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Study on the behaviour of bottom ash on ceramic waste Aggregate Concrete

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ABSTRACT:

It has been assessed that approximately 30 percent of the daily production is discarded as waste in a ceramic industry. The waste disposal has been a major issue for the ceramic industries as the waste piles up every day. This has been discovered as an environmental pollution which needs to be directed by finding ways and means of using this industrial waste for worthwhile purposes in bulk quantity. There has been an unrestricted use of natural resources in concrete-making, resulting in their depletion to an alarming rate. Hence, for the sustainable development of concrete technology as well as for safe environment, the use of industrial waste as an alternative for the conventional ingredients of concrete provides the best possible option. Bottom ash is a byproduct of the combustion of pulverized coal in power plants. Generally power plants produce bottom ash approximately 20 percent of the total ashes. Most of it is disposed in landfills causing environmental and other problems. Therefore bottom ash can be used as a fine aggregate in concrete making to reduce huge consumption of natural resource. Silica fume is a waste by-product of the manufacture of silicon from high purity quartz and coal in a submerged-arc electric furnace. It is a highly reactive pozzolanic material. According to IS: 456-2000, silica fume was added to concrete mix 10 percent by weight of cement, to enhance the impermeability of concrete.

In this study a purposeful attempt is made to find out the suitability and adequacy of the ceramic waste as a possible substitute for conventional crushed stone coarse aggregate and bottom ash as a partial replacement of conventional fine aggregate in the concrete composition. Concrete using ceramic waste as coarse aggregate and bottom ash as fine aggregate is termed as CWBA aggregate concrete. This investigation has been carried out in four stages:

i. Characterization of ceramic waste and bottom ash for the possible use in concrete as coarse and fine aggregates respectively.

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ii. Development of concrete with ceramic waste coarse aggregate and bottom ash fine aggregate (CWBA aggregate concrete).

iii. Comparison of mechanical and durability properties of CWBA aggregate concrete with those of conventional crushed stone aggregate concrete.

The material properties of ceramic waste and bottom ash were determined and compared with conventional crushed stone coarse aggregate. It has been observed that the water absorption and bulk density of ceramic waste aggregate are less than the conventional crushed stone coarse aggregate. Experimental investigation was carried out to determine the properties of fresh and hardened CWBA aggregate concrete and were compared with respective properties of concrete made with crushed stone coarse aggregate.

Test results indicate that the workability of CWBA aggregate concrete is comparable and the strength characteristics are superior to those of the crushed stone coarse aggregate concrete Experiments were carried out to measure the durability properties of CWBA aggregate concrete and the results show that there is no significant change in the basic trend of permeation properties of CWBA aggregate concrete, when compared to the crushed stone coarse aggregate concrete. CWBA aggregate concrete has improved permeability characteristic values than those of the crushed stone coarse aggregate concrete.

KEYWORDS: Alternate aggregates; ceramic waste; bottom ash; silica fume; mechanical properties; durability properties; flexural behaviour

I.INTRODUCTION

In view of the ever-growing population and with expanding urban centers, escalating levels of construction are forecast in the forthcoming years in India as a developing country. The construction Industry has the largest drain of natural materials. Like water the construction materials cannot be recycled naturally. The construction industry needs to be suggest the measures with the approval of environmentally good natured and more sustainable technology. Industrial wastes have continued to increase due to the continued demands of resource used by humans and increasing amount of pollution But also to the problem of the high cost of building materials is currently faced by our nation. It is essential to effectively use the industrial waste in order to conserve the non-renewable natural resources.

USE OF INDUSTRIAL WASTE IN CONCRETE MAKING

The main hope of the use of waste materials is to minimize environmental impact and reduce the huge consumption of natural resources used for concrete applications. A review of earlier research showed that industrial as well as other wastes have been used in concrete making to improve the properties of concrete and to reduce cost. The use of recycled aggregates for concrete-making has been successfully implemented and gaining wider acceptance. Another important aspect to consider is the depleting nature of the concrete

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aggregates has led to recycling of waste aggregates will prove to be economically beneficial and sustainable. In this study the use of the ceramic waste as coarse aggregate and bottom ash fine aggregate as a partial replacement of river sand of its suitability and mechanical properties of concrete were investigated.

SUSTAINABLE CONCRETE TECHNOLOGY

Taking the concept of sustainable development into consideration, the concrete industry has to implement a variety of strategies with regard to future concrete use, for illustration, improvements in the durability of concrete and the better use of recycled materials. According to the living planet report" (WWF) Taipei the concrete industry globally consumes 8 — 12 billion tones, annually of natural aggregates after the year 2010. More recently there has been a growing social and political awareness of environmental issues, particularly where this relates to the deterioration of the environment. This has lead to the passing of laws and regulations of all kinds in an attempt to control and reduce the amount of natural aggregates extracted from quarries and to encourage recycling and reuse. [6] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.

II.LITERATURE REVIEW

Rafat Siddique (2003) , stated that 50 percent replacement of fine aggregate by power plant waste material in concrete indicates significant improvement in the strength properties of concrete such as compressive strength, splitting tensile strength, flexural strength and modulus of elasticity.

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Senthamarai and Devadas Manoharan (2005), investigated the suitability of the ceramic industrial wastes as a possible substitute for conventional crushed stone coarse aggregate. They concluded that the properties of ceramic waste coarse aggregate are well within the range of the values of concrete making aggregates and respective strength characteristics are comparable to those of the conventional concrete.

