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Effect of Ceramic Sludge Waste as a Part of Cement on Chloride Permeability and Compressive Strength of Concrete

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Abstract: ***Concrete is very commonly used construction material. After water concrete is second largest material that is consumed on the planet. The advantage of this material is it can be made by common materials and that are easily available. As consumption of concrete is very high, consumption of cement is also very high. Production of cement produces high amount of CO_2. Around 1 tons of CO_2 produces due to production of 1 tons of clinker. To save environment we have to find alternate solution for making concrete and partial replacement is one of the solution to reduce production of CO_2.In this study, effects of waste material as partial replacement of cement on the Chloride permeability and compressive strength of concretes were experimentally investigated. The main parameter investigated in this study was M30 grade concrete with partial replacement of cement by waste material (CSW-Ceramic Sludge Waste). The percentage of replacement at the levels of 0%, 10%, 20%, 30% and 40% was examined. In this research a detailed experimental study on compressive strength and chloride permeability were carried out at an age of 7,14and28 days. This investigation shows that ceramic sludge waste can be utilized as partial replacement of cement up to 20% without any loss of strength and durability of concrete.***

Index Terms: ***Ceramic sludge Waste(CSW), Compressive strength test, Concrete using waste material, Durability of concrete, RCPT test.***

I. INTRODUCTION AND REVIEW OF PAST WORK

Strong and durable Structures are very essential for human beings. There are many different materials available for construction like concrete, brick, stone, and glass, steel etc. They must have some properties like strength, workability, durability and they need to be molded to any shapes. Concrete is one of the materials which fulfill the entire requirement for easy construction of any structure.

Concrete is mixture of different material like fine aggregate, coarse aggregate, binding material (cement), water and different admixture. Concrete is second largest material after water used by human beings. Cement is the main ingredient used as binding material in concrete. From the statistic portal, India is second largest country after China in production of cement. India reached 290 million metric tons in cement production in the year of 2018[1]. Production of cement creates hazard for earth by large emission of green house gases viz. CO_2 to the atmosphere. One ton of cement is estimated to release 0.9 tons of CO_2 [2,3] and that pollutes atmosphere. To reduce carbon footprint t is inevitable to find replacement of cement. Ample research has been carried out for replacement of cement with different waste materials like GGBFS, fly ash, rice husk ash, silica fume, sludge waste etc…related literature for above mentioned supplementary cementitious material(SCM) are listed in references.

Lowest mean distribution radius for OPC with silica fume gives higher amount of hydration [4]. Dispersion coefficient is high so better packing characteristics observed due secondary pozzolonic reaction between silica fume and OPC [4].effect of glass powder(GP) and ground granulated blast furnace slag (GGBS) as a partial replacement in cement on the properties of concrete was carried out. Addition of GP and GGBS reduced the sorptivity rate and water absorption rate. GP and GGBS can be successfully utilized as an effective mineral admixture in cement concrete with 15% and 35%respectively as a optimal replacement of cement in [5].

Use of supplementary cementitious materials (SCM) reduces heat oh hydration in some of the research shows a reduction in the heat of hydration by partially replacing cement with 45% FA.[7]. HVFA increases workability of concrete. The increment in the slump highest was 21.43%, 7.14% and 0% with the inclusion of 50%, 60% and 70% FA[8].Concrete mixes containing 30% red granite dust (RGD) showed good fresh properties. Better early age strength was encountered for concrete with 30% RGD than similar PFA-based concrete. Up to 50% replacement of cement with RGD mechanical properties of concrete remained acceptable [9].

Effect of combination of different waste material in concrete as aggregate and cement replacement was also carried out. Combined application of stone dust and Fly Ash can be adopted as natural sand and Ordinary Portland cement replacement. The optimum results were obtained at 60% of stone dust and 20% of Fly Ash.[10]

In current days large amount of ceramic sludge waste is generated by ceramic industry and dumping of waste coming out of these industries is becoming critical environmental issue. So use of ceramic sludge waste will lead to eco-friendly concrete. This waste is collected in the form of pest and after drying and hand crushing it is sieved through 90 microns.

Keeping all this view, the aim of this study is to check the behavior of concrete while replacing the ceramic waste with different proportions in concrete.

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Also durability aspect was not covered by majority of researchers, so in this study that aspect is also covered by RCPT test

II. MATERIALS AND EXPERIMENAL PROGRAMME

Cement: (OPC) 53 grade ordinary Portland Cement conforming to IS12269 [11] used for our research work. The basic properties like surface area, specific gravity, initial setting time and final setting time was carried out and results were tabulated in Table1.

