Experimental Study on Mechanical And Durability Properties of Concrete With Partial Replacement of Cement With Metakaolin And Fine Aggregate With Ceramic Waste

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Abstract- *The present study is to understand the behavior and performance of the concrete when partial replacement of metakaolin and waste ceramic is used as the cement and fine aggregate. In these study two Mix's was carried out where Mix-1 was partial replacement of fine aggregate by ceramic waste as 10%, 15% and 20%. And Mix-2 was said to be the combined partial replacement of ceramic waste (C.W) as fine aggregate and metakaolin as the partial replacement of cement by 5%, 10%, 15%, 20% and 25% and fine aggregate will be considered which optimum at Mix-1. For analyzing the suitability of these waste ceramic powder and metakaolin in concrete of M30 mix. The compressive strength test, split tensile strength test, and flexural strength tests for 7 and 28 days has conducted for all mixes. And a Durability test has conducted for 28 days for the optimum mix in Mix-2*

In this research, the effect of combined replacement of metakaolin and ceramic waste was boost on the compressive, flexural and splitting tensile strength of concrete was studied. Based on the laboratory experiment cube, beam and cylindrical specimens have been designed. The optimum percentage of cement replacing with metakaolin and fine aggregate with ceramic waste was determined to be 20% and 15% for compressive strength, tensile and flexural strength.

Keywords*-* Metakaolin, ceramic waste, Compressive Strength, Split Tensile Strength, Flexural Strength, Durability.

I. INTRODUCTION

Cement both in mortar and concrete, is the most important element of the infrastructure and can be a durable construction material. Generally in design of concrete mix, cement , fine aggregates and coarse aggregates are using from long back, which plays a crucial role in designing of a particular grade of concrete. But now a days there is a scarcity in aggregates. So, some new materials which are locally available for low cost have to introduced for replacing the fine aggregates, coarse aggregates and as well as cement to get the same strength. Cement is widely noted to be most expensive constituents of concrete. The entire construction industry is in search of a suitable and effective waste product that would considerably minimize the use of cements and ultimately reduces the construction cost.

However, the environmental aspect of cement has become a growing concern, as cement manufacturing is responsible for about 2.5% of total worldwide waste emissions from industrial sources. One effective way to reduce the environmental impact is to use mineral admixtures, as a partial cement and river sand additive and replacement both in concrete and mortar, which will have the potential to reduce costs, conserve energy and minimizes the waste emissions.
In present world, huge amount of solid wastes are obtaining from manufacturing units and demolitions of construction from human daily habitats. Some researchers are working on solid waste as partial replacing substances based on the locally available industrial wastes such as Fly ash, Sugarcane bagasse ash, Blast furnace slag, Rice husk ash, Palm oil fuel ash, Wheat straw ash, Silica fumes, Metakaolin, waste Ceramic material, glass powder, over burnt bricks, coconut shells etc., are being used as supplementary cement and fine aggregate additive and replacement materials.

When these pozzolanic materials are added to cement, the silica present in these materials reacts with free lime released during the hydration of cement and forms additional calcium silicate hydrate as new hydration products, which improve the mechanical properties of concrete formulation. Use of cheaper material without loss of performance is very crucial to the growth of developing countries.

The present study is to understand the behavior and performance of the waste ceramic material is used as the partial replacement of fine aggregate by 10%, 15% and 20% say M1, M2 and M3 respectively. Combined partial replacement of ceramic waste as fine aggregate where maximum strength obtained in above three mixes will be taken as constant replacement and metakaolin as the partial replacement of cement by 5%, 10%, 15%, 20%, 25% say M4, M5, M6,M7 and M8 respectively. For analyzing the suitability of these waste ceramic material and metakaolin in concrete mix M30 the compressive strength test, split tensile strength test and flexural strength tests for 7 and 28 days are conducted for all mixes. And durability test will be conducted for optimum mix.

METAKAOLIN

Metakaolin is one of recently developed mineral admixture used to replace a part of cement in the manufacture of cement of HPC. Metakaolin is a manufactured by pozzolanic material. The production of Portland cement is not only costly and energy intensive, but it also produces large amount of carbon emission.

