RESEARCH ARTICLE OPEN ACCESS

Partial Replacement of Aggregates with Ceramic Tiles and Rebutted Tyre Waste in Concrete

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ABSTRACT

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

Studies show that about 20-30% of material prepared in the tile manufacturing plants are transforming into waste. This waste material should have to be reused in order to deal with the limited resource of natural aggregate and to reduce the construction wastes.

Crushed waste ceramic tiles, crushed waste ceramic tile powder and Rebutted tyre waste are used as a replacement to the coarse aggregates and fine aggregate. The ceramic waste crushed tiles were partially replaced in place of coarse aggregates by 10%, 20%, 30%, 40% and 50%. Rebutted tyre waste and ceramic tile powder were replaced in place of fine aggregate by 10% along with the ceramic coarse tile. M25 grade of concrete was designed and tested. The mix design for different types of mixes were prepared by replacing the coarse aggregates and fine aggregate at different percentages of crushed tiles and rebutted tyre waste. Experimental investigations like workability, Compressive strength test, Split tensile strength test, Flexural strength test for different concrete mixes with different percentages of waste crushed and rebutted tyre waste after 7, 14 and 28 days curing period has done. It has been observed that the workability increases with increase in the percentage of replacement of rebutted tyre waste and crushed tiles increases. The strength of concrete also increases with the ceramic coarse tile aggregate up to 30% percentage.

Keywords:- Tyre, M25

I. INTRODUCTION

1.1 CONCRETE

Concrete is a composite material consist of mainly water, aggregate, and cement. The physical properties desired for the finished material can be attained by adding additives and reinforcements to the concrete mixture. A solid mass that can be easily moulded into desired shape can be formed by mixing these ingredients in certain proportions. Over the time, a hard matrix formed by cement binds the rest of the ingredients together into a single hard (rigid) durable material with many uses such as buildings, pavements etc., The technology of using concrete was adopted earlier on large-scale by the ancient Romans, and the major part of concrete technology was highly used in the Roman Empire. The colosseum in Rome was built largely of concrete and the dome of the pantheon is the World's largest unreinforced concrete structure. After the collapse of Roman Empire in the mid-18th century, the technology was re-pioneered as the usage of concrete has become rare. Today, the widely used man made material is concrete in terms of tonnage.

1.2 TILE AGGREGATE CONCRETE:

Crushed tiles are replaced in place of coarse aggregate and rebutted tyre powder in place of fine aggregate by the percentage of 10%. The fine and coarse aggregates were replaced individually by these crushed tiles and rebutted tyre powder and also in combinations that is replacement of coarse and fine aggregates at a time in single mix.

For analyzing the suitability of these crushed waste tiles and rebutted tyre powder in the concrete mix, 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 is also conducted for 3, 7 and 28 days curing periods by casting cubes to analyze 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 are used to partially replace coarse aggregate by 10%, 20%, 30%, 40% and 50%. Rebutted tyre powder is also used partial replace fine aggregate by 10%.

1.3 ENVIRONMENTAL AND ECONOMIC BENEFITS OF TILE AGGREGATE CONCRETE:

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

II. MATERIALS AND PROPERTIES

2.1 MATERIALS USED

In this investigation, the following materials were used:

- Ordinary Portland Cement of 53 Grade cement conforming to IS: 169-1989
- Fine aggregate and coarse aggregate conforming to IS: 2386-1963.
- Water.

2.1.1 CEMENT:

Ordinary Portland Cement of 53 Grade of brand name Ultra Tech Company, available in the local market was used for the investigation. Care has been taken to see that the procurement was made from single batching in air tight containers to prevent it from being effected by atmospheric conditions. The cement thus procured was tested for physical requirements in accordance with IS: 169-1989 and for chemical requirement in accordance IS: 4032-1988. The physical properties of the cement are listed in Table – 1

Table-1 Properties of cement

SL.NO	Properties	Test results	IS: 169-1989
1.	Normal consistency	0.32	
2.	Initial setting time	50min	Minimum of 30min
3.	Final setting time	320min	Maximum of 600min
4.	Specific gravity	3.14	
5.	Compressive strength		
	3days strength	29.2 Mpa	Minimum of 27Mpa
	7days strength	44.6 Mpa	Minimum of 40Mpa
	28days strength	56.6 Mpa	Minimum of 53Mpa

2.1.2 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 (silicon dioxide, or SiO_2), usually in the form of quartz, because of its chemical inertness and considerable hardness, is the most common weathering resistant mineral. Hence, it is used as fine aggregate in concrete.

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.

Table 2: Properties of Fine Aggregate

S.No	Description Test	Result
1	Sand zone	Zone- III
2	Specific gravity	2.59
3	Free Moisture	1%
4	Bulk density of fine aggregate (poured density) Bulk density of fine aggregate (tapped density)	1385.16 kg/m3 1606.23 kg/m3

2.1.3 COARSE AGGREGATES:

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. The aggregates were tested for their physical requirements such as 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. The particular specific gravity and water absorption of the mixture are given in table.

Table 3: Properties of Coarse Aggregate

S.No	Description	Test Results
1	Nominal size used	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 of coarse aggregate (Poured density) Bulk density of coarse aggregate (Tapped density)	1687.31kg/m3 1935.3 kg/m3

2.1.4 WATER:

Water plays a vital role in achieving the strength of concrete. For complete hydration it requires about $3/10^{th}$ of its weight of water. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If more water is used, segregation and bleeding takes place, so that the concrete becomes weak, but most of the water will absorb by the fibers. Hence it may avoid bleeding. If water content exceeds permissible limits it may cause bleeding. If less water is used, the required workability is not achieved. Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9

2.1.5 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 partial replacement to the natural coarse aggregate. The tile waste which is lesser than 4.75 mm size was neglected. The crushed tile aggregate passing through 16.5mm sieve and retained on 12mm sieve are used. Crushed tiles were partially replaced in place of coarse aggregate by the percentages of 10%, 20% and 30%, 40% and 50% individually and along with replacement of fine aggregate with granite powder also.

