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# Research on Mechanical Properties of Concrete by Partial Replacement of Coarse Aggregate with Ceramic Tiles in Concrete

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## Abstract

Ceramic wall tiles are used as building material in the field of construction. Manufacturing of ceramic tiles require different raw material like clay, potash, dolomite, feldspar, talc and different chemicals like sodium silicate, sodium triply, phosphate (STPP) in ceramic production. this variation of manufacturing; therefore, there is a pozzolanic reactivity in such material. In ceramic industry about 5-10% production goes as waste in various processes while manufacturing (this waste percentage goes down if the technology is installed in new units.)

In this research the coarse aggregate has been replaced by ceramic waste tiles consequently in the range of 10% 20%, 30%, 40% and 50% by weight of M25 grade. Concrete mixtures were produced, tested and compared in terms of compressive strength, split tensile strength and flexural strength and durability to the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 28,56 and 90 days. Keeping all this view, the aim of the analysis is to study the performance of concrete while replacing the ceramic tiles with different proportions in concrete.

**Key words:** Ceramic tiles, Compressive Strength and some mechanical properties.

## I. INTRODUCTION

Ceramic waste is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Ceramic waste powder is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Ceramic products are part of the essential construction materials used in most buildings. Some common manufactured ceramics include wall tiles, floor tiles, sanitary ware, household ceramics and technical ceramics. They are mostly produced using natural materials that contain high content of clay minerals. However, despite the ornamental benefits of ceramics, its wastes among others cause a lot of nuisances to the environment. As a general note, Omole and Isiorho reported the devastating influence of solid wastes in the Nigerian community.

Ceramic wastes are separated into two categories in accordance with the source of raw materials One category is formed through generated fired ceramic wastes by structural ceramic factories that use only red pastes for product (brick, blocks and roof tiles) manufacture. The second encompasses fired ceramic wastes which are produced in stoneware ceramic (wall, floor tiles and sanitary ware). Meanwhile during ceramic production, studies have shown that about 30% of the material goes to wastes and currently they are not beneficially utilized. This attests to the need for exploring innovative ways of re-using ceramic wastes. Aggregates constitute about 70% of total constituents in concrete production. The cost is increasing as a result of high demand from rural and urban communities. Numerous researchers have identified ceramics as having the potential to replace natural aggregates Some investigations have suggested that ceramic wastes are good materials which could substitute conventional aggregates in concrete The influence of ceramic tiles wastes on the structural properties of concrete made using laterite was recently investigated It was reported that ceramic based laterized concrete performed considerably well when compared to the conventional concrete. Overall, ceramic waste utilization can solve problems of aggregate shortages in various construction sites.

Moreover, it can reduce environmental problems related to aggregate mining and waste disposal. However, most of the previous investigations were carried out using sanitary ware and electrical insulator ceramics, with not much information as regards the use of ceramic floor and wall tiles. Thus, there is a need to explore the usability of ceramic floor and wall tiles, because these ceramic products are produced at different temperatures which invariably determines their microstructures.

Consequently, the current study explores the mechanical characterization of concrete made using ceramic floor and wall tiles wastes from construction and demolition sites as partial replacement of natural aggregates.

### *WASTE FOUNDRY SAND (WFS):*

Foundry sand is high quality silica sand with uniform physical characteristics. It is produced from ferrous and nonferrous metal casting industries, where sand has been used for centuries as a moulding material because of its thermal conductivity. Indian foundries produce approximately 1.71 million tons of waste foundry sand each year (Metal World, 2006). This sand is treated as waste from casting industry and because of high silica content it cannot be disposed easily. Waste foundry sand is made up of mostly natural sand material. Its properties are similar to the properties of natural or manufactured sand, the fineness modulus of waste foundry sand is 3.027.Thus, it can normally be used as a replacement of sand.

