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Experimental Study on the Behaviour of Ceramic Waste as Partial Replacement of Coarse Aggregate in Concrete: A Green Concrete Approach

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Abstract : In most percentage of industrial wastes come in the form of ceramic wastes asindustrial waste obtained in various forms like ceramic powder, brokentiles and slurry waste, the disposal of which creates issues in the form of environmental pollution.These waste materials sometimes can be used to replacement of cement, fineaggregate, coarse aggregate also act as a supplementary addition inconcrete. This research study focused on structural behaviourof the partial inclusion of Ceramic tile Waste (CTW) as coarse aggregates in the concrete. Different percentage of concrete were produced with 0 to 40 % in stepcontent of 10 % as a partial replacement of Ceramic tile Waste (CTW) as coarse aggregates.The results of the research showed thatworkability of the mixes increased with percentage increase in the CTWcontent up to 30% and thereafter decreased. There was gradual decrease in thecompressive strength, spilt tensile strength and Flexural strength of the specimens with increase in the CTW. The water absorption rate of the samples increased withincrease in the CTW content up to 30%. Based on the result obtained, concretemix ratio which contains not more than 40% CWT content is not recommended for use in concrete mix.
Keywords : Coarse aggregate, Ceramic tiles, concrete, compressive strength,workability.

Introduction

Cement and aggregate, which are the most important constituents materials used in production of concrete. These materials are the vital materials needed for the construction industry. Due to this certainly led to a continuous and increasing demand of natural materials used for their production. At present crushed stone as coarse aggregate may not be available this has forced many people to be using gravel as alternative coarse aggregate.Where crushed stone is available, its high cost as coarse aggregate is a major problem to tackle people in the developing countries like India.The need for the utilization of the natural resources for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are recycled as a waste. The aim of this study is to investigate the effect of the use of ceramic tile waste as coarse aggregate in concrete production.

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Literature Review

Jalali S (2010) in their study the ceramic industry, about 15% to 30% of total waste is generated from all production, although the reuse of ceramic waste has been implemented, the amount of waste recycled in this way is still negligible. Therefore, its application is needed in many industries and cities development. The construction industry can become the end user of all ceramic waste, and in this way can help solve this environmental problem. Odero et al., (2015) studied Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste. Salih AA et al,(2014)studied in the ceramic industry, about 15% to 30% of total waste is generated from all production, although the reuse of ceramic waste has been implemented, the amount of waste recycled in this way is still negligible . Therefore, its application is needed in many industries and cities development. The construction industry can become the end user of all ceramic waste, and in this way can help solve this environmental problem. The use of ceramic waste material offer cost reduction, energy saving and fewer hazards in the environment (Amitkumar et al., 2013 and Muralidharan et al., 2018) and according to authors the best way for the construction industry to become a more sustainable one is by using wastes from other industries as building material (Prajapati et al., 2014).Mohd Mustafa Al Bakri et al,(2006) investigate Lightweight, structural concrete has been produced using oil palm shells and demolished masonry waste as aggregates in concrete. An improvement in the modulus of elasticity of concrete was observed with partial replacement of crushed stone coarse aggregate with crushed vitrified soil aggregate.

Objectives of the Research

To study on properties of concrete made with recycled aggregate in different proportions can be investigated to enhance the concrete properties and also to reduce the pollution or waste generation from construction industry.

Materials Used

Cement

The cement used in this research should confirm IS specifications. There are several types of cements available commercially in the market of which Portland cement is very common and it is well known and available everywhere. PPC 43 grade was used for this study. The physical properties of the cement tested according to standard procedure confirm to the requirement of IS 12269:1989. The physical properties of the cement are listed in the Table 1.

Table 1 Physical properties of cement

Sl.No	Material	Cement
1	Fineness by Sieving (%) 90 micron mesh	6%
2	Normal Consistency	32%
3	Initial Setting Time (minutes)	45
4	Final Setting Time(minutes)	520
5	Specific Gravity	3.17

Fine Aggregate

Locally available river sand passing through 4.75mm sieve conforming to the recommendation of IS 383:1970 is used. Specific Gravity of fine aggregate of the sand is 2.64 andis graded to Zone II and medium sand.

Ceramic waste-coarse aggregate

The ceramic waste was obtained from a local ceramic industry and big ceramic tile companies or shops. The ceramic pieces were broken into pieces with hammer into required size and breakage of the tiles into small pieces of about 5mm – 40mm sizes. These small pieces are then fed into vibrator and sieved to get the required coarse aggregate size. From the sieve analysis results ceramic waste coarse aggregate is graded to Zone II and medium sand are shown in Table.2 and Figure.1(a).

