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Development of Mathematical Model to Predict Variation of Compressive Strength on Medium Self-Compact Concrete

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ABSTRACT

This study expresses the behaviour of the compressive strength on medium self-compact concrete at different curing age. This study monitor the system in different dimensions, the study monitor the materials on the stage whereby its mixed design integrate addictive for higher concrete strength, these condition were to determine the material behaviour on self-compacting ability, several studies has been carried out on self-compacting concrete, but deterministic techniques has not been applied, this concept were adopted to monitor the material on compressive strength numerically and analytically, the study also monitor the system influenced by water cement ratios at different mixed proportions', the results express the growth rate of the material to the optimum level recorded at ninety days of curing age, the results shows that between [0.23, 0.40, 0.50] the mixed proportion of [0.23] obtained the highest compressive strength, the derived predictive values were subjected to model validation, and both parameters developed best fits correlations, the study has express the influence from mixed design and variation of its proportion at different curing age, it explained the effect from variation of void ratios and concrete porosity at various mixed design.

Keywords: *mathematical model, Compressive strength, self-compact, and concrete.*

INTRODUCTION

Self-compacting concrete (SCC) at medium level is another developed category of high-performance concrete formation, these are characterized by capability to spread into place under through its own weight without the application of vibration. Self-compacting concrete will develop no segregation and blocking, Self-compacting concrete (SCC) has been the centre for current studies. Several inherent properties of the concrete have not been yet understood. High performance Concrete (HPC) and Self compacting concrete (SCC) has been observed not to the same, both designed material are different, but they are essentially in the application of special admixture [Kisihi et al 2000; Ode and Eluozo 2016a]. This may be due to the application of chemicals including mineral admixtures, that is why the study of its micro cracks are more essential in self-compacting concrete compared to normal compacting concrete [Drutta 2003; Wittmann, 2002,Hamid et al 2012;Ode and Eluozo 2016b].

Experts in several literature has evaluated that increase in densities will definitely increase the compressive strength of concrete including that of tensile strength and it fracture energy, while the characteristics will decrease with an increase in its density[Giaccio et al 2000Ode and Eluozo 2016acHamid et al 2012] more so, fracture behaviour of plain concrete is the fundamental of most conducted research on the observation of reinforced concrete including prestressed concrete structures and that of fracture mechanics, experimental research has ascertained the influence on aggregate fracture behaviour in concrete, it has been investigated by experts that the size in aggregate experienced decrease in brittleness of harden concrete and observed increase in fracture energy including fracture toughness [Amparan et al 2000;App et al 2002; Strange and Bryant 1979Ode and Eluozo 2016d], several studies has been observed in other material application for high concrete strength using 3/8 all in one aggregate, these has produced several result using different admixture and mixed designed, these has also generated the effect from water cement ratio including concrete characteristics[Ode and Eluozo 2016e;Ode and Eluozo 2016f; Jaja et al 2019].

THEORETICAL BACKGROUND

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

Where $A_{(y)}$ and $B_{(y)}$ are function of y

$$\frac{dc}{dy} + A_{(y)} C_{(d)} = B_{(y)} C_d^{\,n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2a)$$

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

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

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)

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

$$\frac{2d\beta}{dy} + (1-n) B(y) \beta = 2(1-n) B(y) \ldots\ldots \quad (4)$$

$$\frac{2d\beta}{dy} + \beta (1-n) B(y) = 2(1-n) B(y) \ldots\ldots \quad (5)$$

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

$$\beta = \frac{1}{\phi^2} \int (1-n) B(y) dy = \frac{1}{\phi^2} (1-n) B(y) Y + K_1 \ldots (6)$$

$$\left[\beta = \frac{(1-n)}{\phi^2} B(y) Y \right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

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 demoulded and subjected to curing for 1-90 days and seven days 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 specimens was calculated by using the following equation below:

Compressive strength (N/mm^2) = Ultimate compressive load (N)

Area of cross section of specimen (mm2)

RESULT AND DISCUSSION

Table1: *Predictive and Experimental Values of Compressive Strength for Medium Self Compact Concrete at Different Curing Age*