**Waste reduction techniques:**

- Change the composition of the product to reduce the amount of waste resulting from the product's use.
- Reduce or eliminate hazardous materials that enter the production process.
- Use technology (including measuring and cutting) to make changes to the production process; equipment, layout or piping; or operating conditions.
- Purchase what you need to avoid waste from unwanted materials.
- Good operating practices such as waste minimization programs, management and personnel practices, loss prevention, and waste segregation help to reduce waste at their source.

**Recycling Techniques:**

- Return waste material to original process.
- Use the waste material as a raw material substitute for another process.
- Process waste material for resource recovery.
- Process waste material as a by-product.
- Investigate contractors to recycle waste material.
- Advertise waste material.
- Use packaging waste again (cardboard, bubble wrap or polystyrene).

**Ceramic waste dust:**

In the study two types of filler have been used, the conventional filler i.e. lime and other is ceramic waste. The lime was obtained from local market and the ceramic waste was collected from Morbi Ceramic industrial area, Rajkot, Gujarat, India. Sieve analysis of powdered form ceramic waste and lime was carried out and result shows that 98.5% of ceramic powder and 58.37% of lime passed through 75µ Sieve as per the Indian coal provision (The chemical properties of the ceramic waste were considered as mentioned Bituminous concrete is the most commonly used pavement material due to its construction procedures. The ever-increasing economic cost and lack of availability of natural material have opened the opportunity to explore locally available waste material l. If industrial waste materials can be suitably used in road construction, the pollution and disposal problems may be partially reduced. As reported, Indian ceramics industry, which is comprised of wall and floor tiles, sanitary ware, bricks and roof tiles, refractory materials and ceramic materials for domestic and others use is producing approximately 15 to 30 MT per annum waste.

The state of Gujarat accounts for around 70% of total ceramic production in India and out of total production 30% goes as waste and dumped in the open spaces. The advantages of using ceramic waste dust in road construction as mineral filler and as aggregate are:

- The ceramic dust available at zero economic cost.
- Chemical and mechanical properties will be consistent.
- Road construction activity approaches to become green.
- Durable, hard and highly resistant to biological, chemical and physical degradation forces. Researches show that potential use of the ceramic wastes in the construction industry is beneficial.

**Figure: Ceramic Aggregate**

**Recycling of Ceramic Waste:**

A lot of waste is generated while producing ceramic wares in the factory, which are usually referred to as rejects. These wastes are from finished products that have such deficiencies that would naturally make them unacceptable in the market because they could constitute health risk. The wares usually have such fault like internal cracks, dusting (cracking of pottery caused by stresses which form during firing and cooling) and bloating. The production molds which are made of Plaster of Paris, usually under normal circumstances, expire after 90 product casts, though some are made to go far more than such tolerable limits. The expired moulds in most instances are dumped after they may have expired. These broken ceramic wares and the expired plaster moulds constitute environmental hazards at dumped sites and result in an unnecessary distraction.

## *CERAMICS INDUSTRY WASTE*

As regards the ceramics industry in Spain, some 30 million tons of ceramic products such as bricks, roof tiles, breeze blocks, etc., were produced in 2006. Although the recent industrial crisis had resulted in a 30% drop in production, the industry continues to generate a significant volume of material unsuitable for commercialization. The percentage of products considered unsuitable for sale and thus rejected depends on the type of installation and the product requirements. Such waste can be considered inert, due to its low capacity for producing contamination. However, dumping constitutes a major disadvantage, producing significant visual impact and environmental degradation. Ceramic factory waste known as masonry rubble, is not sorted according to the reason for rejection, which may include:

- Breakage or deformation, which does not affect the intrinsic characteristics of the ceramic material.

