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Characteristics of Concrete Partially Replaced With Waste Ceramic Aggregates

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Abstract-
A large quantity of ceramic tiles change into wastage, these waste materials are not reusable and recyclable due to their physical and chemical structure. Using ceramic wastage in concrete production could be an effective measure in maintaining the environment and improving the properties of concrete. The present experimental study deals with the investigation of possibility of using waste ceramic tile in concrete. Waste ceramic tile is the least expensive of all the concrete constituents and is much less expensive than natural aggregates and thus the idea is to replace as much of the natural aggregates as possible to save money and to reduce the amount of disposable wastes, as well, but care has to be taken in order not to weaken the concrete by adding too much ceramic tiles. To do so, first, the ceramic waste tiles are collected and then being grind by a hammer. They are used in concrete as the substitute for coarse aggregates with 0 to 50 percent of substitution with W/C ratio of 0.5. Besides, all other parameters are constant. Then a standard series 18 density tests and compressive strength tests were conducted.
The output results obtained from this laboratory program showed reliable data points and promising further research horizons. The optimum value of coarse waste ceramic tile to be used within the concrete mix with a water-cement ratio of 0.5 was determined as about 30%, and the corresponding expected 28-days hardened concrete compressive strength was about 23.2MPa. Also the density of concrete cube decreases as the amount of tile increases. The findings revealed that using waste ceramic tile lead to enhancing the properties of concrete.

Keywords: *Waste ceramic tile; aggregate; concrete; compressive strength; density*

Introduction:

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). Because of the heterogeneous nature of solid wastes, no single method of classification is entirely satisfactory. In some cases it is more important for the solid waste specialist to know the source of waste, so that classifying wastes as domestic, institutional or commercial, for example, is particularly useful. For other situations, the types of waste, garbage, rubbish, ashes, street waste is of greater significance because it gives a better indication of the physical and chemical characteristics of the waste. Based on the source, origin and type of waste a comprehensive classification is described below:

(i) Domestic/Residential Waste:

This category of waste comprises the solid wastes that originate from single and multi-family household units. These wastes are generated as a consequence of household activities such as cooking, cleaning, repairs, hobbies, redecoration, empty containers, packaging, clothing, old books, writing/new paper, and old furnishings. Households also discard bulky wastes such as furniture and large appliances which cannot be repaired and used.

(ii) Municipal Waste:

Municipal waste includes wastes resulting from municipal activities and services such as street waste, dead animals, market waste and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes, institutional wastes and commercial wastes.

(iii) Commercial Waste:
Included in this category are solid wastes that originate in offices, wholesale and retail stores, restaurants, hotels, markets, warehouses and other commercial establishments. Some of these wastes are further classified as garbage and others as rubbish.

(iv) Institutional Waste:
Institutional wastes are those arising from institutions such as schools, universities, hospitals and project institutes. It includes wastes which are classified as garbage and rubbish as well as wastes which are considered to be hazardous to public health and to the environment.

(v) Garbage:
Garbage is the term applied to animal and vegetable wastes resulting from the handling, storage, sale, preparation, cooking and serving of food. Such wastes contain putrescible organic matter, which produces strong odours and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal.

(vi) Bulky Wastes:
In this category are bulky household wastes which cannot be accommodated in the normal storage containers of households. For this reason they require special collection. In developed countries bulky wastes are large household appliances such as cookers, refrigerators and washing machines as well as furniture, crates, vehicle parts, tyres, wood, trees and branches.

(vii) Dead Animals:
This is a term applied to dead animals that die naturally or accidentally killed. This category does not include carcass and animal parts from slaughterhouses which are regarded as industrial wastes. Dead animals are divided into two groups, large and small. Among the large animals are horses, cows, goats, sheep, hogs and the like. Small animals include dogs, cats, rabbits and rats.

(viii) Industrial Wastes:
In the category are the discarded solid material of manufacturing processes and industrial operations. They cover a vast range of substances which are unique to each industry. For this reason they are considered separately from municipal wastes. It should be noted, however, that solid wastes from small industrial plants and ash from power plants are frequently disposed of at municipal landfills.

(ix) Hazardous Wastes:
Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which, because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment. In some cases although the active agents may be liquid or gaseous, they are classified as solid wastes because they are confined in solid containers. Typical examples are: solvents, paints and pesticides whose spent containers are frequently mixed with municipal wastes and become part of the urban waste stream.

(x) Sewage Wastes:
The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derive from the treatment of organic sludge from both the raw and treated sewage. The inorganic fraction of raw sewage such as grit is separated at the preliminary stage of treatment, but because it entrains putrescible organic matter which may contain pathogens, must be disposed off without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but invariably its use for this purpose is uneconomical. The solid sludge therefore enters the stream of municipal wastes unless special arrangements are made for its disposal.