The production of one to of Portland cement produces approximately one ton of CO2 in the atmosphere. Limestone is a raw material available in nature; it is primary need for production of cement material. Earlier it was used directly to form silica flume mortar as a binding material in construction.

Supplementary cementitious materials are often used to reduce cement contents and improve the workability of fresh concrete, increase strength and enhance durability of hardened concrete.

SCMs used in the manufactured concrete products industry as well as a review of blended cements. There are various types of supplementary cementitious material as fly ash, silica fume, slag cement, metakaolin, rice husk ash, coconut shell etc. Out of above Supplementary Cementitious Materials (SCMs) we use Metakaolin as partial replacement of cement and experimental investigation is carried out.

Fig: 1 Metakaolin Powder

Metakaolin is a mineral admixture which confirms class-N pozzolanic specifications. By heating purified kaolin clay within specified temperature range 650-900ºc.The water processed, refined and dried kaolin is thermally activated to make highly reactive Metakaolin. Alkali-silica reaction is a reaction between calcium hydroxide (the alkali) and glass (the silica) which can cause decorative glass embedment in concrete to pop out. Because metakaolin consumes calcium hydroxide, it takes away the alkali and the reaction does not occur.Metakaolin is compatible with most concrete admixtures, such as super plasticizers, retarders, accelerators, etc. If questions arise as to compatibility with any admixtures you use in your mix, consult with the admixture manufacturer for guidance.

CERAMIC WASTE MATERIAL

The ceramic waste is one of the mineral admixtures used as a partial replacement of cement and aggregates. It is available in different sizes and shapes. The ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. Due to the pozzolanic property of ceramic waste the durability is increased.

Indian ceramic 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.

The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry.

As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal. The advancement of concrete technology can reduce the consumption of natural resources. They have forced to focus on recovery, reuse of natural resources and find other alternatives.

The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

Fig: 2 Ceramic Waste material

II. OBJECTIVES OF THE WORK

The following objectives have to identify:

1. To identify the compressive strength, split tensile strength and flexural strength of M30 for 7 and 28 days with waste ceramic material replacement in fine aggregate by 10%, 15% and 20% say as Mix-1.
2. To identify the compressive strength, split tensile strength, flexural strength and Durability characteristic of M30 grade for 7 and 28 days with combination of waste ceramic material partially replaced in fine aggregate where maximum strength obtained by above mix and metakaolin in cement by 10%, 15%, 20%, and 25% respectively say as Mix-2.

III. SCOPE OF THE WORK

The scope of this dissertation was carried out to study the parameters which influence the compressive strength, split tensile strength and flexural strength of the concrete mix M30 by replacing fine aggregate with waste ceramic material and combination by replacing fine aggregate with waste ceramic material and cement with metakaolin as the mixes designated in introduction M1, M2, M3, M4, M5, M6, M7, M8 These concrete mixes were produced, tested and compared with the conventional concrete which is designated as M0 and from M0-M3 was said to be MIX-1 and M4-M8 was said to be MIX-2.

Scope of our present work is cost reduction and at the same time reduction of waste disposal of ceramic waste. By using metakaolin the compressive strength also increases when compared with conventional mix. It also reduces pollution which is caused due to cement production.

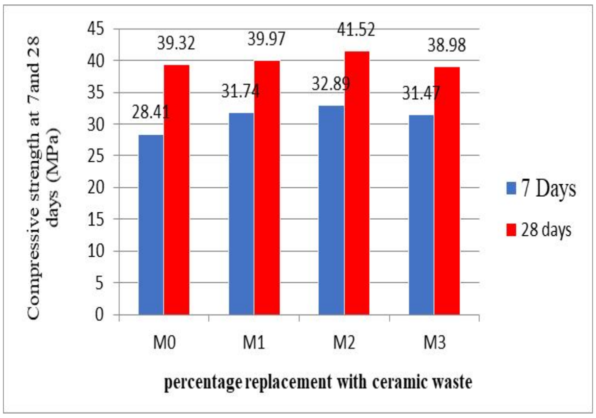
Table 1: Different percentages of Metakaolin & Ceramic waste powder