2.1.6 CERAMIC TILE-FINE AGGREGATE:

The tile aggregate after crushing results in some material which is finer in size. This material is also included in concrete as replacement to fine aggregate since it is also a waste and similar to that of sand. The aggregate which passes through the 4.75mm sieve is used as a partial replacement to fine aggregate of 10% in combination with the coarse aggregate replacement.

Table4: Properties of Ceramic tile aggregate

S.No	Description	Test Results
1	Origin Rock	Feldspar
2	Impact value of crushed tiles	12.5%
3	Specific gravity of crushed tiles	2.6
4	Specific gravity of tile powder (C.F.A)	2.5
5	Water absorption of crushed tiles	0.19%
6	Water absorption of Tile powder(C.F.A)	0.13%

2.1.7 REBUTTED TYRE:

In this M/S Gujarat reclaim has an annual turnover of over Rs.15 crore from its haridwar (uttrakhand) tyre recycling plants, with a production of 20 tones of reclaim rubber per day. Over years, deforestation and extraction of natural aggregates from river beds, lakes and other water bodies have resulted in huge environmental problems. The best way to overcome this problem is to find alternate aggregates for construction in place of conventional natural aggregates. The rubber aggregates from discarded tyre rubber in sizes 20-10 mm, 10-4.7 5mm and 4.75 mm down can be partially replaced natural aggregates in cement concrete construction.

Table 5: Properties of rebutted tyre

S.No	Description	Test Results
1	Specific gravity of rebutted tyre	1.15
2	Water absorption of rebutted tyre	1.43%

III. METHODOLOGY

Different types of mixes were prepared by changing the percentage of replacement of coarse and fine aggregates with crushed tiles, crushed tile powder and rebutted tyre powder. Total 14 types of mixes are prepared along with conventional mixes. The coarse aggregates are replaced by 10%, 20%, 30%, 40% and 50% of crushed tiles and the fine aggregate is replaced by 10% of both crushed tile powder and rebutted tyre powder individually but along with the coarse aggregate. The details of mix designations are as follows:

Table 6: Details of aggregate replacement for mix codes

S.no	Mix Code	Cement (%)	Coarse Aggregate (%)	Fine Aggregate (%)		
				Sand	Crushed tile powder	Rebutted tyre Powder
1	M0	100	100	100	0	0
2	M1	100	90	80	10	10
3	M2	100	80	70	20	10
4	M3	100	70	60	30	10
5	M4	100	60	50	40	10
6	M5	100	50	40	50	10

IV. CONCRETE MIX DESIGN (AS PER IS:10262-2009)

4.1 MIX DESIGN FOR M25 GRADE CONCRETE:

Mix Design Details:

Grade of Concrete : M25

Grade of cement : OPC 53 Grade

Size of Coarse Aggregate : 20mm

Size of Fine Aggregate : passing through 4.75mm

Admixture : No

Final Mix Proportions:

C	:	FA	:	CA	:	WATER
380	:	634	:	1339	:	175
1	:	1.67	:	3.52	:	0.44

In this project the concrete grade M25 is designed with a suitable water-cement ratio for desired concrete strength at various mix replacements of both fine and coarse aggregate.

V. TEST RESULTS

5.1 WORKABILTY:

The ideal concrete is the one which is workable in all conditions i.e, can prepared easily placed, compacted and moulded. In this chapter, the workability is assessed by two methods as follows:

5.1.1 Slump Cone Test: The test was conducted for fresh concrete prepared before the moulding process. A total of 14 concrete mixes are prepared at different times. Workability Results obtained from slump cone test for M25 grade of concrete is shown in table 7.

Table 7: Test results from slump cone test for workability in mm

S.No	Mix Designation	Aggregate Replacements % (CTA+RTW)	Workability (mm)
			M25
1	M0	0+0	62
2	M1	10+10	65
3	M2	20+10	68
4	M3	30+10	73
5	M4	40+10	78
6	M5	50+10	81

The workability from the slump cone test is in increasing manner as the mix proportion replacement increasing. The workability range of concrete increasing as mentioned while being in medium range overall.

5.1.2 Compaction Factor Test:

The compaction factor test was conducted to the same mix that tested for workability by slump cone. The results obtained from the compaction factor test for the workability of various mixes of replacements of M25 grade of concrete are tabulated as follows:

S.No	Mix designation	Aggregate Replacement % (CTA+RTW)	Compaction factor M25
1	M0	0+0	0.82
2	M1	10+10	0.85
3	M2	20+10	0.855
4	M3	30+10	0.83
5	M4	40+10	0.89
6	M5	50+10	0.93

The workability of M25 grade of concrete by compaction factor test is similar to that of slump cone test. The pattern of increment for the mixes is quite same which will be discussed in detail further.