Goo-Dae Kim and Tae-Bong Kim (2007), investigated the use of waste high strength concrete in making modified sulfur concrete. They found that modified sulfur concrete has superior physical properties and chemical resistance.

Isa yuksel et al. (2007), stated that the combination of bottom ash (BA), and granulated blast furnace slag (GBFS) as fine aggregate in concrete making, leads to improvement in resisting high temperature and surface abrasion. But care should be taken to reduce capillarity and drying- wetting resistance of concrete.

Aminul Islam Laskar and Sudip Talukdar (2008), investigated the effect of rice husk ash, fly ash and silica fume as admixture on rheological behavior of high performance concrete. They observed that silica fume is a better material for moderate plastic viscosity needed for the design of high performance concrete.

III.METHODOLOGY

MATERIALS

Ceramic Waste Coarse Aggregate: Ceramic waste obtained from ceramic electrical insulator industry has a glassy outer skin. Initially the glazed surface was removed manually and it was broken in to 100 mm to 150 mm size by a hammer. Then it was fed into the jaw-crusher to get 20 mm graded aggregate.

FIG: WASTE CERAMIC AND CERAMIC AGGREGATES

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BOTTAM ASH FINE AGGREGATE

Bottom ash is the byproduct of coal fired furnace used in thermal power plants. It is sand like material with granular structure with the same upper and lower particle size limits as river sand. Large size bottom ash particles have a porous inner core, and it can be very easily crushed between fingers. But smaller size particles of bottom ash exhibit higher strength.

BOTTAM ASH FINE AGGREGATE **RIVER SAND**

SILICA FUME

In this study the physical properties and chemical composition of silica fume are given by the supplier M/s Elkem India (Pvt) Limited. Silica fume is a by-product in the manufacture of silicon. This is a very fine pozzolanic material composed of amorphous silica. The properties of silica fume to be used in cement concrete are specified in ASTM C 1240. Silica fume undergoes pozzolanic reaction with calcium hydroxide in cement paste to improve the mechanical properties of concrete.

SILICA FUME

Another improvement achieved by the addition of silica fume in concrete is the reduction in permeability of concrete, which effectively stops the ingress of chloride ions and protects the reinforcing steel from corrosion. This reduction in permeability of concrete makes it suitable for marine environment with salt content in water.

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MIX PROPORTIONS

The conventional mix design methods cannot be applied to multiple mineral admixtures with artificial ceramic waste aggregate. Hence, in general, it is recommended that the trial mixes are to be made with suitable adjustments in grading and proportioning to achieve the desired properties of concrete. Considering the above factor and the properties of ceramic waste, bottom ash aggregates, silica fume and sand, mix proportion was carried out by absolute volume method.

CWBA AGGREGATE CONCRETE MIX PROPORTIONS PER CUBIC METER

Sl. No	Mix	W/C	Water Liters	Cement		Fine Aggregate				Coarse Aggregate	
				Kg	m^3	BA kg	Sand kg	BA m^3	Sand m^3	kg	m^3
1	CW_1	0.58	175	300	0.095	370.50	395.69	0.1482	0.1482	1119.3	0.41
2	CW_2	0.50	175	350	0.116	347.50	371.26	0.1390	0.1390	1119.3	0.41
3	CW_3	0.44	175	400	0.127	324.75	346.96	0.1299	0.1299	1119.3	0.41
4	CW_4	0.39	175	450	0.143	302.00	322.00	0.1208	0.1208	1119.3	0.41
5	CW_5	0.35	175	500	0.158	280.37	299.31	0.1121	0.1121	1119.3	0.41
6	CW_6	0.32	175	550	0.175	256.25	273.67	0.1025	0.1025	1119.3	0.41

CRUSHED STONE COARSE AGGREGATE CONCRETE MIX PROPORTIONS PER CUBIC METER

Sl.No	Mix	W/C	Water Liters	Cement		Fine Aggregate		Coarse Aggregate	
				Kg	m^3	kg	m^3	kg	m^3
1	CC_1	0.58	175	300	0.095	827.7	0.31	1119.3	0.41
2	CC_2	0.50	175	350	0.116	784.98	0.294	1119.3	0.41
3	CC_3	0.44	175	400	0.127	742.26	0.278	1119.3	0.41
4	CC_4	0.39	175	450	0.143	699.54	0.262	1119.3	0.41
5	CC_5	0.35	175	500	0.158	659.49	0.247	1119.3	0.41
6	CC_6	0.32	175	550	0.175	614.00	0.230	1119.3	0.41

IV. RESULTS AND ANALYSIS

COARSE AGGREGATE PROPERTIES

Sl. No	Property	Ceramic Waste	Crushed Stone
1	Density (g/cm^3)	2.73	2.78
2	Maximum size (mm)	20	20
3	Fineness modulus	6.92	6.98
4	Water absorption 24 hrs. (percent)	0.71	1.26
5	Surface texture	Smooth	Rough
6	Bulk density (N/m^3)		
	Loose	14100	15430
	Compacted	15230	16710
7	Voids (percent)		
	Loose	48.0	44.00
	Compacted	44.32	39.81
8	Crushing value (percent)	25	23
9	Impact value (percent)	17	16
10	Soundness tests (percent): weight loss after 5 cycles	0.70	1.22
	Weight loss after 30 cycles	3.7	5.5

