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Research Article

Chemical Resistance of Concrete with Ceramic Waste Aggregate

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Abstract

Nowadays there is a huge demand in the natural resources used for making the conventional concrete so to overcome this problem there is a search for use of an alternate material for making concrete. After much investigation we recommend the electrical insulator ceramic waste as an alternate for conventional crushing stone and bottom ash as a partial replacement for river sand. The ceramic waste aggregate concrete shows good resistance to the chemical attacks such as sulphate attack and chloride attack by preventing permeation of these chemicals. The compressive strength of the ceramic waste aggregate concrete is better and there is no considerable change in compressive strength before and after chemical attack. This is due to the material properties of ceramic waste. Ceramic waste aggregate is hard and durable material than the conventional coarse aggregate. It has good thermal resistance and resistance to bio-degradation compare to conventional coarse aggregate. The durability properties of ceramic waste aggregate concrete are also good.

Key words: *Durability, sulphate attack, Chloride Penetration, compressive strength.*

Introduction

At present the construction world is in search of new raw material to overcome the huge demand of traditional concrete making material, so the idea of using industrial waste into the concrete as a replacement for traditional raw materials emerges in the last few decades. From investigations it is recommended to use the industrial waste for making concrete as a replacement. Since the natural raw materials such as sand, gravel are in high deficiency and in huge demand due to depleting of the natural resources for making conventional concrete. Using the industrial waste will give a solution and also leads to safe disposal of hazardous material and economic concrete.

This research is undertaken on the use of lignite-base bottom ash as fine aggregate and ceramic waste as coarse aggregate in structural grade concrete making. Due to the use of ceramic waste as a coarse aggregate the concrete is named as **"Ceramic Waste Aggregate Concrete"**. In ceramic industry, about 30% of production turns to be waste and they are not recycled property at present .Ceramic waste are the waste of electrical insulator and other sanitary products manufacturing industries.

In India, about 100 millions of tons of fly ash are produced in one year by the electrical thermal power plant. In which 20 to 30 percent is bottom ash. Bottom ash is the coarse, solid residue mineral obtained by burning coal in boilers. At present about 80% of coal combustion by products are treated and stored in surface impoundments, mines and quarries.

In most of industries the bottom ash and electrical insulator ceramic waste are used as a land-fill or sluiced to storage lagoons. 30% of bottom ash is used as pond ash. It is potentially usable but the characteristic of bottom ash vary due to its manner of disposal. In this research coarse aggregate is 100% replaced by ceramic waste, and 50% of sand is replaced with bottom ash. Silica fumes added as admixture to strengthen the (ITZ) Interfacial Transition Zone in cement concrete. The concrete properties will be improved by this reaction the use of bottom ash and ceramic waste as coarse aggregate will lead to green environment and serve the natural resources like river sand.

Cement concrete is the most extensively used material for construction of different types of structures such as buildings, bridges, and shell roofs and also for precast products such as pipes, poles, sleeper, etc. In past and even at the present times, too much emphasis is placed on concrete compressive strength rather than on environment factor, which are known to affect concrete durability. This is one of the main reasons for serious deterioration of concrete structures that is prevalent today. Maintenance and repair constructed facilities is presently the most significant challenge facing by the concrete industry in the country, the issue of durability has replaced concerns about strength as the most pressing problem of the day.

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A concrete is said to be durable if it withstands the condition for which it has been designed without deterioration, over a period of years. The term durability of concrete is used to characterize in broad terms the resistance of a concrete to a variety of physical or chemical attacks due to the external causes or by the internal causes. The external causes may be due to weathering, occurrence of extreme temperature, abrasion, electrolytic action and attack of natural or industrial liquids and gases. The internal causes include the alkali aggregate reaction, volume change due to the difference in thermal properties of aggregate and cement paste and above all the permeability of concrete.

Experimental programme

Concrete was prepared in 5 different mix proportions, as shown in Table 3. For each mix proportion, ceramic waste aggregate were used as coarse aggregate and Bottom ash. Tests were carried out to find the durability properties of ceramic waste concrete and also compressive strength was taken for all the mix proportions.