5.2 Compressive strength:

A total of 42 cubes of size 150 x 150 x 150mm were casted and tested for 7 days, 14 days and 28 days testing each of 13 specimens after conducting the workability tests. The results are tabulated below:

Table: 09: Compressive strength results of M25 grade of concrete for 7, 24 and 28 days

S.No	**Mix Designation**	**Aggregate Replacements % (CTA+RTW)**	**Compressive strength of M25 grade in N/mm^2**		
			7 days	**14 days**	**28 days**
1	M0	0+0	20.57	28.54	33.18
2	M1	10+10	24.09	31.39	36.5
3	M2	20+10	26.27	32.8	37.5
4	M3	30+10	27.05	37.53	39.14
5	M4	40+10	23.96	31.77	37.16
6	M5	50+10	22.22	28.83	34.18

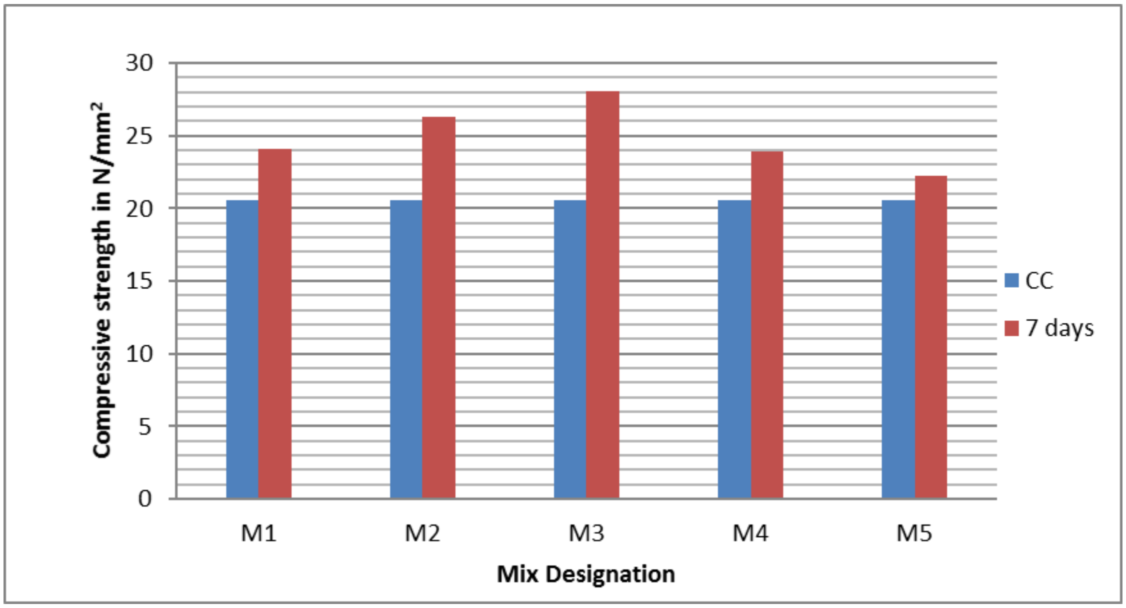

Figure 9: Comparison of Compressive strength of M25 at 7 days

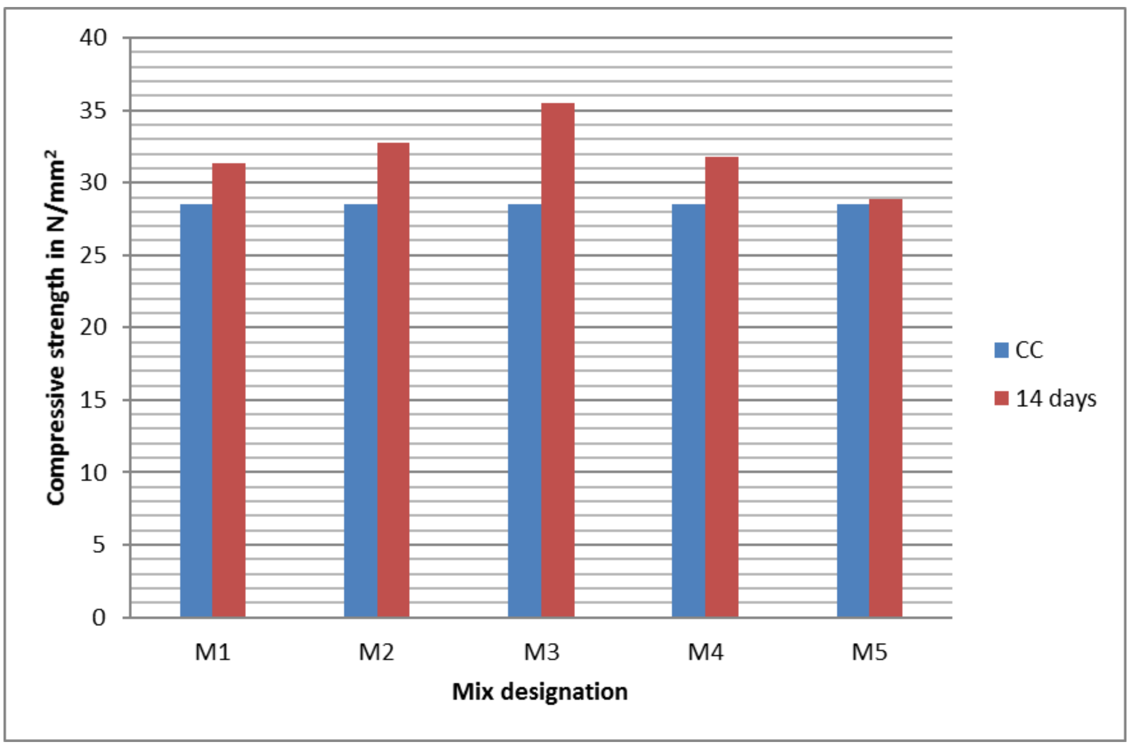

Figure 10: Compressive strength of M25 concrete at 14 days