Table 2: Particle size distribution for ceramic waste coarse aggregate

Sl.No	Sieve size (mm)	Weight of Aggregate retained	Weight retained(%)	Cumulative % weight retained	Percentage passing(%)
1	40	0	0	0	100
2	20	1500	1500	50	67
3	16	800	2300	76.67	18
4	12.5	400	2700	90	10
5	10	240	2940	98	5
6	4.75	36	2976	99.2	0.8

Coarse Aggregate

Coarse aggregate to be used for production of concrete must be strong, impermeable, durable and capable of producing a sufficient workable mix with minimum water cement ratio to achieve proper strength. Locally available coarse aggregate retaining on 4.75 mm sieve is used. Specific Gravity of coarse aggregate was found and the particle size distribution for coarse aggregate is listed below in Table 3. From the sieve analysis results it was found that the combined aggregate of in the range of nominal size of coarse aggregate is 20mm.

Table 3:Particle size distribution cure of normal coarse aggregate

Sl.No	Sieve size (mm)	Weight of Aggregate retained	Weight retained(%)	Cumulative % weight retained	Percentage passing(%)
1	40	0	0	0	100
2	20	1660	1660	55.33	44.66
3	16	704	2364	78.8	21.2
4	12.5	360	2724	90.8	9.2
5	10	240	2964	98.8	1.2
6	4.75	36	3000	100	0

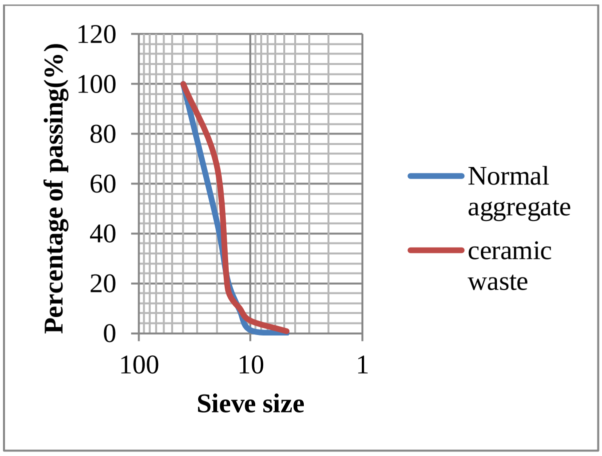

Figure1:a) Particle size distribution cure of normal sand and ceramic waste coarse aggregate b) Ceramic waste

Water

The water used in this research work was, the water available in the laboratory has used. Its PH value is 6.5 to 8.

Experimental Programme

To study the compressive strength, flexural strength and split tensile strength of concrete prepared by using ceramic waste as coarse aggregate waste with different percentage of replacements with normal quarry aggregate. The concrete mix concrete mix design was prepared as per Indian Standard for control concrete. The concrete grade was M20. The replacement levels of sand by ceramic waste aggregate were used in terms of 10%, 20%, 30%,40% and 50% in concrete.In order to study the effect of replacement of sand in various ratio of ceramic waste, cube of 15x150x150 mm size, beams of size 100 mm x 100 mm x 500 mm and cylinders of 150mm diameter to a height of 300mm were cast and used as test specimens to determine the compressive strength, flexural strength and split tensile strength respectively at the age of 7,14 and 28 days. The workability of fresh concrete was measured in terms of slump values.

Results and Discussions

Compaction factor test

In the compaction factor was conducted in the laboratory as per IS1199:1959. The values observed from the test, it has identified that ceramic waste concrete is normal workable concrete in the range of 81 to 0.92 from Table.4 and Figure.2.

Table.4: Compaction Factor Value

Sl.No	Designation of the Specimen	Replacement Level (%)	Compaction Factor value in %
1	NMC	0	81
2	CCA10	10	86
3	CCA20	20	92
4	CCA30	30	91
5	CCA40	40	88
6	CCA50	50	84

