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RESEARCH ARTICLE

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PARTIAL REPLACEMENT OF AGGREGATE WITH CERAMIC TILE IN CONCRETE

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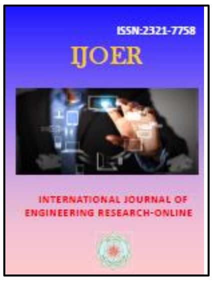


ABSTRACT

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 granite powder 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 Granite powder 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%. Granite powder and ceramic tile powder were replaced in place of fine aggregate by 10% along with the ceramic coarse tile. M15, M20 and M25 grades of concrete were 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 granite powder. 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 granite powder 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 granite powder and crushed tiles increases. The strength of concrete also increases with the ceramic coarse tile aggregate up to 30% percentage.

Keywords: Crushed tiles, Compressive strength, Flexural strength, Granite powder, Split Tensile strength.

1. Introduction

1.1 General: In the present construction world, the solid waste is increasing day by day from the demolitions of constructions. There is a huge usage of ceramic tiles in the present constructions is going on and it is increasing in day by day construction field. 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 disturbance to the environment. And also in other side waste tile is also producing from demolished wastes from construction. Indian tiles production is 100 million ton per year in the ceramic industry, about 15%-30% waste material generated from the 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, we selected these waste tiles as a replacement material to the basic natural aggregate to reuse them and to decrease the solid waste produced from demolitions of construction. Waste tiles and granite powder were collected from the surroundings.

1.2 Crushed Tile Concrete: Crushed tiles are replaced in place of coarse aggregate and granite powder in place of fine aggregate by the percentage of 10%. The fine and coarse aggregates were replaced individually by these crushed tiles and granite 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 granite 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%. Granite 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 granite powder since it is readily available at very low cost and there-by reducing the construction pollution or effective usage of construction waste.

2. MATERIALS AND PROPERTIES

2.1 MATERIALS USED

In this study, the following materials were used:

- OPC 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: 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 20mm size produced from local crushing plants were used. The aggregate exclusively passing through 25mm 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. 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 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 4.75mm size was neglected. The crushed tile aggregate passing through 16mm sieve and retained on 12.5mm 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.

Figure 1: Ceramic Tile Aggregate Sample

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	12.50%

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 GRANITE POWDER: Since granite powder is obtained from crushing of granite rocks, the chemical and mineral composition of granite is similar to that in cement and natural aggregates. It is chosen to test the behaviour of concrete along with the ceramic tile waste.

Table 5: Properties of Granite Powder

S.No	Description	Test Results
1	Specific gravity of granite powder	2.4
2	Water absorption of granite powder	0.10%

From Industry granite powder will be collect; 4.75 mm passed materials was separated to use it as a partial replacement to the fine aggregate. Granite powder was partially replaced in place of fine aggregate by the percentages of 10% along with replacement of coarse aggregate with crushed tiles also.

3. Methodology: The methodology of research includes the collection of required materials from the various sources and determining the properties of all the materials gathered. Designing the concrete mix proportions for all types of replacements and Preparation of the concrete mix, Moulding and curing. The testing of concrete includes Slump cone test, compaction factor test for determining workability of concrete in fresh state and compressive strength, split tensile test and flexural test for determining the strength of concrete in hardened state.

Total 13 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 granite powder individually but along with the coarse aggregate. The details of mix designations are as follows:

Details of aggregate replacement for mix codes

S.no	Mix Code	Cement (%)	Coarse Aggregate (%)		Fine Aggregate (%)		
			Natural Coarse Aggregate	Crushed Tiles	Sand	Crushed tile powder	Granite Powder
1	M0	100	100	0	100	0	0
2	M1	100	90	10	100	0	0
3	M2	100	80	20	100	0	0
4	M3	100	70	30	100	0	0
5	M4	100	60	40	100	0	0
6	M5	100	50	50	100	0	0
7	M6	100	90	10	90	10	0
8	M7	100	80	20	90	10	0
9	M8	100	70	30	90	10	0
10	M9	100	60	40	90	10	0
11	M10	100	90	10	90	0	10
12	M11	100	80	20	90	0	10
13	M12	100	70	30	90	0	10
14	M13	100	60	40	90	0	10

4. CONCRETE MIX DESIGN

Since, the properties of concrete are dependent on the quantities of materials used, the concrete mixes for desired strength are calculated. The mix design for M15, M20 and M25 grades of concrete for all the replacements are determined as per the IS: 10262-2009 code.