S.NO	MIX Designation	Percentage replacement ofcement with Metakaolin	Percentage replacement of Fineaggregate with Ceramic waste
1	M0	0%	0%
2	M1	0%	10%
3	M2	0%	15%
4	M3	0%	20%
5	M4	5%	15%
6	M5	10%	15%
7	M6	15%	15%
8	M7	20%	15%
9	M8	25%	15%

IV. RESULTS

Table2:Compressive strength results for MIX-1

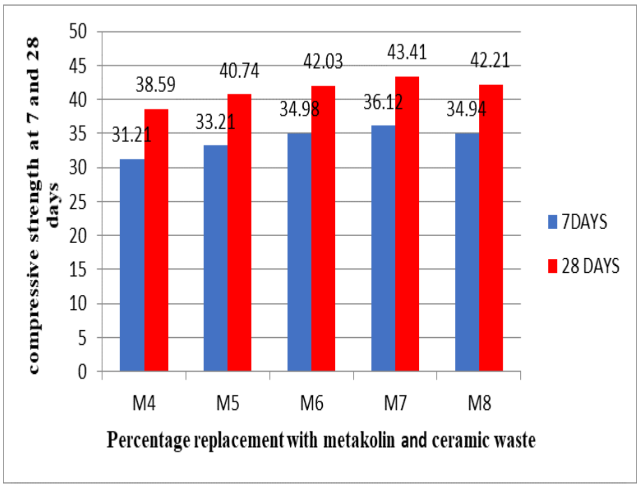
MIX Designation MIX-1	Percentage replacement in Fine aggregate		Compressive Strength N/mm^2	
	F.A	C.W	7 days	28 days
M0	100%	0%	28.41	39.32
M1	90%	10%	31.74	39.97
M2	85%	15%	32.89	41.52
M3	80%	20%	31.47	38.98



Graph 1: Compressive strength at 7 days and 28 days for nominal mix and partial replacement with Ceramic waste for MIX-1

Table3: Test result for Compressive strength by using ceramic waste and metakaolin for MIX-2

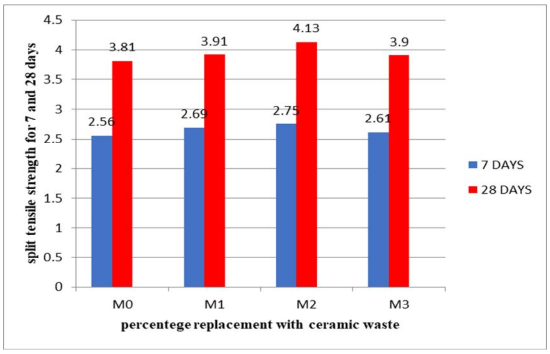
MIX Designation MIX-2	Percentage replacement in cement		Percentage replacement in F.A		Compressive Strength N/mm²	
	Cement	Meta kaolin	F.A	C.W	7 days	28 days
M4	95%	5%	85%	15%	31.21	38.59
M5	90%	10%	85%	15%	33.21	40.74
M6	85%	15%	85%	15%	34.98	42.03
M7	80%	20%	85%	15%	36.12	43.41
M8	75%	25%	85%	15%	34.94	42.21



Graph 2: Compressive strength at 7 and 28 days Vs % replacement with Metakaolin & Ceramic waste for MIX-2