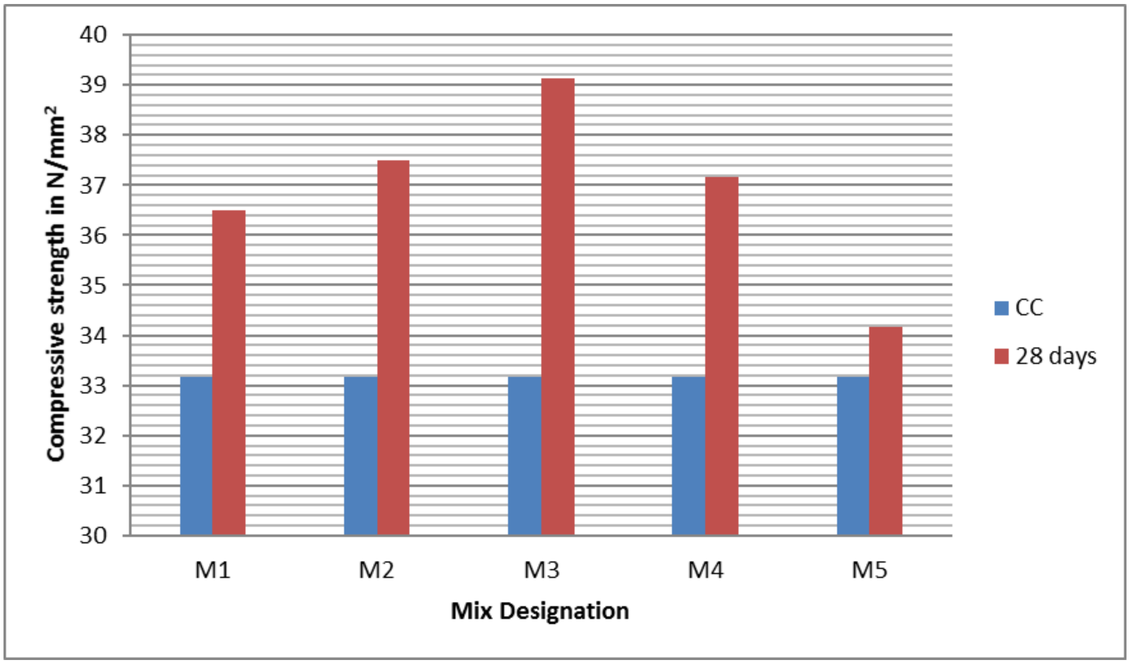

Figure 11: Compressive strength of M25 concrete at 28 days

The results obtained from compression testing gives comprehensive outcome of the project as the replacement the replacement of tile aggregates produces a concrete with suitable properties as conventional.

5.3 Split Tensile strength:

The split tensile strength obtained by testing the cylindrical specimen for M25 grade of concrete to all the mixes designed for various replacements are given below:

Table 10: Split tensile strength results for M25 grade of concrete

S.No	Mix Designation	Aggregate Replacements % (CTA+RTW)	Split Tensile Strength of M25 grade in N/mm^2		
			7 days	14 days	28 days
1	M0	0+0	1.67	2.18	2.56
2	M1	10+10	1.67	2.19	2.61
3	M2	20+10	1.69	2.24	2.615
4	M3	30+10	1.71	2.26	2.65
5	M4	40+10	1.69	2.21	2.59
6	M5	50+10	1.67	2.16	2.52