Material Properties

Fine aggregate used for preparation of concrete was a mix of sand (50%) and bottom ash (50%) obtained from powdered coal combustion residues from the thermal power plant of Neyveli Lignite Corporation. The combined fine aggregate was conforming to particle size distribution of grading zone II. The chemical properties of bottom ash are presented in Table1

Crushed ceramic aggregate was used as coarse aggregate for preparation of concrete. The crushed ceramic aggregates had maximum size of 20mm. Physical properties of the crushed ceramic aggregates are presented in table 2. For comparison with normal concrete, 20mm size stone aggregates were also used for preparation of mixes. Figs.1 and 2 show the ceramic aggregates and stone aggregates respectively.

Table 1 Chemical properties of bottom ash

S.No.	Chemical Property	Percentage
1	Loss on ignition	11.93
2	Silica (SiO_2)	52.71
3	Iron Oxide (Fe_2O_3)	29.36
4	Titanium Oxide (TiO_2)	0
5	Alumina (Al_2O_3)	1.53
6	Calcium Oxide (CaO)	0
7	Magnesia (MgO)	1.76
8	Sodium Oxide (Na_2O)	0.23
9	Potassium Oxide (K_2O)	0.41
10	Sulphur Trioxide (SO_3)	2.07

Table 2 Physical properties of crushed ceramic aggregate

Sl. No.	Property	Value
1	Specific gravity	2.73
2	Maximum size	20 mm
3	Fineness Modulus	6.05
4	Surface texture	Smooth
5	Bulk density (Loose)	1410 kg/m^3
6	Bulk density (Compacted)	1523 kg/m^3
7	Voids (Loose)	48.00%
8	Voids (Compacted)	44.32%
9	Crushing strength	17 kg/mm^2
10	Impact strength	8 J/m^2

Fig.1 Ceramic waste aggregates used in the experiment

Ordinary Portland Cement (OPC) was used for mixing concrete. Different water cement ratios were adopted for preparation of concrete.

Mix Proportions

Table 3 Concrete mixes adopted for the investigation

S.No	Mix no	w/c ratio	Cement kg/m^3	Mix proportion by weight
1	Cw_2	0.5	350	1:2.41:3.73
2	Cw_3	0.44	400	1:1.56:2.79
3	Cw_4	0.38	450	1:1.27:2.48
4	Cw_5	0.35	500	1:1.05:2.24
5	Cw_6	0.32	550	1:0.86:2.04

The concrete mixes with ceramic waste aggregate were prepared. The fine aggregate for ceramic waste concrete was made up of 50% sand and 50% bottom ash obtained from Neyveli Lignite Corporation and 10% of silica fume in addition with cement. Table 3 shows the mixes of concrete used in this experimental investigation. The mix ratio the mix ratios Cw_2, Cw_3, $Cw_{4,}$ Cw_5 andCw_6 were prepared using ceramic waste aggregate to replace the stone aggregate.

Experimental Programme

Twelve cylindrical specimens having 100mm diameter and 200mm length were prepared for Chloride penetration test. Cube specimens of size 100mm were prepared for durability study on ceramic waste concrete and compressive strength. For each mix designation, four specimens were prepared and tested after 28 days and 56 days curing. The compressive strength was taken.

Rapid chloride penetration test

According to ASTM C1202 test, a water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to a 60 v applied DC voltage for 6 hours using the apparatus and the cell arrangement is shown in Figure-1. In one reservoir is a 3.0% NaCl solution and in the other reservoir is a 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included as Table 4 (ASTM C1202) test setup shown in Fig 2 RCPT test results were shown in table 5

Table 4 RCPT ratings (per ASTM C1202)

Charge passed (coulombs)	Chloride Ion penetrability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

Testing of specimens

The specimens were fit in the chamber with the required brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60V is passed continuously. The data logger records the readings of corresponding cells at the every record time with its initial readings. At the end of log time, the system halts after taking the final reading. Average current flowing through one cell is calculated by, Q = 900 * 2 * I Cumulative coulombs.

