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EXPERIMENTAL STUDY ON TRIPLE BLENDED HIGH PERFORMANCE CONCRETE WITH CERAMIC WASTE AND METAKAOLIN

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Abstract: - The Ceramic waste is generated in large quantity during manufacturing process of tiles and other ceramic products. These creates many hazards to both environment and human being. The development of High-Performance Concrete is essential requirement of construction industry without harming the environment and Mechanical properties of concrete. Metakaolin is also one of waste material which possesses good physical and chemical properties. The Ceramic waste and Metakaolin have been incorporated in this experimental study as a partial replacement of cement. The Metakaolin helps concrete to protect against alkali silicate reaction and sulphate attack. It is widely used mineral admixture with concrete. This study is based on trial and error approach with various proportion of ceramic waste and metakaolin as a replacement. The percentage of ceramic waste is taken constant and variation is allowed in percentage of Metakaolin.

***Keywords**: - High Performance Concrete; Ceramic waste; Metakaolin; Mechanical Properties; Mix Design etc.*

I. INTRODUCTION

The Concrete is the backbone and most consumed material of construction industry. Concrete has the highest area occupancy in the construction work and stability requirement is on top priority. The researchers and scientists have been working on improving conventional concrete in such a way that it exhibits extraordinary compressive strength, good durability, and performance in long run etc. from the past few years, the direction of research have been moved towards looking into new cementitious material that can partial or fully replace the Portland cement. As we know, the Cement manufacturing process involves emitting many toxic gases which are hazardous for environment and human being as well. Under this progress, many waste material have been searched out like Metakaolin, Ceramic Waste, Ground Granulated Blast Furnace Slag, Sugarcane Ash, Microfine. Millet husk etc. which are available in abundant quantity.
The High-Performance concrete is high quality

Cementitious material which can fulfill requirement of better stability, great strength, and extraordinary performance during service life of structure. In this experimental study, the waste material of Ceramic industry and Metakaolin have been incorporated into the concrete mix as a replacement of cement. The Triple blend mixture consists of cement, ceramic waste and metakaolin with various proportion as per mix design based on trial and error approach. Many previous studies have shown positive results on adding this material on early stage but reported some negative results on late age strength and

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performance. The major aim of this study is to explore the effect of metakaolin and ceramic waste on mechanical properties of concrete. The target strength was taken as 60 MPa for various proportions used for this study. Metakaolin is the waste material which is made up of warm porcelain mud. Metakaolin is used to strengthen cement by filling the pores and voids of the concrete mixture. It also makes cement stable against sensitivity to gases. It is obtained by the process of calcination in which kaolinite clay is heated at very high temperature ranges between 650º C to 850º C. The Ceramic waste is found in the manufacturing process of ceramics and demolition of civil structure. The high-performance concrete is basically designed to get better mechanical properties and resistance to sulphate and chemical attack. The scientists and researchers have been continuously working on searching out alternative cementitious material which can not only replace the Portland cement but also provide addition stability to conventional concrete.

II. MATERIALS

A. Materials

a. Metakaolin:

It is highly reactive supplementary cementitious material that is produced by the process of hydroxylation. The natural clay mineral kaolin is heated at high temperature to form into metakaolin. It is fine grained powder having average particle size 2.5 μm. It has good binding property and helps to reduce the rate of corrosion. It is added into the concrete to improve the strength and performance of concrete.

- Physical Composition:

Material Color: Off White
Specific Gravity: 2.60
Physical form: Powder
Avg. Particle Size: less than 2.5 μm

- Chemical Composition (Major Element):

Al_2O_3: 21.50%
SiO_2: 57.50%
L.O.I: 16.13%

b. Ceramic Waste:

The ceramic industry has been expanding exponentially to approximately 800 million Sq. m. in India. The Ceramic product is made up of glazes, stains and clay which contains toxic metals like cadmium, copper, and chromium. These wastes have potential to use into the concrete mix as a replacement of cement. The feasibility of using this material is main challenge for this kind of experimental study.

