Comparitive Study of Various Tests to Determine Properties of Concrete Using Metakaoline and Microsilica

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Abstract-*Concrete is one of the most widely used construction material, because of the good durability to cost ration. However, when it is subjected to severe environmental condition, its durability can be significantly decline due to corrosion of embedded steel and hence degradation of concrete. The study here comprises of use of mineral admixtures such as Metakaoline and Micro Silica. In Concrete with partial replacement of Cement with these Mineral Admixture upto approximately 15% to 20% aids in gaining the strength as compared to the normal concrete which in turn increases the durability of concrete by minimizing the voids in the concrete.*

Keywords-Metakaoline, Micro Silica, UPV, Resistivity, RCPT

I. INTRODUCTION

Today's scenario in India is of fast construction, Vertical Construction, long span bridges etc. And these too within the time limit. To maintain the quality of concrete, quality control tests are performed to verify the workability and strength properties in situ. Moreover, rapid growth of construction industries also lacks sometimes the quality of the concrete in terms of durability that has to be there in concrete. And because of this lacking, deterioration part dominates after some time. However, the strength and workability during the construction stage are taken care of. But it's a question mark whether the concrete will be durable or not. To have durable concrete, the main property that works here is the porosity in the concrete. Lesser the porosity, more durable will be the concrete

The principle that works to creates porosity in the concrete is given below. When water (H2O) reacts with Cement, Calcium Hydroxide (CH) and Calcium Silicate Hydrate (CSH) released as per the reaction given below.

2 C3 S + 6 H → C3 S2 H3 + 3 C H
2 C2 S + 4 H → C3 S2 H3 + C H

C-S-H gel is the component which imparts strength to the concrete. And C-H leaches out when comes in contact with water thus increases the porosity in concrete. C-H content is approximately about 20 – 22% in concrete and is a waste product alone.

However, when it comes in contact with Mineral Admixtures, it reacts with it and forms additional C-S-H gels that fills up the voids and impart strength to the concrete.

Metakaolin: Metakaolin is refined kaolin clay that is calcined under carefully controlled environment to create an amorphous Aluminosilicate which is reactive in concrete. Like other Pozzolans (Fly Ash and Silica Fume are two common pozzolans), metakaolin reacts with the calcium hydroxide byproducts produced during cement hydration.

Kaolin is converted into Metakaoline when it is heated upto the temperature between 600 and 850 degree Celcius. Metakaolin is a very reactive pozzolana, but its physical and chemical properties greatly depends on the raw material used, the temperature during calcination and finishing process; however, Metakaoine with a highly disorganized structure has been produced by normal cooling as well. The temperature of calcination and duration depends on the mineralogical composition of raw material (kaolin). It has been reported that higher aluminite content in kaolin requires higher temperature of calcination and low alunite content gives good calcined kaolin on low temperature.

II. LITERATURE REVIEW

- K.A. Gruber, Terry Ramlochan, Andrea Boddy, R.D. Hooton, M.D.A. Thomas (2001) carried out study durability increase by using High Reactive Metakaolin. They reported that the inclusion of HRM (High Reactive Metakaolin) will significantly reduce the Chloride ion diffusion coefficient of the concrete. The use of 10% HRM is sufficient to prevent deleterious expansion in concrete prism containing high reactive aggregate after 1 year of storage at 38 degC.

- Mohammed Seddik Meddah and Arezki Tagnit-Hamou (2009) stated that at a given age and w/b, concrete with Portland cement generally has a higher total porosity than blended cement. Within the hydration process, the reduction of larger volume pores is more important for concrete containing mineral admixtures than for ternary blend concrete. The experimental results reveal that using mineral admixtures in concrete, especially SF, is more effective in minimizing total porosities.

- H. N. Atahan, D. Dikme (2011) stated that Ettringite (3CaO.Al2O3.3CaSO4.3H2O) formation in concrete under internal and external sulphate attack is the main reason for deterioration. Sulphate ions diffuse in concrete from external environment however it is also possible that the source of the ions can also be the concrete mixing materials. The author here concludes that 4 to 6% of Nano Silica are effective for limiting the expansion caused by internal sulphate attack. This is because of high purity (> 99%) and very high surface area (> 80000 m2/kg). External sulphate attack can also be controlled by only 2% replacement of NS.