Table 1. Properties of OPC 53 grade cement

Parameters	Result Obtained	Limits as per IS:12269 [19].
Fineness-Specific Surface (m^2/Kg.)	285	Minimum -225.0 (m^2/Kg.)
Standard consistency in (%)	30	---
Initial setting time(Min.)	47	Minimum - 30 Minute
Final setting time(Min.)	260	Maximum- 600 Minute
By Le-chat Expansion in (mm)	2.12	Maximum-10.00 mm
Compressive Strength in (Mpa)		
3 Days	30.56	Minimum- 27.00 Mpa
7 Days	39.81	Minimum- 37.00 Mpa
28 Days	56.14	Minimum- 53.00 Mpa

Fine aggregate: In our research work we have used natural river sand having specific gravity 2.67. Grading of fine aggregate conforming IS 383-1970 [12]. Other properties are tabulated in Table 2.

Table 2 Properties of fine aggregate

Parameters	Observation	Limits
Sand Falls in Zone	II	--
Finess Modulus of sand	3.0	---
Water Absorption (%)	1.1	Max - 2 %
Sp.Gravity of Sand	2.67	2.6 - 2.7
Silt Content (finer than 75 mic. (%))	2.2	max.- 3 %

Coarse aggregate: Grading of coarse aggregate used for this research work was conforming IS 383-1970. Specific gravity found out for coarse aggregate was 2.81 [12]. Other properties of coarse aggregates tabulated in Table 3. Maximum size of aggregate used for research was 20 mm.

Table 3. Properties of coarse aggregate

Parameters	Observation	Limits
Water Absorption in (%)	0.97	Max. - 2.0 %
Sp.Gravity	2.81	2.6 - 2.9
Elongation Index in (%)	12.34	--
Flakiness Index in (%)	10.70	--
Aggregate Impact value (%)	14.35	Max.-45.0 %
Aggregate Crushing Value (%)	17.37	Max.-45.0 %
Aggregate Abrasion Value (%)	17.40	Max.-45.0 %

Ceramic sludge Waste (CSW): Ceramic sludge waste was collected from locally available dumping site near himmatnagar city. Specific surface area of CSW was 728 m2/kg. Specific gravity of ceramic sludge waste was 2.47. Other chemical properties are tabulated in Table 4.

Table 4. Chemical composition of selected material

Types of test	Result obtained
SiO_2	72.41
Al_2O_3	20.6
Fe_2O_3	0.10
CaO	3.97
SO_3	0.11
Loss of ignition	1.44
Fineness-Specific surface(m^2/kg)	728
Particle retained on 45µ sieve	9.20
Specific Gravity	2.47
Lime reactivity avg compressive strength(N/mm^2)	9.20
Compressive strength at 28 days(%)	85.19%

Water used for this work for mixing and curing was good quality and having Ph value within permissible limits (IS 456 :2007)[13].

Mix design and methodology of work

For finding out the effects of CSW on the concrete we have casted concrete of grade M30 in this investigation. We have followed Indian standard for mix design. As per mix design detailed quantity of each material is mentioned in Table 5. Ceramic sludge waste was used as partial replacement of cement in varying percentage of 0% (MIX 1-control mix), 10% (MIX10), 20% (MIX 20), 30% (MIX30) and 40% (MIX40). The basic parameter for this investigation was effect of CSW on mechanical properties of concrete. For determining the mechanical properties of concrete specimen of size 150mm * 150mm * 150mm cube ware casted. For durability test, 100 mm diameter and 50 mm height cylinder specimens were cast for RCPT test.

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Water cement (binder) ratio was 0.5 and slump value was varying from 50 to 70 mm.

Table 5: mix design of M30 Concrete(W/Binder=0.5)

MIX	Cement (Kg)	Water (lit.)	CA (Kg)	FA (Kg)	CW (Kg)
MIX1	20.20	9.10	60.44	34.40	0.00
MIX10	18.18	9.10	60.44	34.40	2.02
MIX20	16.16	9.10	60.44	34.40	4.04
MIX30	14.14	9.10	60.44	34.40	6.06
MIX40	12.12	9.10	60.44	34.40	8.08

III. TESTS, RESULTS AND DISCUSSION

A. Effect of CSW on compressive strength of concrete.

Quality of concrete is determined by the mechanical and durability properties of concrete. Compressive strength tests were carried out as per IS 516:1956[14] and results were tabulated in Table 6. The arrangement of compressive strength test was shown in Figure 1. Based on average compressive strength of three numbers of specimens for each day final compressive strength was counted.

