermal expansion coefficient and color value of tiles. A basic mixture, suitable for producing ceramic wall tiles with raw materials provided from the Yurtbay Ceramic

Company (Eskişehir/Turkey), with the same composition as used in industry, was prepared.

The use of sewage sludge in the production of ceramic floor tiles(2014)

Scientists proved that municipal sewage sludge contains many dangerous pathogens, toxic heavy metals, endocrine disruptors, drains, storm water runoff, hospitals, and industrial plants. Sewage sludge represents an extremely high ecological hazard to the environment. Due to the increasing amount of sludge generated from the wastewater treatments plants a strong demand for environmentally and effective safe reuse has arisen. One potential use of that waste is its incorporation in the production of ceramic tiles. The main aim of present work was to study the possibility of usage of this hazardous waste in floor ceramic tiles industry. A dried sludge waste was added in percentages from 5% up to 35% to a standard floor tile mix, molded, pressed uniaxially at 30 MPa and then fired at temperatures reaching 1150 C for 15 min soaking time. The properties of both green and fired tiles were investigated as function of percent waste added. The vitrification parameters, which are linear firing shrinkage, water absorption, apparent porosity, and mechanical property, were determined and compared with ISO standards. Fired samples of the proposed mixtures were investigated by scanning electron microscope (SEM). It was possible to obtain tiles that abided by ISO standards for maximum addition of 7% sludge fired at 1150 C (for water absorption <10%), and 10% sludge or 5% sludge for tiles fired at 1150 C and 1100 C, respectively (forwater absorption > 10%), which are recommended for both their economic.

B. Anatase as Antibacterial Material in Ceramic Tiles(2014)

Anatase is one of a common and favorable material use in the manufacturing industry due to its uniqueness and functional performances to human and environment. The study was focused on the performance of anatase mixed with glaze and applied on ceramic tiles by a dip coating method. Two different sizes (micron and nano size) of anatase powder were used to observe their performance as antibacterial materials. The anatase powder in micron size was varied at 5 wt%, 10 wt % and 15 wt%, whereas nano size anatase was fixed at 10 wt%. The anatase powders were mixed with the glaze compound and then coated on the tile surface. Sample produced were characterized through physical appearance, scanning electron microscopy (SEM) analysis and antibacterial test. Antibacterial testing by using E.Coli was done on tiles and was observed by counting the colonies of bacterial growth in 0 hr, 2 hrs, 4 hrs and 8 hrs. The addition of anatase slightly change the colour of the tile produced. Whereas SEM results show the distribution of anatase powder in the tiles surface. The antibacterial properties increased when the composition of anatase increased. However, nano size anatase gave better antibacterial properties compared to micron size because of larger surface area of the antibacterial agents on th

E. Testing Quality of Ceramic Tiles to Evaluate Condition of the Manufacturing Process:(2010)

Problem of the research on quality of ceramic floor tiles remains still open. Their strength, and as a consequence possible application, depend both on the constitution of ceramic composite, and on their degree of homogeneity. The method of controlling tile strength should be based on evaluating this feature in various cross-sections. Such measurements are very important because their mechanical properties are often not uniform across the whole surface. Standard control tests are not compliant with this requirement because they anticipate only destructive strength tests in their middle cross section. Application of the ultrasound method allows for the easy homogeneity estimation of ceramic composite in the tile. Transformation of the direct results for the resistance of material requires scaling of the measuring device what considerably expands the scope of research, however resistance parameters are not always necessary. Paper presents the research on the probe composed of 23 floor tiles with dimensions 600 x 600 and 600 x 300 mm. Tiles has been sampled from the lot of material that had been built in the floor and shown excessive defectiveness (broken edges, pop-offs and breaks). The main purpose of experimental tests was to determine the homogeneity of ceramic material in various cross-sections of each tile. Big variation of ultrasound wave velocity within the range of many tiles shown the cause of quick loss of expected serviceable properties. In addition, has been carried out the measurements of the length, width and deformation of the surface of tiles. Dimensional deviations and deformations didn't exceed the admissible values. SEM results show the distribution of anatase powder in the tiles surface. The antibacterial properties increased when the composition of anatase increased. However, nano size anatase gave better antibacterial properties compared to micron size because of larger surface area of the antibacterial agents on the tiles.

Muge Tarhan, Baran Tarhan & Tuna Aydin :(2017)

This study investigated the effects of fine fire clay waste on ceramic wall tiles. As the amount of FFC waste increased, bulk density and bending strength increased whereas firing shrinkage decreased. Moreover, the water absorption and open porosity of investigated bodies increased. In the production of wall tiles, trends are moving towards larger-format wall tiles. The moisture expansion of larger-format wall tiles is one of the most important factors that determine the quality of their service lives. The most important findings in this study are related to moisture expansion. The addition of FFC waste resulted in a decrease in moisture.