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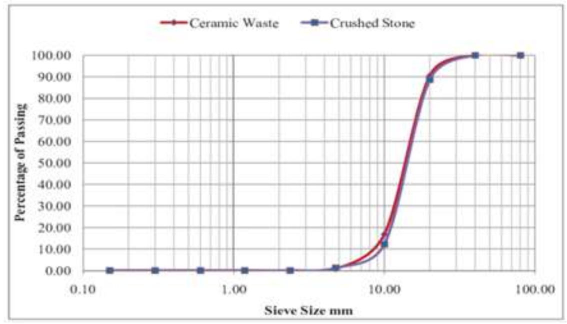
PARTICLE SIZE DISTRIBUTION OF COARSE AGGREGATE

Sl. No.	Sieve Size	Cumulative Percentage of Passing	
		Ceramic Waste	Crushed Stone
1.	80 mm	100	100
2.	40 mm	100	100
3.	20 mm	90.47	88.63
4.	10 mm	16.83	12.19
5.	4.75 mm	0.7	1.2
6.	2.36 mm	0	0
7.	1.18 mm	0	0
8.	600μm	0	0
9.	300μm	0	0
10.	150μm	0	0



PROPERTIES OF FINE AGGREGATES

Sl. No	Property	Bottom Ash	River Sand
1	Density (g/cm^3)	2.52	2.67
2	Fineness modulus	2.80	2.72
3	Bulk density (N/m^3)		
	Loose	14160	16200
	Compacted	16030	18300
4	Voids (percent)		
	Loose	43.2	36.52
	Compacted	38.42	30.71
5	Water absorption (percent)	2.1	1.8

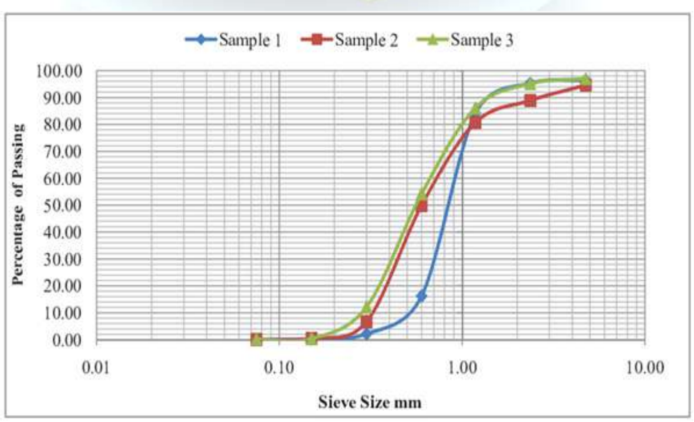
SIEVE ANALYSIS

PARTICLE SIZE DISTRIBUTION OF BOTTOM ASH

SL No.	Sieve Size	Sample 1 Percentage of Passing	Sample 2 Percentage of Passing	Sample 3 Percentage of Passing
1	4.75 mm	96.40	94.60	97.00
2	2.36 mm	95.30	88.90	95.10
3	1.18 mm	84.00	80.70	86.10
4	600 μm	16.20	49.90	54.20
5	300 μm	2.20	06.70	12.20
6	150 μm	0.30	0.50	0.40
7	75 μm	0.10	0.10	0.20

ZONE OF RIVER SAND

Sl. No.	Aperture Size	Zone I	Zone II	Zone III	Zone IV
1	10.0 mm	100	100	100	100
2	4.75 mm	90 – 100	90 – 100	90 – 100	95 - 100
3	2.36 mm	60 95	75 100	85 - 100	95 100
4	1.18 mm	30 70	55 90	75 100	90 100
5	600 μm	15 – 34	35 – 59	60 – 79	80 – 100
6	300 μm	05 – 20	08 – 30	12 – 40	15 – 50
7	150 μm	00 10	00 10	00 10	00 - 15



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SILICA FUME

PHYSICAL AND CHEMICAL PROPERTIES

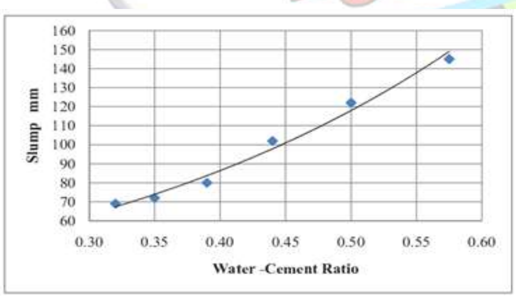
Sl. No.	Property	Value
1	Loss ignition	≤2 percent
2	Specific surface	13,000 to 30,000 m^2/kg
3	Particles size	≤ 1μm
4	Bulk density – as produced	1300 to 4300 N/m^3
5	Bulk density – slurry	13200 to 14400 N/m^3
6	Bulk density – densified	4800 to 7200 N/m^3

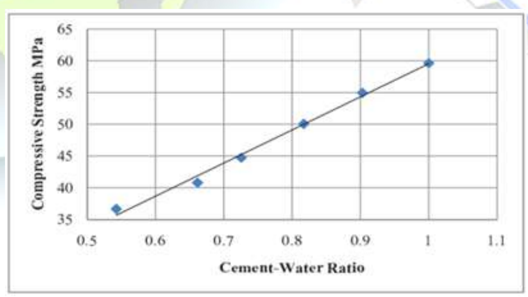
Sl. No.	Component	Percentage by Mass
1	Silicon dioxide (SiO_2)	85 – 97
2	Moisture content (H_2O)	≤2
3	Calcium Oxide (CaO)	≤1
4	Free Carbon (C)	≤2.5

