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Development of Mathematical Model to Predict Increase Rate of Compressive Strength Influenced By Metakaoline Substance for High Strength Concrete

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ABSTRACT

The study try to monitor the strength development of concrete modified with metakaoline content, this addictive has been applied in mix design for high strength concrete, the study monitor the behavior of concrete modified metakaoline content at different mix design concept, these are under various water cement ratios proportion, the rate of strength achieved from various water cement ratios were observed in the study to predict the behaviour of the material modified with this addictive' s, the application of deterministic modeling techniques were observed to express the decrease and increase rate of concrete strength development, these developed model generated simulation parameters that express the behavior of high strength concrete from mix proportion modified with metakaoline content. The study expresses simulation that predicts the compressive strength at every twenty four hours. Validations of predictive model were carried out, and both parameters generated favorable fits.

Keywords: *mathematical model predict, compressive strength, metakaoline and substance*

INTRODUCTION

The pursuit for the growth of high strength including high performance concretes has improved significantly in current times; these are due to the demands from most of these construction industry. It has been observed in these last three decades, additional cementations materials such as fly ash, silica fume and ground granulated blast furnace slag have been thought fully used as cement replacement materials because it has been observed that it can meaningfully enhance the strength and stability characteristics of concrete as compared with ordinary Portland cement (OPC) alone, this because it has been providing adequate required curing (Neville 1997 Ode and Eluozo 2016c Eluozo 2016d).

Nevertheless, once there is desired for high strength concrete, the application of silica fume is more useful (Basu 2003 Eluozo 2016a Ode and Eluozo 2016b). These types addictive's have generated a very good particle packing and, because of its strong pozzolanic property escalates the resistance of the concrete in these aggressive environments (Abdul and Wong 2005 Ode and Eluozo 2016). Metakaolin (MK).More so claimed kaolin, other type of pozzolan, produced by calcinations has the ability to substitute silica fume as an alternative material. In India MK can be generates a very high amount of quantities, these are processed product of kaolin mineral, these a very wide spread proven reserves available in the country (Basu et al. 2000; Tiwari and Bandyopadhyay 2000 Ode and Eluozo 2016c).Previously, researchers have shown a lot of interest in MK as it has been found to possess both pozzolanic and micro filler characteristics (Poon et al. 2001; Wild and Khatib 1997; Eluozo 2016e: Wild et al. 1996).

It has also been used successfully for the development of high strength self-compacting concrete using mathematical modeling (Dvorkin et al. 2012(Basu 2003; Basu et al. 2000, Pal et al. 2001, Patil and Kumbhar 2012 Ode and Eluozo 2016 f).

Theoretical Background

Nomenclature

C = Compressive Strength

$A_{y\,(1-n)}$ = water cement Ratio

Φ^2 = Compendious Material/Additive's

B_y = Specific Gravity

Y = Curing Age

$$\frac{dc}{dy} + A_{(y)}C_{(d)} = B_{(y)}C_d{}^n; n_{\geq 2}\ldots\ldots\ldots \quad (1)$$

Divided by (1) through by $C_d{}^{-n}$ we have obtain

$$C_d{}^{-n}\frac{dc}{dy} + A_{(y)}C_d{}^{1-n} = B_{(y)} \quad (2)$$

Let $\beta = C_d{}^{1-n}$

$$\frac{d\beta}{dy} = (1-n)C_d{}^{-n}\frac{dc}{dy}$$

Multiplying Equation (2a) through by (1- n)

$$(1-n)C_d{}^{1-n}\frac{dc}{dy} + (1-n)A_{(y)}C_d{}^{1-n} = (1-n)B_{(y)} \quad (3)$$

