EXPERIMENTAL STUDY OF PARTIAL REPLACEMENT OF COARSE AGGREGATE ON CONCRETE BY CERAMIC TILES

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ABSTRACT

Due to day by day innovations and developments in construction field, the use of natural aggregates is increased tremendously and at the same time, the production of solid wastes from the demolition of construction is also quite high. Because of these reasons the reuse of demolished construction wastes like ceramic tiles came into picture to reduce the solid waste and to reduce the scarcity of natural aggregates for making concrete. The ceramic tiles waste is not only occurring from the demolition of structures but also from the manufacturing unit.

Crushed waste ceramic tiles, crushed waste ceramic tile powder are used as a replacement to the coarse aggregate and fine aggregate. The ceramic waste crushed tile were partially replaced in place of coarse aggregate by 5%,10%,15% and 20%. Experimental investigations like workability test, compressive strength test, split tensile strength test, flexural strength test for different concrete mixes with different percentage of waste after 7,14 and 28 days curing period has done . It has been observed that the workability of concrete increases with increase in percentage of replacement of crushed tile increases. The Compressive strength of concrete also increases with the ceramic tile aggregate up to 4% and slightly increases up to 11% on split tensile strength test on cylinders.

Keywords: Ceramic tiles, Crushed waste, Coarse aggregate replacement, Strength.

1. INTRODUCTION

In the recent construction world, the solid waste is increasing day by day from the demolitions of construction. There is a huge usage of ceramic tiles in present construction is going on and it is increasing day by day. Ceramic products are part of essential construction material that is used in most buildings. Some common manufactured ceramics includes wall tile, floor tile, sanitary ware, household ceramics and technical ceramics. They are mostly used natural materials that contain high content of clay materials.

However, despite the ornamental benefits of ceramics, its wastes among others cause a lot of nuisance to the environment. And also in other side waste tile is also produced from demolished wastes from construction. Indian tiles production is 100 million ton per year in ceramic industry, about 15-30% waste material generated from total production. This waste is not recycled in any form at present, however the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces, so to reduce the solid waste produced from demolition of construction. Waste tile is collected from the surroundings.

There are some researchers are also going on solid waste from construction to reuse them again in the construction to reduce the solid waste and to preserve the natural basic aggregates. These researches promotes to use recycled aggregates in the concrete mix and they got good result when adding some extent percentages of recycled aggregates in place of natural coarse aggregates.

Crushed tiles are replaced in place of coarse aggregates and in place of fine aggregate by the percentage of 5%. The fine and coarse aggregates were replaced individually by these crushed tiles and also in combination that is replacement of coarse and fine aggregates in a single mix.

For analysing the suitability of the crushed materials in the concrete mix, the workability test was conducted for different mixes having different percentages of these materials. Slump cone test is used to performing workability test on concrete. And compressive strength test is also conducted for 3,7 and 28 days curing periods by casting cubes to analyse the strength variation by different percentages of waste materials.

This present study is to understand the behaviour and performances of ceramic solid waste in concrete. The waste crushed tiles are used to partially replace aggregate by 5%, 10%, 15% and 20%.

The usage of tile aggregate as replacement to coarse aggregate in concrete has the benefits in the aspects of cost and reduction in pollution from construction industry. The cost of concrete manufacturing will reduce considerably over conventional concrete by including tile aggregate since it is readily available at low cost and thereby reducing the construction pollution or effective usage of construction waste .

2. LITERATURE REVIEW

N. SAI TRINATH KUMAR , CHAVA SIVA, INTERNATIONAL JOURNAL OF RESEARCH IN ENGNEERING AND TECHNOLOGY, eISSN: 2319-7308.

The ceramic waste adopted is broken tiles. Ceramic waste concrete (CWC) made with these tiles at 0%, 15%, 20%, 25% and 30%. M20 grade concrete is adopted, a constant water cement ratio of 0.48 is maintained for all concrete mixes. The characteristics properties of concrete such as workability for fresh concrete, also compressive strength, split tensile strength are found at 3,7, and 28 days. The paper suggests that the replacement of waste tile aggregate should be in the range of 5- 30% ad also it is suitable to ordinary mixes like M15 and M20.

