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Assessment of Strength and Electrical resistance of Ternary blend concrete

Rama Mohan Rao.P[1]*, Vinothkumar.S[2]

[1]CDMM, VIT University, Vellore, Tamil Nadu, India
[2]VIT University, Vellore, Tamil Nadu, India

Abstract: The use of fly ash and metakoalin in concrete is phenomenal due to superior pozzolanic action which accounts for the strength gain and reduction in concreting cost. Recently there has been a great demand for high quality concrete structures with high performance. The present study aims the influence of fly ash and metakoalin on the hardened properties of concrete. The strength properties of compressive, split tensile and flexural strength and electrical resistivity of ternary blend concrete mixes has been tested at different ages. The addition of metakaolin to concrete mix improves the early age strength .The electrical resistivity values of different concretes measured at different ages. Prediction of electrical resistivity of ternary mixes at 28 day has an error of 4-5 %.
Key words : metakaolin-compressive- electrical resistivity.

1. Introduction

1.1 General:

The quality control of the compressive strength of concrete is typical performed on standardized specimens at the age of 28 days. Even then, the insistence to fulfill construction deadline and the need to control the costs by reducing construction time has resulted in continuous construction, where early age specimens are tested to obtain some insight as to what the 28-day compressive strength of concrete might be. In addition, the removal of formwork is usually performed at the earliest convenient time possible to speed up the construction process. The strength properties of concrete can be determined by use of conventional methods and the electrical resistivity of the concrete can be determined by using four probe method. It is one of the non destructive testing generally suggested in performance-based quality control programs .As electrical resistivity increases when the concrete dries out and when it carbonates, in particular for Portland cement concrete. The effect of the penetration of chloride ions is relatively small. There are different test methods are being used for measuring the electrical resistivity of concrete. Of these four-electrode (Wenner) method appears to be a very simple and convenient test method. With increase in metakaolin content from 0 to 10%, there is a marginal increase in compressive strength beyond which it has been reduced and chloride ion permeability of high performance concrete indicates that metakaolin has the ability to considerably reduce the permeability has been noticed. [1]

For the given mixture proportions, metakaolin offers better workability than Silica Fume and replacement level increases, the strength of the metakaoline concrete also increases at all ages [2]. The synergy between the different types of fly ashes was considered the main reason for the excellent performance of the ternary mixtures[3] The binary blends of metakaolin or Class C fly ash reduced expansion by 55–90% and 25–37% compared to the control concrete. and ternary blends with metakaolin and Class C fly ash resulted in a marginally higher expansion than binary blends incorporating the same amount of metakaolin has been observed[4]. There is a strong relationship between electrical resistivity and durability indicators at a given age.

A relationship was suggested similar to the Arrhenius equation that can be used for conversion of electrical resistivity measurements to a reference temperature. Based on these equations, the electrical resistivity and compressive strength of concrete at 28 days is predicted using values of electrical resistivity of up to 7 day and errors depend on the equation used but approximately 5 % up to 28 days[5]

In present work, the strength and durability properties of ternary blend concretes were studied by replacing cement partially by metakaolin and class C fly ash with various replacement levels. The scope of the present work is to compute electrical resistance and the effectiveness of the metakaolin as mineral admixture along with class C fly ash in the binder portion with the ternary blended concrete The Class C fly ash replacement levels of 40% and 50% and metakaoline replacement levels 5%, 10%, 15 % and 20% by cement were added in the binder portion.

2.1 Materials used

Cement: Ordinary Portland cement (OPC) **-** 53 grade conforming to IS: 12269 – 1987 was used in entire study. The properties of cement were tested and their values are given in table 1.0

Table 1 Physical properties of cement:

S.No	Property	Test results
1.	Specific gravity	3.15
2	Standard consistency	27%
3.	Initial setting time	95 min
4.	Final setting time	210 min
5.	Compression test at 7 days	30.5N/mm^2
6.	Compression test at 28 days	53.2 N/mm^2

Fly ash:

Fly ash was obtained from Neyveli thermal power plant (Neyveli Lignite Corporation, Tamil Nadu, India) was used. Fly ahs was replaced by cement as per IS 3812(part I) and its specific gravity is 1.96.