Firing defects, due to excessive heat or insufficient heat (under-firing), faults particularly associated with the use of old kilns and which may affect the physico-chemical characteristics of the product

**Figure: Ceramic factory waste**

Ceramic products are made from natural materials which contain a high proportion of clay minerals. These, through a process of dehydration followed by controlled firing at temperatures of between 700ºC and 1000ºC, acquire the characteristic properties of "fired clay". Thus, the manufacturing process involved in ceramic materials requires high firing temperatures which may activate the clay minerals, endowing them with pozzolanic properties and forming hydrated products similar to those obtained with other active materials. Research carried out into the influence of firing temperatures on waste product properties has found that the chemical and mineralogical composition of ceramic masonry rubble resulting from incorrect firing temperatures (over- or under-firing) varies significantly from that of products obtained from optimal firing conditions. However, the temperature applied (around 900ºC) is sufficient to activate the clay minerals, with the result that the different rejects acquire similar pozzolanic properties. Furthermore, studies have been carried out into the viability of substituting cement by using ceramic rejects or masonry rubble as raw materials in prefabricated concrete, exploiting their pozzolanic properties.

## *SCOPE OF WORK:*

Adding of waste ceramic tiles to concrete as a supplement actually decreases the construction cost and more or less maintains the concrete properties. In addition to that, when these waste materials are processed properly, have shown to be effective as construction materials and readily meet the design specifications. The aim of this project is to utilize solid waste materials in the best way in construction field without any hazardous effect on strength

**Objectives:**

- To study the coarse aggregate has been replaced by ceramic tiles accordingly in the range of 10% 20%, 30%, 40% and 50% by weight of M25 grade

- To evaluate the mechanical properties for 7, 28,56 and 90 days.
- To investigation on strength of concrete and optimum percentage of the partial replacement by replacing coarse aggregate via 10%, 20%, 30%, 40% and 50% of ceramic tiles.
- to study the performance of concrete while replacing the ceramic waste with different proportions in concrete.

## II.LITERATURE REVIEW

**Bayram, KasımMermerdaş (2012)** Current tendencies aimed at reducing negative environmental impacts and encouraging sustainable construction have resulted in ever increasing demands for the use of waste materials in the production of asphalt mixes. The basic objective of this research was to analyze research conducted so far with regard to the use of various waste materials as replacement for traditional fillers in asphalt mixes. The analysis of individual filler replacement in asphalt mixes was selected due high influence of filler on the quality of asphalt. According to research made by many authors, it can be concluded that waste glass, cement industry waste materials, concrete, bricks, ceramics, fly ash and other raw materials can be used as replacement for standard filler in bituminous mixes. It can also be concluded that the use of various non-conventional fillers should additionally be studied through construction of trial sections in order to enable better analysis of behavior of such asphalt layers in actual use. The use of various waste fillers in the production of asphalt mixes has lead to the fall in the price of mixes, and in a more acceptable influence of asphalt industry on natural environment.

**R. E. Long and R.W. Floyd (1982)** studied that aggregate shortages and increased transportation costs have greatly increased prices of related construction items in areas of Texas which is not blessed with natural aggregates. Some natural aggregates are not performing up to expectations as documented by stripping, rutting and other visual signs of pavement distress noted throughout the Department. Because of these spiralling construction costs and need to field evaluate bottom ash, District 1, supported by the Materials and Tests Division, decided to construct three field test pavements substituting bottom ash for part of the natural aggregates in hot mix asphaltic concrete (HMAC).They conclude that that bottom ash blend mixes require more asphalt than natural aggregates, mixes produce lower compacted density, mixes cool fast, requiring adequate rollers working closely behind the laying operation, mixes exhibit high internal friction with no lateral displacement during compaction, this mix has maintained acceptable skid values after 14 months of interstate traffic, the cost of bottom ash blend mixes is somewhat higher based on additional asphalt used and aggregate transportation costs.

**K.Karthik et al (2012)** studied the carbon fiber modified bitumen in bituminous macadam. In the present study, an attempt has been made to study the effects of use of a mineral fiber called Carbon fiber is used as an additive in Dense Bituminous Macadam (DBM). An experimental study is carried out on conventional bitumen and fiber modified binder. Using Marshall Procedure, Optimum Fiber Content (OFC) and Optimum Binder Content (OBC) for DBM are found respectively. Detailed laboratory investigations will be carried out by preparing asphalt concrete mixtures by adding carbon fiber with dosages of 0.5%to 2.5% by weight of binder. Volumetric properties of the mixes will be determined and various strength tests such as marshal stability will be conducted. Four of different aggregate gradations with two types of fillers, such as Hydrated Lime and Crushed Stone Dust have been tried for preparation of mixes. First three gradations; upper, middle, and lower curves, middle gradation curve had better Marshall Properties of them. For fourth gradation that modified curve, crushed Stone has been improves the Marshall properties such as Marshall Stability and unit weight values more than Hydrated Lime. Hydrated Lime of SMA mixes has been improves air voids and Moisture Susceptibility in the same gradations of samples with Crushed Stone.