UMAPATHY U, MALA C, SIVA K, (INTERNATIONAL JOURNAL OF ENGINEERING JOURNAL AND APPLIED SCIENCES)

ISSN:2248:9622, VOLUME 4, ISSUE 5 MAY 2014:

The amount of tile waste generation is enough to use in concrete as a replacement to coarse aggregate. The use of ceramic tile waste has a positive effect on environment and in the cost aspects too. By the use of tile aggregate, the self weight of concrete is reduced about 4% which makes the structure economical. Coming to the strength aspect, the tile aggregate replacement has a negative effect on both th compressive and split tensile strength of concrete. But this paper studied maximum replacement of tile waste which can be further divide into smaller percentage and can be utilised in concrete with desirable properties.

N. SIVACHANDRAN, A. MAGESH (INTERNATIONAL JOURNAL OF PURE AND APPLIED SCIENCE) VOLUME 119 NO 10, 2018 167-177: ISSN:1314-3395:

The study concentrates on the ceramic wastes from industries in Spain. The concrete design is done as per the Spanish concrete code and the recycled ceramic aggregates met all the technical requirements imposed by current Spanish legislation. The ceramic aggregates are replaced up to 100% replacement of coarse aggregate. Appropriate tests were conducted to compare the mechanical properties with conventional concrete

M.ROHIT VARMA, M.MANOJ PARVARLY, INTERNATIONAL JOURNAL OF MODERN TRENDS N SCIENCE AND TECHNOLOGY VOLUME 5 ISSUE III, MARCH 2017 :

A large quantity of ceramic tile goes into wastage during processing, transporting and fixing due to its brittle nature. The crushed ceramic tiles are used in concrete as a replacement of natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution in concrete. The study states that the use of ceramic tiles aggregate in concrete enhances its properties and it has been observed an increase in both compression and flexural strength.

YIOSSE A.O.AYYOLA, A.R. UGONNA, M.C. ADEWALE A.K. (IJSER) VOLUME 9 ISSUE 8, AUGUST 2018 :

Crushed waste tile and granite powder were used as replacement to the coarse aggregates and fine aggregates. The combustion of waste crushed tiles were replaced in place of coarse aggregates by 10%, 20%, 30% and 40% and granite powder was replaced in place of fine aggregate by 10%, 20%, 30% and 40% without changing the mix design. M25 grade of concrete was designed to prepare the mix. Without changing the mix design different types of mixes were prepared by replacing the coarse aggregate and fine aggregate at different percentages of crushed tile and granite powder. The workability of concrete increased with increase in granite powder and it has been observed that the compressive strength is maximum at 30% of coarse aggregate replacement.

E.E. JKPONMWASA AND S.O. EHIKUENMAN, NIGERIAN JOURNAL OF TECHNOLOGY (NIJOTECH) VOL 36, NO 3, JULY 2017 pp 69-696 :

A research paper on utilisation of ceramic waste tile for industries. A partial replacement to coarse aggregate has been studied. Three different grades of concrete has been prepared and tested. The results are not appropriate with the conventional, but considering the strength properties, it is advisable to use ceramic tile aggregate in concrete. It is finally concluded that, about 20% of ceramic tile usage in M20 grade of concrete is preferable.

IRANIAN JOURNAL OF SCIENCE AND TECHNOLOGY, TRANSACTION B, ENGINEERING, VOL 31, NO 5, pp 561-565 ISLAMIC REPUBLIC OF IRAN 2007 :

Use of ceramic waste will ensure an effective measure in maintaining environment and improving properties of concrete. The replacement of aggregates in concrete by ceramic wastes will have major environmental benefits. In ceramic industry, about 30% production goes on waste. The ceramic waste material is hard and durable material than the conventional coarse aggregate. It has good thermal resistance. The durability properties of ceramic waste aggregate are also good. The research studied that fine aggregate replacement of ceramic tiles fine aggregate accordingly in the range of 10% and coarse aggregate accordingly in the range of 30%, 60%, 100% by weight of M30 grade concrete. This paper recommends that waste ceramic tiles can be used as an alternative construction material to coarse and fine aggregate in concrete, it has good strength properties i.e., 10% CFA and 60% CCA being the maximum strength.