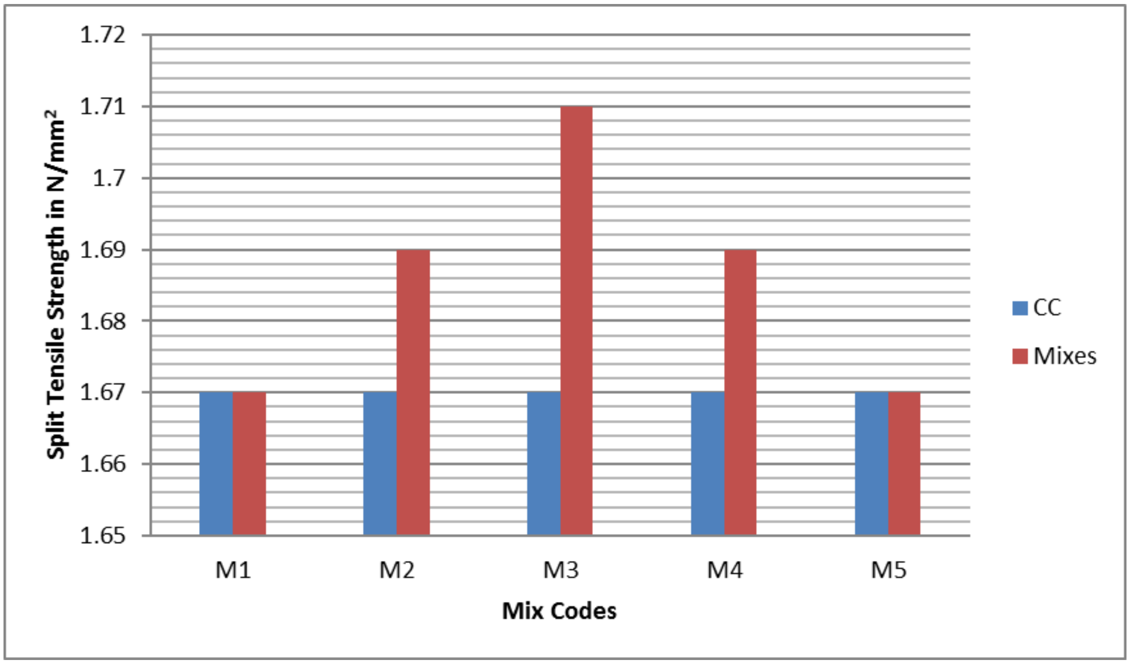

Figure 12: Split tensile strength for M25 at 7days

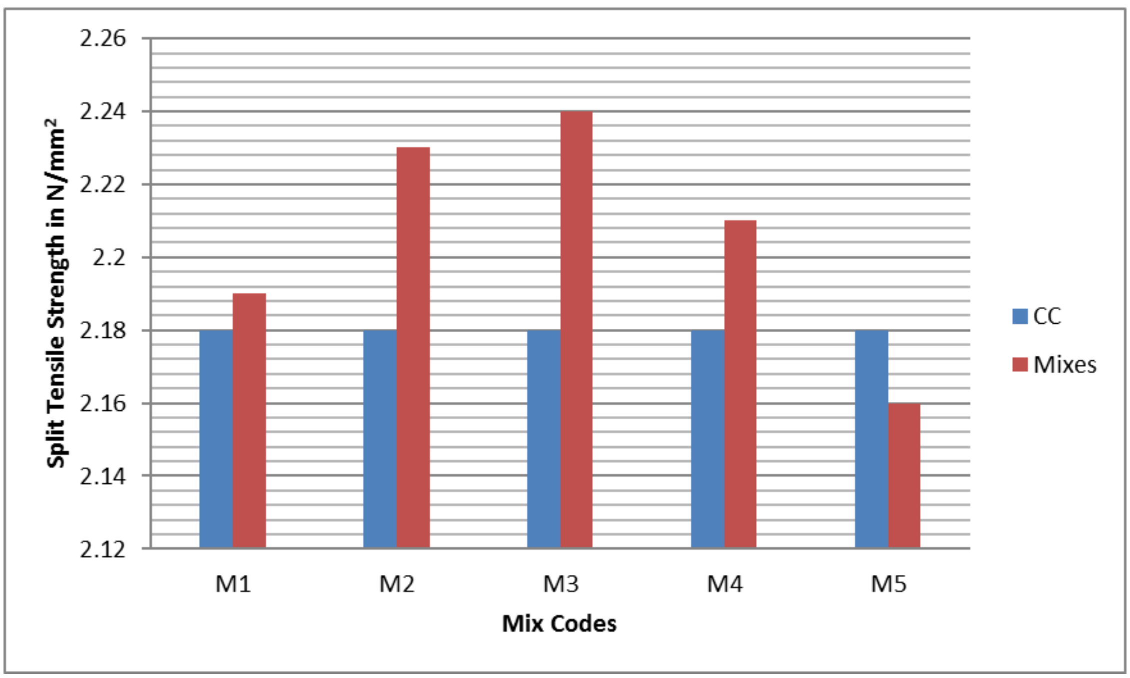

Figure 13: Split tensile strength of M25 concrete at 14days

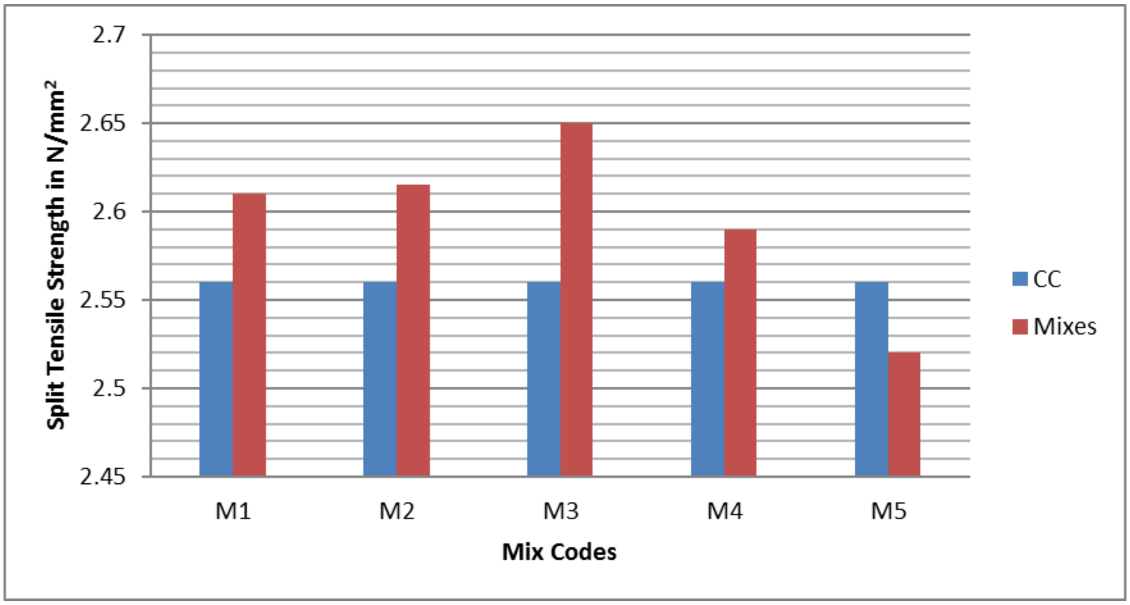

Figure 14: Split tensile strength of M25 concrete at 28days

The strength i.e., the tensile strength, from the results is clearly in an increment way compared to the conventional concrete at all the curing ages of 7days, 14 days and 28 days. The replacement of aggregates by various proportions has positive effect on the strength of the concrete.