CWBA AGGREGATE CONCRETE

CRUSHED STONE COARSE AGGREGATE CONCRETE

MIX DESIGN GUIDELINES





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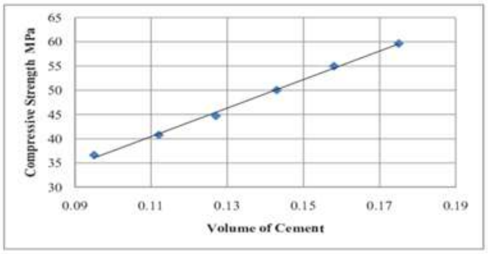
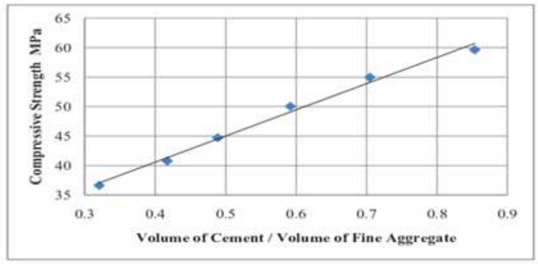
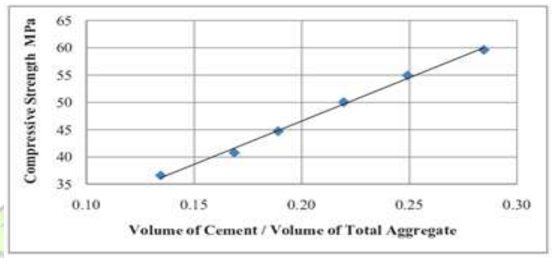
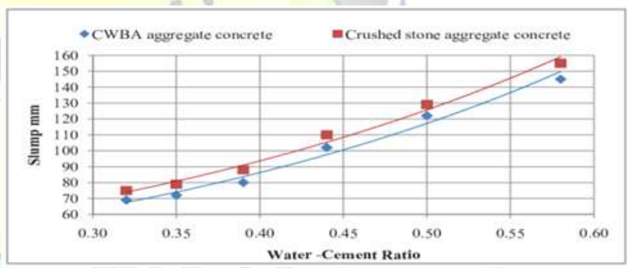




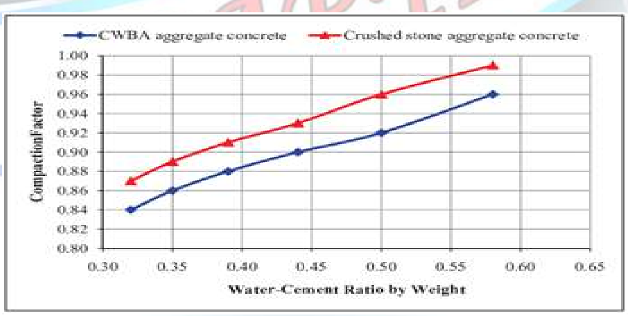


SLUMP CONE TEST

Sl.No	W/C	Slump mm		Compaction Factor	
		CWBA Aggregate Concrete	Crushed Stone Coarse Aggregate Concrete	CWBA Aggregate Concrete	Crushed Stone Coarse Aggregate Concrete
1	0.32	69	75	0.84	0.87
2	0.35	72	79	0.86	0.89
3	0.39	80	88	0.88	0.91
4	0.44	102	110	0.90	0.93
5	0.50	122	129	0.92	0.96
6	0.58	145	155	0.96	0.99



COMPACTION RESULTS



COMPRESSIVE STRENGTH

CWBA AGGREGATES

CRUSHED STONE AGGREGATE

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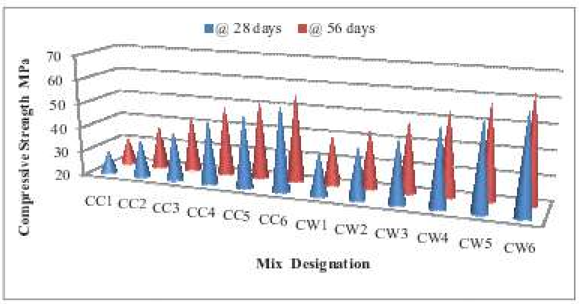
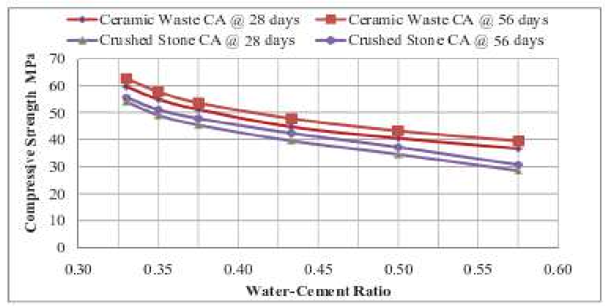
SI.No	Mix	Average Compressive Strength MPa		Average Split Tensile Strength MPa		Average Modulus of Rupture MPa		Average Modulus of Elasticity MPa	
		@28 d	@56 d	@28 d	@56 d	@28 d	@56 d	@28 d	@56 d
1	CW1	36.63	39.84	4.25	4.30	5.68	5.75	30,261	31,559
2	CW2	40.48	42.25	4.40	4.45	5.88	5.95	31,812	32,500
3	CW3	44.72	45.79	4.68	4.72	6.26	6.31	33,437	33,834
4	CW4	50.14	51.61	4.92	4.98	6.58	6.66	35,405	35,920
5	CW5	53.95	56.69	5.16	5.20	6.90	6.95	36,725	37,646
6	CW6	59.63	62.57	5.31	5.33	7.10	7.13	38,610	39,551