Curing Age	Predictive Values of Compressive Strength for Medium Self-Compact Concrete KN/m^2 [W/C 0.23]	Experimental Values of Comprehensive Strength for Medium Self-Compact Concrete KN/m^2 [W/C 0.23]
7	5.271823291	5.271
8	6.024940904	6.024
9	6.778058517	6.777
10	7.53117613	7.53
11	8.284293743	8.283
12	9.037411356	9.036
13	9.790528969	9.789
14	10.54364658	10.542
15	11.2967642	11.295
16	12.04988181	12.048
17	12.80299942	12.801
18	13.55611703	13.554
19	14.30923465	14.307
20	15.06235226	15.06
21	15.81546987	15.813
22	16.56858749	16.566
23	17.3217051	17.319
24	18.07482271	18.072
25	18.82794033	18.825

26	19.58105794	19.578
27	20.33417555	20.331
28	21.08729316	21.084
29	21.84041078	21.837
30	22.59352839	22.59
31	23.346646	23.343
32	24.09976362	24.096
33	24.85288123	24.849
34	25.60599884	25.602
35	26.35911646	26.355
36	27.11223407	27.108
37	27.86535168	27.861
38	28.61846929	28.614
39	29.37158691	29.367
40	30.12470452	30.12
41	30.87782213	30.873
42	31.63093975	31.626
43	32.38405736	32.379
44	33.13717497	33.132
45	33.89029259	33.885
46	34.6434102	34.638
47	35.39652781	35.391
48	36.14964542	36.144
49	36.90276304	36.897
50	37.65588065	37.65
51	38.40899826	38.403
52	39.16211588	39.156
53	39.91523349	39.909
54	40.6683511	40.662
55	41.42146872	41.415
56	42.17458633	42.168
57	42.92770394	42.921
58	43.68082155	43.674
59	44.43393917	44.427
60	45.18705678	45.18
61	45.94017439	45.933
62	46.69329201	46.686
63	47.44640962	47.439
64	48.19952723	48.192
65	48.95264485	48.945
66	49.70576246	49.698
67	50.45888007	50.451
68	51.21199768	51.204
69	51.9651153	51.957
70	52.71823291	52.71
71	53.47135052	53.463
72	54.22446814	54.216
73	54.97758575	54.969
74	55.73070336	55.722
75	56.48382098	56.475
76	57.23693859	57.228
77	57.9900562	57.981
78	58.74317381	58.734
79	59.49629143	59.487
80	60.24940904	60.24

81	61.00252665	60.993
82	61.75564427	61.746
83	62.50876188	62.499
84	63.26187949	63.252
85	64.01499711	64.005
86	64.76811472	64.758
87	65.52123233	65.511
88	66.27434994	66.264
89	67.02746756	67.017
90	67.78058517	67.77

Table2: *Predictive Values of Compressive Strength for Medium Self Compact Concrete at Different Water Cement Ratio and Curing Age*