Metakaolin:

Metakaolin was used as mineral admixture in the concrete. The chemical properties of metakaolin are presented in table 2. The specific gravity and bulk density are 2.5 and 2.7 respectively.

Table 2.0 Properties of Metakaolin

S.No	Components	Value (%)
1.	Silicon dioxide (SiO_2)	52.54
2.	Aluminum oxide ($Al_2 O_3$)	43.48
3	Ferric oxide ($Fe_2 O_3$)	0.86
4.	(Sio_2) + ($Al_2 O_3$) + ($Fe_2 O_3$)	96.88
5.	Magnesium (Mg)	0.08
6.	Sodium oxide ($Na_2 O$)	0.56
7.	Potassium oxide ($K_2 O$)	0.06
8.	Calcium oxide (CaO)	0.06
9.	Loss of ignition	0.39
10.	Chloride	-
11.	Titanium oxide	1.35

Aggregates:

The natural river sand conforming to zone II as per IS 383 – 1987 was used. The specific gravity and fineness modulus were 2.60 and 2.64 respectively. Crushed granite aggregates conforming to IS 383 – 1987 was used in this study. Coarse aggregate passing through 20mm and retained on 16 mm sieve was used. The coarse aggregate have specific gravity and fineness modulus 2.8 and 7.2 respectively.

Water:

Water is an important ingredient of concrete as it actively participated in chemical reaction with cement. Potable water conforming to IS 456 – 2000 was used for preparation of concrete specimens.

4. Concrete mix and specimens :

3.0 Concrete Mix proportions (kg/m^3)

Mix	F1	MF105	MF110	MF115	MF120	F2	MF205	MF210	MF215	MF220
C	308	169.6	154	138.6	123.2	277	124.65	110.8	96.95	83.1
Ash	123.2	123.2	123.2	123.2	123.2	138.5	138.5	138.5	138.5	138.5
MK	0.0	15.4	30.8	46.2	61.6	0.0	13.85	27.7	41.55	55.4
CA	1148	1148	1148	1148	1148	1207	1207	1207	1207	1207
FA	704	704	704	704	704	609	609	609	609	609
W	185	185	185	185	185	180	180	180	180	180

Note : C = cement, Ash = fly ash, MK= metakaoline, CA=coarse.agg, FA= fine agg, W= water

The mixture proportion for the controlled concrete of M25 grade was arrived from the trial mixes as per DOE method and found to be 1:0.67:0.6:2.3:3.7(w/b=0.50). The details of mix proportions were used is given in table 3.0. Cubes of size 100 mm, prisms of size 100x100x500 mm and cylinders of size 100 x50 mm were used for studying the strength and electrical resistance of ternary blend concrete mixes.

5. Test Methods

Compressive strength:

Compression test conducted on hardened concrete using a compression testing machine of capacity 2000 kN is available in structures lab. The compressive strength results at the age of 7 and 28 days are shown in the Fig .1

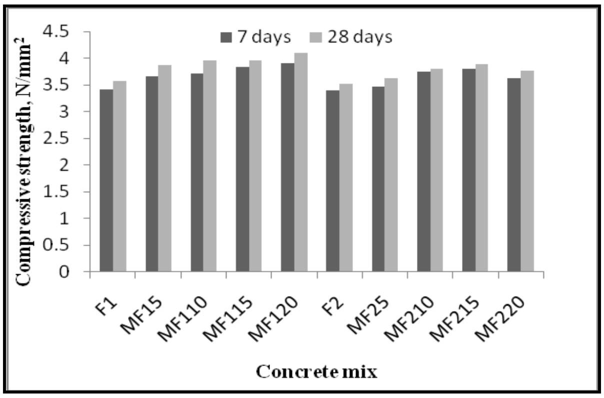


Fig.1 Compressive Strength of concrete mixes

Split tensile strength of concrete:

The indirect method of applying tension in the form of split was conducted to evaluate the effect on tensile properties of concrete. The split tensile strength as per IS 5816 is a more reliable technique to evaluate tensile strength of concrete compared to other methods. The split tensile strength of 100 mm diameter and 200 mm high concrete cylindrical specimens was determined.