Let $\dfrac{2}{2-\beta} = \phi^2$

$$\beta = \frac{1}{\phi^2}\int(1-n)B(y)dy = \frac{1}{\phi^2}(1-n)B(y)Y + K_1 \quad (4)$$

$$\left[\beta = \frac{(1-n)}{\phi^2}B(y)Y\right] \quad (5)$$

Materials and Method

Experimental Procedures

Compressive Strength Test Concrete cubes of size 150mm×150mm×150mm were cast with and without copper slag. During casting, the cubes were mechanically vibrated using a table vibrator. After 24 hours, the specimens were remolded and subjected to curing for 1-90 days and seven day interval to 28 days in portable water. After curing, the specimens were tested for compressive strength using compression testing machine of 2000KN capacity. The maximum load at failure was taken. The average compressive strength of concrete and mortar specimens was calculated by using the following equation 5.1. Compressive strength (N/mm2) = Ultimate compressive load (N) Area of cross section of specimen (mm2)

Table1. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
7	20.44	19.0447
8	23.36	22.0593
10	26.28	28.0783
11	29.21	31.0827
12	32.12	34.0837
13	35.04	37.0813
14	40.88	40.0755
15	43.81	43.0663
16	46.72	46.0537
17	49.64	49.0377
18	52.56	52.0183
19	55.48	54.9955
20	58.41	57.9693
21	61.32	60.9397
22	64.24	63.9067
23	67.16	66.8703
24	70.08	69.8305
25	73.11	72.7873
26	75.92	75.7407
27	78.84	78.6907
28	81.76	81.6373
29	84.68	84.5805
30	87.61	87.5203
31	90.52	90.4567
32	93.44	93.3897

33	96.36	96.3193
34	99.28	99.2455
35	102.21	102.1683
36	105.12	105.0877
37	108.04	108.0037
38	110.96	110.9163
39	113.88	113.8255
40	116.81	116.7313
41	119.72	119.6337
42	122.64	122.5327
43	125.56	125.4283
44	128.48	128.3205
45	131.41	131.2093
46	134.32	134.0947
47	137.24	136.9767
48	140.16	139.8553
49	143.08	142.7305
50	146.01	145.6023
51	148.92	148.4707
52	141.84	151.3357
53	154.76	154.1973
54	157.68	157.0555
55	160.61	159.9103
56	163.52	162.7617
57	166.44	165.6097
58	169.36	168.4543
59	172.28	171.2955
60	175.21	174.1333

Table2. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	**Predictive Values of Compressive Strength KN/m2**	**Experimental Values of Compressive Strength KN/m2**
7	19.1447	19.9671
8	22.1593	22.8911
10	28.2783	28.7391
11	31.2827	31.6631
12	34.2837	34.5871
13	37.2813	37.5111
14	40.1755	40.4351
15	43.1663	43.3591
16	46.1537	46.2831
17	49.1377	49.2071
18	52.1183	52.1311
19	54.9956	55.0551
20	57.9696	57.9791
21	60.9597	60.9031
22	63.9367	63.8271
23	66.8723	66.7511
24	69.8335	69.6751
25	72.7883	72.5991
26	75.7427	75.5231
27	78.6937	78.4471
28	81.6473	81.3711
29	84.5825	84.2951
30	87.5223	87.2191
31	90.5567	90.1431
32	93.5897	93.0671
33	96.3293	95.9911
34	99.3455	98.9151

35	102.3683	101.8391
36	105.0877	104.7631
37	108.3337	107.6871
38	110.9163	110.6111
39	113.8355	113.5351
40	116.7333	116.4591
41	119.6437	119.3831
42	122.5527	122.3071
43	125.4483	125.2311
44	128.5215	128.1551
45	131.2293	131.0791
46	134.2947	134.0031
47	136.9777	136.9271
48	139.8653	139.8511
49	142.7345	142.7751
50	145.5423	145.6991
51	148.5717	148.6231
52	151.4357	151.5471
53	154.2973	154.4711
54	157.1555	157.3951
55	159.9123	160.3191
56	162.7627	163.2431
57	165.6197	166.1671
58	168.5543	169.0911
59	171.3955	172.0151
60	174.2333	174.9391