Fig 2 Specimens in RCPT test setup

Fig 3 Sulphate attack test

Table 5 RCPT test results

S.No	Mix (Kg\m3)	Charge passed (Coulombs) (Q)	Chloride permeability as per ASTM C 1202
1	350	258.3	Very low
2	400	217.8	Very low
3	450	209.7	Very low
4	500	168.3	Very low
5	550	144.9	Very low

permeability. This property will lead to increase the improvement in durability of concrete.

Sulphate Resistance

Concrete cube specimens of size 100 mm were cast and kept in the aggressive medium of 15 cycles (1 cycle = 24 hours wetting and 24 hours drying). The concentrate for the medium is 5% of sodium sulphate solution plus 5% of magnesium sulphate solution by volume. After 15 cycles, alternate wet and dry process, the concrete specimens are taken out and exposed to normal atmospheric condition so as to obtain surface dry. The percentage of difference in weight of the cubes. Then the cubes are followed to compression test and compression strength values are observed and the results are as shown in the table 4 and 5.

Table 6 Sulphate attack test results for ceramic waste aggregate concrete from 28 days

Duration (cycles)	Percentage of weight difference @ 28 days				
	350 kg/m^3	400 kg/m^3	450 kg/m^3	500 kg/m^3	550 kg/m^3
1	0.04	0.04	0.03	0.03	0.02
2	0.12	0.08	0.07	0.07	0.06
3	0.26	0.2	0.22	0.09	0.09
4	0.28	0.24	0.22	0.2	0.2
5	0.32	0.24	0.22	0.24	0.22
6	0.32	0.24	0.24	0.24	0.22
7	0.32	0.31	0.26	0.24	0.24
8	0.36	0.4	0.33	0.31	0.28
9	0.42	0.47	0.35	0.4	0.32
10	0.47	0.51	0.49	0.42	0.36
11	0.58	0.6	0.55	0.47	0.4
12	0.75	0.7	0.64	0.51	0.42
13	0.76	0.76	0.64	0.52	0.44
14	0.81	0.82	0.7	0.58	0.48
15	1.12	1.01	0.97	0.64	0.51

The magnesium solutions readily react with the calcium hydroxide present in Portland cement pastes to form soluble salts of calcium. Compressive strength of ceramic concrete is higher after sulphate attack. There is no surface cracking due to the action of sulphate acting on the surface of concrete.

Table 7 Sulphate attack test results for ceramic waste aggregate concrete @ 56 days

Duration (cycles)	Percentage of weight difference @ 56 days				
	350 kg/m^3	400 kg/m^3	450 kg/m^3	500 kg/m^3	550 kg/m^3
1	0.46	0.33	0.28	0.21	0.19
2	0.46	0.41	0.3	0.26	0.31
3	0.49	0.46	0.33	0.38	0.35
4	0.53	0.55	0.35	0.4	0.35
5	0.55	0.57	0.43	0.42	0.35
6	0.57	0.66	0.51	0.44	0.37
7	0.57	0.66	0.57	0.48	0.47
8	0.66	0.66	0.6	0.5	0.49
9	0.66	0.68	0.62	0.53	0.52
10	0.66	0.71	0.65	0.55	0.53
11	0.66	0.72	0.68	0.57	0.57
12	0.72	0.77	0.72	0.61	0.58
13	0.77	0.83	0.74	0.63	0.61
14	0.96	0.98	0.76	0.66	0.63
15	1.14	1.11	0.98	0.7	0.65

When concrete cracks, it permeability increase and the aggressive water penetrates more easily into the interior, thus accelerating the process of deterioration.

Table 8 Compressive strength of ceramic waste aggregate concrete before and after Sulphate attack

	Compressive strength before sulphate attack N/mm^2		Compressive strength after sulphate attack N/mm^2	
Mix design	28 days	56 days	28 days	56 days
CW-350	39.25	42.57	43.57	46.28
CW-400	43.82	47.6	49.34	53.46
CW-450	48.4	52.2	53.62	57.56
CW-500	55.48	59.28	59.85	63.25
CW-550	59.42	63.22	63.42	67.23

From the observations, the compressive strength of ceramic weight concrete at 28 days and 56 days are slightly increased after sulphate attack.

Results and Discussion

The durability properties of ceramic waste aggregate concrete were determined by the following tests.