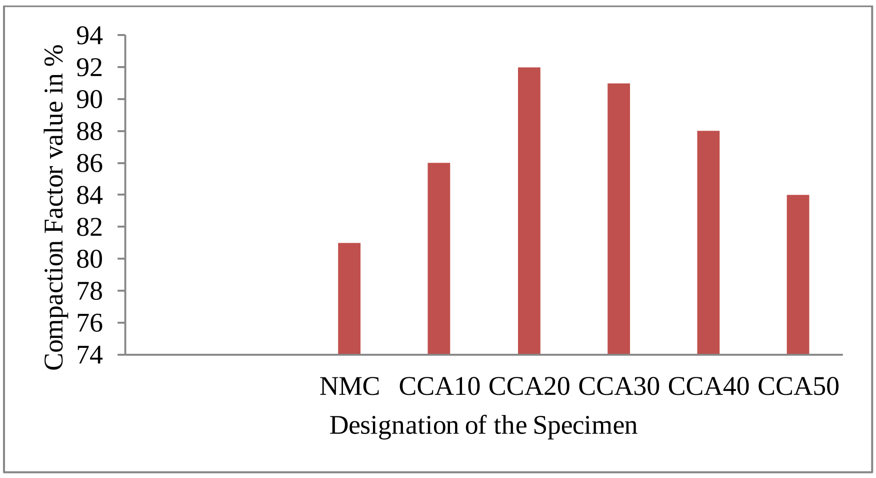

Figure.2 : Compaction Factor Values for ceramic replacement and normal concrete

Slump Test

Workability of concrete made by using waste ceramic tiles was determined with different replacement level. The values of workability in terms of slump are given in Table.5. The same results are shown in graphical form in Figure.3 for visual observation. From the results it evident that from the table and figure that workability of concrete made using ceramic waste decreased with increase in replacement level.

Table.5: Slump value of normal sand and ceramic waste concrete

Sl.No	Designation of the Specimen	Replacement Level (%)	Slump (mm)
1	NMC	0	100
2	CCA10	10	110
3	CCA20	20	120
4	CCA30	30	70
5	CCA40	40	60
6	CCA50	50	50

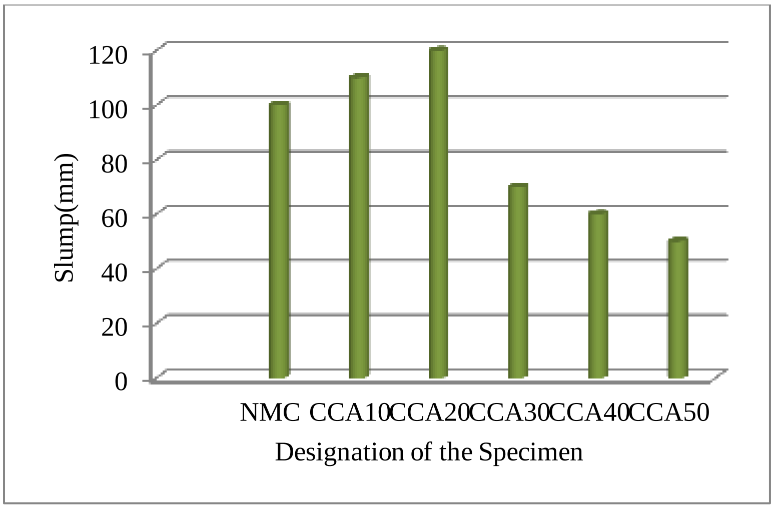

Figure.3: Slump value of normal sand and ceramic waste concrete

The Compression Strength test

The compressive test was conducted in universal testing machine (UTM) in a capacity of 40 tonnewas used. Three concrete cubes of 150mm size for M20 using the above mentioned mix ratio were prepared. For each mix ratio , three waste replacement cubes plus one with normal aggregates cubes were casted for testing .The compressive strength test displayed in Figure 4 shows that ceramic tile waste has effect on the compressive strength of concrete. The compressive strength values were consistent increase in the curing age increases. The maximum compressive strengths were recorded for both ages of concrete and it occurred at 30% replacement of granite with ceramic tile waste. The percentage increase was waste tile addition was 12% for 7 days curing age and 13% for 14 day curing age for 28 days age of concrete its strength increases were 17%. A steady fall of strength with waste replacement beyond this optimum point was observed. However, the compressive strength at 28 day age is consistently higher than the control specimen.

Table.6:Compressive strength values of ceramic waste concrete for 7,14 and 28days

Sl.No	Specimen	Compressive Strength (MPa)		
		7 days	14 days	28 days
1	NMC	24	31.25	39.25
2	CCA10	26	32	41
3	CCA20	27	34	43
4	CCA30	28.6	35	32.91
5	CCA40	19.98	24.97	36.96
6	CCA50	18.67	21.25	36.25