(xi) Construction and Demolition Wastes:

Construction and demolition wastes are the waste materials generated by the construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. Building materials account for about half of all materials used and about half the solid waste generated worldwide. Rapid industrial development causes serious problems all over the world such as depletion of natural aggregates and creates enormous amount of waste material from construction and demolition activities. It consists mostly of inert and non-biodegradable material such as concrete, sand, stone, gravel, tiles, marble, glass, aluminum, wood, plastic, paper, paints, plumbing pipes, electric parts and asbestos, and other materials. These wastes are heavy, having high density, often bulky and occupy considerable storage space either on the road or communal waste bin/container. It is not uncommon to see huge piles of such waste, which is heavy as well, stacked on roads especially in large projects, resulting in traffic congestion and disruption. Waste from small generators like individual house construction or demolition, find its way into the nearby municipal bin/vat/waste storage depots, making the municipal waste heavy and degrading its quality for further treatment like composting or energy recovery. Often it finds its way into surface drains, choking them.

Characteristics of Construction and Demolition Waste-

The characteristic of construction and demolition waste is complex due to the different types of building materials being used but in general may comprise the following materials

Major components

- Cement concrete
- Bricks
- Tiles
- Cement plaster
- Steel
- Rubble
- Stone (marble, granite, sand stone)
- Timber/wood (especially demolition of old buildings)

Minor components

- Conduits (iron, plastic)
- Pipes (GI, iron, plastic)
- Electrical fixtures (copper/aluminum wiring etc)
- Panels (wooden, laminated)

Figure: Different components of C & D wastes

Storage of Construction and Demolition Waste

These wastes are best stored at source, i.e., at the point of generation. If they are scattered around or thrown on the road, they not only cause obstruction to traffic but also add to the workload of the local body. All attempts should be made to stick to the following measures:

- All construction/demolition waste should be stored within the site itself. A proper screen should be provided so that the waste does not get scattered and does not become an eyesore.
- Attempts should be made to keep the waste segregated into different heaps as far as possible so that their further gradation and reuse is facilitated.
- Material, which can be reused at the same site for the purpose of construction, leveling, making road/pavement etc. should also be kept in separate heaps from those, which are to be sold or land filled.
- For large projects involving construction of bridges, flyovers, subways etc., special provision should be made for storage of waste material.

Recycling and Reuse of Construction and Demolition Waste

The reuse and recycling of these materials is effective in reducing both cost and environment impact. The standard point of energy saving and conservation of natural resources, the use of alternative constituents in construction materials is now a global concern. The use of these materials basically depends on their separation and condition of the separated material. A majority of these materials are durable and therefore, have a high potential of reuse. It would, however, be desirable to have quality standards for the recycled materials. Construction and demolition waste can be used in the following manner:

- Reuse (at site) of bricks, tiles, stone slabs, timber, conduits, piping railings etc. to the extent possible and depending upon their condition. Among these the ceramic tiles are used in this project.
- Sale / auction of material which can not be used at the site due to design constraint or change in design.
- Plastics, broken glass, scrap metal etc. can be used by recycling industries.

- Rubble, brick bats, broken plaster/concrete pieces etc. can be used for building activity, such as, leveling, under coat of lanes where the traffic does not constitute of heavy moving loads.
- Larger unusable pieces can be sent for filling up low-lying areas.
- Fine material, such as, sand, dust etc. can be used as cover material over sanitary landfill.

History of Ceramic Tiles

It is believed that the first clay tiles were produced seven to eight thousand years ago in the area now known as the Holy Land. Many sources independently verify that the actual known history of Tiles (and the known usage of wall and floor tile coverings) can be traced back as far as the fourth millennium BC (4000 BC) to Egypt. In those days, in Egypt, tiles were used to decorate various houses.

Clay bricks were dried beneath the sun or baked, and the first glazes were blue in colour and were made from copper, very exquisite. During that period ceramics were also known to be found in Mesopotamia. These ceramics bore decorations, which were white and blue striped and later possessed more varied patterns and colours. Later on, in China too, the Great Center of Ceramic Art, a fine, white stoneware with the earliest Chinese glaze was produced during the Shang-Yin dynasty (1523-1028 BC).

Today Ceramic tile throughout the world is not hand-made or hand-painted for the most part. Automated manufacturing techniques are used and the human hand does not enter into the picture until it is time to install the tile. They are used in an almost infinite number of ways and you don't have to consider yourself wealthy to own them. In commercial buildings, where both beauty and durability are considerations, ceramic tiles will be found, particularly in lobby areas and restrooms. In fact most modern houses throughout use Ceramic tiles for their bathrooms and kitchens and in every vital area of the premise. Ceramic tiles are also the choice of industry, where walls and floors must resist chemicals. And the Space Shuttle never leaves Earth without its protective jacket of high-tech, heat resistant tiles.

Ceramic Tile Manufacturing Process

The ceramic tile manufacturing process consists of a series of successive stages, which can be summarized as follows:

1. Raw materials preparation
2. Tile forming (Pressing or Extrusion)
3. Drying of the green body
4. Firing, with or without glazing
5. Sorting and packing

Depending on whether the product to be made is glazed or not, and whether single fire, twice fire or third fire is involved, the tile will or will not be glazed in a given process, or the order of the glazing and firing stages will be suitably rearranged as shown in figure.