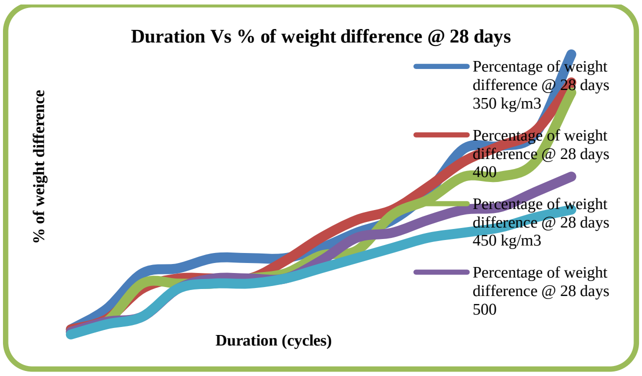

Fig 4 Percentage of weight difference due to sulphate attack at 28 days

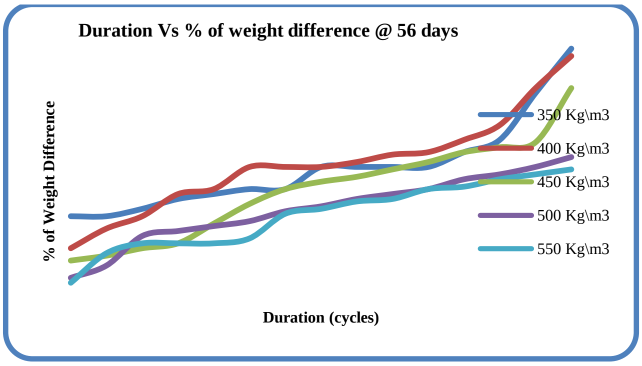

Fig 5 Percentage of weight difference due to sulphate attack at 56 days

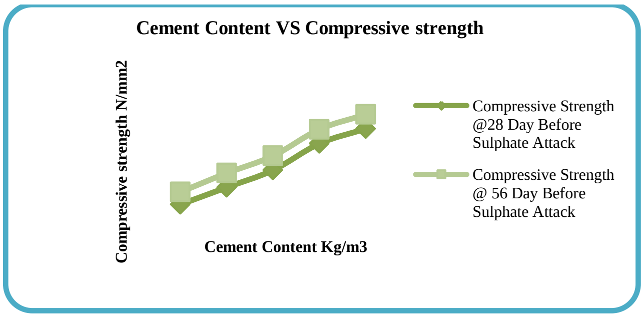

Fig 6 Compressive strength of ceramic waste aggregate concrete before sulphate attack

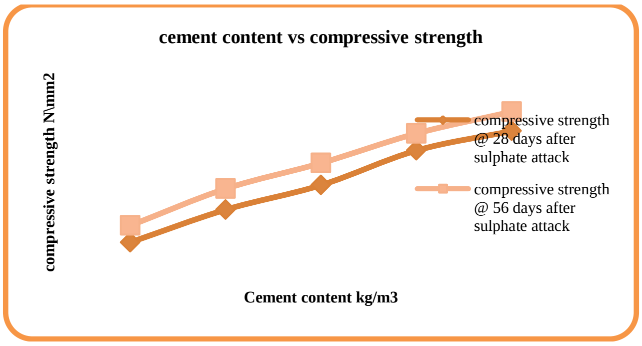

Fig 7 Compressive strength of ceramic waste aggregate concrete after sulphate attack

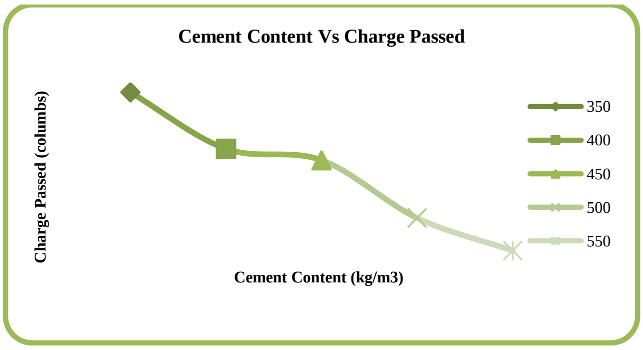

Fig 8 Rapid Chloride Penetration Test Result

Conclusion

With reference to the experimental program carried out, the following conclusions are arrived.