Flexural strength of concrete:

This test was carried out on a concrete beam with loading at the third points according IS 516. .The loading machine should be able of applying the loads at a uniform rate without interruption. In this test the prism size 100x100x500 mm were used. The flexural strength results are shown in table 4.

Table 4.0 Flexural strength values at 28 days (N/mm^2)

Mix	F1	MF15	MF10	MF15	MF20	F2	MF25	MF210	MF215	MF220
28days	6.66	7.73	8.80	9.40	9.18	5.27	7.00	6.73	7.30	6.80

Electrical resistivity:

The electrical resistivity of the concrete specimens was performed using a four-point Werner electrode according to published recommendations and internal laboratory test procedure. Measurements were performed on 150mm size cube specimens. Prior to measurements, the specimen surface was cleared of excess water with a dry cloth and place on a dry wooden support. The specimens were measured in different ways: - the cubes are measured on two lateral surfaces1 and the bottom surface with two reading, 90 º apart (total six values per specimen). The test was performed at different ages up to 28 days.

6 . Result and Discussion

Compressive strength:

Compressive strength of concrete mixes made with and without blend was determined at 7, 28days. It can be observed that, the gain of compressive strength of different types of ternary blend concrete at the age of 7 to 28days varies from 75-85%. The compressive strength of concrete gains maximum strength at early age was observed for all the meatkaolin based concrete mixes when compared with control concrete. The ternary blend concrete mix with 40% fly ash shows higher compressive strength when compared with 50% fly ash ternary blend concrete mixes at 7 and 28 days. It was observed from fig. 1.0, there was maximum strength improvement of 20% metakaolin concrete mixes at 7 and 28 days. It can be noticed that, the compressive strength decreases with increase in fly ash replacement level in the blended concrete. The role of metakaolin in the concrete mix at the early ages was very significant for strength improvement has been observed.

2 Split tensile strength:

The test results of splitting tensile strength of concrete mixes with and without metakaolin was measured at 7, 28 days are shown in figure 2.0. Splitting tensile strength of concrete decreases with the increase in the different percentage of metakaolin for 40%,50% fly ash replacement of ternary blended concrete mixes has been observed. The rate of increase of splitting tensile strength of metakaolin with 40% fly ash replacement level at the age of 7, 28 days compared with 50% fly ash replacement of ternary blended concrete mixes. At the age of 28 days the improvement in tensile strength of MF210 mix was 14.36% when compared with F1 concrete mix. The improvement in split tensile strength of MF215 mix was observed 12% compared with F2 concrete mix. At the age of 7 and 28 days, the 20% replacement of metakaolin ternary concrete mixes attains maximum split tensile strength has been observed in fig.2.

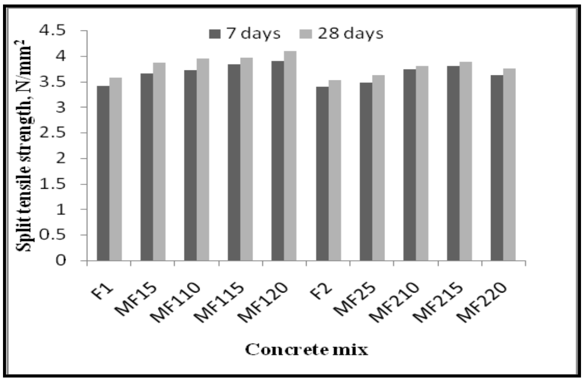


Fig. 2 Split tensile Strength of concrete mixes

7.3 Flexural strength:

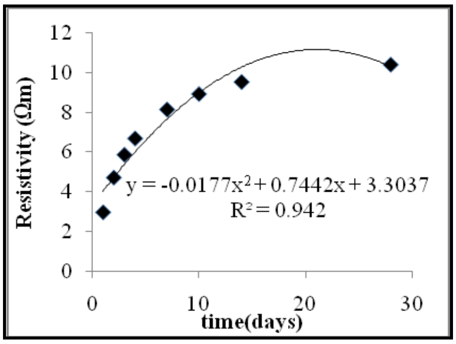
The flexural strength test results of ternary blended concrete are shown in the table 4.0. The concrete mix MF15 attains maximum flexural strength at the age of 28 days and as the metakaolin percentage increases beyond the value of 15%, the flexural strength decreases. The same trend has been observed in the 50% fly ash replacement blended with different percentage of metakaolin concrete mixes. The improvement in flexural strength of MF115 mix was 41.28% when compared with F1 concrete mix. The improvement in flexural strength of MF215 mix was 37.78% when compared with F2 concrete mix. The flexural strength decreases with increase in fly ash replacement level has been observed from the test results.