5.4 Flexural Strength:

The flexural test was conducted for M3 mix only since it has the highest compressive and split tensile strength to compare it with conventional i.e.,M0. A Total of 2 beams were casted and tested as follows:

Table 11: Flexural test results for 7, 14 and 28 days

S.No	Grade of concrete	Mix Code	Flexural Strength in N/mm^2		
			7days	14 days	@ 28 days
2	M25	M0	3.25	4.75	5.3
3	M25	M3	3.19	4.81	5.33

VI. DISCUSSION

6.1 Workability:

6.1.1 Slump Cone Test:

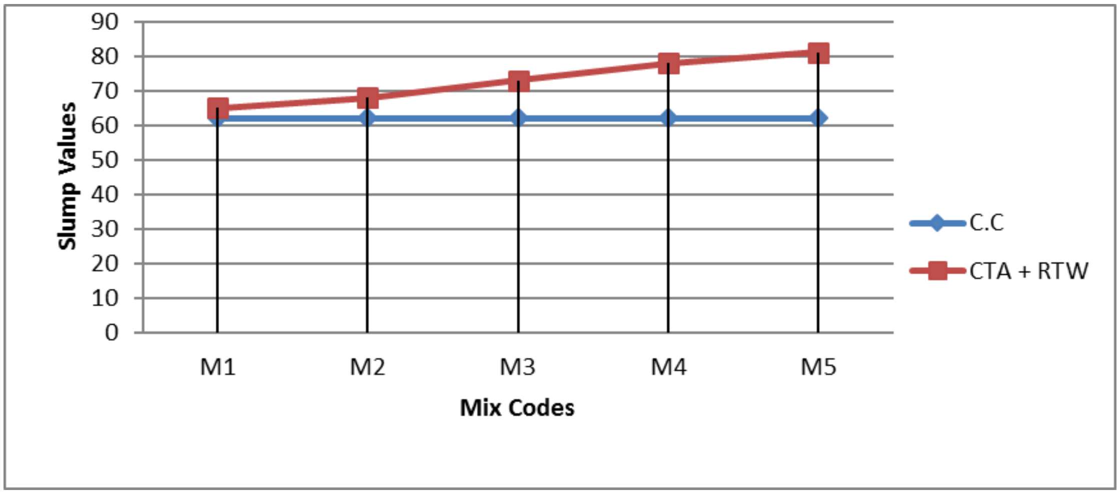

Figure 15: Comparison of workability for different mixes of M25 Grade

From the results it is observed that the workability is increased by an amount of 4.8%, 9.6%, 17.7%, 25.8%, 30.6%, 1.6%, 8%, 14.5%, 22.5%, 16.1%, 27.4%, 38.7% and 64.5% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 mixes respectively over conventional M25 concrete grade(M0).

6.1.2 Compaction Factor Test:

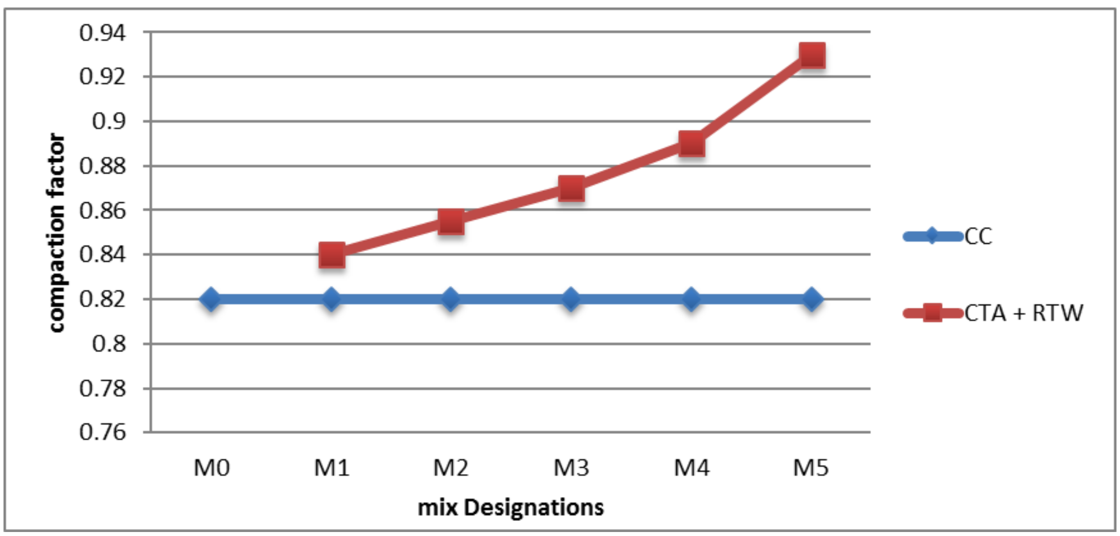

Figure 16: Comparison of compaction factor for various mixes with conventional concrete for M25 grade

From the results it is observed that the workability is increased by an amount of 2.4%, 4.3%, 6.1%, 8.5%, 13.4%, 1.2%, 4.9%, 7.3%, 10.9%, 3.6%, 9.7%, 13.4% and 15.8% and 64.5% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 mixes respectively over conventional M25 concrete grade(M0).

The workability from both slump cone and compaction factor tests is similar in increasing manner. The workability increases with increase in ceramic coarse tile aggregate but a little deviation with the addition of ceramic fine aggregate. The addition of rebutted tyre powder has significant improvement on the workability of concrete.