The test was carried out at three different ages 7, 14 and 28 days of curing. There was noticeable reduction on compressive strength of concrete of MIX30 and MIX 40 at 7 days. The reductions on compressive strength of MIX30 and MIX40 at 7 days were found to be less by 8.38% and 25.80% respectively. The compressive strength of (10 % replacement) MIX10 and (20% replacement) MIX20 at 7 days curing was not much affected. Same effect of CSW on concrete was encountered after 14 days curing. The reduction in compressive strength of MIX30 and MIX40 was found 11.42% and 35.71% respectively after 14 days of curing. The compressive strength of (10 % replacement) MIX10 and (20% replacement) MIX20 at 14 days curing was not much affected. Similarly the reduction of compressive strength at 28 days curing for MIX30 and MIX40 was 26.63. % and 40.16%.

It has been inferred that the maximum percentage of replacement of cement without considerable loss of strength by CSW is 20%. Amount of cement is very essential for hydration process. As percentage of cement replacement is increase the required amount of cement available for hydration is less and the extra waste material is left as inert material so it will reduce the strength of concrete.

Table 6: Compressive Strength of M30 Concrete (W/Binder=0.5)((N/mm^2)

MIX DESIGN	COMPRESSIVE STREGTH AT DIFFERENT AGE		
	7 DAYS	14 DAYS	28 DAYS
MIX1	22.96	31.11	36.15
MIX10	23.11	31.26	35.56
MIX20	23.56	33.19	36.00
MIX30	21.04	27.56	26.52
MIX40	17.04	20.00	21.63

Figure 1: Compressive Strength test setup

B. RCPT Test for durability performance of concrete with CSW

A durability property of concrete is very important. There are several tests available for measuring durability of concrete in this research chloride permeability of concrete with ceramic sludge waste as partial replacement of cement was carried out as per ASTM C1202. Various concrete sample of mixes MIX1, MIX10, MIX20, MIX30 and MIX40 were prepared. According to ASTM C1202[15] cylindrical sample of diameter 100 mm and 50 mm thickness were prepared. According to ASTM C1202 test, specimen is subjected to a 60 v DC voltage for 6 hours. Test setup for RCPT test was as per Figure 2.

As per ASTM C1202 [15] amount of charge passed through samples of various mix was recorded at different interval of time. Average current passed was recorded and tabulated in Table 7. Criteria to rate the chloride permeability of various mix tabulated in Table 8[24]. It was observed that as % of ceramic sludge waste increases chloride permeability of mix decreases. According to ASTM C1202 [15] MIX1 concrete chloride penetration is at moderate level. It was recorded that chloride permeability of MIX10 and MIX20 is also at moderate level. Chloride permeability of MIX30 and MIX40 was found at low level. With addition of ceramic sludge waste chloride permeability of MIX30 and MIX40 reduced by 42.74% and 57.18 % of control mix (MIX1) for 28 days.

Table 7 : RCPT test results

MIX DESIGN	RCPT (CHARGE PASSED IN COULOMBS)
	28 DAYS
CM	3088
CW10	2595
CW20	2184
CW30	1768
CW40	1322

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Figure 2: RCPT test setup

Table 8 : RCPT Ratings as per ASTM C1202[15]

CHARGE PASSED IN COULOMBS	CHLORIDE ION PERMEABILITY
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

IV. CONCLUSION

The effect of ceramic sludge waste on the strength and durability properties of concrete was performed in this study. Following conclusions have need derived from the study:

- Ceramic sludge waste can be successfully used as partial replacement of cement in concrete which reduces not only CO_2 emission in atmosphere from cement production but also reduces land pollution.
- Up to 20 % replacement of cement with ceramic sludge waste gives good compressive strength. Higher amount of replacement of cement reduces the strength because of extra amount of ceramic sludge waste is working as filler material and reduces the amount of cement for hydration process.
- The concrete mix with replacement of cement with ceramic sludge waste shows good resistance against chloride permeability compare to normal mix. This phenomenon was attributed due to alkali binding and low interconnecting voids due to higher amount of ceramic sludge waste. It means that such concrete will give higher resistance against chloride attacks which are serious concern in marine environment.
- As there is no cost of ceramic sludge waste (except transportation cost), concrete with partial replacement of cement with ceramic sludge waste will give economical solution.

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