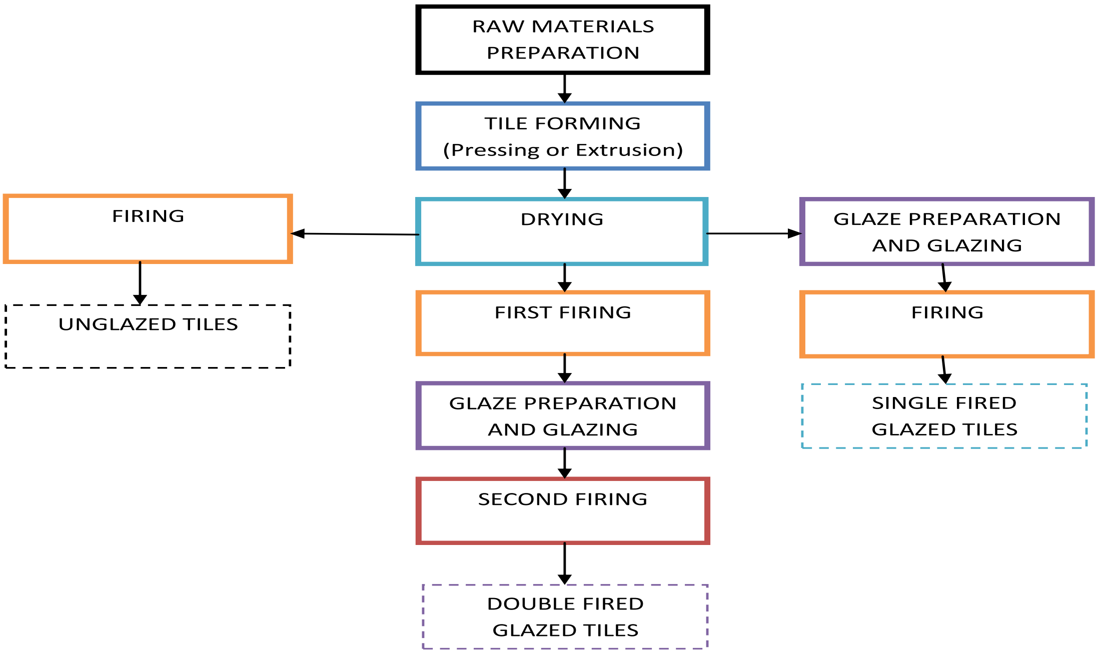

Figure: Ceramic Tile Manufacturing Process

Raw materials preparation

The ceramic process starts by selecting the raw materials required for the body composition, which are mainly clays, feldspars, sands, carbonates and kaolins. In the traditional ceramic industry, the raw materials are generally used as mined or after some minor treatment.

(i) Dry or wet milling

After a first mixing of the body components, the mixture is usually dry milled (hammer or pendulum mills) or wet milled (continuous or batch ball mills).The resulting milled material exhibits different characteristics depending on whether dry or wet milling is used. In dry milling, fragmentation occurs and particle aggregates and agglomerates remain, with a larger particle size (there are particles larger than 300 microns) than by the wet method (all particles are smaller than 200 microns). A decisive factor in selecting the type of milling to be used is the capital outlay required in each case.

(ii)Wet milling and spray drying

Wet milling and subsequent spray drying are currently the most widely implemented methods in ceramic floor and wall tile manufacture by the single -fire process, owing to the important technical improvements they provide. In wet milling, the raw materials can be wholly or partially fed into the ball mill, which is normally the case, or they can be directly dispersed. Part of the water contained in the resulting suspension (slip) is removed by spray drying to obtain a product with the required moisture for each process stage. Spray drying is the most widely implemented drying method in tile manufacture. In this drying process, the fine drops of sprayed suspension come into contact with hot air to yield a solid with a low water content.

(iii) Mixing

In this body preparation stage, the water and raw materials making up the body composition are closely mixed to a consistent paste that is readily mouldable by extrusion.

Classification of Ceramic Tiles
Ceramic tiles are classified by their shaping or production method (either dry pressed or extruded), and the level of water absorption measured as a percentage.

(i) Porcelain (fully vitrified)
Either unglazed or glazed and characterized by a low water absorption of less than 0.5%, porcelain tiles are normally dry pressed.

(ii) Vitrified and semi vitrified
These can either be unglazed or glazed and made by dry pressing or extruding. Such tiles fall into two main categories based on the water absorption of the tile body measured as a percentage.
(a) Vitrified tiles dry pressed and extruded have a water absorption of between 0.5% to 3%.
(b) Semi-vitrified tiles dry pressed and extruded have a water absorption of between 3% to 6%.

(iii) Terracotta
Literally meaning 'cooked earth', terracotta is made from local natural clays with a minimum of processing, tend to be unglazed and normally have a water absorption more than 10%. Tiles of this type generally have a more porous surface and need surface treatments to enhance staining resistance and cleaning properties.

(iv) Glazed porous body
The majority of standard wall tiles have glazed porous bodies with a water absorption between 10% and 20%. When the face of such tiles is covered with a vitreous glazing either gloss or satin they are suitable for a wide variety of internal applications. Such tiles are not frost resistant and should only be used in internal conditions above sub zero temperatures.

(v) Glazed vitrified
The porcelain vitrified and semi-vitrified tiles possess similar technical properties when glazed and can be used for internal cladding applications
Only vitrified and porcelain tiles with a water absorption value lower than 3% should be used for external cladding applications in conditions that are subject to frost.

(vi) Mosaics
Mosaics are defined by size (generally less than 25 mm). Mosaics are composed from a variety of product types (made from individual tessarae that could be porcelain, vitrified or earthenware ceramic, glass or natural stone) and can be unglazed or glazed.