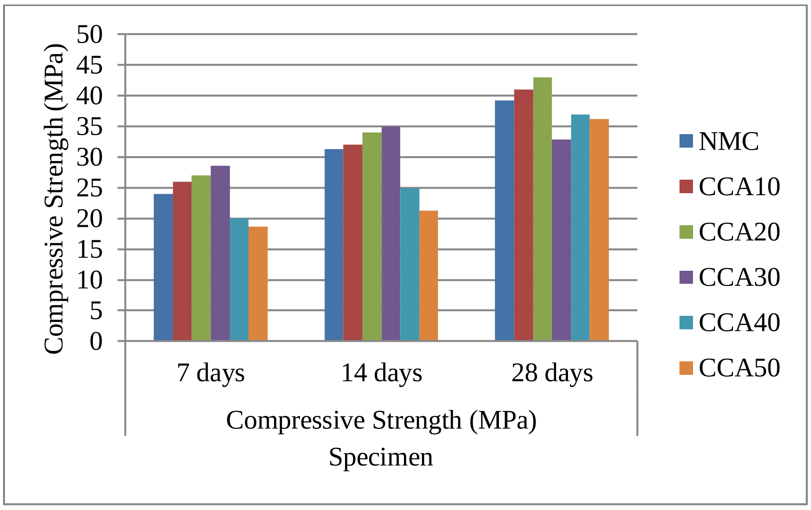

Figure.4 :Compressive strength values of ceramic waste concrete for 7,14 and 28days

The split tensile strength test

The test was conducted using the same UTM to determine the tensile strength of concrete specimens. The split tensile test was done using cylindrical specimens of 150mm diameter, and 300mm length. The specimens also were tested immediately after taking them from water at 7th, 14th and 28th day. From it was observed that after beyond 30% replacement of ceramic waste the strength was reduced.Table.7 shows the split tensile strength of the ceramic waste and normal concrete specimens and Figure.5 shows its visual observation. Split tensile strength increases steadily with increasing percentage of ceramic tile waste replacement and the optimum strength is at 30% for 7 and 28 curing ages. At 10% replacement level, split tensile strength incr21%,25% and 8% for eased by 4% ,20% and 7% for 7,14 and 28 curing ages over the control strength for 14 curing ages also 13%,26% and 24% for 7,14 and 28 curing ages over the control strength respectively. Also It is evident that at 28 day the split tensile strength is consistently higher than the control value for all the percentage replacements considered.

Table.7: Split Tensile strength values of ceramic waste concrete for 7,14 and 28days

Sl.No	Specimen	Split Tensile strength (MPa)		
		7 days	**14 days**	**28 days**
1	NMC	2.3	2.9	3.75
2	CCA10	2.4	3.51	4.04
3	CCA20	2.6	3.64	4.65
4	CCA30	2.8	3.81	4.40
5	CCA40	2.57	2.92	3.61
6	CCA50	2.25	2.55	3.40

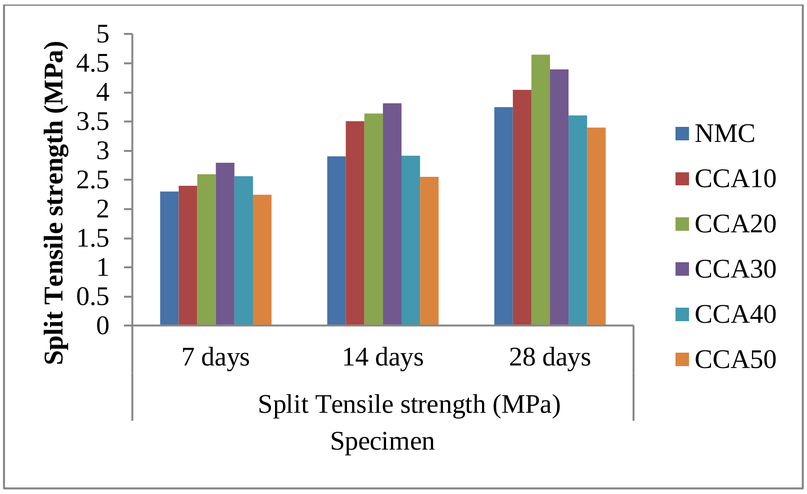

Figure.5: Split tensile strength values of ceramic waste concrete for 7,14 and 28days

Conclusions

Based on the experimental study for the use of ceramic waste in concrete as a replacement of coarse aggregate, the following conclusions were observed.

The test results clearly shows that the ceramic waste can be used as are placement materials for natural granite aggregate in concrete

While using ceramic tiles as partial replacement of coarse aggregate, workability decreases with increase in replacement level of ceramic waste.

The replacement of natural granite aggregate using 30% ceramic waste in concrete gives the required strength and can be considered as optimum percentage.

Optimum replacement level of natural granite aggregate with ceramic waste is 30%.

Further increase in the percentage addition of ceramic waste, reduces the mechanical properties (Compression and Split Tensile strength) of concrete.

Ceramic waste can effectively be used as alternative & supplementary materials in concrete.

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