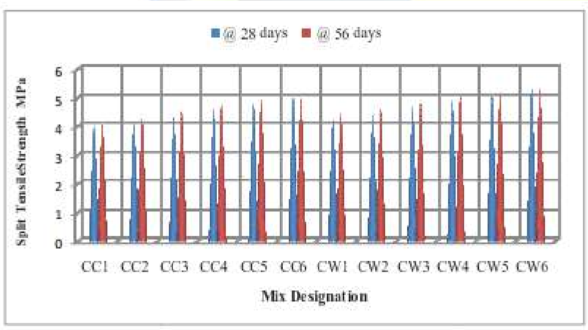
SL No	Mix	Average Compressive Strength MPa		Average Split Tensile Strength MPa		Average Modulus of Rupture MPa		Average Modulus of Elasticity MPa	
		@28 d	@56 d	@28 d	@56 d	@28 d	@56 d	@28 d	@56 d
1	CC1	28.48	29.68	3.51	3.80	4.69	5.08	26,683	27,240
2	CC 2	35.56	37.17	3.98	4.11	5.32	5.50	29,816	30,484
3	CC 3	40.55	42.38	4.46	4.48	5.86	5.99	31,839	32,550
4	CC 4	46.39	47.20	4.68	4.74	6.26	6.30	34,055	34,351
5	CC 5	50.00	51.07	4.80	4.91	6.42	6.52	35,355	35,732
6	CC 6	54.42	55.62	4.98	5.00	6.66	6.69	36,885	37,289