Table3. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	**Predictive Values of Compressive Strength KN/m2**	**Experimental Values of Compressive Strength KN/m2**
7	10.22	10.2188
8	11.68	11.6788
9	13.14	13.1388
10	14.61	14.5988
11	16.06	16.0588
12	17.52	17.5188
13	18.98	18.9788
14	20.44	20.4388
15	21.91	21.8988
16	23.36	23.3588
17	24.82	24.8188
18	26.28	26.2788
19	27.74	27.7388
20	29.21	29.1988
21	30.66	30.6588
22	32.12	32.1188
23	33.58	33.5788
24	35.04	35.0388
25	36.51	36.4988
26	37.96	37.9588
27	39.42	39.4188
28	40.81	40.8788
29	42.34	42.3388
30	43.82	43.7988
31	45.26	45.2588
32	46.72	46.7188
33	48.18	48.1788
34	49.64	49.6388
35	51.11	51.0988

36	52.56	52.5588
37	54.02	54.0188
38	55.48	55.4788
39	56.94	56.9388
40	58.42	58.3988
41	59.86	59.8588
42	61.32	61.3188
43	62.78	62.7788
44	64.24	64.2388
45	65.71	65.6988
46	67.16	67.1588
47	68.62	68.6188
48	70.08	70.0788
49	71.54	71.5388
50	73.11	72.9988
51	74.46	74.4588
52	75.92	75.9188
53	77.33	77.3788
54	78.84	78.8388
55	80.31	80.2988
56	81.76	81.7588
57	83.22	83.2188
58	84.68	84.6788
59	86.14	86.1388
60	87.61	87.5988

Table4. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
7	10.3188	10.3371
8	11.6798	11.7975
9	13.3388	13.2579
10	14.5998	14.7183
11	16.2588	16.1787
12	17.5288	17.6391
13	18.9798	19.0995
14	20.5388	20.5599
15	21.8998	22.0203
16	23.5588	23.4807
17	24.8388	24.9411
18	26.6788	26.4015
19	27.7588	27.8619
20	29.3988	29.3223
21	30.7588	30.7827
22	32.3488	32.2431
23	33.6788	33.7035
24	35.4588	35.1639
25	36.5988	36.6243
26	37.9688	38.0847
27	39.5288	39.5451
28	40.8798	41.0055
29	42.5388	42.4659
30	43.8988	43.9263
31	45.4588	45.3867
32	46.7588	46.8471
33	48.4788	48.3075
34	49.6588	49.7679
35	51.3988	51.2283
36	52.6588	52.6887

37	54.4188	54.1491
38	55.5788	55.6095
39	56.9488	57.0699
40	58.5988	58.5303
41	59.8688	59.9907
42	61.4288	61.4511
43	62.7888	62.9115
44	64.5388	64.3719
45	65.6998	65.8323
46	67.5588	67.2927
47	68.6388	68.7531
48	70.4788	70.2135
49	71.6388	71.6739
50	72.9989	73.1343
51	74.4598	74.5947
52	75.9388	76.0551
53	77.5788	77.5155
54	78.8488	78.9759
55	80.4988	80.4363
56	81.7598	81.8967
57	83.4188	83.3571
58	84.7788	84.8175
59	86.3488	86.2779
60	87.6888	87.7383

Table5. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
7	20.44	18.34
14	27.69	30.32
21	30.66	32.15
28	31.19	34.23

Table6. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
7	19.38	19.414
14	28.24	26.0948
21	30.66	33.5204
28	40.81	41.6908
35	51.11	50.606
42	61.32	60.266
49	71.54	70.6708
56	81.76	81.8204
60	87.62	88.526

Table7. *Predictive Values of Compressive Strength at Different Curing Age*

Metakaoline Content %	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
5	16.01	15.85
10	32.22	32.677
15	49.82	49.504
20	66.43	66.331
25	83.04	83.158

Table8. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Curing Age	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
7	13.85	11.2553

14	20.44	21.3871
21	23.39	30.4115
28	40.88	38.3285
35	49.45	45.1381
42	51.51	50.8403
49	53.66	55.4351
56	57.23	58.9225
60	61.32	60.4181

Table9. *Predictive Values of Compressive Strength at Different Curing Age*

Metakaoline Content %	Predictive Values of Compressive Strength KN/m2	Experimental Values of Compressive Strength KN/m2
5	14.61	14.59
10	29.21	29.21
15	43.81	43.83
20	58.41	58.45
25	73.11	73.07