**David Q. Hunsucker (1992)** conducted an experimental bituminous surface overlay, which was placed in October 1987 on State Route 3 in Lawrence County, Kentucky. The experimental section utilized bottom ash aggregate, limestone and natural sand aggregate.He concludes that because of the absorptive characteristics of bottom ash aggregate, nearly fifty percent more bitumen is required in the mixture. The increased asphalt content results in a higher unit bid price for the bituminous concrete material. The combination of bottom ash aggregates with limestone and natural sand aggregate appears to improve the overall performance of a bituminous surface mixture, especially with respect to its skid resistant properties.

**Musselman et al. (1994)** performed a two-year demonstration project has been initiated where bottom ash was used as a 50% substitute aggregate in a asphalt pavement. The demonstration project includes noteworthy testing of possible environmental influences and pavement performance both in the laboratory and at the demonstration roadway. Data was gathered which include analytical data on groundwater and surface water quality impacts, surface run-off and suction lysimeter samples. Physical roadway performance was monitored through remote sensing using strain resistance and temperature probes as well as in situ and destructive pavement analysis. They conclude that the use of bottom ash as a fractional substitute for conventional aggregate in pavement seems to be a feasible ash utilization skill. Bottom ash fraction of somewhat less than 50% is suggested for future testing. Gyratory test methods were done which was successful in predicting better pavement performance at a lower asphalt content in comparison with the Marshall test methods. Public acceptance of the concept of ash utilization in this fashion was obtainable for this demonstration project.

## III.METHODOLOGY

Waste Crushed tiles are replaced in place of coarse aggregate and waste foundry sand in place of fine aggregate by the percentage of 0%, 10%, 20%, 30%, 40% and 50%. The coarse aggregates were replaced by these waste crushed tiles. workability test was conducted for different mixes having different percentages of these materials. Slump cone test is used for performing workability tests on fresh concrete. And compressive strength test, split tensile strength and flexural strength is also conducted for 7-, 28,56- and 90-days curing periods by casting cubes to analyse the strength variation by different percentage of this waste materials. This present study is to understand the behavior and performance of ceramic solid waste in concrete. The waste crushed tiles and waste foundry sand are used to partially replace with fine and coarse aggregate by 0%,10%, 20%, 30%, 40% and 50%.

**Ceramic waste**:Ceramic waste is produced from ceramic bricks, roof and floor tiles and stoneware industries**.** Indian ceramic production is 100 million ton per year. In the ceramic industry, about 15%-30% waste material generated from the total production. The principal waste coming into the ceramic industry is the ceramic powder, specifically in the powder forms. Ceramic wastes are generated as a waste during the process of dressing and polishing. Ceramic waste powder is settled by sedimenta- tion and then dumped away which results in environmental pollution.

Ceramic tile waste is durable, hard and highly resistant to Biological, Chemical and Physical degradation forces. Ceramic tile aggregate are hard having considered value of specific gravity, rough surface on one side and smooth on other side, are lighter in weight than normal stone aggregates. Ceramic wastes can be separated in two categories in accordance with the source of raw materials. The first one are all fired wastes generated by the structural ceramic factories that use only red pastes to manufacture their products, such as brick, blocks and roof tiles. The second one is all fired waste produced in stoneware ceramic such as wall, floor tiles and sanitary ware. These producers use red and white pastes, nevertheless, the usage of white paste is more frequent and much higher in volume The ceramics industry is comprised of the following subsectors: wall and floor tiles, sanitary ware, bricks and roof tiles, refractory materials, technical ceramics and ceramic materials for domestic and ornamental use was used as coarse aggregate (20 mm and 10 mm) in this experimental investigation. Aggregates were obtained from Chikhli local quarry around Surat city, in the state of Gujarat, India. The sizes of aggregate and stone dust were used as per specification