M. Marangoni , B. Nait-Ali, D.S. Smith, M. Binhussain, P. Colombo & E. Bernardo :(2013)

the body of conventional ceramic tiles warms up to environmental temperature through conduction, convection and radiation. A strategy to reduce the penetration of this heat into the building is to use a highly porous substrate, which reduces the thermal conductivity of the tile, coupled with a highly reflective glaze. The approach leads to the concept of “cool” iles, aimed at improving the thermal efficiency of buildings. The present paper provides a first example, based on layered wollastonite-hardystonite glass-ceramics developed by double pressing of powders and additives followed by sinter-crystallization

Bohdan Stawiski & Tomasz Kania :(2012)

Problem of the research on quality of ceramic floor tiles remains still open. Their strength, and as a consequence possible applications, depend both on the constitution of ceramic composite, and on their degree of homogeneity. The method of controlling tile strength should be based on evaluating this feature in various cross-sections. Such measurements are very important because their mechanical properties are often not uniform across the whole surface. Standard control tests are not compliant with this requirement because they anticipate only destructive strength tests in their middle cross section.

G. Timellini, R. Resca and M.C. Bignozzi :(2015)

All the phases, productive sections, processes of the ceramic tile manufacture are characterised by emissions into the atmosphere of gases (air) containing different pollutant. In an area with a high concentration of ceramic tile manufacturing units, important pollutant emissions into the atmosphere occurred.l The consequences were both excesses over the air quality standards in force in that time, and environmental problems, with detrimental effects on both cattle and some kinds of plants.

CHAPTER 3 METHODOLOGY

3.1 PROPERTY OF AGGRIGATE

It is important to determine the properties of different types of aggregates through testing and measurement.

The properties of a good aggregate are:

3.2 PARTICLE SHAPE AND SIZE :

Particle size, shape and texture can have considerable effects on various design properties and are generally specified within certain limits. Rounded aggregate can lead to instability in a bituminous mixture yet be ideal as a concrete aggregate where good workability of the mix is essential for placing and compaction. The shape and surface texture of aggregates influence considerably the strength of concrete, especially the flexural strength. This is because they both influence the bonding between the aggregate and the cement paste. A rougher texture surface such as those of crushed particles results in greater adhesion between the particles in the cement matrix. Smooth surfaced particles have very poor bond thus gives concrete of lower strength which are unsatisfactory. Shape of aggregate can be depicted as regular, irregular, angular, rounded or flaky. Surface texture is depicted as smooth or rough.

3.3 SPECIFIC GRAVITY

Introduction

Absolute specific gravity

refers to the ratio of the weight of the solid referred to vacuum, to the weight of an equal volume of gas – free distilled water both taken at stated temperature. The volume of solid referred is the volume excluding all the pores. Thus in order to eliminate the effect of totally enclosed impermeable pores, the material has to be pulverizedIt . This test is both laborious and sensitive and it is not normally required in concrete technology.

3.4 Apparent specific gravity

This is the ratio of the weight of the aggregate dried in an oven at 100◦C – 110◦C for 24 hours to the weight of the water occupying a volume equal to that of the solid including the impermeable pores. The latter weight is determined using a vessel (pycnometer) which can be accurately filled with water to a specified volume. The apparent specific gravity of aggregate depends on the specific gravity of the minerals of which the aggregate is composed and on the amount of voids.

Absolute dry specific gravity, Sap = Wod ÷ (Wsd-Ww)

Specific gravity on saturated surface-dry basis, Ssd = Wsd ÷ (Wsd-Ww)

CHAPTER 4 CONCLUSION

4.1. SILICA FUME

The compressive strength of silica fume concrete reached 84.2 MPa in about 1 month, well ahead of the plain concrete strength of 71.2 MPa, resulting in an increase of 18.3%. The shrinkage of plain concrete has significantly reduced by using silica fume in concrete for various ages, giving a reduction of 34.9% at 30 days. The measured creep of plain concrete was consider-ably reduced by using silica fume in concrete for various ages, showing a reduction of 18.5% at 30 days. The presence of silica fume in concrete reduced the total deformation considerably compared with plain concrete, giving a reduction of 20.8% at 30 days. Silica fume concrete has the potential to decrease the time-dependent deformation of concrete, which is beneficial for concrete structural applications such as prestressed concrete members where prestress losses are influenced mainly by creep and shrinkage.

4.2. CERAMIC TILE

These conclusions further show that the effects on mechanical behaviour as a result of coarse aggregate replacement are more variable than traditional concrete, and rely on the mechanical properties of the ceramic waste material used in the replacement scheme. Ceramic materials that are more porous will exhibit a higher water absorption which will necessitate presoaking. Relatively dense ceramics that are strong in compression but are brittle and will increase the elastic modulus of the concrete they are incorporated into. This, therefore, illustrates that it is important to understand the effects of the different constituent material characteristics on the mechanical behaviour of the resulting concrete. Once these effects are understood, a set of guidelines may then be drawn up for integration into building codes so that ceramic recycling may become a more mainstream concrete building material choice. Additionally, following a systematic, strict testing regime that limits the number of variables provides more linear results when compared to tests performed in other studies, indi-cating that strict control of the source material properties lends to improved prediction capabilities of concrete products produced

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