3. MATERIALS AND PROPERTIES

3.1.1 CEMENT

The ordinary Portland cement conforming to IS 4031 was used for the preparation of specimens. OPC 53 grade was used. Ordinary Portland cement of 53 grade of brand name ultra tech company, available in market was used for the investigation. The physical properties of cement are listed in the table below

S.NO	DESCRIPTION	VALUE	IS 169-1989
1	NORMAL CONSISTENCY	0.32	
2	INITIAL SETTING TIME	50 min	Minimum of 30 min
3	FINAL SETTING TIME	320 min	Minimum of 600 min
4	SPECIFIC GRAVITY	3.28	

5	COMPRESSIVE STRENGTH		
	A) 3 DAYS	a) 29.2 MPa	a) Minimum of 27 MPa
	B) 7 DAYS	b) 44.6 MPa	b) Minimum of 40 MPa
	C) 28 DAYS	c) 56.6 MPa	c) Minimum of 53 MPa

3.1.2 FINE AGGREGATES:

Sand is a natural granular material which is mainly composed of finely divided rocky material and mineral particles. The most common constituent of sand is silica (SiO_2), usually in the form of quartz, because of its chemical inertness and considerable hardness, is the most common weathering resistant material. Hence, it is used as fine aggregate in concrete

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

PROPERTIES OF FINE AGGREGATE

S.NO	DESCRIPTION	VALUE
1	SAND ZONE	ZONE III
2	SPECIFIC GRAVITY	2.59
3	FREE MOISTURE	1%
4	BULK DENSITY	1385.16 kg/m^3

3.1.3 COARSE AGGREGATE:

Crushed aggregates of size less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10 mm sieve is selected. The aggregates were selected for its physical requirements like gradation, fineness modulus, specific gravity, and bulk density in accordance with IS 2386 – 1963. The individual aggregates were mixed to induce the required combined grading.

PROPERTIES OF COARSE AGGREGATE

S.NO	DESCRIPTION	VALUE
1	NOMINAL SIZE	20mm
2	SPECIFIC GRAVITY	2.9
3	IMPACT VALUE	10.5
4	WATER ABSORPTION	0.15
5	SIEVE ANALYSIS	20mm
6	AGGREGATE CRUSHING VALUE	20.19
7	BULK DENSITY	1687.13kg/m^3

3.1.4 WATER:

Water is the most important and least expensive ingredient of concrete. A part of mixing water is utilized in the hydration of cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix has harden. The remaining water serves as a lubricant between the fine and coarse aggregate and makes concrete workable. If less water is used, the required workability is not achieved. Potable drinking water is required to be used in the concrete and it should have the pH value ranges between 6 to 9 .

3.1.5 CERAMIC TILE AGGREGATE:

Broken tiles were collected from the solid waste of ceramic manufacturing unit and from demolished building. 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 an partial replacement for natural coarse aggregate. The tile waste which is lesser than 4.75 mm size was neglected. The crushed tile aggregate passing through 16.5 mm sieve and retained on 12 mm sieve are used. They were partially replaced in place of coarse aggregate by the percentage of 5%, 10%, 20%, 30% and 40% along with replacement of fine aggregate also.