- A.V.S.Sai. Kumar, Krishna Rao B (2014) examined the Effect on mechanical properties of concrete by inclusion of metakaolin reported that metakaolin inclusion increases the compressive, tensile, flexural and bend strength and modulus of elasticity of concrete considerably; however, the workability is slightly compromised. It was proposed to investigate the properties of concrete, cast with partial replacement of cement with 25% of quarry dust which was made from experimental results and further cement content is optimized with 0%, 2.5%, 5%, 7.5%, 10% and 12.5% of proportions of metakaolin proportions and cured in water. 10% replacement of cement with MK shows dominating results of Compressive, Tensile and flexural test.

- Rahul M Jadhav, Pradip D Jadhao and Shantanu G Pande (2015) present the experimental results of Recycled Aggregate Concrete (RAC) prepared with different amount of Recycled Coarse Aggregate (RCA). Six mixes of concrete with 0%, 20%, 40%, 60%, 80%, 100% replacement of natural aggregate with recycled aggregate (RCA) were cast respectively with target compressive strength 25 MPa. In addition to this partial replacement to the weight of cement is done with Metakaolin (20%) for all mixes. The result show that using Metakaolin 20% in concretes it is economical to the replace the recycled aggregate to the natural aggregate.

- Vipat A.R., Kulkarni P. M. (2016) Four proportions of concrete mixtures are prepared for M20 and M25 concrete each. One mix is prepared as normal concrete and remaining three mixes are prepared with 10%, 15% and 20% replacement of metakaolin by weight of cement. Mix is prepared without any admixture. They concludes that the maximum compressive strength achieved at 15% replaced cement with metakaoline. It also improves tensile strength and bond strength.

From this literature survey, it was found that cement can be replaced effectively with Supplementary Cementitious Materials (SCM's) like Silica Fume, Micro Silica, Metakaolin, GGBS etc. The SCM's show better results than normal mix in case of strength and durability. However, Metakaolin requires more super plasticizer to achieve desired workability and setting time. Also, it reduces the setting time of pastes as compared to control mixes. When compared with cement, the use of Metakaolin may be uneconomical due to its high cost whereas it is economical in the aspects of durability and strength.

However, it is seen from various literatures the RCPT test is time consuming and relatively costly. Hence, we have tried to correlate the results of this test with low cost - time saving test such as Resistivity Test and UPV Test. At the same time comparative study of strength will also be done.

III. EXPERIMENTAL STUDY

In the present study, we will investigate the following properties of metakaolin and micro silica blended concrete.

1) Compressive Strength Test
2) Flexural Strength Test
3) Split Tensile Strength
4) Resistivity Test
5) Ultrasonic Pulse Velocity Test
6) Rapid Chloride Penetration Test
7) Water Permeability Test
8) Chemical Test – pH, Sulphate and Chloride Test

In this experimental investigation, M25 and M30 grade of concrete has been used which was designed as per IS 10262-2009.

Following mixes are used to cast the specimen to find the above properties.

1. Ordinary Portland Cement 53 Grade normal.
2. Ordinary Portland cement replaced with Micro Silica at 5%, 10% and 15%.
3. Metakaolin replaced Ordinary Portland cement in proportion of 10%, 15% and 20%.

Cement- Ordinary Portland Cement of Brand – J K Lakshmi 53 Grade has been used in the present experimental study

SR. NO.	TYPE OF TEST	TEST RESULT	PHYSICAL REQUIREMENT AS PER IS: 269–2015
1	Consistency (%)	32.00%	-
2	Setting Time		
a	Initial Setting Time, min	105	Shall not be < 60 Minutes
b	Final Setting Time, min	260	Shall not be > 600 Minutes
3	Soundness, Le'chatlier, mm	1.96	Shall be < 10mm
4	Specific Surface By Blain's A.P	402	Shall be More Than 225 m^2/kg
5	Compressive Strength, N/mm^2		
a	72 ± 1 h, Min	28.69	Shall not be < 27 N/mm^2
b	168 ± 2 h, Min	41.13	Shall not be < 37.5 N/mm^2
c	672 ± 4 h, Min	59.39	Shall not be > 53N/mm^2

Micro Silica (MS)- Elkem Make micro silica has been used with reactivity more than 96%. The characteristic properties of the same have been tabulated.

SR. NO.	TYPE OF TEST	UNIT	TEST RESULT	REQUIREMENT AS PER ASTM C1240
1	SiO_2	%	96.1	Min 85%
2	Moisture Content	%	1.3	Max 3.0%
3	Loss on lgnition (L.O.l)	%	1.5	Max 6.0%
4	Percent Retained On 45µm	%	0.3	Max 10.0%
5	Bulk Density	Kg/m^3	605	--

Metakaolin (MK)- Metacem 85C from 20 Micron, Vadodara has been used in the study. Metacem is water processed to remove unreactive impurities producing an almost 100% reactive material. IS 456 recommends use of Metakaolin as mineral admixture.