On the study of Ceramic tile waste used in concrete as a replacement for natural coarse aggregate with 0%, 10%, 20% 30%, 40% and 50% of the substitution and M25 grade concrete. The concrete moulds were casted and tested for Compressive Strength and Split Tensile Strength after a curing period of 7, 28,56,90 days. The results indicate that, the maximum compressive strength is obtained for the 40% replacement of ceramic tile aggregate with natural coarse aggregate

Aggregate material tests were carried out based on Indian standards, in order to ascertain the physical and mechanical properties of the material to be used in the samples of Marshall Stability mixtures.

**Ceramic properties:**

The properties of ceramic materials, like all materials, are dictated by the types of atoms present, the types of bonding between the atoms and the way the atoms packed together. This is known as atomic scale structure. Most ceramics are made up of two or more elements. This is called compound. The two most common chemical bonds for ceramic materials are covalent and ionic. The chemical bond is called the metal- lic bond ceramic materials wide range of properties; they are used for a multitude of applications.

In most ceramics are: -

- Hard
- Wear-resistant
- Brittle
- Refractors
- Thermal insulators
- Electrical insulators
- Nonmagnetic
- Oxidation resistant
- Prone to thermal shock
- Chemically stable

**Coarse Aggregate:**

Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected.

**Fine Aggregate:**

River sand locally available in the market was used in the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity in accordance with IS: 2386-1963.The sand was surface dried before use.

**Waste Ceramic Tile Aggregate:**

The waste tiles were crushed into small pieces by manually and by using crusher. The required size of crushed tile aggregate was separated to use them as partial replacement to the natural coarse aggregate. The tile waste which is lesser than 4.75 mm size was neglected. Crushed tiles were partially replaced in place of coarse aggregate by the percentages of 10%, 20% and 30%, and 40% individually.

## IV.RESULTS AND DISCUSSION

The evaluation of ceramic waste for use as a replacement of cement material begins with the concrete testing. Concrete contains cement, water, fine aggregate, coarse aggregate and grit. With the control concrete, i.e. 10%, 20%, 30%, and 40%, of the cement is replaced with ceramic waste, the data from the ceramic waste is compared with data from a standard concrete without ceramic waste.

**TESTS CONDUCTED**

- Workability
- Compressive strength
- Split tensile strength
- Flexural strength

**WORKABILITY:**

Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or Segregation In this study, the slump-cone test is carried out to determine the workability of concrete.

**Table: Results of workability**

| S.no | % of replacement | Slump(mm) |
|---|---|---|
| 1 | 0% | 27 |
| 2 | 10% | 42 |
| 3 | 20% | 76 |
| 4 | 30% | 85 |
| 5 | 40% | 97 |
| 6 | 50% | 120 |

**COMPRESSIVE STRENGTH:**

**Compressive strength results for 7, 28, 56, 90 days**

| % of replacement | 7 days Mpa | 28 days Mpa | 56 days Mpa | 90 days Mpa |
|---|---|---|---|---|
| 0 | 20.57 | 28.54 | 33.18 | 42.82 |
| 10 | 24.09 | 31.39 | 36.50 | 54.86 |
| 20 | 26.27 | 32.8 | 39.52 | 56.30 |
| 30 | 28.05 | 37.53 | 43.14 | 59.53 |
| 40 | 23.96 | 31.77 | 37.16 | 53.65 |
| 50 | 22.22 | 28.88 | 34.18 | 46.48 |