CERAMIC TILE AGGREGATE

4. MIX PROPORTIONS:

Cement = 495 kg/m^3

Water = 197 litre/m^3

Fine aggregate = 726.7 kg/m^3

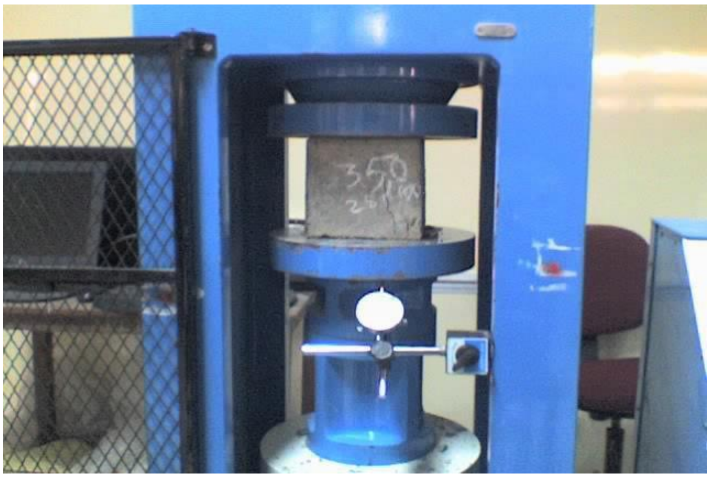
Coarse aggregate = 1009kg/m^3

Water-cement ratio = 0.40

5. EXPERIMENTAL PROGRAM

5.1 Compression test for cubes:

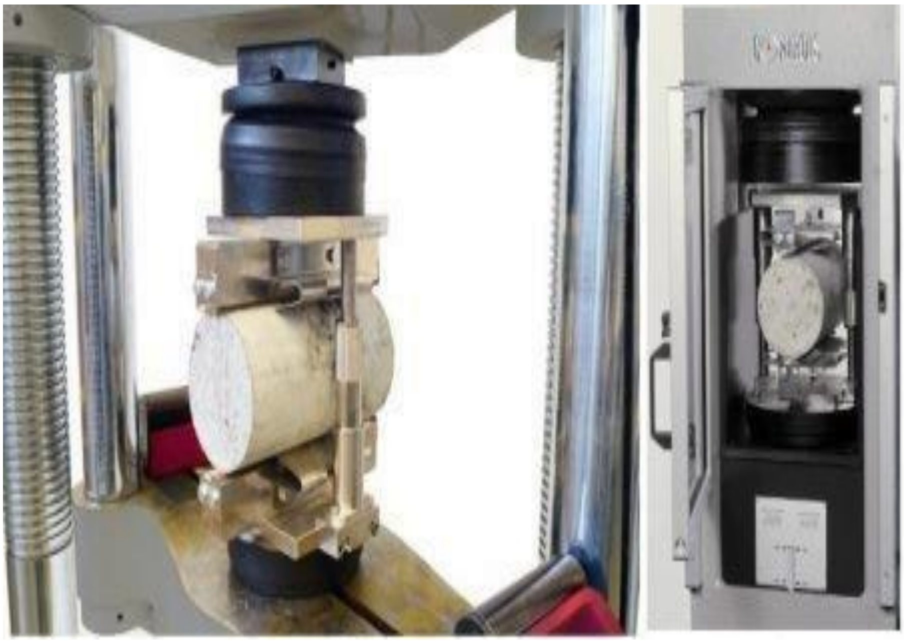
For the above mix proportions, the concrete cubes were cast with the moulds. Here manual mixing was done with the aggregates and cement. The cubes of dimension 150x150x150mm were cast for each design mixes. The water-cement ratio was fixed to 0.40. Testing of concrete cubes was done in the universal testing machine of 100T capacity. The cubes were taken out from curing tank and were dried out each time for their testing.



Compression test

5.2 Split tensile strength for Cylinders:

Cylinder moulds were cleaned thoroughly using a waste cloth and then properly oiled along its faces. Cylinder moulds of diameter 150mm and height 300mm were cast. The crude oil was applied as seen earlier along the inner surfaces of the mould for the easy removal of the casted cylinder from the mould.



Split tensile strength

5.3 Flexural strength test

The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which declines flexural strength. Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points. Centre the loading system in relation to the applied force. Bring the block applying force in contact with the specimen surface at the loading points.

Applying loads between 2 to 6 per cent of the computed ultimate load.

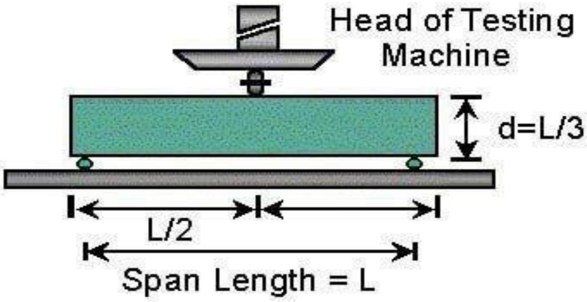
Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more.