Table10. *Predictive Values of Compressive Strength influenced by Variations of Water Cement Ratio at Different Curing Age*

W/C	0.23	0.25	0.27	0.3	0.35	0.4	0.45	0.5
FCu 7	5.27	5.13	4.99	4.79	4.45	4.11	3.75	3.42
FCu 14	10.54	10.26	9.99	9.58	8.9	8.22	7.53	6.85
FCu 21	15.81	15.41	14.99	14.38	13.35	12.32	11.29	10.27
FCu 28	21.09	20.54	19.99	19.17	17.81	16.43	15.06	13.69

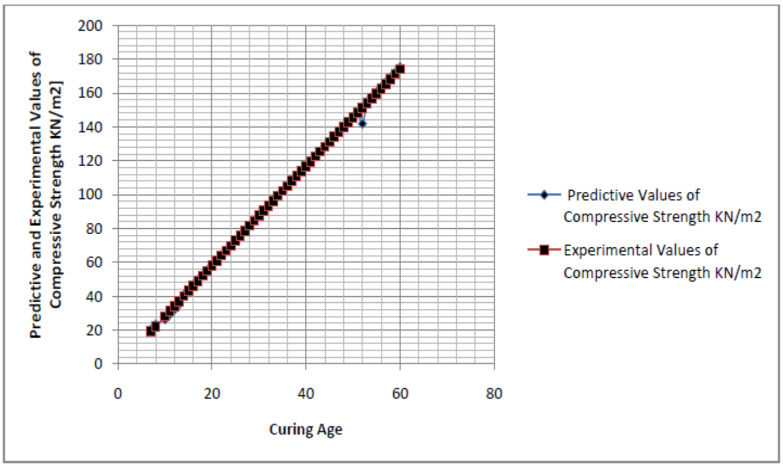

Figure1. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

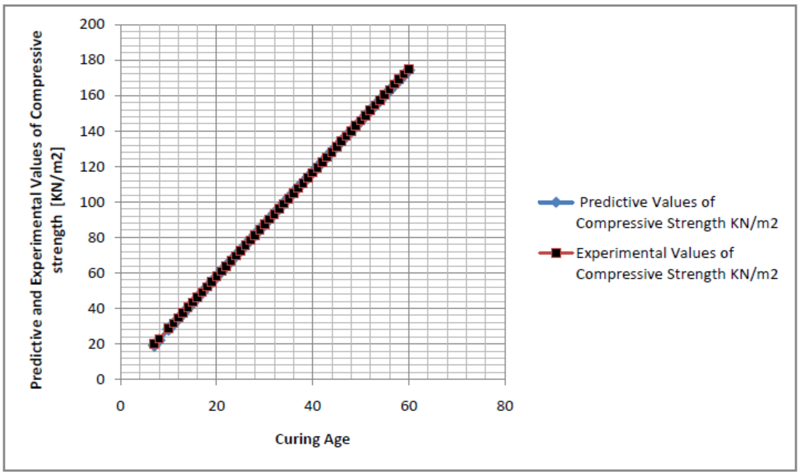

Figure2. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

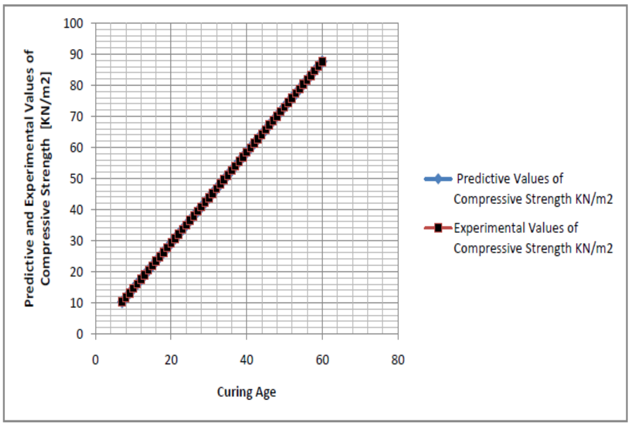

Figure3. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

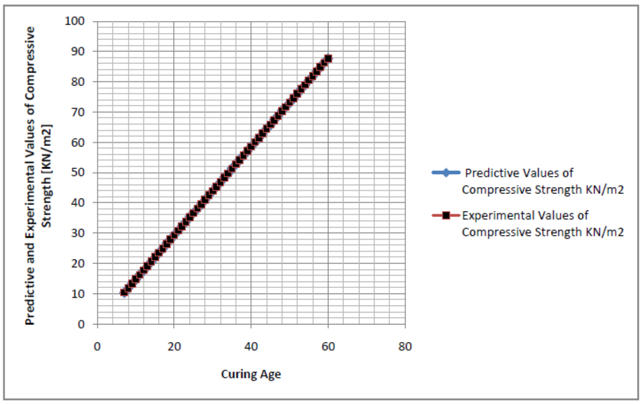

Figure4. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

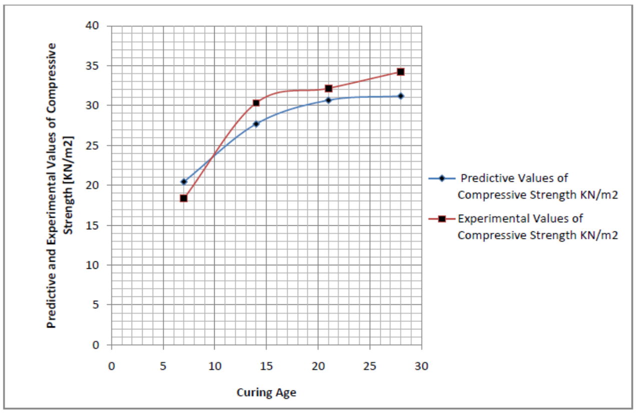

Figure5. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

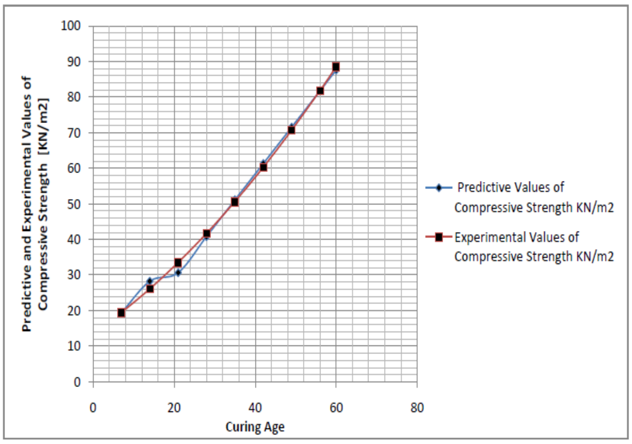

Figure6. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

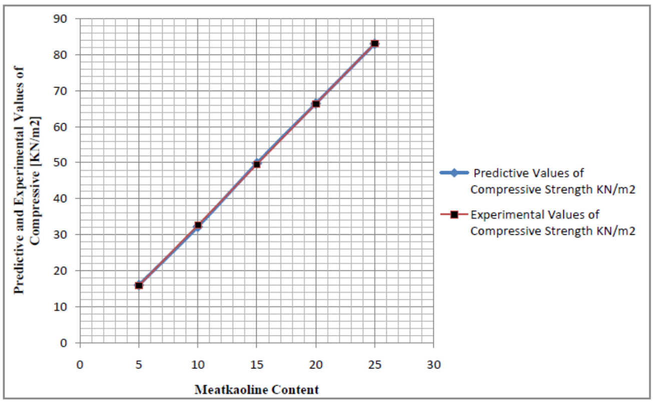

Figure7. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

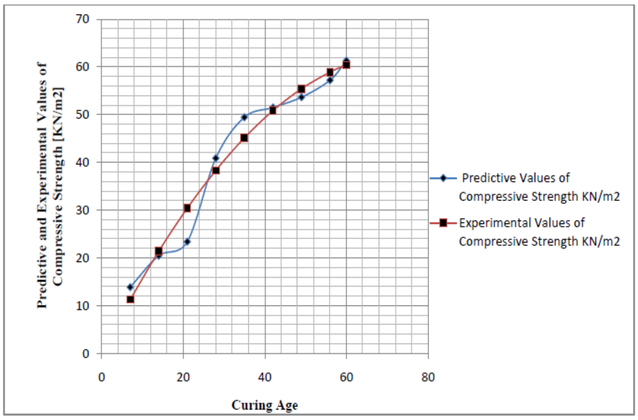

Figure8. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

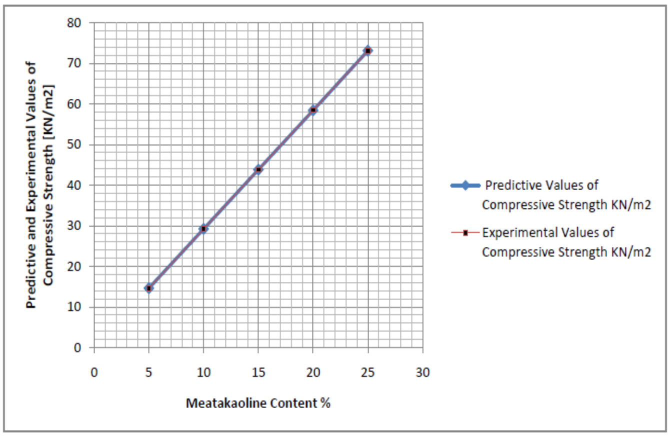

Figure9. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

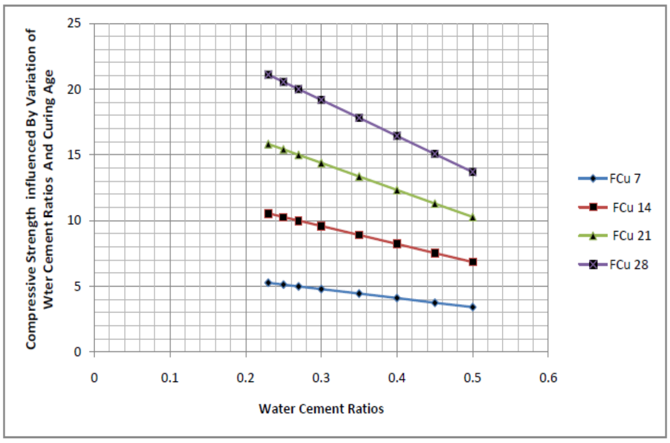