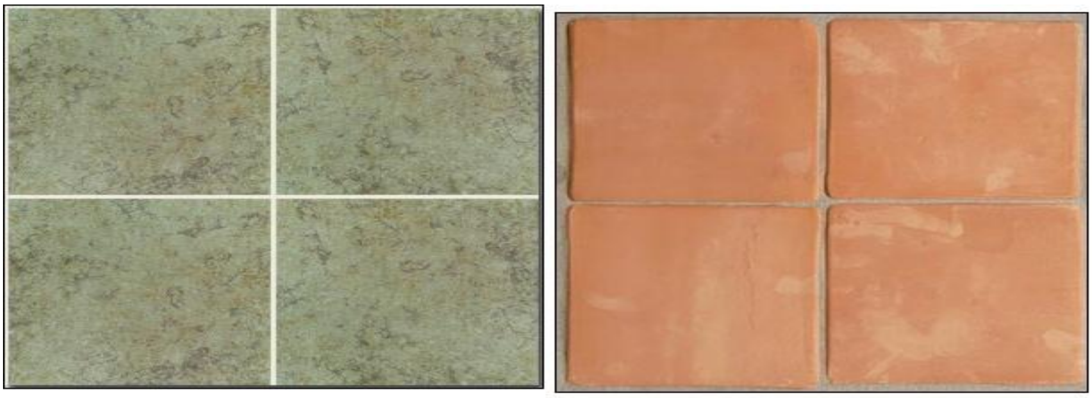

Figure: Glazed and Unglazed ceramic tiles

1.6 Problem Statement
Many studies have been emerging worldwide highlighting the reuse of waste ceramic tiles in construction technology. The idea is that the waste tiles can be used as an aggregate in the concrete

mix by replacing some of the natural aggregates such as gravel and sand. Thus, the possible benefits are as follows:

- Less ceramic tile is thrown away saving landfill space.
- The use of fewer natural aggregates (which are the components of concrete) saving our natural resources.
- Less labor is used by not shipping raw materials from distant places to where ceramic tile is available saving time and money.

There has been an increasing significant interest in the development of concrete mixes with waste ceramic tiles, besides, recycling waste tiles as an aggregate is effective for environmental conservation and economical advantage. Therefore, samples of the most common waste ceramic tiles in Aligarh is to be collected and crushed to be included in concrete as a partial occupant in the concrete mix replacing fine and coarse aggregates, and a basic experimental study on the physical and mechanical properties of concrete containing waste ceramic tiles is to be carried out.

Aim and Objectives

This paper focuses on studying the effect of waste ceramic tiles on the properties of concrete mixtures as a partial replacement of coarse aggregates with W/C ratio of 0.5. The successful use of waste tiles will aid in reducing the environmental problems related to the disposal of waste tiles and the scarcity of land area needed for disposal.

Within the scope of this study, the main goal is to investigate the possibility to improve the compressive strength over a range of waste tiles percentages. Waste tile is the least expensive of all concrete constituents and is much less expensive than natural aggregates and sand, thus the idea is to replace as much of the natural aggregates and sand as possible to save money and to reduce the amount of disposable wastes, as well, but care has to be taken in order not to weaken the concrete by adding too much tiles.

The main objective of this paper is to study the effect of waste tiles on the properties of concrete mixes as a partial replacement of coarse aggregate with W/C ratio of 0.5. This objective can be achieved through the following objectives:

- Study the influence of waste ceramic tiles on hardened properties of concrete mixes such as unit weight and compressive strength.
- Determine the optimum waste ceramic tiles content to be added as a partial replacement of coarse aggregate.

Properties of concrete composite materials
This section summarizes the properties of all the components used in the various concrete mixes. Concrete is a structural material that contains some simple elements but when mixed with water would form a rock like material. Concrete mix is comprised of coarse aggregates usually gravel, fine aggregates usually sand, cement, water, and any necessary additives. Concrete possesses many favorable properties as a structural material, among which are its high compressive strength and its property as a fire-resistant element to a considerable extent.

Consistency test, initial setting time test, final setting time test:
In order to carry out tests for standard consistency, initial setting time, and final setting time Vicate’s apparatus is used. This apparatus consists of a frame with a movable rod is attached. An indicator is attached to the movable rod with the help of which penetration of the needle can be measured. There is a cylindrical mould which can be split into two halves as and when required. The mould is always used by keeping it on non-porous plate. Vicate’s apparatus consists of three attachments- square needle, plunger and needle with annular collar. Square needle is used for

determining initial setting time. Needle with annular collar is used for final setting time and plunger for normal or standard consistency test.

Consistency Test:

This test is carried out to determine the percentage of water required for preparing cement paste of standard consistency. Take 300gm of cement by weight and mix it with 30% i.e. 90 gm of water. The mixing of cement and water is done in a non-porous plate, so that no water is lost during mixing. Fill the vicate'smould with this paste and level its surface with the help of trowel blade.

Now plunger is attached to the movable rod of vicat's apparatus. The plunger is brought in contact of the paste filled in the mould and gently left to penetrate by itself under the load of rod only.