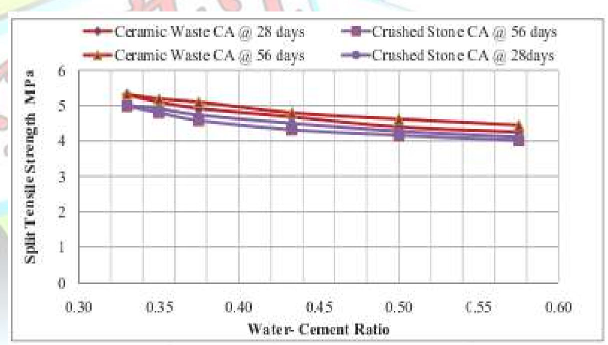
COMPRESSIVE STRENGTH

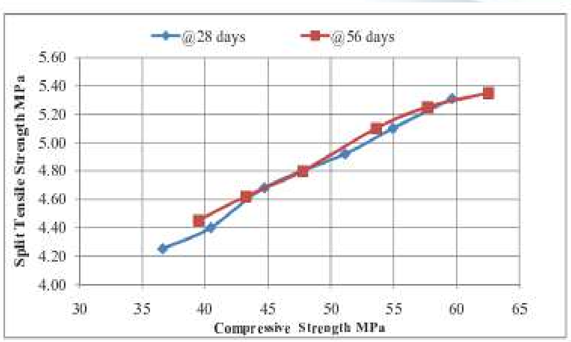


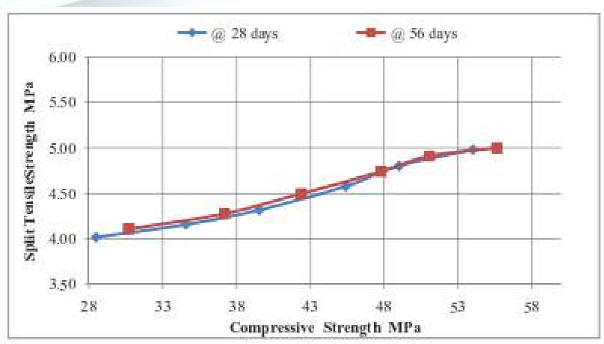


SPLIT TENSILE STRENGTH









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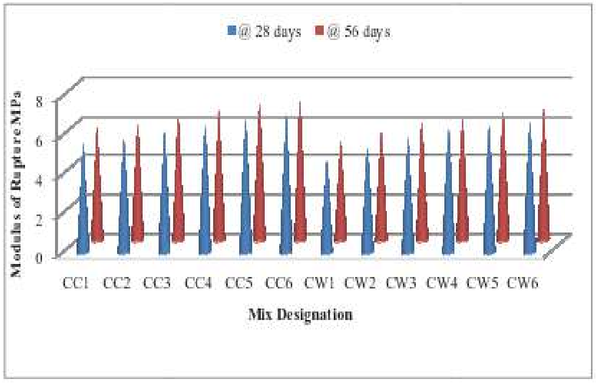
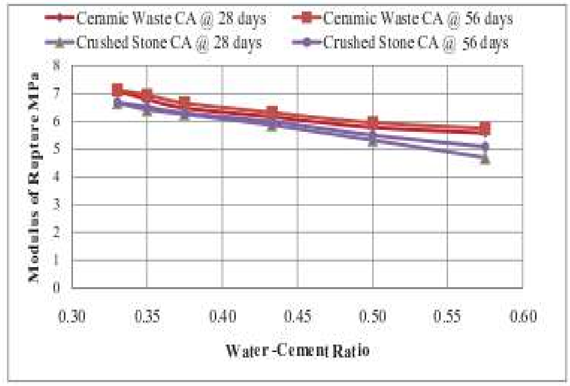
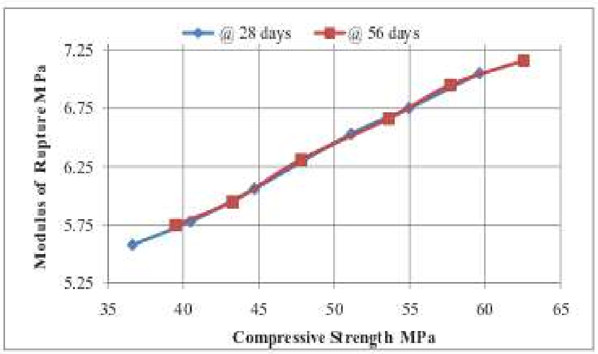
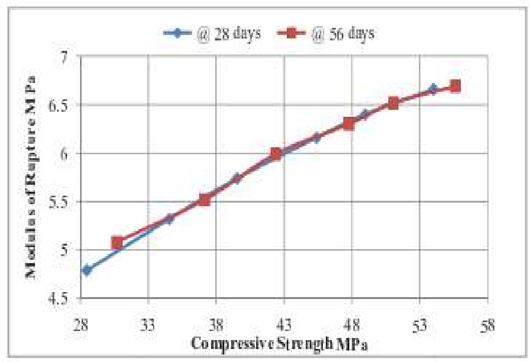
MODULUS OF RUPTURE

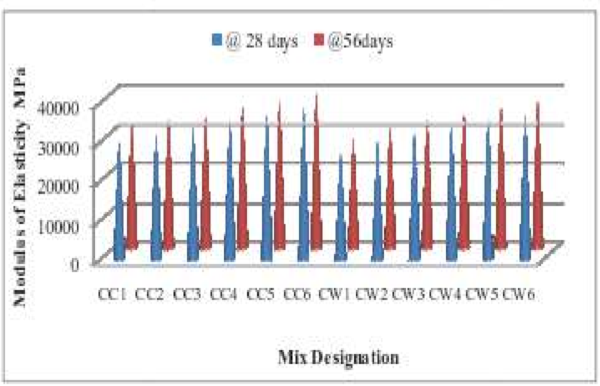


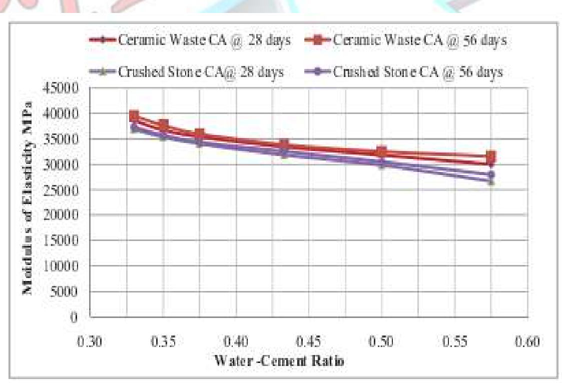






MODULUS OF ELASTICITY





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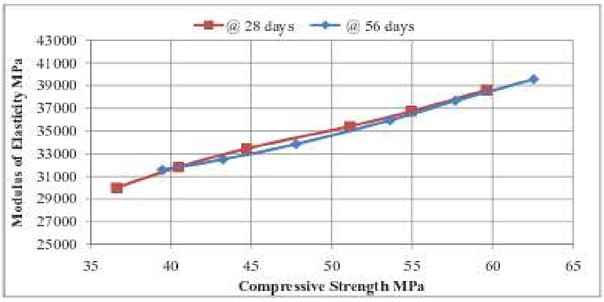
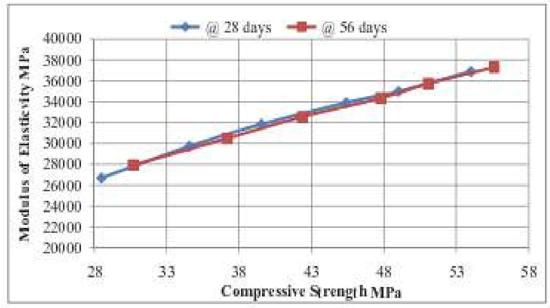
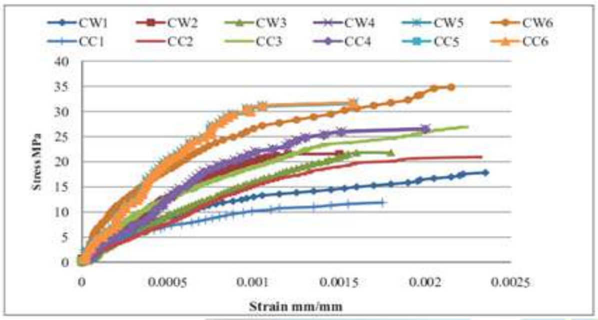
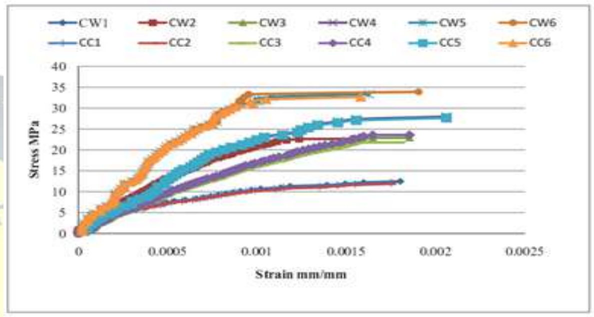