- Chemical Composition (Major Element):

Al_2O_3: 13.43%
SiO_2: 70.00%
L.O.I: 8.37%

c. Portland Cement:

The Cement is the core binding ingredient of concrete. The physical and chemical strength of cement makes a vital impact on overall strength and performance of concrete. The OPC 53 grade Cement have been used in this study. The cement must be finely graded and have decent amount of Tri calcium silicate to control rheological factor.

d. Fine and Coarse Aggregate:

The High-Performance concrete requires the high quality of fine and coarse aggregate in terms of strength, dispersion of material, gradation etc. The size, shape and texture of aggregate make a direct impact on compressive strength and performance of concrete. The coarse aggregate ranges from 9.5

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mm to 12.5 mm have been used in this study. The interlocking between all ingredient mainly depends on coarse aggregate because of largest volume covering in the concrete mixture.

e. Admixture:

In this experimental study, the admixture Perma Plast PC-405 have used for improving strength and performance. The benefit of using this admixture to control segregation and bleeding for better fixing of ingredient results into better bonding. The doses were decided as per mix design requirement. The amount of admixture was taken as 0.9% by weight of cement. It reduces water quantity also and provide efficient workability.

III. METHODS AND EXPERIMENTAL DATA

a. Cement Test Results

Testing Parameters	Result Obtained	Criteria as Per IS 12269:2013	IS Code
Specific Gravity	3.14	-	IS 4031-part 11
Consistency (%)	31	-	IS 4031-part 4
Initial Setting Time	45 mins	30 mins	IS 4031-part 5
Final Setting Time	338 mins	600 mins	IS 4031-part 5
Compressive Strength (N/mm^2)			IS 4031-part 6
3 Days	30.35	27	
7 Days	42.30	37	
28 Days	54.25	53	

Table 1: Cement Test results Various parameter

b. Coarse and Fine Aggregate Test Results

Sr. No.	Parameters	Result values (12.5 mm)	Result values (10 mm)
1.	Specific gravity	2.72	2.67
2.	Water absorption %	4.32	4.12
3.	Fineness modulus	3.17	4.33
4.	Bulk density (loose) (kg/m3)	1520	1450
5.	Bulk density (compacted) (kg/m3)	1620	1575
6.	Impact Value %	15.62	17.18

Table 2: Coarse Aggregate Test Results on Various Parameters

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Sr.No.	Parameters	Values Observed
1	Specific gravity	2.61
2	Water absorption %	0.47
3	Fineness modulus	2.77
4	Bulk density (loose) (kg/m3)	1520
5	Bulk density (compacted) (kg/m3)	1680

Table 3: Fine Aggregate Test Results on Various Parameters

c. Mix Design Proportion of Concrete Ingredients:

Sr. No.	Description	Mix Design Proportion				
		M-1	M-2	M-3	M-4	M-5
1.	OPC 53 (Kg)	507	430.95	405.6	380.24	354.9
2.	Metakaolin (kg)	0	25.35 (5% of Cement)	50.7 (10% of Cement)	76.06 (15% of Cement)	101.4 (20% of Cement)
3.	Ceramic Waste (kg)	0	50.7 (10% of Cement)			
4.	Fine Aggregate (kg)	802	802	802	802	802
5.	Coarse Aggregate (kg)	965	965	965	965	965
6.	Water (Ltr.)	162	162	162	162	162
7.	Admixture (Ltr.)	4	4	4	4	4

Table 4: Mix Proportions as per mix design

d. Compressive Strength Test Results:

Sr. No.	Mix	Sample	7 Days		28 Days	
			CS	Avg. CS	CS	Avg.CS
1.	M-1	S-1	39.80	41.00	58.60	57.40
2.		S-2	43.30		56.60	
3.		S-3	39.90		57.10	
4.	M-2	S-1	46.10	46.80	59.00	60.00