Penetration of the plunger is noted. Now the mould is filled again with cement paste, but by varying moisture content a little and penetration of the plunger is such that it remains only 5 mm to 7 mm from the base of the mould. The consistency of cement paste corresponding to the penetration of 5 to 7 mm from the bottom of the mould is known as standard or normal consistency.

The time interval, between addition of water to the cement of filling the mould is known as gauging time and this should not be more than 3 to 5 minutes.

TABLE: NORMAL CONSISTENCY TEST OF CEMENT

TRIAL NO.	% WATER ADDED	Ht. PENETRADED (mm)	Ht. NOT PENETRATED (mm)	CONSISTENCY (mm)
1	25	25	15	
2	28	29	11	30
3	30	33	07	

Initial Setting Time Test:

For this test, the vicat'smould is filled with cement paste of standard consistency. Square needle of 1mm*1mm is attached to the movable rod of the vicat's apparatus. The needle is brought in contact of the cement paste and quickly released and allowed to penetrate the cement paste. In the beginning, needle penetrates completely. The process of bringing needle in contact of paste and quick released, is repeated at suitable interval and every time the penetration of needle will go on decreasing. The process is kept repeating till a stage is reached, when needle penetrates up to about 5 mm measured from bottom of the mould.

The interval between the addition of water to cement and the stage, when needle ceases to penetrate 5 mm layer of paste measured from the bottom, is known as initial setting time of the cement.

TABLE: INITIAL SETTING TIME TEST OF CEMENT

TRAIL	TIME (MIN)	PENETRATION (mm)
1	0	40
2	5	40
3	10	40
4	15	39
5	20	38
6	25	37
7	30	37
8	35	36
9	40	35

RESULT: The initial setting time of given cement sample is found to be **40 min.**

TABLE: COMPRESSIVE STRENGTH OF CEMENT

S. NO.	CRUSHING LOAD (KN)	AFTER 28 DAYS COMPRESSIVE STRENGTH (N/mm^2)
1	200	40.012
2	190	38.011
3	220	44.013
AVG		40.678

Fig.: Cement Cube Specimens

TABLE: PROPERTIES OF CEMENT

Property	Value
Normal consistency	30%
Initial setting time	40 minute
28 days compressive strength	40.678MPa

Aggregates

Aggregates are very important ingredients of concrete as they provide body and strength to the concrete (role of aggregates is similar to that of bones in human body). They occupy about 75% volume of concrete and being comparatively cheaper as compared to the other ingredients, they govern economy of concrete. Not only the strength of concrete but also other properties are governed by aggregates such as durability, workability, shrinkage, volume, stability, etc.

Earlier it was believed that aggregates are inert material but later on it was established that some of the aggregates (depending upon their chemical composition) are chemically active. Therefore, it is necessary to study each and every property of aggregates namely, size, shape, grading, surface texture, specific gravity, density, impact and crushing strength, abrasion value, soundness and chemical composition.

Aggregates, used in concrete, can be natural or artificial type and are broadly classified as coarse aggregates (size >4.75 mm) and fine aggregates (size <4.75 mm). The coarse aggregates are generally available in 80, 40, 20, 10 and 4.75 mm sizes. The fine aggregates can be conveniently grouped into coarse, medium and fine sand. Aggregates available for manufacturing of concrete can be broadly put under two categories, i.e. Natural Aggregates and Artificial Aggregates.

Natural aggregates are those which are available naturally (e.g. sand in the river bed or sea shore, etc.) or are manufactured from the naturally available rocks/stone by manipulating their sizes, shape and surface texture only and other properties remain unchanged Artificial aggregates are those, which are manufactured artificially (e.g. burnt clay, colored ceramic aggregates) or are obtained as byproduct/waste of industries (e.g. blast furnace slag, ceramic tile etc.).

Oven dry aggregates would absorb water to fill its own internal voids and in doing so would reduce the water cement ratio. If this occurs, then the hydration process is not permitted to continue and the strength of the concrete mix would be reduced by a considerable amount. Air dry aggregates would absorb some water but not to an extraneous degree like the oven dry aggregates. The surface would appear dry and thus some water is absorbed and reduces the water cement ratio. Thus the strength of the concrete is reduced by a small amount. Saturated dry surface aggregates have their internal voids fill with water and thus cannot absorb any more water. These aggregates would keep the water cement ratio constant and the concrete would retain its full strength Aggregates have their internal voids and surface area saturated with water. Instead of absorbing water, the aggregates would add water to the mixture and in doing so; the water cement ratio is increased, decreasing the strength of the concrete.

Natural coarse aggregate

The locally available crushed quartzite aggregate of maximum nominal size of 20mm, was used as coarse aggregate as shown in figure.

Figure: Sample of the natural coarse aggregate for concrete mix

Natural coarse aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste. Identification of the constituents of an aggregate cannot alone provide a basis for predicting the behavior of aggregates in service. Visual inspection will often disclose weaknesses in coarse aggregates.

Therefore sieve analysis was carriedout as per **IS 383: 1970 because** the gradation of aggregates affects both fresh and hardened concretes and is shown in table and figure. **Also** some laboratory tests were conducted in order to find out the physical properties as per IS:2386 -1963 and are shown in table.