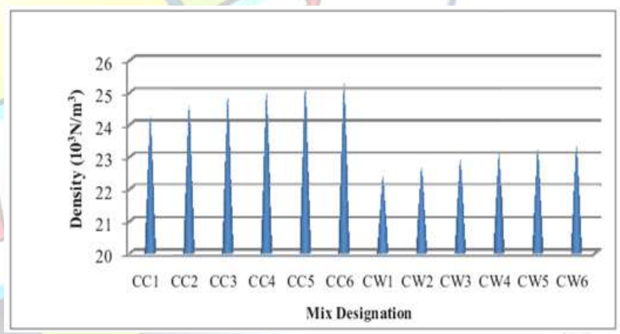


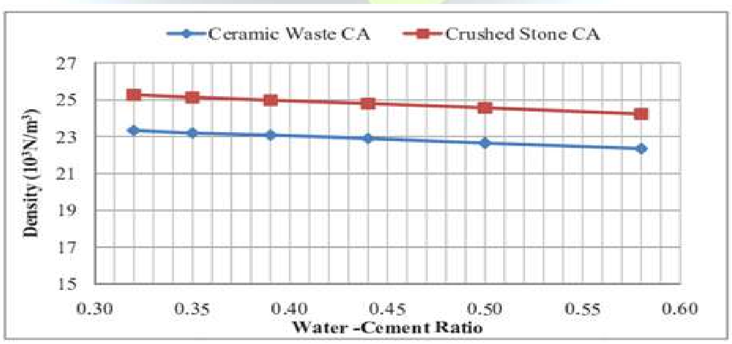


DURABILITY PROPERTIES

DENSITY

Sl.No	Mix	W/C	Dry Density x10³ N/m³
1	CW1	0.58	22.35
2	CW2	0.50	22.65
3	CW3	0.44	22.91
4	CW4	0.39	23.09
5	CW5	0.35	23.20
6	CW6	0.32	23.34
7	CC 1	0.58	24.34
8	CC 2	0.50	24.57
9	CC 3	0.44	24.80
10	CC 4	0.39	24.98
11	CC 5	0.35	25.14
12	CC 6	0.32	25.27





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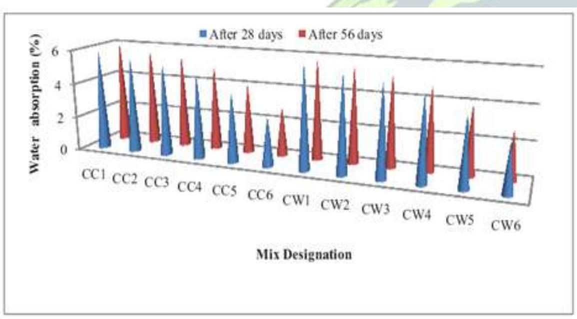
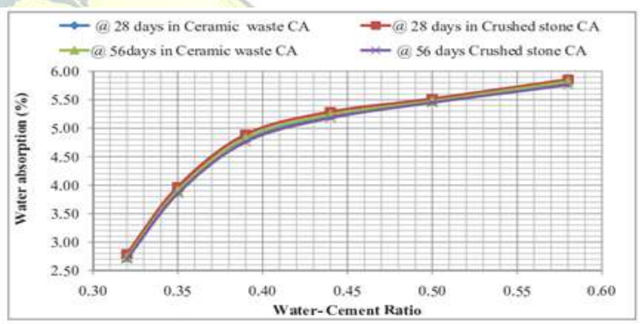
SATURATED WATER ABSORPTION (SWA) FOR CWBA AGGREGATE CONCRETE AND COARSE AGGREGATE CONCRETE

Sl.No	Mix	W/C	Saturated Water Absorption (Percent)	
			28 d	56 d
1	CW1	0.58	5.84	5.76
2	CW2	0.50	5.50	5.45
3	CW3	0.44	5.25	5.18
4	CW4	0.39	4.81	4.76
5	CW5	0.35	3.93	3.85
6	CW6	0.32	2.75	2.70

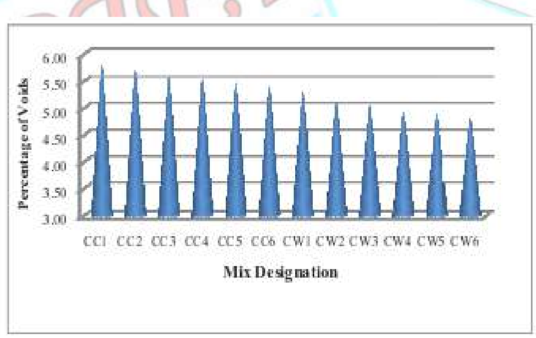
Sl.No	Mix	W/C	Saturated Water Absorption (Percent)	
			28 d	56 d
1	CC1	0.58	5.86	5.82
2	CC 2	0.50	5.52	5.48
3	CC 3	0.44	5.29	5.24
4	CC 4	0.39	4.89	4.83
5	CC 5	0.35	3.97	3.90
6	CC 6	0.32	2.79	2.73