SR. NO.	TYPE OF TEST	UNIT	TEST RESULT	REQUIREMENT AS PER ASTM C1240
1	Appearance		Off White Powder	
2	Bulk Density (Loose)	gm/lit	319	270 – 370
3	Oil Absorption	gm/100gm	48.23	45 - 65
4	Moisture	%	0.28	0 - 0.5
5	pH (10% Aq. Slurry)	--	7.21	5 - 8
6	Residue on 45µm	%	0.11	0 – 0.5
7	PSD-D50	□	1.5 – 2.0	1.56
8	Specific Gravity	□	2.5 – 2.7	2.53

Fine Aggregate- The fine aggregates used are from the Sankheda River.

ZONE – II

Sieve Size	Retained gms	% Retained	Cum. % Retained	%, Passing	I.S. Requirement for Zone II
10mm	0	0	0.00	**100.00**	**100**
4.75mm	96	4.8	4.82	**95.18**	**90-100**
2.36mm	218	10.9	15.72	**84.28**	**75-100**
1.18mm	281	14.0	29.77	**70.23**	**55-90**
600µ	633	31.7	61.43	**38.57**	**35-59**
300µ	289	14.5	75.89	**24.11**	**8-30**
150µ	428	21.4	97.27	**2.73**	**0-10**
75µ	55	2.7	100.00	**0.00**	--

Coarse Aggregate- The Coarse aggregates used are from the Sevalia Source, Lunawada, District- Panchmahal

Sieve Size	% of Passing	
	20mm DN	10mm DN
40mm	100.00	--
20mm	89.60	--
12.5mm	--	100.00
10mm	5.50	71.64
4.75mm	0.00	0.90
2.36mm	--	0.00

Sr. No.	TYPE OF TEST	RESULTS	
		20mm DN	10mm DN
1	Water Absorption, %	0.69	0.71
2	Specific Gravity	2.880	2.867
3	Density, gm/cc	1.450	1.464
4	Impact Value, %	9.80	--
5	Flakiness Index, %	12.23	11.69
6	Elongation Index, %	10.6	9.58

Superplasticiser: Brocrete C 800 formulated by Mr Mukund Kadu, Fairmate has been used to have workability as desired. It conforms to I.S. 9103-1999.

IV. MIX DESIGN

- Mix Design has been conducted as per is 10262-2009.

Mix Proportion of M25 Grade of Concrete for 1m^3 of Concrete

Sr. No.	Mix	Water	Cement	MK	SF	Aggregate			w/b ration
						Sand	20 mm	10 mm	
		kg	kg	kg	kg	kg	kg	kg	
1	TM 01	198.10	401.20	0.00	0.00	803.87	492.85	599.63	0.49
2	TM 02	198.10	361.08	**40.12**	0.00	803.87	492.85	599.63	0.49
3	TM 03	198.10	341.02	**60.18**	0.00	803.87	492.85	599.63	0.49
4	TM 05	198.10	320.96	**80.24**	0.00	803.87	492.85	599.63	0.49
5	TM 06	198.10	381.14	0.00	**20.06**	803.87	492.85	599.63	0.49
6	TM 07	198.10	361.08	0.00	**40.12**	803.87	492.85	599.63	0.49
7	TM 08	198.10	341.02	0.00	**60.18**	803.87	492.85	599.63	0.49

Mix Proportion of M30 Grade of Concrete for 1m3 of Concrete

Sr. No.	Mix	Water	Cement	MK	SF	Aggregate			w/b ration
						Sand	20 mm	10 mm	
		kg	kg	kg	kg	kg	kg	kg	
1	TM 08	197.67	**445.80**	0.00	0.00	736.98	788.04	336.20	0.44
2	TM 09	197.67	**401.22**	**44.58**	0.00	736.98	788.04	336.20	0.44
3	TM 10	197.67	**378.93**	**66.87**	0.00	736.98	788.04	336.20	0.44
4	TM 11	197.67	**356.64**	**89.16**	0.00	736.98	788.04	336.20	0.44
5	TM 12	197.67	**423.51**	0.00	**22.29**	736.98	788.04	336.20	0.44
6	TM 13	197.67	**401.22**	0.00	**44.58**	736.98	788.04	336.20	0.44
7	TM 14	197.67	**378.93**	0.00	**66.87**	736.98	788.04	336.20	0.44