Curing Age	Predictive Values of Compressive Strength KN/m^2 [W/C 0.27]	Predictive Values of Compressive Strength KN/m^2 [W/C 0.40]	Predictive Values of Compressive Strength KN/m^2 [W/C 0.50]
7	4.99796234	4.107914251	3.423261877
8	5.71195696	4.694759144	3.912299288
9	6.42595158	5.281604037	4.401336699
10	7.1399462	5.86844893	4.89037411
11	7.85394082	6.455293823	5.379411521
12	8.56793544	7.042138716	5.868448932
13	9.28193006	7.628983609	6.357486343
14	9.99592468	8.215828502	6.846523754
15	10.7099193	8.802673395	7.335561165
16	11.42391392	9.389518288	7.824598576
17	12.13790854	9.976363181	8.313635987
18	12.85190316	10.56320807	8.802673398
19	13.56589778	11.15005297	9.291710809
20	14.2798924	11.73689786	9.78074822
21	14.99388702	12.32374275	10.26978563
22	15.70788164	12.91058765	10.75882304
23	16.42187626	13.49743254	11.24786045
24	17.13587088	14.08427743	11.73689786
25	17.8498655	14.67112233	12.22593528
26	18.56386012	15.25796722	12.71497269
27	19.27785474	15.84481211	13.2040101
28	19.99184936	16.431657	13.69304751
29	20.70584398	17.0185019	14.18208492
30	21.4198386	17.60534679	14.67112233
31	22.13383322	18.19219168	15.16015974
32	22.84782784	18.77903658	15.64919715
33	23.56182246	19.36588147	16.13823456
34	24.27581708	19.95272636	16.62727197
35	24.9898117	20.53957126	17.11630939
36	25.70380632	21.12641615	17.6053468
37	26.41780094	21.71326104	18.09438421
38	27.13179556	22.30010593	18.58342162
39	27.84579018	22.88695083	19.07245903
40	28.5597848	23.47379572	19.56149644
41	29.27377942	24.06064061	20.05053385
42	29.98777404	24.64748551	20.53957126
43	30.70176866	25.2343304	21.02860867
44	31.41576328	25.82117529	21.51764608
45	32.1297579	26.40802019	22.0066835

46	32.84375252	26.99486508	22.49572091
47	33.55774714	27.58170997	22.98475832
48	34.27174176	28.16855486	23.47379573
49	34.98573638	28.75539976	23.96283314
50	35.699731	29.34224465	24.45187055
51	36.41372562	29.92908954	24.94090796
52	37.12772024	30.51593444	25.42994537
53	37.84171486	31.10277933	25.91898278
54	38.55570948	31.68962422	26.40802019
55	39.2697041	32.27646912	26.89705761
56	39.98369872	32.86331401	27.38609502
57	40.69769334	33.4501589	27.87513243
58	41.41168796	34.03700379	28.36416984
59	42.12568258	34.62384869	28.85320725
60	42.8396772	35.21069358	29.34224466
61	43.55367182	35.79753847	29.83128207
62	44.26766644	36.38438337	30.32031948
63	44.98166106	36.97122826	30.80935689
64	45.69565568	37.55807315	31.2983943
65	46.4096503	38.14491805	31.78743172
66	47.12364492	38.73176294	32.27646913
67	47.83763954	39.31860783	32.76550654
68	48.55163416	39.90545272	33.25454395
69	49.26562878	40.49229762	33.74358136
70	49.9796234	41.07914251	34.23261877
71	50.69361802	41.6659874	34.72165618
72	51.40761264	42.2528323	35.21069359
73	52.12160726	42.83967719	35.699731
74	52.83560188	43.42652208	36.18876841
75	53.5495965	44.01336698	36.67780583
76	54.26359112	44.60021187	37.16684324
77	54.97758574	45.18705676	37.65588065
78	55.69158036	45.77390165	38.14491806
79	56.40557498	46.36074655	38.63395547
80	57.1195696	46.94759144	39.12299288
81	57.83356422	47.53443633	39.61203029
82	58.54755884	48.12128123	40.1010677
83	59.26155346	48.70812612	40.59010511
84	59.97554808	49.29497101	41.07914252
85	60.6895427	49.88181591	41.56817994
86	61.40353732	50.4686608	42.05721735
87	62.11753194	51.05550569	42.54625476
88	62.83152656	51.64235058	43.03529217
89	63.54552118	52.22919548	43.52432958
90	64.2595158	52.81604037	44.01336699

Table3. *Predictive Values of Compressive Strength for Medium Self Compact Concrete at Different Water Cement Ratio*

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
FCu 60	45.19	44.01	42.39	41.08	38.14	35.21	32.28	29.34
FCu 90	67.78	66.02	64.25	61.61	57.22	52.81	48.41	44.01