Table 4: Split Tensile strength test result for 7 and 28 days for MIX-1

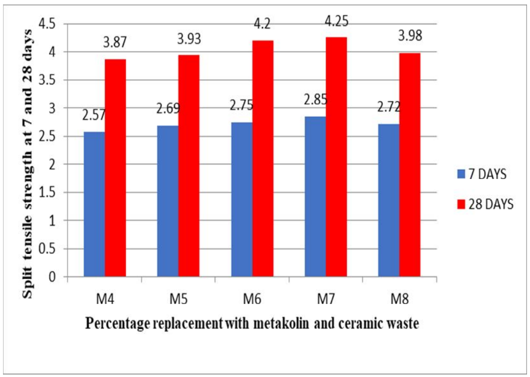
MIX Designation MIX-1	Percentage replacement in Fine aggregate		Split Tensile Strength N/mm²	
	F.A	C.W	7 days	28 days
M0	100%	0%	2.56	3.81
M1	90%	10%	2.69	3.91
M2	85%	15%	2.75	4.13
M3	80%	20%	2.61	3.90



Graph 3: split tensile strength for 7 and 28 days replacement with ceramic waste

Table 5: Split Tensile strength at 7 and 28 days replacement with Metakaolin & Ceramic waste for MIX-2

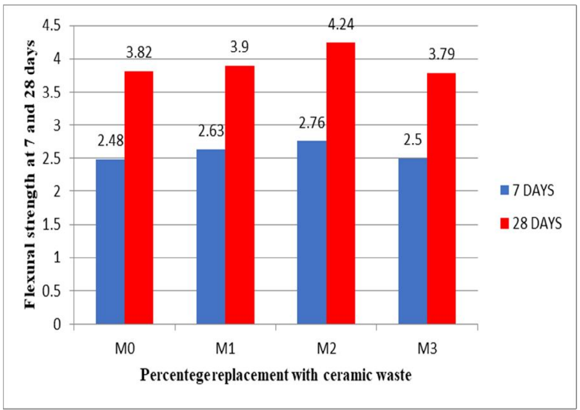
MIX Designation MIX-2	Percentage replacement in cement		Percentage replacement in F.A		Split Tensile Strength N/mm²	
	Cement	Metakaolin	F.A	C.W	7 days	28 days
M4	95%	5%	85%	15%	2.57	3.87
M5	90%	10%	85%	15%	2.69	3.93
M6	85%	15%	85%	15%	2.75	4.20
M7	80%	20%	85%	15%	2.85	.25
M8	75%	25%	85%	15%	2.72	3.98



Graph 4: Split Tensile strength at 7 and 28 days replacement with Metakaolin & Ceramic waste for MIX-2.

Table 6: Flexural strength test result at age of 7 and 28 days for MIX-1

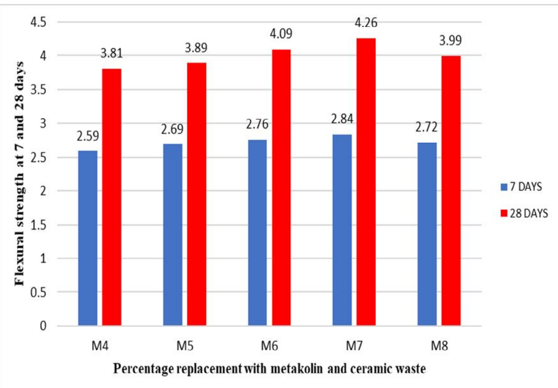
MIX Designation MIX-1	Percentage replacement in Fine aggregate		flexural Strength N/mm²	
	F.A	C.W	7 days	28 days
M0	100%	0%	2.48	3.82
M1	90%	10%	2.63	3.90
M2	85%	15%	2.76	4.24
M3	80%	20%	2.50	3.79



Graph5: Flexural strength at 7 and 28 days Ceramic waste

Table 7: Flexural strength at 28 days Vs %replacement with Metakaolin& Ceramic waste

MIX Designation MIX-2	Percentage replacement in cement		Percentage replacement in F.A		Flexural Strength N/mm²	
	Cement	Metakaolin	F.A	C.W	7 days	28 days
M4	95%	5%	85%	15%	2.59	3.81
M5	90%	10%	85%	15%	2.69	3.89
M6	85%	15%	85%	15%	2.76	4.09
M7	80%	20%	5%	15%	2.84	4.26
M8	75%	25%	85%	15%	2.72	3.99



Graph 6: Flexural strength at 28 days Vs %replacement with Metakaolin& Ceramic waste

V. DURABILITY STUDY

Cement is not completely impervious to acids. Most corrosive arrangements will gradually or quickly break down Portland bond concrete contingent on the sort and convergence of corrosive. The strength of cement in this test work was completed by measuring corrosive resistance at various periods of curing.