V. RESULTS

1. Compressive Strength Test Result

Sr. No.	Mix	Compressive Strength, N/mm^2	
		7	28
TM 01	OPC25	24.1	32.6
TM 02	OPC25 + 10% M	25.1	33.9
TM 03	OPC25 + 15% M	**28.3**	**36.9**
TM 04	OPC25 + 20% M	27.4	36.2
TM 05	OPC25 + 5% SF	26.0	33.5
TM 06	OPC25 + 10% SF	**29.1**	**35.3**
TM 07	OPC25 + 15% SF	27.5	34.1
TM 08	OPC30	28.9	39.6
TM 09	OPC30 + 10% M	29.2	42.1
TM 10	OPC30 + 15% M	32.6	46.0
TM 11	OPC30 + 20% M	33.5	44.1
TM 12	OPC30 + 5% SF	28.0	40.2
TM 13	OPC30 + 10% SF	33.9	45.7
TM 14	OPC30 + 15% SF	32.4	43.0

2. Flexural Strength Test

Sr. No.	Mix	Flexural Strength, N/mm^2	
		7	28
TM 01	OPC25	3.44	4.00
TM 02	OPC25 + 10% M	3.51	4.08
TM 03	OPC25 + 15% M	3.72	4.25
TM 04	OPC25 + 20% M	3.66	4.21
TM 05	OPC25 + 5% SF	3.57	4.05
TM 06	OPC25 + 10% SF	3.78	4.16
TM 07	OPC25 + 15% SF	3.67	4.09
TM 08	OPC30	3.59	4.40
TM 09	OPC30 + 10% M	3.78	4.54
TM 10	OPC30 + 15% M	4.00	4.75
TM 11	OPC30 + 20% M	4.05	4.65
TM 12	OPC30 + 5% SF	3.70	4.44
TM 13	OPC30 + 10% SF	4.08	4.73
TM 14	OPC30 + 15% SF	3.98	4.59

3. Ultrasonic Pulse Velocity Test Result:

Sr. No.	Mix	UPV, km/s	
		7	28
TM 01	OPC25	3.53	3.78
TM 02	OPC25 + 10% M	3.67	3.81
TM 03	OPC25 + 15% M	3.78	3.89
TM 04	OPC25 + 20% M	3.77	3.88
TM 05	OPC25 + 5% SF	3.70	3.82
TM 06	OPC25 + 10% SF	3.79	3.92
TM 07	OPC25 + 15% SF	3.81	3.98
TM 08	OPC30	3.63	3.89
TM 09	OPC30 + 10% M	3.76	3.88
TM 10	OPC30 + 15% M	3.82	3.96
TM 11	OPC30 + 20% M	3.80	3.93
TM 12	OPC30 + 5% SF	3.78	3.92
TM 13	OPC30 + 10% SF	3.96	4.11
TM 14	OPC30 + 15% SF	3.97	4.18

4. Resistivity Test Result:

Sr. No.	Mix	Resistivity, Ohm-m
		28
TM 01	OPC25	173
TM 02	OPC25 + 10% M	256
TM 03	OPC25 + 15% M	289
TM 04	OPC25 + 20% M	312
TM 05	OPC25 + 5% SF	225
TM 06	OPC25 + 10% SF	235
TM 07	OPC25 + 15% SF	282
TM 08	OPC30	192
TM 09	OPC30 + 10% M	283
TM 10	OPC30 + 15% M	325
TM 11	OPC30 + 20% M	396
TM 12	OPC30 + 5% SF	217
TM 13	OPC30 + 10% SF	226
TM 14	OPC30 + 15% SF	234

VI. CONCLUSION

1. Compressive Strength, Split Tensile Strength and Flexural Strength increases upto Metakaoline dosage of 15% and Micro Silica Dosage of 10%.
2. Resistivity test results indicates increase in the value as we keeps on increasing the dosage of mineral admixtures which in turn indicates that the possibility of reduction in corrosion.
3. In Concrete with partial replacement of Cement with Micro Silica, UPV results tends to increase till the dose of 15% (under study) indicates the denser state of concrete with increased MS. Moreover, in Metakaoline replaced concrete, UPV trends as per the Compressive Strength results.
4. Correlation of the Resistivity and UPV may not be established till 28 days of study but indicates positive results in terms of durability.

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