Estimating electrical resistivity of concrete :

Table 5.0 Equation variables for the estimation of 28 days electrical resistivity

Mix	Estimation (Ωm)	Error (%)	a	b	ρmax (Ωm)
F1	10.42	5.8	0.087	0.250	11.42
MF105	17.98	2.6	0.047	0.241	21.27
MF110	22.71	1.5	0.035	0.253	28.57
MF115	29.66	0.8	0.025	0.244	40.00
MF120	28.05	1.0	0.027	0.242	37.04
F2	13.34	1.6	0.060	0.418	16.78
MF205	30.30	0.7	0.024	0.252	41.67
MF210	30.24	2.1	0.026	0.198	38.46
MF215	15.97	6.1	0.057	0.157	6.37
MF220	13.90	4.6	0.064	0.223	4.48

The possibility of estimating future values based on early age measurements can play a vital role in quality control and an effective update of the design of the durable concrete structures can be performed. Three equations have been proposed for estimating early age development of electrical resistivity, until 28 days. From the data in Table 5, only data up to 7 days is used to perform the estimations. The test results of the electrical resistivity measurements of various concrete mixes are shown in fig 3 to fig. 12.



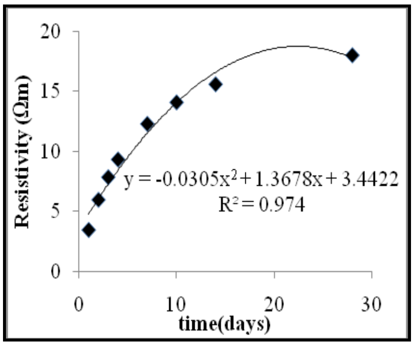
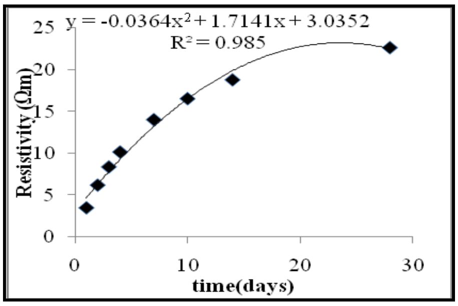


Fig:3& 4 hyperbolic equation vs. measured electrical resistivity for F1 and MF105 mixes



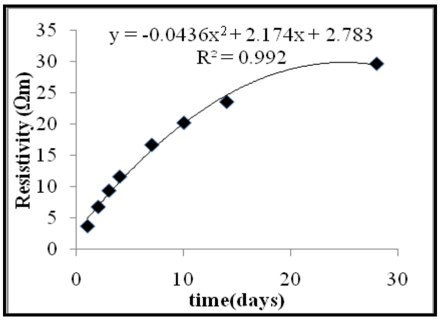
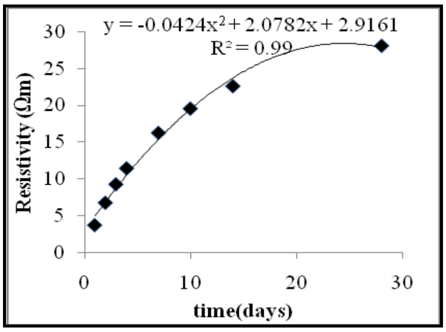


Fig: 5& 6 hyperbolic equation vs. measured electrical resistivity for MF110 and MF115 mixes



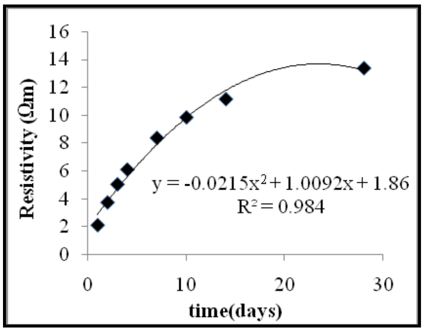
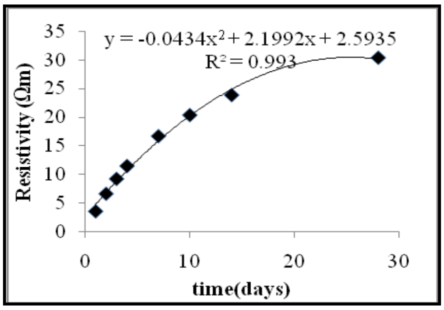