TABLE: IMPACT VALUE TEST OF NATURAL AGGREGATE

S. NO.	DETAIL OF SAMPLE	VALUES OF NATURAL AGGREGATE
1.	Total weight of aggregate sample filling the cylinder measure (w_1)	328 gm
2.	Weight of aggregate passing 2.36 mm sieve after the test (w_2)	52.5 gm
3.	Weight of aggregate retained on 2.36 mm sieve (w_3)	275 gm
4.	Aggregate impact value = w_2/w_1x 100	52.5/328 x 100 =16.006 %

Figure:Impact testing machine

TABLE: CRUSHING VALUE TEST OF COARSE AGGREGATES

S. NO.	DETAIL OF SAMPLE	VALUES OF NATURAL AGGREGATE
1.	Total weight of aggregate sample filling the cylinder measure (w_1)	3175 gm
2.	Weight of aggregate passing 2.36 mm sieve after the test (w_2)	455 gm
3.	Weight of aggregate retained on 2.36 mm sieve (w_3)	2720 gm
4.	Aggregate crushing value = w_2/w_1x 100	455/3175 x 100 = 14.33 %

TABLE: SUMMARY OF SIEVE ANALYSIS DATA FOR COARSE AGGREGATES

IS Sieve Size	Weight retained(gm)	Cumulative wt. retained(gm)	Cumulative % retained	Cumulative % passing
20mm	547.5	547.5	10.95	89.05
12.5mm	3621	4168.5	83.37	16.63
10mm	633	4801.5	96.03	3.97
4.75mm	189	4989.5	99.79	0.21
2.36mm	3.5	4994	99.88	0.12
Pan	6	5000	100	zero
Nominal size of aggregate =20mm,single size (confirming IS 383-1970)				

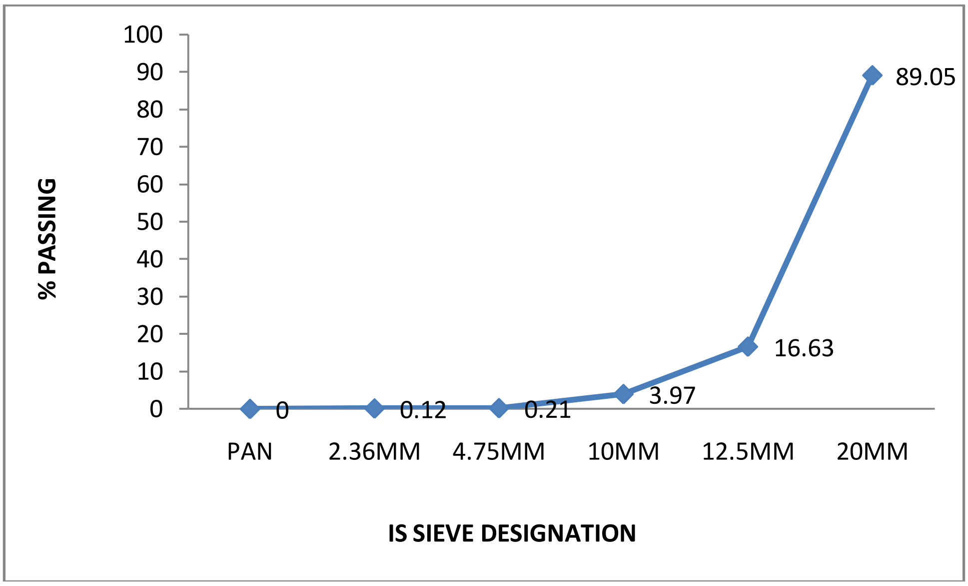

Figure: Grain size distribution curve of coarse aggregate

TABLE: PROPERTIES OF NATURAL COARSE AGGREGATES

Property	Observed value
Maximum size (mm)	20
Crushing value (%)	14.33
Impact value (%)	16.00

TABLE: SUMMARY OF SIEVE ANALYSIS DATA FOR FINE AGGREGATES

IS Sieves	Weight retained (grams)	Percentage weight retained	Percentage weight passing	Cumulative percentage weight retained	Cumulative percentage weight passing
10.00 mm	0.00	0.00	100.00	0.00	100.00
4.75 mm	22.0	2.2	97.8	2.2	97.8
2.36 mm	35.0	3.5	96.5	5.7	94.3
1.18 mm	97.0	9.7	90.3	15.4	84.6
600 micron	418.0	41.8	58.2	57.2	42.8
300 micron	370.0	37.0	63	94.2	5.8
150 micron	52.0	5.2	48	99.4	0.6
75 Micron	4.0	0.4	99.6	99.8	0.2
Pan	2.0	0.2	-	100	0.00
Total	1000.0			373.9	
Fineness modulus=373.9/100=3.739					
Sand corresponds to grading zone-II (From IS 383-1970)					