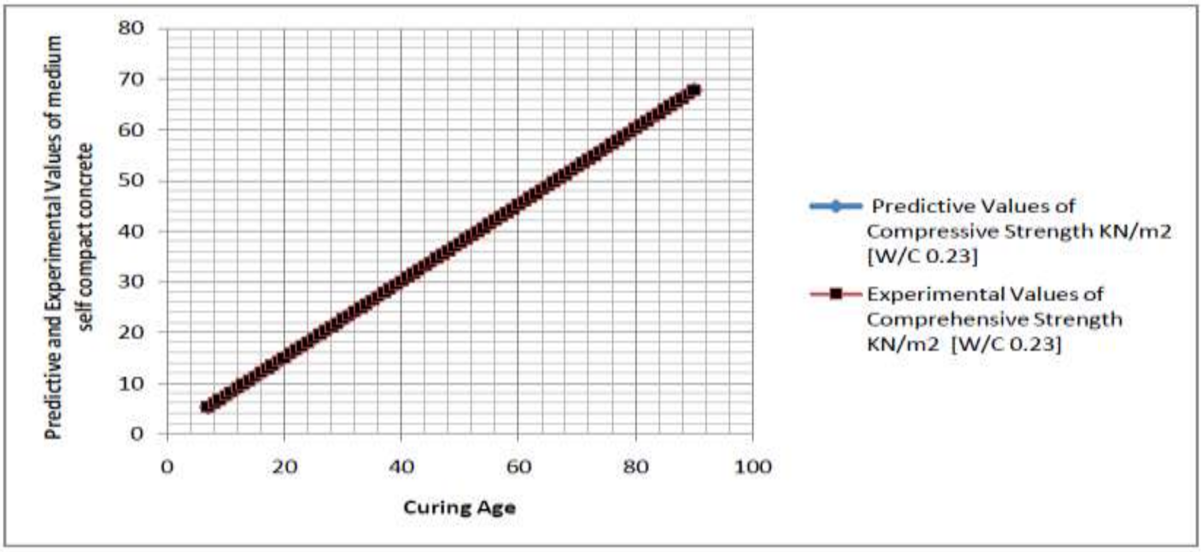

Figure1. *Predictive and Experimental Values of Compressive Strength for Medium Self Compact Concrete at Different Curing Age*

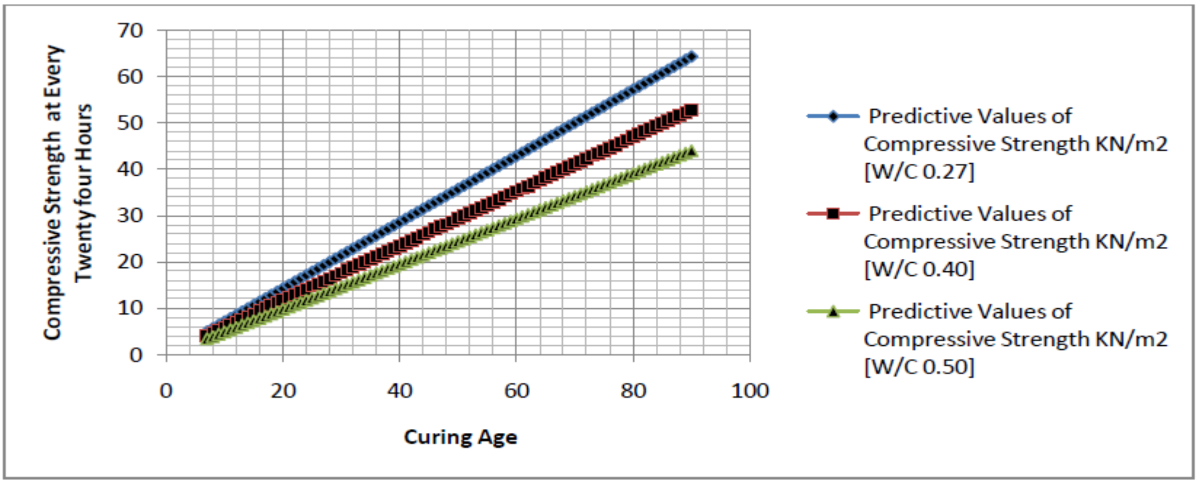

Figure2. *Predictive Values of Compressive Strength for Medium Self Compact Concrete at Different Water Cement Ratio and Curing Age*