Eliminate any gap greater than 0.10mm using leather shims (6.4mm thick and 25 to

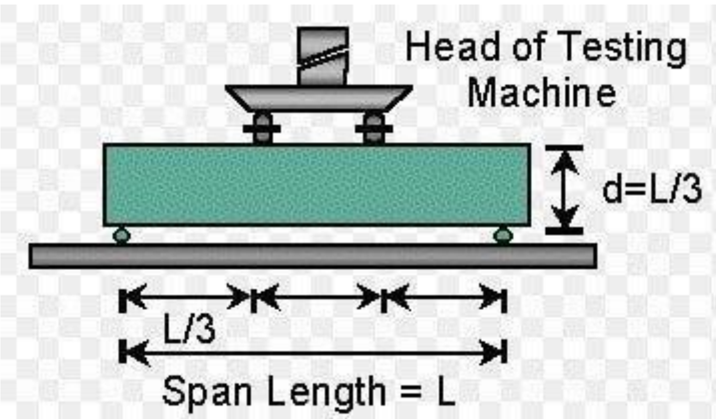
50mm long) and it should extend the full width of the specimen.

Capping or grinding should be considered to remove gaps in excess of 0.38mm.

Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 kg/min for 150mm specimen and 180kg/min for 100mm specimen, stress increase rate 0.06+/-0.04N/mm^2.s according to British standard).



Center point load test



TWO-point load test

6. RESULTS AND DISCUSSIONS

6.1 COMPRESSIVE STRENGTH

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is used primarily to resist compressive stress. In those cases where strength in tension or in shear is of primary importance, the compressive strength is primarily used as a measure of these properties the compressive strength of concrete cubes with 0%, 10%, 15%, 20% of replacements were determined.