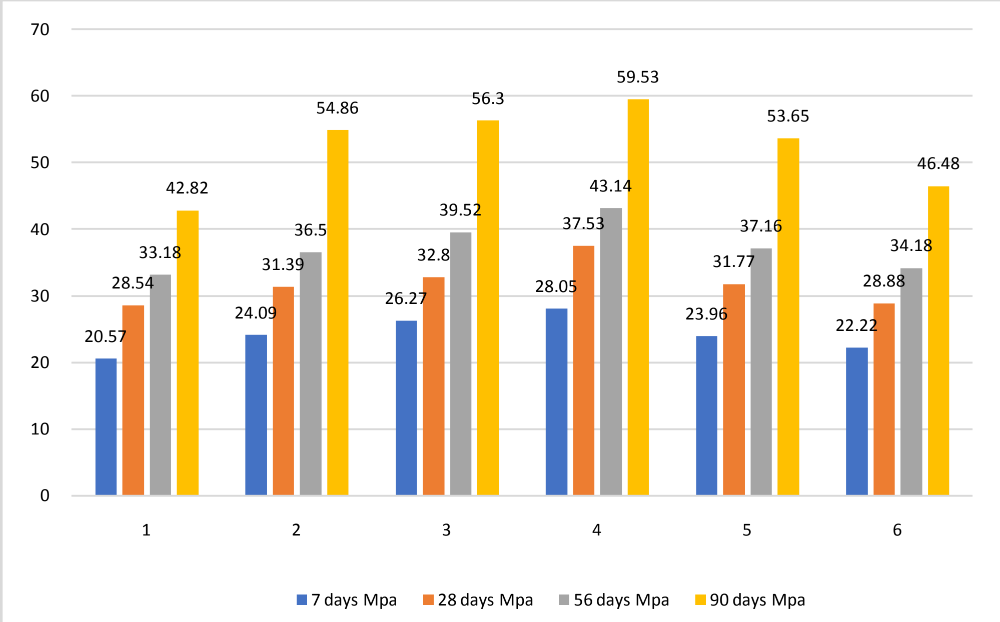
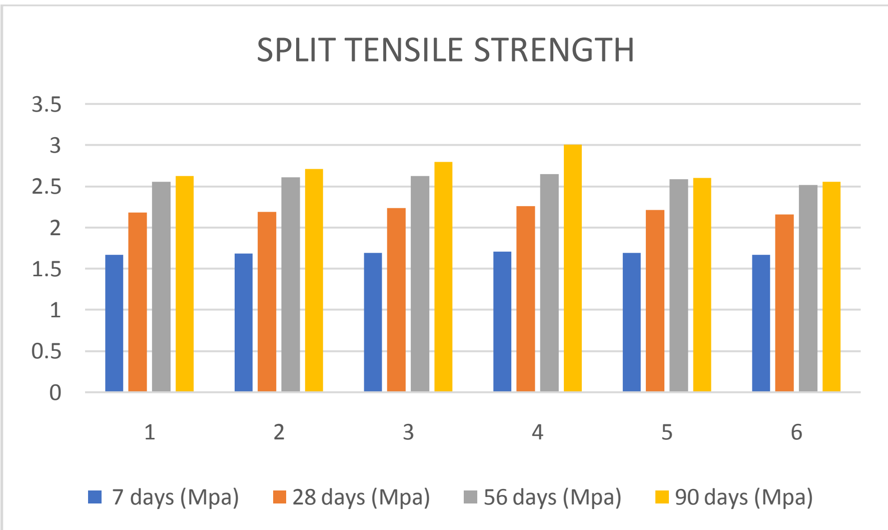