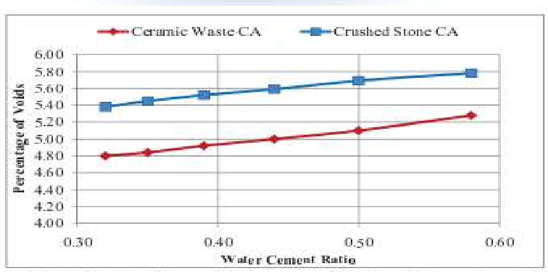




PERCENTAGE OF VOIDS

SL No.	Mix Designation	Percentage of Voids
1	CW1	5.28
2	CW2	5.10
3	CW3	5.05
4	CW4	4.92
5	CW5	4.89
6	CW6	4.80
7	CC1	5.78
8	CC2	5.69
9	CC3	5.59
10	CC4	5.52
11	CC5	5.45
12	CC6	5.38





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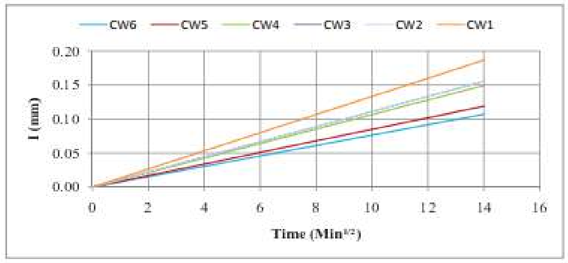
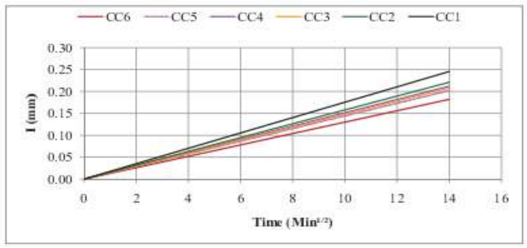
SORPTIVITY

SL No.	Mix Designation	Sorptivity
1	CW1	0.1002
2	CW2	0.0800
3	CW3	0.0760
4	CW4	0.0750
5	CW5	0.0643
6	CW6	0.0600
7	CC1	0.1192
8	CC2	0.1058
9	CC3	0.1051
10	CC4	0.1024
11	CC5	0.1021
12	CC6	0.1008





CONCLUSIONS

1. Ceramic waste and bottom ash could be transformed into useful coarse aggregate and fine aggregate respectively for concrete making through proper processing.
2. The specific gravity of bottom ash fine aggregate is 5.6 percent less than that of river sand.
3. The bulk density of bottom ash fine aggregate is 12.40 percent less than that of river sand.
4. Water absorption of bottom ash fine aggregate is 16.60 percent higher than that of river sand.
5. The specific gravity of ceramic waste coarse aggregate and that of crushed stone coarse aggregate is more or less same.
6. The water absorption of ceramic waste coarse aggregate is 43.61 percent less than that of crushed stone coarse aggregate.
7. The mechanical properties of ceramic waste coarse aggregate are well within the range of the values of concrete making aggregate.
8. The slump values of CWBA aggregate concrete are lower than those of crushed stone coarse aggregate concrete at the respective water-cement ratio.
9. As far as the strengths are concerned, the basic trend in behaviour of CWBA aggregate concrete is not significantly different from those of crushed stone coarse aggregate concrete.
10. There is no much difference in the rate of development of compressive strength of CWBA aggregate concrete when compared to crushed stone coarse aggregate concrete at 28 and 56 d.

11. The basic trend in the relationship between compressive strength and w/c ratio of CWBA aggregate concrete is similar to that of crushed stone coarse aggregate concrete at 28 and 56 d.
12. As in the case of crushed stone coarse aggregate concrete, the strength of CWBA aggregate concrete increases with increase in cement-aggregate ratio.
13. As in the case of crushed stone coarse aggregate concrete, the compressive strength, split tensile strength, modulus of rupture and modulus of elasticity of CWBA aggregate concrete increases with decrease in w/c ratio.
14. Compressive strength of CWBA aggregate concrete is 8 percent to 29 percent and 8 percent to 34 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.
15. Split tensile strength of CWBA aggregate concrete is 5 percent to 21 percent and 5 percent to 13 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.
16. CWBA aggregate concrete has lower tensile to compressive strength ratio when compared to crushed stone coarse aggregate concrete.
17. Modulus rupture of CWBA aggregate concrete is 5 percent to 13 percent and 6 percent to 17 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.
18. The trend in the stress strain behaviour at compression is similar for both CWBA aggregate concrete and crushed stone coarse aggregate concrete with higher modulus of elasticity in CWBA aggregate concrete.
19. Modulus of elasticity of CWBA aggregate concrete is 9 percent to 18 percent and 16 percent to 25 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.
20. The strain at ultimate stress for CWBA aggregate concrete is higher than that of crushed stone coarse aggregate concrete. The area under the stress strain curve is more in CWBA aggregate concrete than crushed stone coarse aggregate concrete

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