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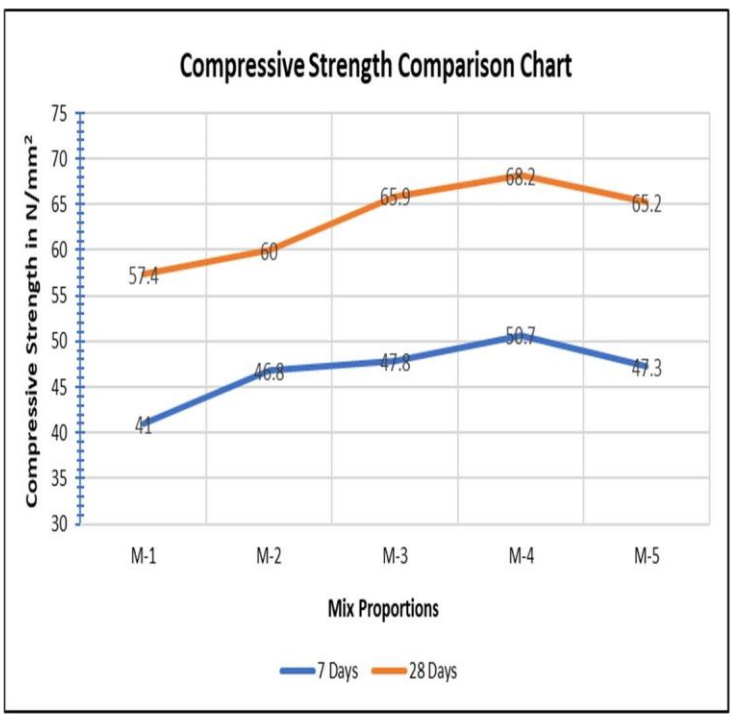
5.		S-2	47.40		63.00	
6.		S-3	46.80		58.10	
7.	M-3	S-1	48.80	47.80	63.00	65.90
8.		S-2	48.20		67.90	
9.		S-3	46.30		66.90	
10.	M-4	S-1	48.70	50.70	68.30	68.20
11.		S-2	52.70		66.60	
12.		S-3	50.80		69.70	
13.	M-5	S-1	48.00	47.30	62.70	65.20
14.		S-2	47.80		65.70	
15.		S-3	46.1		67.10	

Table 5: Compressive Strength Test Results



Graph 1: Compressive Strength Comparison Chart

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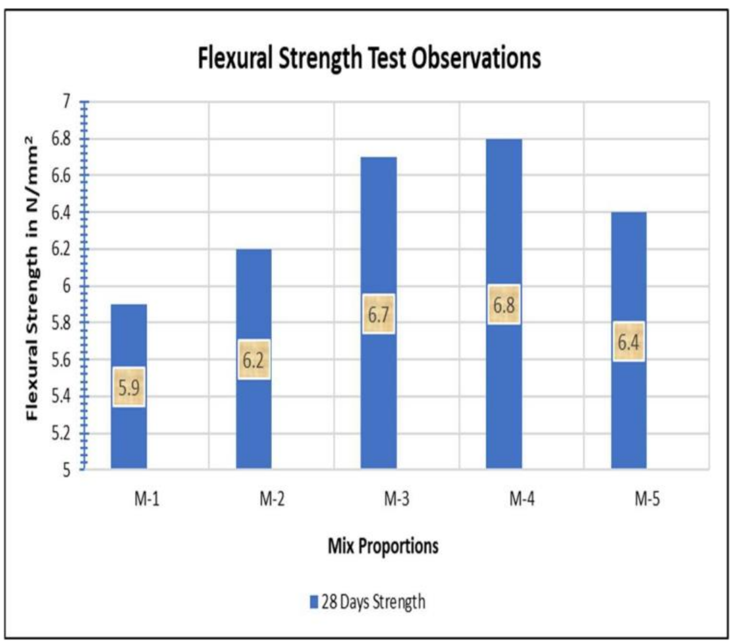
e. Flexural Strength Test Results

Sr. No.	Mix	Sample	28 Days Observations		
			Flexural Strength (N/mm²)	Avg. Flexural Strength	% Increase in Strength from 0% MK
1.	M-1	S-1	6.00	5.90	-
2.		S-2	5.50		
3.		S-3	6.10		
4.	M-2	S-1	6.10	6.20	5.08 %
5.		S-2	6.20		
6.		S-3	6.30		
7.	M-3	S-1	6.40	6.70	13.55%
8.		S-2	6.80		
9.		S-3	6.80		
10.	M-4	S-1	6.60	6.80	15.25%
11.		S-2	6.80		
12.		S-3	6.90		
13.	M-5	S-1	6.30	6.40	8.47%
14.		S-2	6.50		
15.		S-3	6.40		

