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Research Article

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Partial Replacement of Microsilca on Compressive Strength Concrete: Applying Predictive Model

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Abstract

Monitoring the rate of micro-silica variation was carried out to determine different rate of strength developed applying various dosage, these are the pozzolanic reaction which occurs between silica fume and CH producing additional CSH in many of the voids around hydrated cement particles. This is due to high surface area of silica fume that normally affect the mobility of water within concrete segregation, this include bleeding of concrete that are virtually eliminated . This application detailed on the reactions from micro-silica reflection of it are influential factors on rapid increase of concrete strength, these are based on the mixed designed output, such application reflects the significant growth rate of concrete performance in the study, mathematical model application using analytical solution generated derived model for the study, this derived model techniques developed predictive values through simulation, the predictive were applied on the reflection of various water cement ratios including variation of micro-silica dosage numerically to ninety days of curing, water cement ratios influence of strength development were expressed in the study, variation of concrete permeability and void ratios are also detailed as an influential factor in concrete formations, the study has express its significant influence based on the developed strength within seven and ninety days of curing.

Keywords: Application, Micro-Silica, Compressive Strength, and Predictive Model

Introduction

The application Ordinary Portland Cement (OPC) is recognized as the main construction material applied globally. The manufacture rate is roughly about 2.1 billion tons per year, it is expected to grow to about 3.5 billion tons per year by 2015 or more [1,2]. According to Adepegba, but in Nigeria the annual cement requirement in Nigeria is about 8.2 million tones and only 4.6 million tons of Portland cement are generated locally [3,4]. The balance of 3.6 million tons or more is imported. If alternative cheap cement can be manufacture locally, the demand for Portland cement will reduce. The search for suitable local materials to manufacture pozzolana cement was therefore intensified [3,5]. A large amount increase in cement demand could be met through the application of supplementary cementing materials, this to ensure there is reduction of green gas emission [6,7]. Industrial wastes, such as silica fume, blast furnace slag, fly ash are being applied as partial replacement cement materials and recently, agricultural wastes are also applied as pozzolanic materials in concrete [8, 9, 10]. Developed High strength concrete that is refers as uniaxial compressive strength; these are greater than the normal strength concrete obtained in a particular region. More so high strength including it high performance concrete are being broadly used throughout the world and to produce them, it is necessary to reduce the water binder ratio and increase the binder content [11-18]. High strength concrete means good abrasion, impact and cavitation's resistance.

Theoretical Backgrounds

Nomenclature

C	=	compressive strength
$A_{(x)}$	=	Cementious Materials
$B_{(x)}$	=	concrete void ratio
C^{-n}-$[\alpha_{1x}]$	=	Water cement Ratios/flexural Strength
x	=	curing Age

$$\frac{dc}{dx} + A_{(x)}\, C_d + B_{(x)}\, C_d^n = 0 \quad \text{.....................................} \quad (1)$$

Transform the above Bernoulli's Equation to a linear first order DE gives:

$$\frac{dk}{dx} + (1-n)k = (1-n)\, B_{(x)} \quad \text{.....................................} \quad (2)$$

Let I.F = $\ell^{-\alpha x_{1x}}$

Use I.F to Solve (2) above

Hence, the general Solution becomes:

$$C_d^{1-n} = -\frac{B}{A} + Ce^{-\alpha_1 x} \quad \text{.........................} \quad (3)$$

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. Seven day interval, the specimens were demoulded and subjected to curing for 7-28 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 3.1.

Compressive strength (N/mm^2) = Ultimate compressive load (N)
Area of cross section of specimen (mm^2)

Results and Discussion

Table 1: Variation of Experimental Values of compressive strength at various Water Cement Ratios