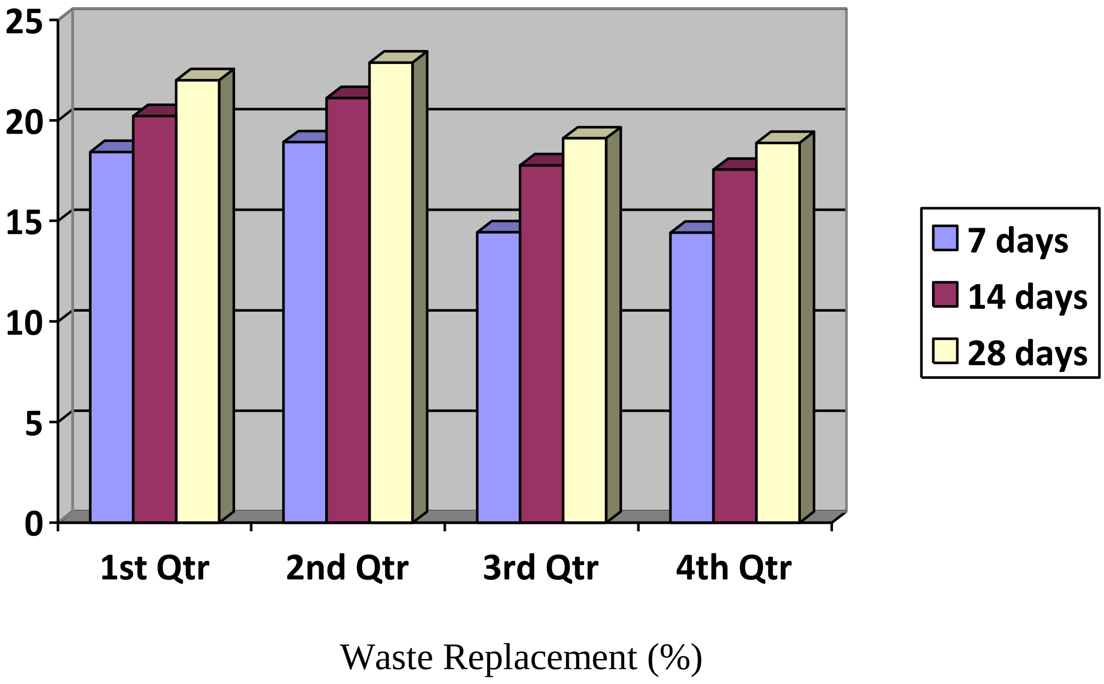


Fig 1 Compression tests results at 7, 14 and 28 days

The compressive strength results are presented in Fig 1. It can be seen that the compressive strength of concrete with partial replacement of ceramic tiles with 5% has slightly increased by 4%. Then beyond 5% results suggests that the continuous partial replacement would result in gradual decrease of strength. The early increased strength from 22 to 22.88MPa has decreased up to 18.88MPa with replacement of 15% at 28 days.

Waste Replacement (%)	**Compressive strength at 7 Days (N/mm^2)**	**Compressive strength at 14 Days (N/mm^2)**	**Compressive Strength at 28 Days (N/mm^2)**
0	18.44	20.22	22
5	18.92	21.11	22.88
10	14.44	17.77	19.11
15	14.42	17.55	18.88

6.2 SPLIT TENSILE STRENGTH TEST:

Direct tensile strength of concrete cannot be determined owing to difficulty in preparation of test specimen and applying a truly axial tensile load. This test is an indirect method of finding out tensile strength of concrete.

The split tensile strength is determined using cylinders of 150 mm diameter and 300 mm long. The test results of various proportions at 7 and 28 days are given below.

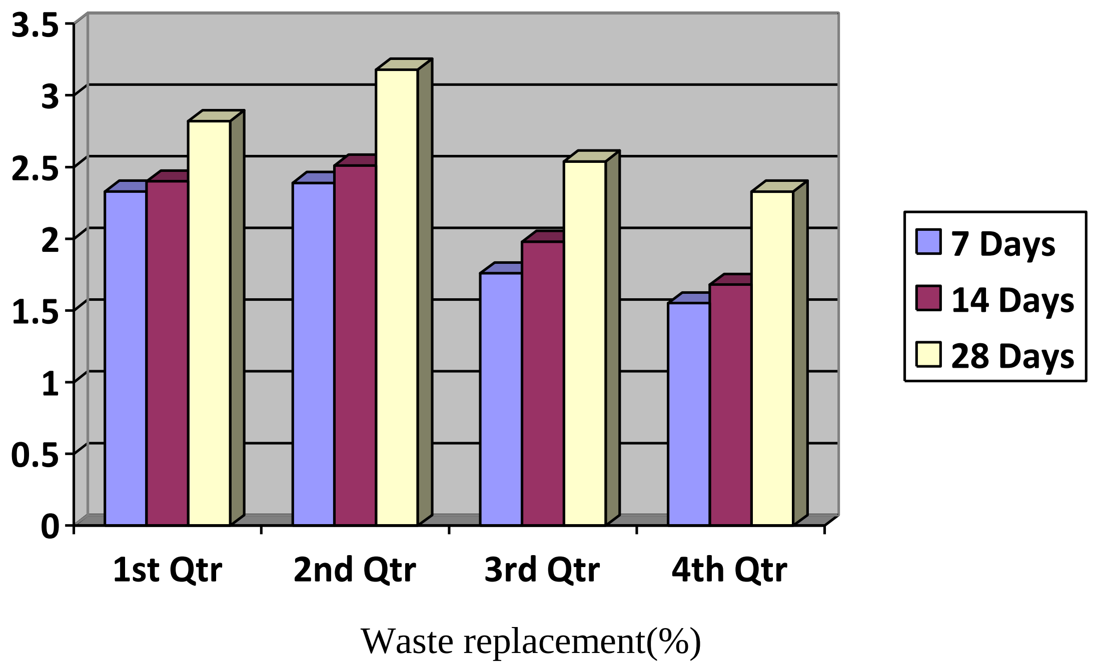


Fig 2 Split tensile strength for 7, 14 and 28 days

Split tensile results are presented in Fig 2. It can be seen that the split tensile strength of concrete with partial replacement of ceramic tiles with 5% has slightly increased by 11%. Then beyond 5% results suggests that the continuous partial replacement would result in gradual decrease of strength. The early increased strength from 2.82 to 3.18 MPa has decreased up to 2.33MPa with replacement of 15% at 28 days.