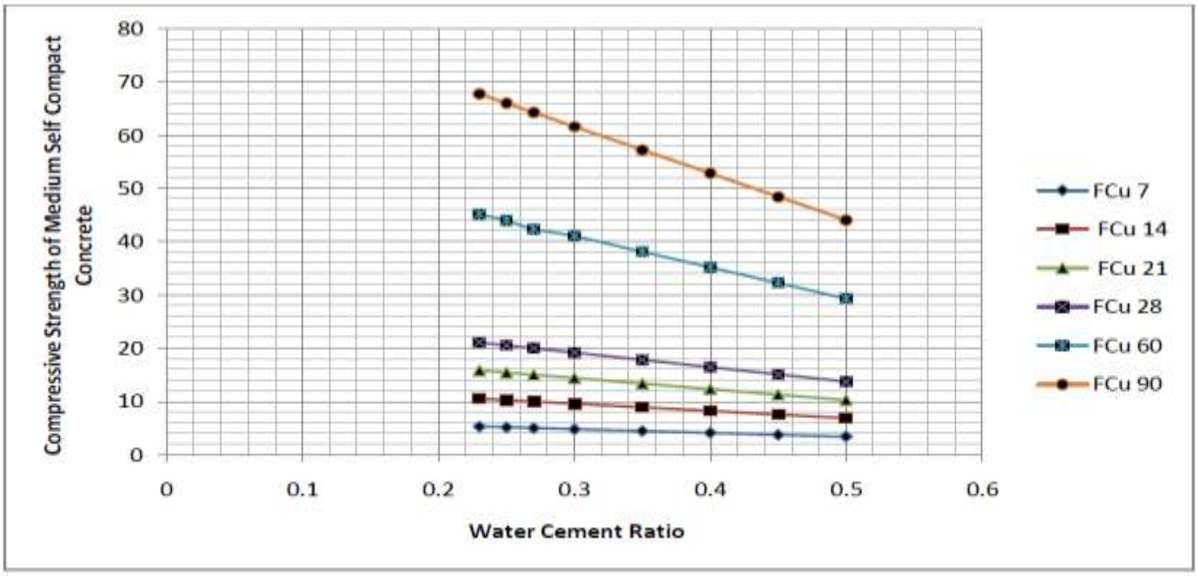

Figure3. *Predictive Values of Compressive Strength for Medium Self Compact Concrete at Different Water Cement Ratio*

Figure one explained the growth rate of the material on linear trend as observed from the figure, this implies that the compressive strength experienced homogeneous growth to the optimum values recorded at ninety days of curing age, similar condition were observed on the experimental values as they develop best fits correlation. Figure two explain numerical behaviour of compressive strength of concrete at different water cement ratios, the growth rate experienced linear trend to the optimum values, but the growth of 0.23 develop the optimum compressive strength, while water cement ratio of 0.50 generated the lowest compressive strength. Figure three express the compressive strength analytically where at interval of seven days of curing age, compressive strength were observed to the optimum values at ninety days

CONCLUSION

Self-compacting concrete (SCC) at medium level is another developed category of high-performance concrete formation, these are characterized by capability to spread into place under through its own weight without the application of vibration. self-compact concrete will develop no segregation and blocking, this are new conceptual techniques in construction industries, it has the ability to flow into underweight thus filling perfectly the formwork without the application of vibration, this will be done without segregation of concrete between the cement paste and aggregate, the concept allow to obtain a balance condition between deformability and stability, based on these factors, there is need to increase the strength development in other to achieved high percentage of this result, the application of addictive's are introduced, this materials are fly ash and super plasticizers etc. other advantage includes the application of such substances that provide saving environmental benefits due to its consumptions of by- product. The study applied these techniques to monitor the behaviour of its strength development in the application of it in construction industries, the strength generated has its required breakthrough of applying it for construction at the same time achieve the required results, since these concept has been applied, this paper applied modeling and simulation to monitor the material growth rate numerically and analytically, the influences from water cement ratios were observed in the system as the material express variation of it strength in different designed mixed proportions. The generated results were compared with experimental values, and the results developed best fits correlations.

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