Variation of W/C]	[0.23]	0.25]	0.27]	0.30]	0.35]	0.40]
7fcu	8.504452345	8.278688275	8.052924205	7.7142781	7.149867926	6.585457752
8fcu	9.746154728	9.488138648	9.230122569	8.843098449	8.19805825	7.553018051
9fcu	10.98785711	10.69758902	10.40732093	9.971918798	9.246248574	8.52057835
10fcu	12.2295595	11.9070394	11.5845193	11.10073915	10.2944389	9.488138648
11fcu	13.47126188	13.11648977	12.76171766	12.2295595	11.34262922	10.45569895
12fcu	14.71296426	14.32594014	13.93891602	13.35837984	12.39081955	11.42325925
13fcu	15.95466665	15.53539052	15.11611439	14.48720019	13.43900987	12.39081955
14fcu	17.19636903	16.74484089	16.29331275	15.61602054	14.48720019	13.35837984
15fcu	18.43807141	17.95429126	17.47051111	16.74484089	15.53539052	14.32594014
16fcu	19.6797738	19.16374164	18.64770948	17.87366124	16.58358084	15.29350044
17fcu	20.92147618	20.37319201	19.82490784	19.00248159	17.63177116	16.26106074
18fcu	22.16317856	21.58264239	21.00210621	20.13130194	18.67996149	17.22862104
19fcu	23.40488095	22.79209276	22.17930457	21.26012229	19.72815181	18.19618134
20fcu	24.64658333	24.00154313	23.35650293	22.38894263	20.77634214	19.16374164
21fcu	25.88828572	25.21099351	24.5337013	23.51776298	21.82453246	20.13130194
22fcu	27.1299881	26.42044388	25.71089966	24.64658333	22.87272278	21.09886224
23fcu	28.37169048	27.62989425	26.88809802	25.77540368	23.92091311	22.06642253
24fcu	29.61339287	28.83934463	28.06529639	26.90422403	24.96910343	23.03398283
25fcu	30.85509525	30.048795	29.24249475	28.03304438	26.01729376	24.00154313
26fcu	32.09679763	31.25824537	30.41969312	29.16186473	27.06548408	24.96910343
27fcu	33.33850002	32.46769575	31.59689148	30.29068508	28.1136744	25.93666373
28fcu	34.5802024	33.67714612	32.77408984	31.41950542	29.16186473	26.90422403
29fcu	35.82190478	34.8865965	33.95128821	32.54832577	30.21005505	27.87178433
30fcu	37.06360717	36.09604687	35.12848657	33.67714612	31.25824537	28.83934463
31fcu	38.30530955	37.30549724	36.30568493	34.80596647	32.3064357	29.80690493
32fcu	39.54701194	38.51494762	37.4828833	35.93478682	33.35462602	30.77446523
33fcu	40.78871432	39.72439799	38.66008166	37.06360717	34.40281635	31.74202552
34fcu	42.0304167	40.93384836	39.83728003	38.19242752	35.45100667	32.70958582
35fcu	43.27211909	42.14329874	41.01447839	39.32124787	36.49919699	33.67714612
36fcu	44.51382147	43.35274911	42.19167675	40.45006821	37.54738732	34.64470642
37fcu	45.75552385	44.56219949	43.36887512	41.57888856	38.59557764	35.61226672
38fcu	46.99722624	45.77164986	44.54607348	42.70770891	39.64376797	36.57982702
39fcu	48.23892862	46.98110023	45.72327184	43.83652926	40.69195829	37.54738732
40fcu	49.480631	48.19055061	46.90047021	44.96534961	41.74014861	38.51494762
41fcu	50.72233339	49.40000098	48.07766857	46.09416996	42.78833894	39.48250792
42fcu	51.96403577	50.60945135	49.25486694	47.22299031	43.83652926	40.45006821