4.1 MIX DESIGN FOR M15 GRADE CONCRETE:

Final Mix Proportions:

C	:	FA	:	CA	:	WATER
320	:	695	:	1368	:	165
1	:	2.17	:	4.32	:	0.5

4.2 MIX DESIGN FOR M20 GRADE CONCRETE:

Final Mix Proportions:

C	:	FA	:	CA	:	WATER
355	:	683	:	1320	:	175
1	:	1.92	:	3.72	:	0.48

4.3 MIX DESIGN FOR M25 GRADE CONCRETE:

Final Mix Proportions:

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

5. TEST RESULTS

5.1 WORKABILTY

5.1.1 Slump Cone Test: The pattern of workability obtained is True Slump. Workability Results obtained from slump cone test for various grades of concrete are shown in following

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

S.No	Mix Designation	Aggregate Replacements % (CCA+CFA+GP)	Workability (mm)		
			M15	M20	M25
1	M0	0+0+0	55	58	62
2	M1	10+0+0	58	61	65
3	M2	20+0+0	62	63	68
4	M3	30+0+0	67	67	73
5	M4	40+0+0	72	72	78
6	M5	50+0+0	78	78	81
7	M6	10+10+0	57	58	63
8	M7	20+10+0	61	61	67
9	M8	30+10+0	65	65	71
10	M9	40+10+0	69	69	76
11	M10	10+0+10	67	67	72
12	M11	20+0+10	74	76	79
13	M12	30+0+10	81	85	86
14	M13	40+0+10	88	95	102

5.1.2 Compaction Factor Test: The results obtained from the compaction factor test for the workability of various mixes of replacements of M15, M20 and M25 grades of concrete are tabulated as follows:

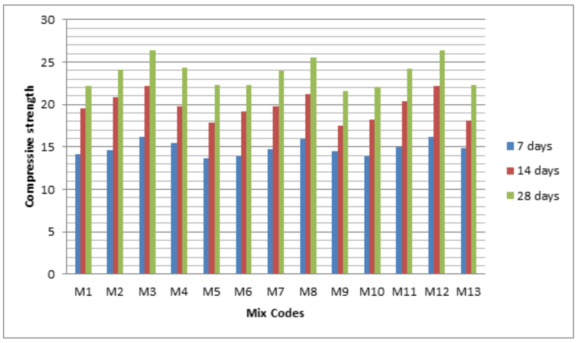
Table 8: Test results of compaction factor test for workability

S.No	Mix Designation	Aggregate Replacements % (CCA+CFA+GP)	Compaction Factor		
			M15	M20	M25
1	M0	0+0+0	0.8	0.82	0.82
2	M1	10+0+0	0.82	0.825	0.84
3	M2	20+0+0	0.82	0.84	0.855
4	M3	30+0+0	0.85	0.87	0.87
5	M4	40+0+0	0.86	0.88	0.89
6	M5	50+0+0	0.87	0.91	0.93
7	M6	10+10+0	0.82	0.83	0.83
8	M7	20+10+0	0.82	0.85	0.86
9	M8	30+10+0	0.84	0.86	0.88
10	M9	40+10+0	0.84	0.89	0.91
11	M10	10+0+10	0.84	0.84	0.85
12	M11	20+0+10	0.87	0.89	0.9
13	M12	30+0+10	0.91	0.92	0.93
14	M13	40+0+10	0.92	0.95	0.95

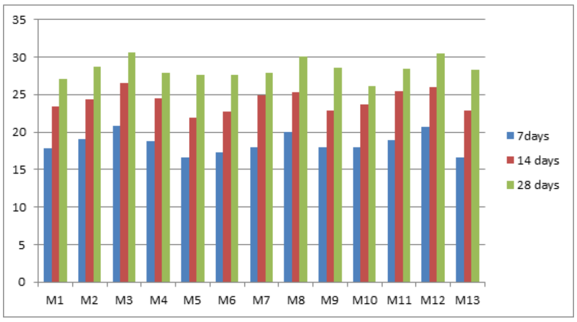
Comparison of workability for different mixes of all Grade

5.2 Compressive strength: A total of 126 cubes of size 150 x 150 x 150 mm were cast for 7 days, 14 days and 28 days testing. For each grade of concrete 42 cubes are tested, 14 each for 7, 14 and 28 days and the results are tabulated below:

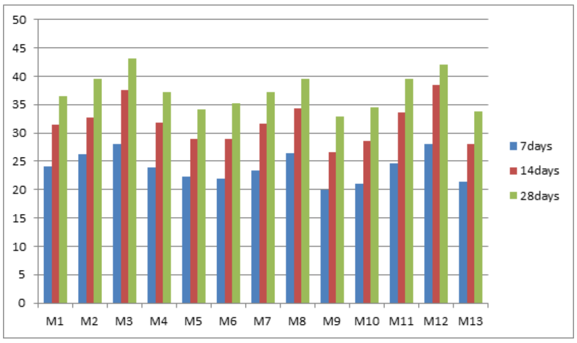
S.No	MIX Code	Grade Of Conc	Compressive strength at		
			7 days	14 days	28 days
1	M0	M15	12.96	18.06	21.25
2	M0	M20	16.56	22.87	28.0
3	M0	M25	20.57	28.54	33.18



Strength gain and comparison of M15 concrete at 7, 14 and 25 days



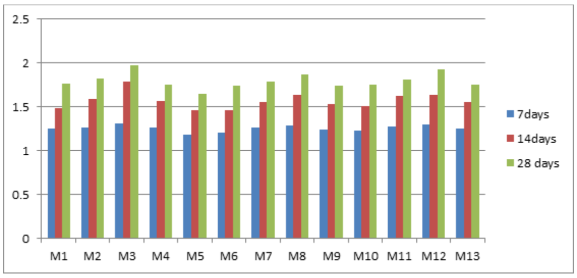
Strength gain and comparison of M20 concrete at 7, 14 and 25 days



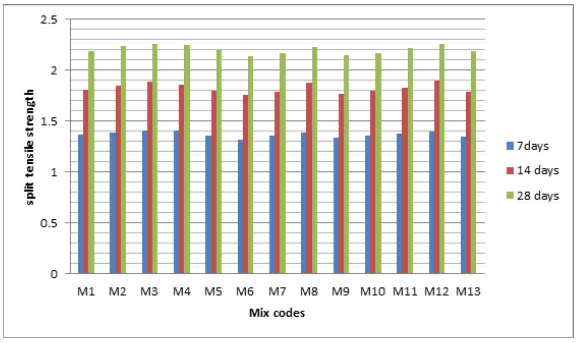
Strength comparison at 7, 14 and 28 days for M25 concrete

5.3 Split Tensile strength: The split tensile strength obtained by testing the cylindrical specimen for M15, M20 and M25 grades of concrete to all the mixes designed for various replacements are given in graphical representation as follows:

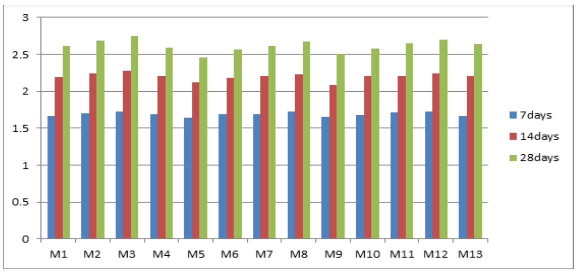
S.No	MIX Code	Grade Of Conc	Compressive strength at		
			7 days	14 days	28 days
1	M0	M15	1.19	1.44	1.73
2	M0	M20	1.33	1.76	2.14
3	M0	M25	1.67	2.18	2.56



Comparison of split tensile strength variation for M15 concrete



Split tensile strength development for M20 concrete mixes



Split tensile strength for M25 concrete mixes

5.4 Flexural Test:

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

Table 15: Flexural test results for 7, 14 and 28 days

S.No	Grade of concrete	Mix Code	Flexural Strength in N/mm^2		
			7 days	14 days	28 days
1	M15	M3	3.78	4.67	5.18
2	M20	M3	6.69	6.95	7.36
3	M25	M3	8.88	9.15	10.28

6. DISCUSSION

Slump Cone Test

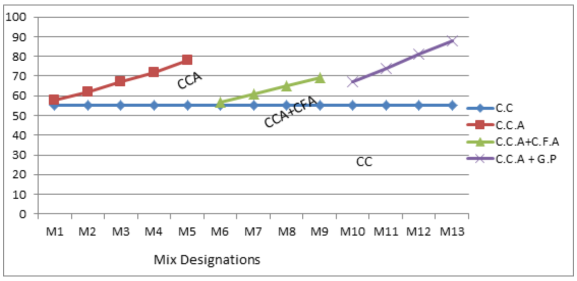


Figure 27: Comparison of workability for different mixes of M15 Grade

From the graph it is observed that the workability is increased by an amount of 5.4%, 12.7%, 21.8%, 30.9%, 41.8%, 3.6%, 10.9%, 18.2%, 25.5%,21.8%, 34.5%, 47.27%, 60% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 mixes respectively over conventional M15 concrete grade(M0).