6.2 Compressive strength:

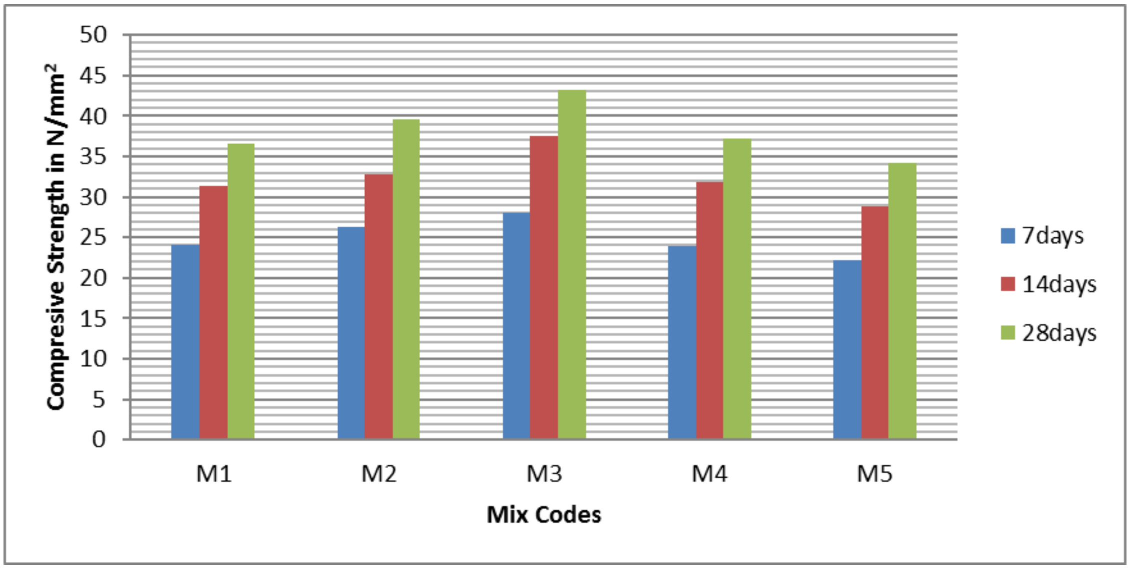

Figure 17: Strength comparison at 7, 14 and 28 days for M25 concrete

The Compressive strength of concrete varies as 17.11%, 27.7%, 36.36%, 16.4%, 8.02%, 6.85%, 13.8%, 28.82%, -2.72%, 2.33%, 19.59%, 36.6% and 3.64% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12 and M13 compared with the conventional concrete after 7days of curing.

The Compressive strength of concrete varies as 9.99%, 14.92%, 31.49%, 11.31%, 1.19%, 1.61%, 10.72%, 20.53%, -6.62%, 0.3%, 17.65%, 34.54% and -1.57% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12 and M13 compared with the conventional concrete after 14days of curing.

The Compressive strength of concrete varies as 10%, 19.04%, 30%, 11.99%, 3.01%, 5.99%, 11.99%, 19.04%, 0.8%, 3.97%, 19.04%, 27% and 1.98% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12 and M13 compared with the conventional concrete after 28days of curing.

On comparing the strengths of all mixes, M3, M8 and M12 has the highest i.e., 30% replacement of coarse aggregate. The addition of rebutted tyre powder has positive effect on strength while improving the workability also.

6.3 SPLIT TENSILE STRENGTH:

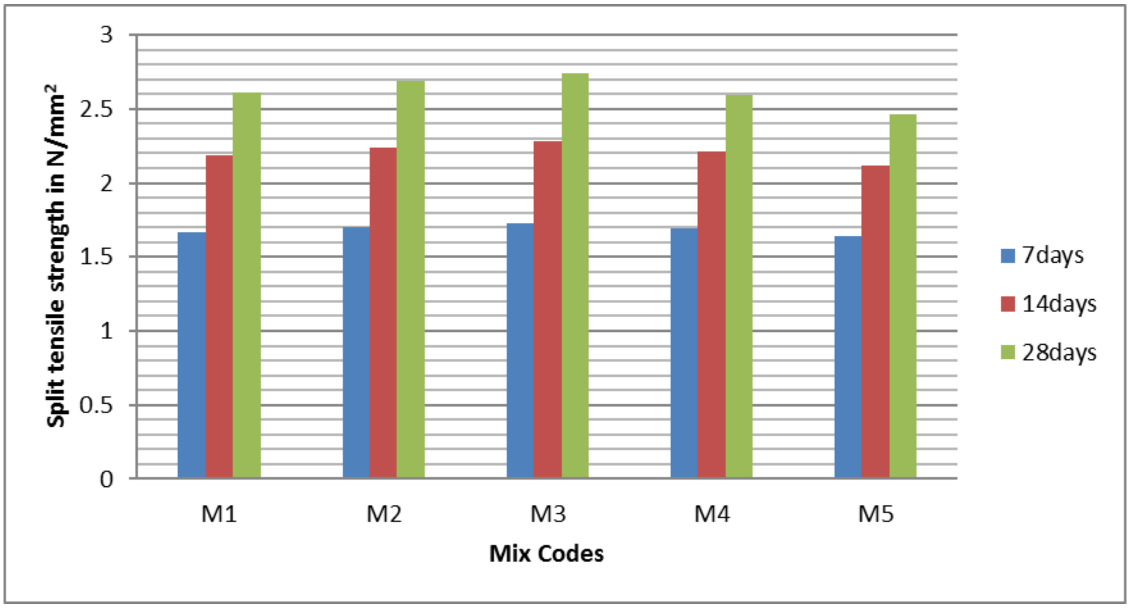

Figure 18: Split tensile strength for M25 concrete mixes

The split tensile strength of concrete varies as 0%, 1.2%, 2.4%, 1.2%, 0%, 1.2%, 1.2%, 1.8%, -1.2%, 0.59%, 2.4%, 3.0% and 1.2% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 compared with the conventional concrete after 7days of curing.

The split tensile strength of concrete varies as 0.46%, 2.7%, 4.6%, 1.4%, -2.7%, 0%, 1.37%, 2.3%, 0.46%, 0.92%, 1.37%, 2.75% and 0.92% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 compared with the conventional concrete after 14days of curing.