Compressive strength of ceramic waste aggregate was investigated, using 30 specimens tested at 28 or 56 days of curing. Fine aggregate for the concrete was made up of sand conforming to grading zone-II (50%) and bottom ash obtained from powdered coal furnace of Neyveli Lignite Corporation (NLC) power plant (50%).Following deductions are made from the experimental results:

- Compressive strength achieved by ceramic waste aggregate concrete was good.
- Reduction in water cement ratio resulted in increase of compressive strength for the ceramic waste aggregate concrete.
- Reduction in water cement ratio led to increase in compressive strength upto 85% at 28 days and 95% at 56 days for ceramic waste aggregate concrete.
- The properties of Ceramic waste (Electrical insulator scrap) and Bottom ash are nearer to the properties of conventional aggregate. Hence it suited for concrete making.
- The Mechanical properties of Ceramic concrete are good, this due to the replacement of sand by Bottom ash and an addition of admixtures (highly reactive Silica fume).
- The Durability properties of Ceramic concrete are good and better, this is due to presence of fewer pores in concrete.
- Permeation characteristics of Ceramic concrete are less; this is due to addition of ceramic waste aggregate and silica fume.
- Density of Ceramic waste aggregate concrete is nearer to conventional concrete. The ceramic waste aggregate concrete shows good resistance to sulphate attack since there is no considerable damage in concrete.
- The permeation properties are low in ceramic waste aggregate concrete since low values were obtained in rapid penetration test.

Therefore by results, the ceramic waste aggregate concrete may be used for constructions.

References

Senthamarai RM and Devadas Manoharan P.(2005) Concrete with ceramic waste aggregate, *Cement and concrete composites J.*, vol.27,pp. 910-913.

Nisnevich M., Sirotin G., Dvoskin L and Eshel Y. (2001) Effect of moisture content of highly porous bottom ash on properties of concrete mixtures and hardened concrete , *Magazine of concrete Research J.*,Vol.53, No.4, august 2001.

Ghafoori N. and Bucholc J. (Aug 1996) Investigation of Lignite-Based bottom ash for structural grade concrete, *Journal of Materials in Civil Engineering*.

De Brito J., Pereira A.S and Correia J.R (2004), Durability of recycled aggregate concrete: a safe way to sustainable development *Cement and concrete Composites J.*, Vol. 25, pp. 223 – 232

We Energies Coal Combustion Products Utilization –Hand Book.

American Coal Ash Association.919960 (1997), Coal Combustion Product – Production and Use .Alexandria, Virginia

Ay N. and Unal M. (2001) The use of ceramic title in cement production ,*Cement and Concrete Research J.*, (31), pp. 161-162.

Pera J., Coutaz L., Ambrosie J and Chababbet M. (1997) Use of incinerator bottom ash in concrete, *Cement and Concrete Research J.*, Vol.27, No.1, pp. 1-5.

Dawson A.R. and Bullen F (Oct 1991) Furnance bottom ash; its engineering properties and its useas a sub-base material ,*Proc. Instn Civ. Engrs*.

Ghafoori N. and Yuzheng Cai. (April 1998) Laboratory – made roller compacted concretes containing dry bottom ash: part 1 – mechanical properties ,*ACI Materials Journal J.*, Vol. (95), NO.2.

Kumar Mehta P. and monteiro P.J.M (1999) Concrete – Microstructure, Properties and Materials, *Indian Concrete Institute*, Chennai, India.

Kropp K. and Hilsdrof H.K (1995) Performance criteria for concrete durability, E & FN SPOON, London, RILEM report 12.

Mindess S. and Francis Young J. (1981) Concrete, *Prentice-Hall, Inc.*, E Wnglewood Cliffs, New Jersey.

RM. Senthamarai, P. Devadas Manoharan, D. Gobinath (May 2011), concrete made from ceramic industry waste : Durability properties Original Research Article Construction and Building Materials, Volume 25, Issue 5, Pages 2413-2419