Fig: 7&8 hyperbolic equation vs. measured electrical resistivity for MF120 and F2 mixes



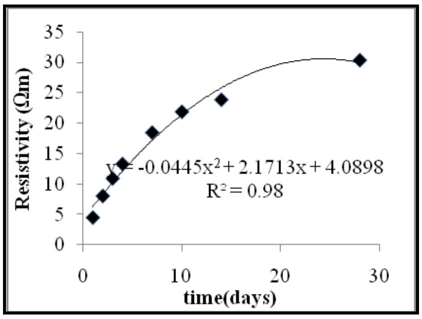
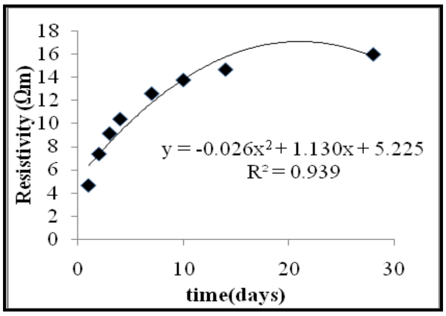


Fig: 9&10 hyperbolic equation vs. measured electrical resistivity for MF205 and MF210 mixes



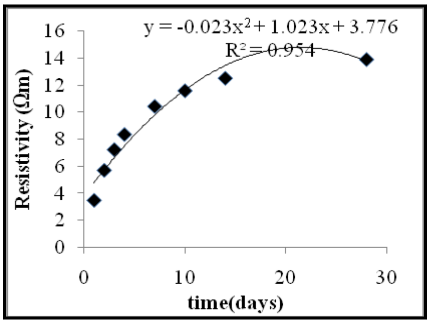


Fig 11&12 hyperbolic equation vs. measured electrical resistivity for MF215 and MF220 mixes

Hyperbolic equation:

Due to the curvature of the electrical resistivity vs. time curve, a hyperbolic equation is proposed to simulate the development with time. From equation it can be seen that.

$$y = \frac{x}{a * x + b} \rightarrow \frac{x}{y} = a * x + b \rightarrow \frac{t}{\rho} = a * t + b$$

in which 't' is time in days and ρ is electrical resistivity in Ωm. From the equation it can be seen that, 't' → ∞, $\rho max = \frac{1}{a}$. The proposed equation can be linearized which facilitates the calculation of the equation parameters. Figure 3to 12 illustrates the best fit of the 7 day data to the linearized hyperbolic equation versus electrical resistivity. The coefficient of correlation obtained (R^2=0.99) indicate that equation adjusts well. Table 5 shows the parameter determined and the error associated with the estimates. Prediction of 28 day values has an error of 4-5 %. This equation cannot be used for estimating values further than 28 days as the ρ max has already been reached with in this period. As can be seen, after 28 days the curve no longer accompanies the development of the measurements.

8. Conclusions:

Based on the experimental results obtained from the tests, the following conclusions were drawn.

1. With the increase in metakaolin content with 40% fly ash, there is marginal improvement in compressive strength but, decreases with % of metakaolin. Atat 5% metakaolin with 50% fly ash concrete shows compressive strength of 39.41N/mm^2 at 28 days.
2. The concrete mix with 40% fly ash and 20% metakaoline shows maximum spilt tensile strength when compared with other ternary blend mixes at 28 days.
3. The improvement in flexural strength of MF115 and MF215 concrete mixes is in the range 37.7 to 41.28 % when compared with F1and F2 mixes.
4. The proposed equations for electrical resistivity estimation are limited to 28 day values, with the exception of the hyperbolic equation. With the limitation, and based available data, the estimations are relatively accurate with 6.1% of error.
5. The hyperbolic equation allows estimations at later ages without hindering increasing the error in the estimations. Estimations depend on number days in data set and the time of estimation.

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