The split tensile strength of concrete varies as 1.95%, 5%, 7%, 1.18%, -1.6%, 0.39%, 1.9%, 3.1%, -2.3%, 0.78%, 3.5%, 3.9% and 2.3% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 compared with the conventional concrete after 28days of curing.

6.4 Flexural Test:

The flexural test is conducted for the mixe, which has maximum compressive strength and split tensile strength i.e., M3 (30% of CCA) and the results are plotted below:

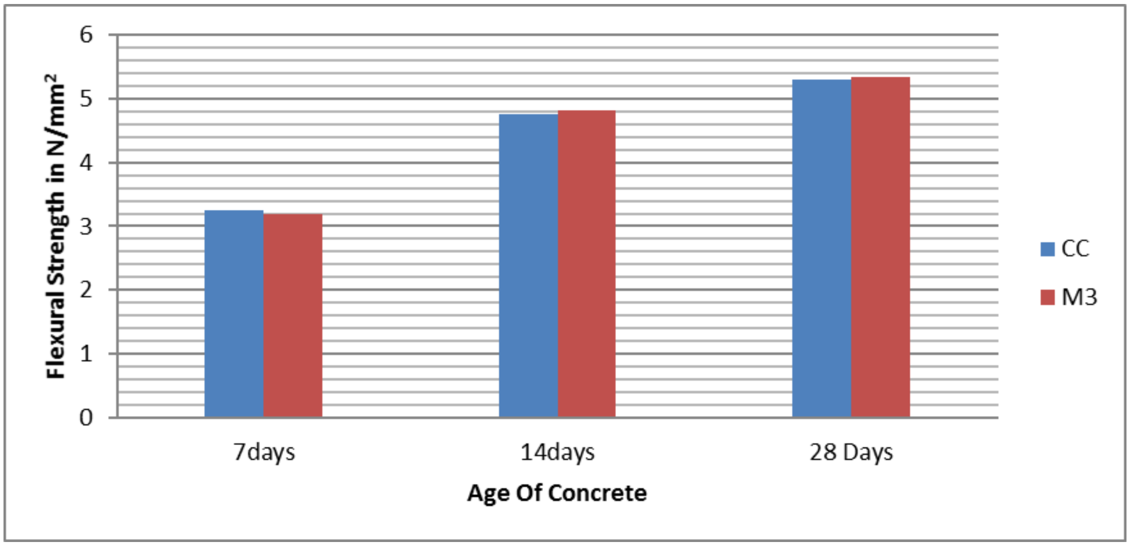

Figure 19: Flexural strength comparison M25 grades for M3 mix with conventional

The strength gaining of beam is linearly increasing. The strength variation for three grades is in increasing manner. The flexural strength of conventional varies as 12.6%, 1.8% and 3.32% of increment at 7, 14 and 28 days respectively for M3 mix. The 7days strength gain is quite same for three grades but after 14 days M25 has the rapid growth of strength. Even though we are not comparing with the conventional concrete but the attainment of strength for is satisfactory.

VII. SUMMARY AND CONCLUSION

7.1 General:

The basic objective of the study is to prepare a concrete much more stable and durable than the conventional by replacing aggregates both coarse and fine. Mix designs for all the replacements of materials has done and a total of 90 specimens (42 cubes, 42 cylinders, 6 beams) are prepared and tested in the aspect of strength calculation and also comparisons has done.

7.2 Conclusions:

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

- The workability of concrete increases with the increase in tile aggregate replacement. The workability is further increased with the addition of rebutted tyre powder which acts as admixture due to its chemical properties.
- The properties of concrete increased linearly with the increase in ceramic aggregate up to 30% replacement later it is decreased linearly.
- M3 mix of concrete produced a better concrete in terms of compressive strength, split tensile strength and flexural strength than the other mixes. But the mixes up to 50% of ceramic coarse aggregate can be used.
- The usage of ceramic fine aggregate has some effect on the properties of concrete in decrement manner.
- Rebutted tyre powder using as fine aggregate has more influence on the concrete than the ceramic fine because of chemical composition it is made of and works as admixture.
- The addition of rebutted tyre powder along with the ceramic coarse aggregate improves the mechanical properties of concrete slightly since mineral and chemical properties are of rebutted tyre.
- The split tensile strength of ceramic tile aggregate is very much in a straighter path

compared to the conventional grades of concrete.

VIII. FUTURE SCOPE OF WORK

There is a vast scope of research in the recycled aggregate usage in concrete especially ceramic tile wastes in the future. The possible research investigations that can be done are mentioned below:

- The usage of marble floor tiles can be studied as it is similar to that of tile waste generation and also it is quite hard compared to the natural crushed stones using in conventional concrete.
- The usage of rebutted tyre waste in concrete as an admixture to improve the workability of concrete and the strength parameters can also be studied at various percentages.
- A combination of different tiles (based on their usage) in different proportions in concrete and their effects on concrete properties like strength, workability etc can be determined.
- By the use of ceramic tile aggregate in concrete, the physical properties like durability, permeability etc., can be analyzed to prepare a concrete with more advantageous than conventional concrete.
- A study on properties of concrete made with combination of recycled aggregate and tile aggregate in different proportions can be investigated to enhance the concrete properties and also to reduce the pollution or waste generation from construction industry.
- A further investigation on the use of rebutted tyre powder alone as a replacement to fine aggregate can be carried out the possibility of using such waste generation from industries.
- The mechanical properties of concrete with marble aggregate (waste) either from manufacturing units or from construction demolition can be investigated to improve the properties like permeability; resistance to sound can also be studied.
- Ceramic tile aggregate in high strength concrete can be studied further to check the possibility of its use in high rise buildings.

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