Table 6: Flexural Strength Test Observations



Graph 2: Flexural Strength Test Observations

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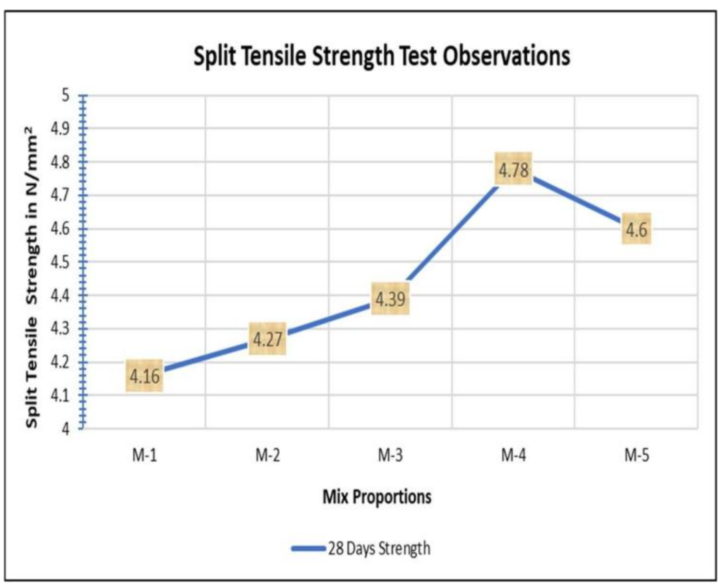
f. Split Tensile strength Test

Sr. No.	Mix	Sample	28 Days Observations		
			Split Strength (N/mm^2)	Avg. Split Strength	% Increase in Strength from 0% MK
1.	M-1	S-1	4.11	4.16	-
2.		S-2	4.18		
3.		S-3	4.20		
4.	M-2	S-1	4.22	4.27	2.58%
5.		S-2	4.26		
6.		S-3	4.33		
7.	M-3	S-1	4.38	4.39	5.52%
8.		S-2	4.35		
9.		S-3	4.44		
10.	M-4	S-1	4.75	4.78	16.10%
11.		S-2	4.79		
12.		S-3	4.82		
13.	M-5	S-1	4.63	4.60	10.57%
14.		S-2	4.37		
15.		S-3	4.82		

Table 7: Split Tensile Strength Test Observations



Graph 3: Split Tensile Strength Test Observations

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g. Carbonation Depth Test

Sr.No.	Mix	Sample	Carbonation Depth (mm)	Average
1.	M-1	S-1	12.4	12.2
2.		S-2	12.2	
3.		S-3	11.9	
4.	M-2	S-1	11.2	11.9
5.		S-2	12.5	
6.		S-3	12.1	
7.	M-3	S-1	11.1	11.3
8.		S-2	11.9	
9.		S-3	10.8	
10.	M-4	S-1	8.9	8.7
11.		S-2	8.5	
12.		S-3	8.7	
13.	M-5	S-1	9.2	9.8
14.		S-2	9.9	
15.		S-3	10.3	

Table 8: Carbonation Test Observations

h. NDT Test (Ultra Sonic Pulse Velocity Test)

Mix		Pulse Velocity Observation (Km/Sec)			
		Direct Approach	Avg. and Grading	Semi Direct Approach	Avg. and Grading
M-4	S-1	5.19	5.03 (Excel.)	4.1	4.13 (Good)
	S-2	5.4		4.1	
	S-3	4.5		4.2	

Table 9: Ultrasonic Pulse Velocity Test Observation

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IV. CONCLUSIONS

Based on above observations and results, following conclusions can be given:

- Addition of waste material into the concrete have positive impact on concrete mechanical properties. Ceramic waste and metakaolin found feasible adding into concrete mixture.
- The Compressive strength found maximum 68.20 MPa on adding 15% Metakaolin and 10% Ceramic waste as replacement of cement.
- The flexural strength found maximum 6.80 MPa for M-4 Mix proportion and which is 15.25% better result compared to convention concrete.
- The Split Tensile Strength Test was found maximum 4.78 MPa which is 16.10% higher than results found for conventional concrete without adding Ceramic waste and Metakaolin.
- Depth of Carbonation found minimum 8.7 mm for Mixture-4 in which metakaolin was added 15% and ceramic waste 10% by the weight of cement as a replacement.
- The Mixture-4 also tested for Non-Destructive Test. Ultra sonic pulse velocity test showed that dispersion of material and homogeneity of concrete mixture was excellent.
- Overall, it could be said that Ceramic waste and Metakaolin can be used as a partial replacement of cement. The economical factor is also important factor which can be satisfied using waste material without compromising strength and performance of oncrete mixture.

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