Waste Replacement (%)	Split Tensile strength at 7 Days N/mm^2	Split Tensile strength at 14 Days N/mm^2	Split Tensile strength at 28 Days N/mm^2
0	2.33	2.4	2.82
5	2.39	2.51	3.18
10	1.76	1.98	2.54
15	1.55	1.68	2.33

6.3 FLEXURAL STRENGTH TEST:

Flexural strength of concrete cannot be determined owing to difficulty in preparation of test specimen and applying a flexural load. This test can be an indirect method of finding out the flexural strength of concrete.

The flexural strength is determined using beam size 10x10x50 cm. The test results of various proportions at 14 and 28 days are given below.

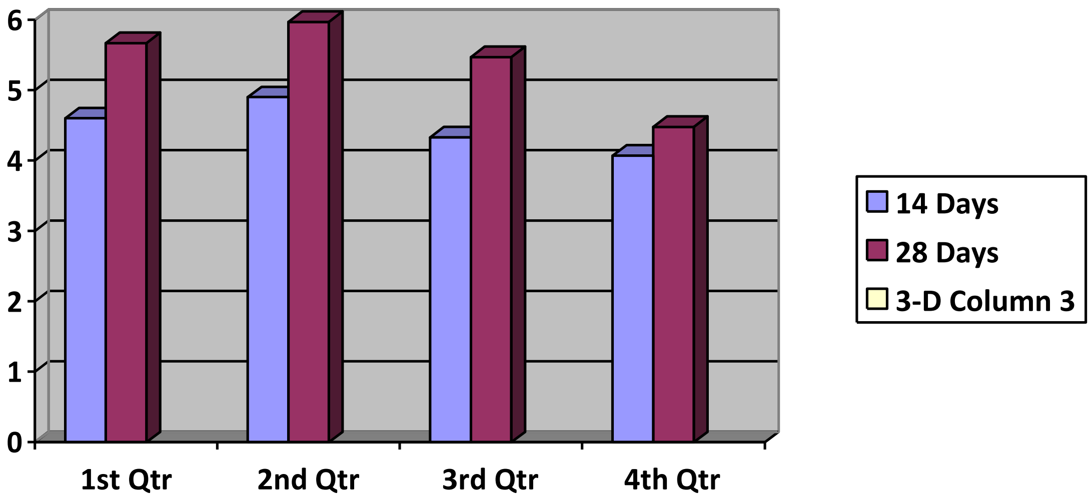


Fig 3 Flexural strength of concrete a 14 and 28 days

Flexural test results are presented in Fig 3, the flexural strength of concrete with partial replacement of fine aggregates by 5% of ceramic tile waste has increased by 5% from 5.67MPa to 5.97MPa, while the continuous replacement results in gradual decrease of the strength, where the increase in replacement above 5% has decreased up to 4.48 MPa with 15% replacement at 28 days.

Waste Replacement (%)	**Flexural Strength for 14 Days curing**	**Flexural Strength for 28 Days curing**
0	4.6	5.67
5	4.9	5.97
10	4.33	5.47
15	4.07	4.48

CONCLUSION

Based on experimental investigation on the compressive strength and split tensile strength and flexural strength test of concrete the following observations were made .

1. Regarding the strength characteristics of ceramic tile waste replaced concrete, results showed that all strengths, i.e., compressive strength, split tensile test and flexural strength test for the concrete slightly increased up to 4%,11% and 5% respectively until the partial replacement of coarse aggregate by ceramic tile waste in concrete gets 5%.
2. Finally, as an consequence of the application, the environment protection would be easily improved. It is recommended that the mixing water cement ratio should be carefully selected for avoiding a longer curing period which would increase the water absorption due to the presence of clay in ceramic tiles wastes.

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