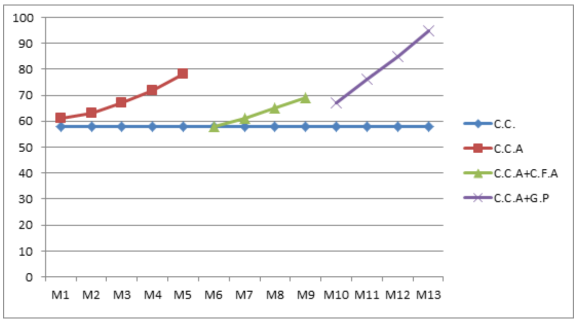


Figure 28: Comparison of workability for different mixes of M20 Grade with the conventional concrete

From the graph it is observed that the workability is increased by an amount of 5.1%, 8.6%, 15.5%, 24.1%, 34.5%, 0%, 5.1%, 12%, 18.9%, 15.5%, 31%, 46.5% and 63.8% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 mixes respectively over conventional M20 concrete grade(M0).

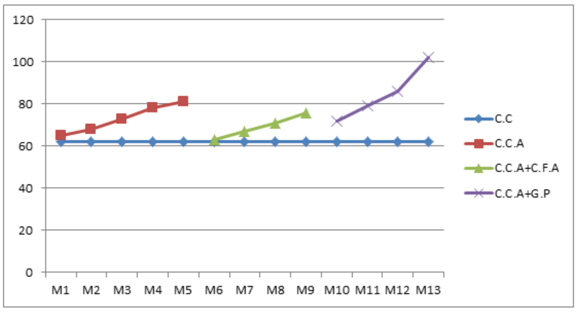


Figure 29: Comparison of workability for different mixes of M25 Grade

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

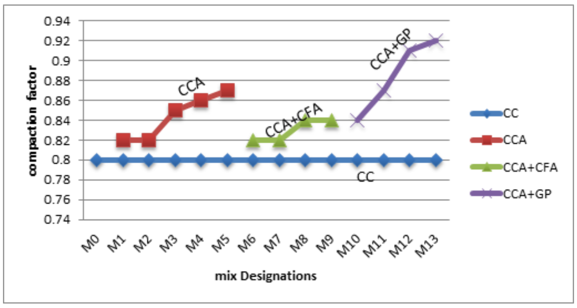


Figure 30: Comparison of compaction factor for various mixes with conventional concrete for M15 grade

From the results it is observed that the workability is increased by an amount of 2.5%, 2.5%, 6.25%, 7.5%, 8.75%, 2.5%, 2.5%, 5%, 5%, 5%, 8.75%, 13.75% and 15% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 mixes respectively over conventional M15 concrete grade(M0).

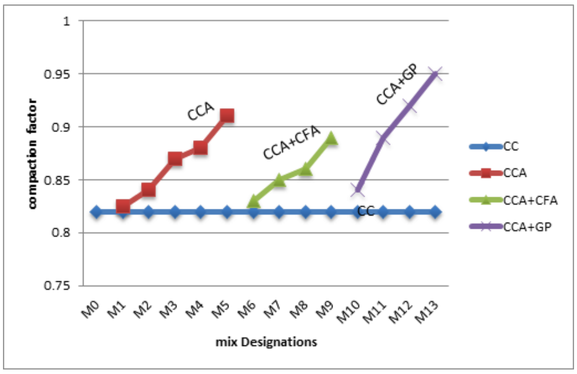


Figure 31: Comparison of compaction factor for various mixes with conventional concrete for M20 grade

From the results it is observed that the workability is increased by an amount of 0.61%, 2.4%, 3.66%, 7.3%, 10.9%, 1.2%, 3.65%, 4.8%, 8.5%, 2.4%, 8.5%, 12.2% and 15.8% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 mixes respectively over conventional M20 concrete grade(M0).

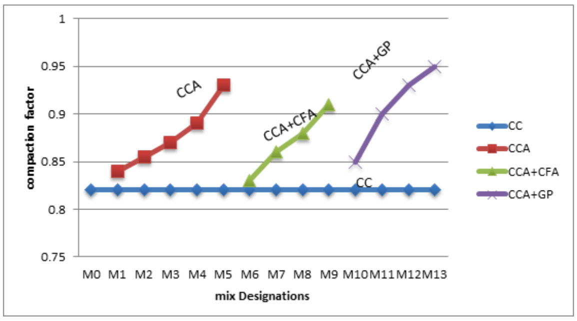


Figure 32: Comparison of compaction factor for various mixes with conventional concrete for M25 grade

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 granite powder has significant improvement on the workability of concrete.

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

M15 Grade: The Compressive strength of concrete varies as 9%, 12.8%, 24.5%, 19.1%, 5.4%, 6.7%, 13.4%, 23.1%, 11.9%, 7.4%, 15.9%,25% and 14.9% for for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 compared with the conventional concrete after 7days of curing.