Figure10. *Predictive and Experimental Values of Compressive Strength at Different Curing Age*

Results and Discussion

The figure 1-10 express the behavior of compressive strength at different curing age, linear trend were observed in most of the figures from 7- 90days of curing age, the compressive strength experienced gradual and rapid increase to the optimum rated recorded in most of the figures, monitoring the compressive strength modified with metakaoline content at different percentage also express its behavior in terms of strength development, the expression from the strength also show the rate of increase influenced by increase rate of metakaoline content to the optimum rate recorded at ninety days, fluctuation on the variation of metakaoline content for concrete strength were experienced in some figures influenced by percentage of metakaoline, the predictive values were subjected to validation with experimental values, and both parameter developed best fits correlations, variations influenced from different water cement ratios observed decrease in compressive strength as water cement ratios increase, while the decrease in water cement ratios increase compressive strength of the concrete, these express the behavior of various mix design for high strength concrete at different water cement ratios. These were observed at different curing age, compressive strength also achieved strength monitoring at every twenty four hours of curing age to ninety day, these concept also shows the rate of strength increase influenced by various mix design concrete placement and various curing techniques.

Conclusion

The study has shown the rate of efficiency from metakaoline in the various conditions from different mix designed integrating metakaoline, variation of strength development from various percentage of metakaoline were observed from the rate of compressive strength, these were experienced from various compressive strength at different curing age at every twenty four hours, while others observed strength from simulation that experienced fluctuation at every seven days interval, the efficiency of mix design for high strength influenced by variation of water cement ratios were monitor for various addition of metakaoline content, the develop model express the behavior of compressive strength modified with metakaoline at every percent increase on strength development. The study applying deterministic concept has generated developed model that express predictive rate of high compressive strength from metakaoline as a modifier for high strength concrete. Validation carried has shown that the developed model has high percentage authenticity in its application.

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