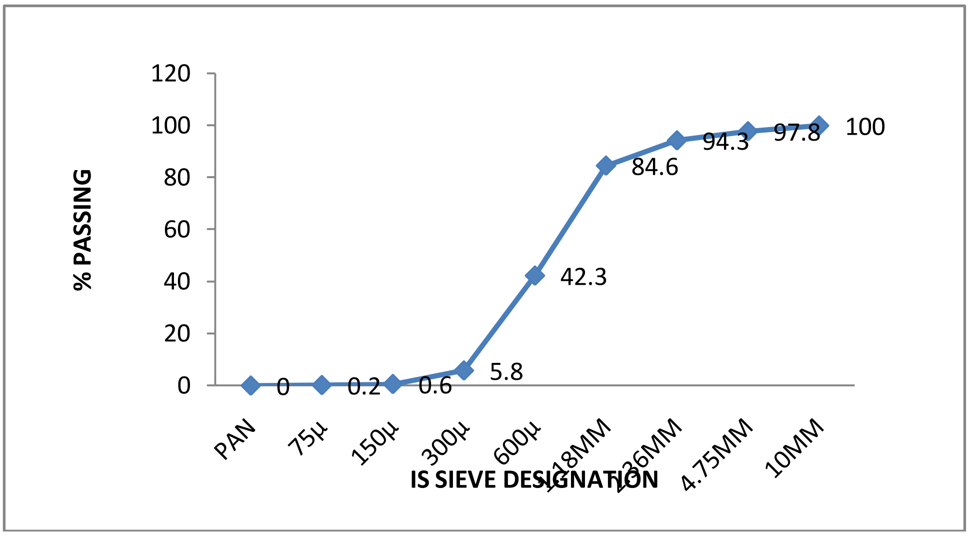

Figure: Grain size distribution curve of fine aggregates

Compressive strength of concrete

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. In those cases where strength in tension or shear is of primary importance, the compressive strength is frequently used as a measure of these properties. No exact quantitative relationship between compressive strength and flexural strength, tensile strength, modulus of elasticity, wear resistance, fire resistance or permeability have been established yet. Strength of concrete is its resistance to rupture. It may be measured in a number of ways, such as strength in compression, in tension, in shear or in flexure. All these indicate strength with reference to a particular method of testing. When concrete fails under a compressive load the failure is essentially a mixture of crushing and shear failure.

Factors affecting the compressive strength of concrete

The factors influencing the compressive strength of concrete are as follows

- Quality of cement
- Water cement ratio
- Grading of aggregate
- Degree of compaction
- Efficiency of curing
- Temperature during curing
- Age at the time of testing

The strength of concrete will not increase merely by increasing the quantity of cement unless the water/cement ratio is decreased. But, at the same time, the amount of water directly controls the workability which increases with increase in water. Thus an optimum water/cement is required that will give maximum workability and strength.

Testing program results

According to the experimental testing program set previously, the final output results for 6 different sample groups regarding unit weight and compressive strengths for hardened concrete are listed in Table1 and 2. The following sections will analysis comprehensively all obtained results.

TABLE1: COMPRESSIVE STRENGTH OF CONCRETE WITH DIFFERENT COARSE WASTE TILE CONTENTS

Group	Sample1 (kN)	Sample2 (kN)	Sample3 (kN)	Average Compressive Strength (MPa)
C5-00	490	500	480	21.8
C5-10	530	540	550	24.1
C5-20	540	550	530	23.9
C5-30	510	520	530	23.2
C5-40	460	470	480	21.1
C5-50	430	440	450	19.7

TABLE2: UNIT WEIGHT OF CONCRETE WITH DIFFERENT COARSE WASTE TILE CONTENTS

Group	Sample1 (kg)	Sample2 (kg)	Sample3 (kg)	Average Unit Weight (kg/m^3)
C5-00	7.5	7.6	7.4	2225
C5-10	7.46	7.4	7.51	2213
C5-20	7.4	7.42	7.44	2198
C5-30	7.35	7.38	7.41	2186
C5-40	7.31	7.34	7.37	2175
C5-50	7.27	7.29	7.31	2160

Effect of waste ceramic tile aggregate on concrete density

The density of concrete is a measurement of concrete's solidity. The density of each concrete cube is determined in the laboratory. First of all, the cubes are taken out from the cure tank and then dried. After that the dimensions of each cube is measured and then overall volume computed in cubic meters. The cubes then weighted in digital weighing balance in kilograms. Then the density of each cube is calculated as the ratio of dried weight to the volume.

Figures1 illustrate the effect of coarse waste ceramic tile content into the concrete mix on the mass density of the hardened concrete. More specifically, as we increase the substitution amount of ceramic tile aggregate, the unit weight decreases and it is due to the less unit weight of tile. That is, for 50 percent of ceramic tile substitution this decrease has been turned out to be about 6.5percent. Therefore, it can be concluded that the weight of a structure can be decreased up to 6.5 percent. As a whole, it can be asserted that using tile causes a decrease in unit weight and hence it helps the load bearing capacity of structures.