The Compressive strength of concrete varies as 8%, 15.33%, 22.5%, 9.3%, -1.4%, 6.3%, 9.6%, 17.67%, -3.1%, 0.94%, 12.9%, 22.7% and 0% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 with the conventional concrete after 14 days of curing period.

The Compressive strength of concrete varies as 4.3%, 13.3%, 23.8%, 14.3%, 5%, 5%, 12.9%,20.3%, 1.6%, 4%, 14%, 24.3% and4.9% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 with the conventional concrete after 28 days of curing period.

M20 Grade: The Compressive strength of concrete varies as 7.6%, 14.7%, 25.4%, 13.67%, 0.25%, 4.6%, 8.4%, 20.5%, 8.6%, 8.4%, 14.3%, 24.7% and 0.06% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 compared with the conventional concrete after 7days of curing.

The Compressive strength of concrete varies as 2.1%, 6.2%, 16%, 6.9%, -3.9%, -0.5%, 8.7%, 10.8%, 0.3%, 3.4%, 11.5%, 13.8% and 0.3% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 compared with the conventional concrete after 14days of curing.

The Compressive strength of concrete varies as -3%, 2.7%, 9.5%, -0.4%, -1.4%, -1.1%, -0.3%, 7.5%, 2%, -6%, 1.8%, 9% and 2% for M1, M2, M3, M4, M5,M6,M7,M8,M9,M10,M11,M12,M13 compared with the conventional concrete after 28days of curing.

M25 Grade of 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.

6.3 Split Tensile: The linear development of strength can be seen from the graph. The strengths are quite good compared to the conventional concrete. M3 being the maximum of all mixes along with the M12 mix which uses the granite powder.

6.3.1 M15 Grade: The split tensile strength of concrete varies as 5%, 6.7%, 10%, 5.8%, -0.84%, 1.7%, 5.8%, 8.4%, 4.2%, 3.36%, 7.5%, 9.2% and 5% 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 2.8%, 10.4%, 24.3%, 9%, 1.4%, 1.4%, 7.6%, 13.8%, 6.25%, 4.9%, 13.2%, 13.9% and 7.6% 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 1.7%, 5.2%, 14.5%, 1.2%, -4.6%, 0.58%, 3.5%, 8%, 0.58%, 1.2%, 4.6%, 11.6% and 1.2% for M1, M2, M3, M4, M5, M6, M7, M8,M9,M10,M11,M12,M13 compared with the conventional concrete after 28days of curing.

M20 Concrete: The split tensile strength of concrete varies as 3%, 4.5%, 6%, 6%, 2.3%, -0.75%, 2.3%, 4.5%, 0.75%, 2.25%, 3.75%, 5.3% and 1.5% 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 2.8%, 5.1%, 7.4%, 5.7%, 2.27%, 0%, 1.7%, 6.8%, 0.56%, 2.3%, 3.9%, 7.9% and 1.7% 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 split tensile strength of concrete varies as 0.93%, 2.3%, 3.7%, 2.8%, 2.3%, 0%, 1.4%, 2.8%, 0.46%, 1.4%, 2.8%, 4.2% and 2.3% for M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12 and M13 compared with the conventional concrete after 28days of curing.

M25 Concrete: 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 Strength:

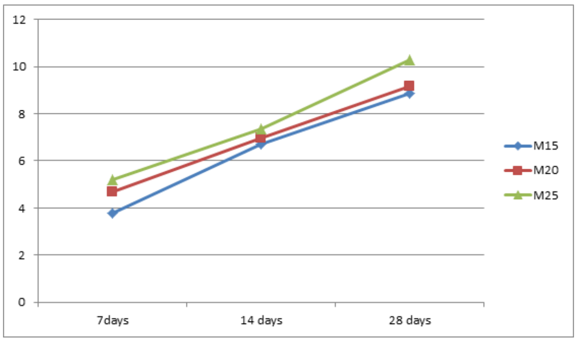


Figure 39: Flexural strength comparison of M15,M20 and M25 grades for M3 mix

The strength gaining of beam is linearly increasing. The strength variation for three grades is in increasing manner. 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 three grades is satisfactory

7. 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 261 specimens (126 cubes, 126 cylinders, 9 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 granite 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.
- Granite 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 granite powder along with the ceramic coarse aggregate improves the mechanical properties of concrete slightly since mineral and chemical properties are of granite.
- The split tensile strength of ceramic tile aggregate is very much in a straighter path compared to the conventional grades of concrete.

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 granite powder 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 granite 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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