The solid corrosive resistance was seen by two sorts of tests named as Acid assault component test and Acid toughness variable test. The convergences of acids in water are 0.5% HCL and H2SO4. Concrete can be assaulted by fluids with pH esteem under 6.5 and assault is extreme when pH quality is underneath 5.5. At pH esteem beneath 4.5, the assault is exceptionally extreme. As the assault continues, all the concrete mixes are split down and drained away. Here HCL and H_2SO_4 which are having pH esteem 4.75 and 2.75 which cause an exceptionally extreme assault is utilized to consider the sturdiness properties.

Concrete with Ordinary Portland Cement is the significant arrangement in present constructional exercises. A solid structure was great in quality can likewise be great in giving administration life. Solidness is of solid structure is advocated just when it demonstrates unwavering quality in its life time. More solidness means more administration life of structure. The solid under marine environment and presented to forceful synthetic assault through water are the significant issues in diminishing the life time of structure. To defeat this issue, legitimate solidness studies are required for cement before cementing a structure.

Requirements of Study:

To check the Acid resistance of concrete Hydro Chloric acid (HCl), Sulphuric Acid (H_2SO_4) is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

Table 8: Summary of brief details for durability study

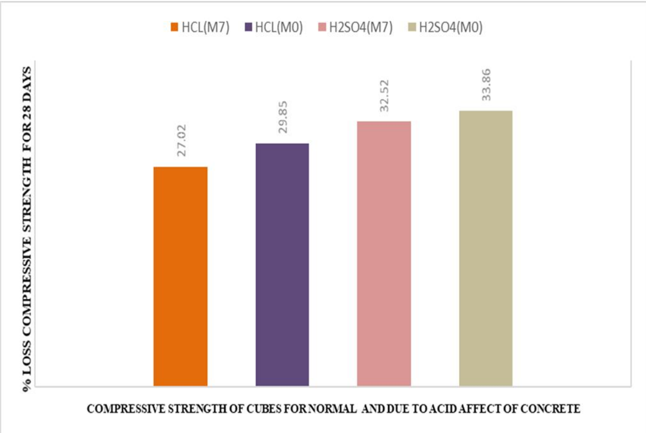
Acids used	HCL, H_2SO_4
Concentrations for trails	0.5% in water
Number of days of testing	and 28 days

Table 9: Durability Compressive strength results for mix M7:

Combined replace of metakaolin and ceramic waste	28 Days (HCl)	28 Days (H_2SO_4)
	% loss of Compressive Strength after 28 days of acid curing (MPa)	% loss of Compressive Strength after 28 days of acid curing (MPa)
20%&15%	27.02	32.52

Table 10: durability compressive strength results formix M0:

Nominal mix	28 Days (HCL)	28 Days (H_2SO_4)
	% loss of Compressive Strength after 28 days of acid curing (MPa)	% loss of Compressive Strength after 28 days of acid curing (MPa)
Mix(M0)	29.85	33.86



Graph 7: Compressive strength of concrete due to acid affect

VI. CONCLUSIONS

- The compressive strength at the age of 7 days and 28 days was increased at mix M7 of about 11.41% than the conventional mix M0.
- The split tensile strength at the age of 7 days and 28 days was more at mix M7 of about 9.63% when compared to conventional mix M0.
- The flexural strength at the age of 7 days and 28 days has increased at mix M7 of about 10.22% when compared to conventional mix M0.
- Durability compression strength results were satisfied when compared to mix M7 and nominal mix MO.
- From the experimental investigations we found a possible alternative solution of safe disposal of ceramic waste.
- By this experimental study we can reduce the cost of concrete. Now a day's river sand price is gradually increasing by replacing it with ceramic waste there will be economical benefit and the natural resource (River sand) is also saved.

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