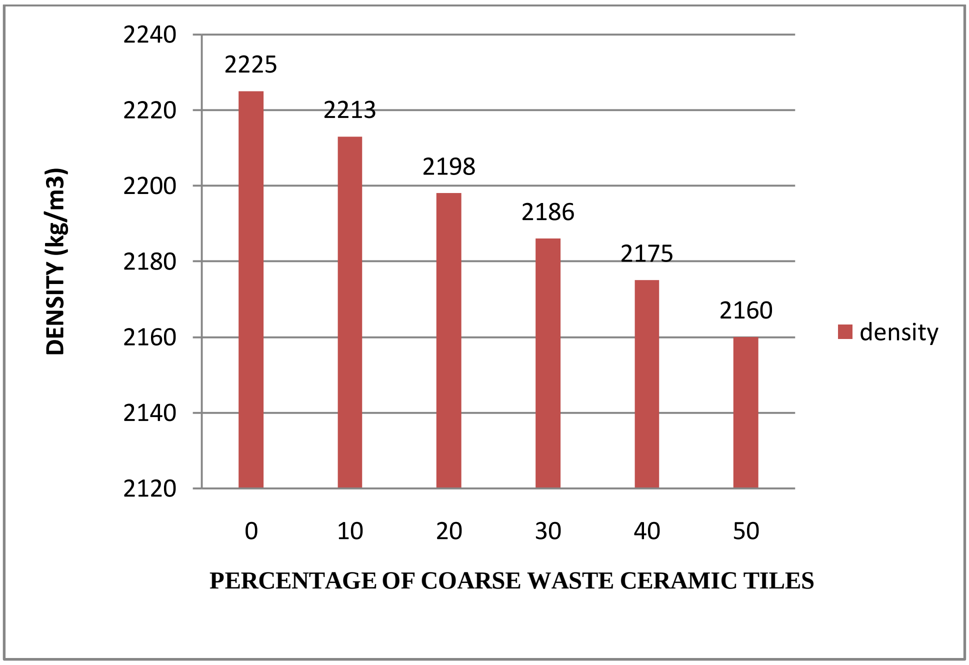

Figure: concrete density versus percentage of waste ceramic tile aggregates

Effect of waste ceramic tile aggregate on compressive strength of concrete

It was observed that 28-days compressive strength is improved for w/c ratio of 0.5 up to 30%coarse waste ceramic tile aggregate as compared to reference concrete. Beyond 30% coarse waste ceramic tile aggregate the compressive strength is decreased as compared to reference concrete. Further, the highest reported strength belonged to the sample which included 10 percent tile whose compressive strength has increased about 3.5 percent.

It shows that using tile as a coarse aggregate not only cause no reduction in the strength of concrete, but also increase the compressive strength of it up to 30 percent for w/c ratio of 0.5. Also bear no negative impact on compressive strength. The strength of the samples which include tile has been reported to be very similar to each other. On the contrary, the compressive strength decreased considerably as the amount of tile aggregate increased beyond 30%. One reason for decreasing the strength of samples as a result of enhancing the amount of tile may be the increase in the flaky aggregate. The tile aggregates especially in bigger sizes have flaky shapes, as the use of this aggregate increase in concrete the percent of flaky aggregate in it and in turn lead to the decrease of strength. Further, another reason could be due to lack of engagement of aggregates with concrete, as a result of the smooth surface of aggregates.

Figure1: Typical testing reference cube (left) and waste ceramic tile cube (right) after failure for determining concrete compressive strength

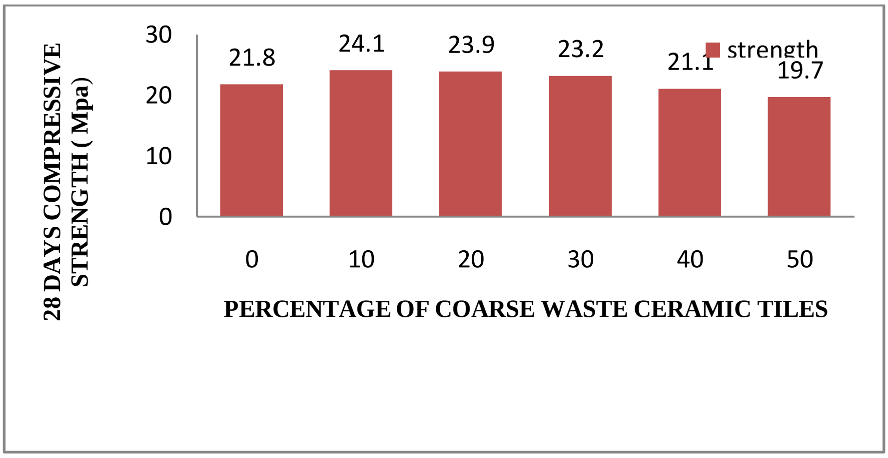

Figure: 28-Days concrete compressive strength versus percentage of coarse waste ceramic tile in the mix

Conclusions

The possibility of using ceramic wastage as aggregates in concrete was investigated in the present study. The process of substituting 0 to 50 percent waste ceramic tile as coarse aggregate was studied and then parameters of compressive strength and unit weight were measured. Finally, the following conclusions can be highlighted from the output of this project and can be summarized as follows:

1) It was noticed that the density of concrete gradually decreased with the increase of quantity of waste ceramic tile content.
2) Compressive strength of concrete gradually increased with the increase of quantity of coarse waste ceramic tile aggregate up to 30%. The greatest compressive strength was observed for C5-10 concrete.
3) Using ceramic wastage in concrete production causes no remarkable negative effect in the properties of concrete. The optimal case of using waste ceramic tiles as coarse aggregates is found to be 10 to 30 percent. In these measures, not only an increase happens in compressive strength, but also a decrease in unit weight is reported.
4) Using waste ceramic tiles in concrete leads to removal of those materials from environment. Besides, decreasing the use of raw materials, using the wastage is considered positive economically.
5) Using waste ceramic tiles in concrete, with regard to reducing the costs and keeping the environment clean along with wastage management, and ameliorating the strength of structures, is an effective measure in sustainable development.

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