**Figure: Comparision of Compressive strength results of M25 grade of concrete for 7,28,56 and 90 days**

**SPLIT TENSILE STRENGTH:**

**Table: Split tensile strength results for M25 grade of concrete**

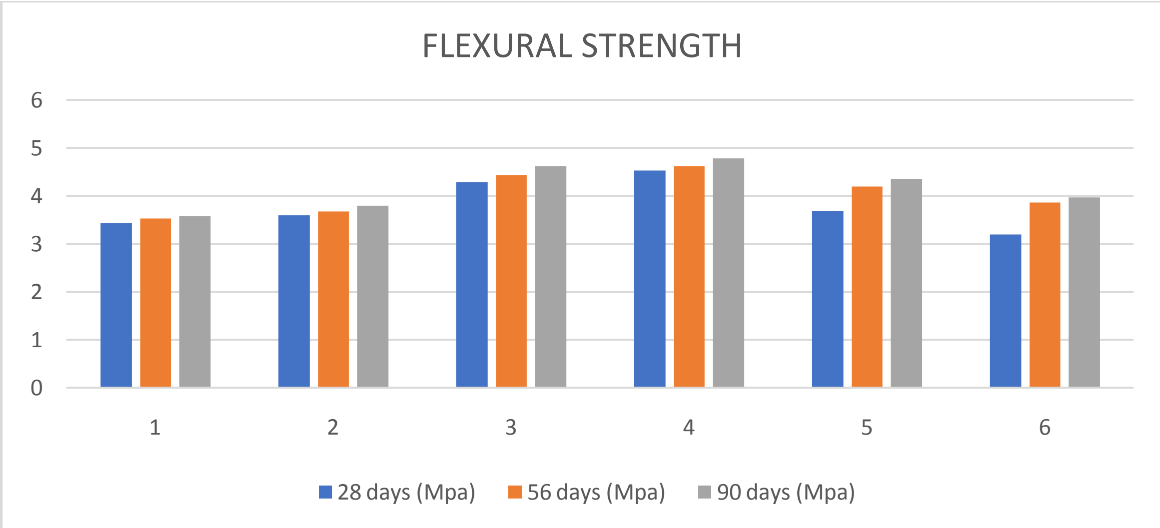
| % of replacement | 7 days (Mpa) | 28 days (Mpa) | 56 days (Mpa) | 90 days (Mpa) |
|---|---|---|---|---|
| 0 | 1.67 | 2.18 | 2.56 | 2.63 |
| 10 | 1.68 | 2.19 | 2.61 | 2.71 |
| 20 | 1.69 | 2.24 | 2.63 | 2.80 |
| 30 | 1.71 | 2.26 | 2.65 | 3.01 |
| 40 | 1.69 | 2.21 | 2.59 | 2.60 |
| 50 | 1.67 | 2.16 | 2.52 | 2.56 |




**Graph: Comparision of Split tensile strength results for M25 grade of concrete 7,28,56 and 90 days**

### 5.4 FLEXURAL STRENGTH

| % of replacement | 28 days (Mpa) | 56 days (Mpa) | 90 days (Mpa) |
|---|---|---|---|
| 0 | 3.43 | 3.53 | 3.58 |
| 10 | 3.59 | 3.68 | 3.79 |
| 20 | 4.29 | 4.43 | 4.62 |
| 30 | 4.53 | 4.62 | 4.79 |
| 40 | 3.69 | 4.20 | 4.36 |
| 50 | 3.20 | 3.86 | 3.97 |




**Graph: Comparision of Flexural strength results for M25 grade of concrete 7,28,56 and 90 days**

## V.CONCLUSIONS

The following conclusions are made based on the experimental investigations on compressive strength and split tensile strength and flexural strength considering the environmental aspects also:

Depending upon above results and methodology adopted following conclusion were made regarding properties of concrete incorporating waste ceramic tile

- It is found that compressive strength of concrete mix increases with increase in the percentage waste ceramic tiles compared to regular concrete 90 days after curing was maximum for 30 % replacement after that it reduces.
- It is also found that split tensile strength increases with increase in percentage of waste waste ceramic tiles up to 30 % replacement after that it reduces.
- It is also found that Flexural strength strength increases with increase in percentage of waste waste ceramic tiles up to 30 % replacement after that it reduces.
- Workability of concrete mix increases with increase in percentage of waste ceramic tiles as compare to conventional concrete.
- As waste ceramic tiles is waste from construction industries therefore both wastes can be effectively use in concrete mix hence an eco-friendly construction material.

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