43fcu	53.20573816	51.81890173	50.4320653	48.35181066	44.88471958	41.41762851
44fcu	54.44744054	53.0283521	51.60926366	49.480631	45.93290991	42.38518881
45fcu	55.68914292	54.23780247	52.78646203	50.60945135	46.98110023	43.35274911
46fcu	56.93084531	55.44725285	53.96366039	51.7382717	48.02929056	44.32030941
47fcu	58.17254769	56.65670322	55.14085875	52.86709205	49.07748088	45.28786971
48fcu	59.41425007	57.8661536	56.31805712	53.9959124	50.1256712	46.25543001
49fcu	60.65595246	59.07560397	57.49525548	55.12473275	51.17386153	47.22299031
50fcu	61.89765484	60.28505434	58.67245384	56.2535531	52.22205185	48.19055061
51fcu	63.13935723	61.49450472	59.84965221	57.38237345	53.27024218	49.15811091
52fcu	64.38105961	62.70395509	61.02685057	58.5111938	54.3184325	50.1256712
53fcu	65.62276199	63.91340546	62.20404894	59.64001414	55.36662282	51.0932315
54fcu	66.86446438	65.12285584	63.3812473	60.76883449	56.41481315	52.0607918
55fcu	68.10616676	66.33230621	64.55844566	61.89765484	57.46300347	53.0283521
56fcu	69.34786914	67.54175659	65.73564403	63.02647519	58.5111938	53.9959124
57fcu	70.58957153	68.75120696	66.91284239	64.15529554	59.55938412	54.9634727
58fcu	71.83127391	69.96065733	68.09004075	65.28411589	60.60757444	55.931033
59fcu	73.07297629	71.17010771	69.26723912	66.41293624	61.65576477	56.8985933
60fcu	74.31467868	72.37955808	70.44443748	67.54175659	62.70395509	57.8661536
61fcu	75.55638106	73.58900845	71.62163585	68.67057693	63.75214541	58.83371389
62fcu	76.79808345	74.79845883	72.79883421	69.79939728	64.80033574	59.80127419
63fcu	78.03978583	76.0079092	73.97603257	70.92821763	65.84852606	60.76883449
64fcu	79.28148821	77.21735957	75.15323094	72.05703798	66.89671639	61.73639479
65fcu	80.5231906	78.42680995	76.3304293	73.18585833	67.94490671	62.70395509
66fcu	81.76489298	79.63626032	77.50762766	74.31467868	68.99309703	63.67151539
67fcu	83.00659536	80.8457107	78.68482603	75.44349903	70.04128736	64.63907569
68fcu	84.24829775	82.05516107	79.86202439	76.57231938	71.08947768	65.60663599
69fcu	85.49000013	83.26461144	81.03922276	77.70113972	72.13766801	66.57419629
70fcu	86.73170251	84.47406182	82.21642112	78.82996007	73.18585833	67.54175659
71fcu	87.9734049	85.68351219	83.39361948	79.95878042	74.23404865	68.50931688
72fcu	89.21510728	86.89296256	84.57081785	81.08760077	75.28223898	69.47687718
73fcu	90.45680967	88.10241294	85.74801621	82.21642112	76.3304293	70.44443748
74fcu	91.69851205	89.31186331	86.92521457	83.34524147	77.37861962	71.41199778
75fcu	92.94021443	90.52131369	88.10241294	84.47406182	78.42680995	72.37955808
76fcu	94.18191682	91.73076406	89.2796113	85.60288217	79.47500027	73.34711838
77fcu	95.4236192	92.94021443	90.45680967	86.73170251	80.5231906	74.31467868
78fcu	96.66532158	94.14966481	91.63400803	87.86052286	81.57138092	75.28223898
79fcu	97.90702397	95.35911518	92.81120639	88.98934321	82.61957124	76.24979928
80fcu	99.14872635	96.56856555	93.98840476	90.11816356	83.66776157	77.21735957
81fcu	100.3904287	97.77801593	95.16560312	91.24698391	84.71595189	78.18491987
82fcu	101.6321311	98.9874663	96.34280148	92.37580426	85.76414222	79.15248017
83fcu	102.8738335	100.1969167	97.51999985	93.50462461	86.81233254	80.12004047
84fcu	104.1155359	101.406367	98.69719821	94.63344496	87.86052286	81.08760077
85fcu	105.3572383	102.6158174	99.87439658	95.7622653	88.90871319	82.05516107
86fcu	106.5989407	103.8252678	101.0515949	96.89108565	89.95690351	83.02272137
87fcu	107.840643	105.0347182	102.2287933	98.019906	91.00509383	83.99028167
88fcu	109.0823454	106.2441685	103.4059917	99.14872635	92.05328416	84.95784197
89fcu	110.3240478	107.4536189	104.58319	100.2775467	93.10147448	85.92540227

fcu90	111.5657502	108.6630693	105.7603884	101.406367	94.14966481	86.89296256

Table 2: Variation of Experimental Values of Compressive strength at Various Water Cement Ratios

Variation of W/C]	0.23	0.25	0.27	0.3	0.35	0.4
7fcu	8.5044	8.279	8.0529	7.7141	7.1499	6.5857
8fcu	9.7461	9.4885	9.2301	8.8429	8.1981	7.5533
9fcu	10.9878	10.698	10.4073	9.9717	9.2463	8.5209
10fcu	12.2295	11.9075	11.5845	11.1005	10.2945	9.4885
11fcu	13.4712	13.117	12.7617	12.2293	11.3427	10.4561
12fcu	14.7129	14.3265	13.9389	13.3581	12.3909	11.4237
13fcu	15.9546	15.536	15.1161	14.4869	13.4391	12.3913
14fcu	17.1963	16.7455	16.2933	15.6157	14.4873	13.3589
15fcu	18.438	17.955	17.4705	16.7445	15.5355	14.3265
16fcu	19.6797	19.1645	18.6477	17.8733	16.5837	15.2941
17fcu	20.9214	20.374	19.8249	19.0021	17.6319	16.2617
18fcu	22.1631	21.5835	21.0021	20.1309	18.6801	17.2293
19fcu	23.4048	22.793	22.1793	21.2597	19.7283	18.1969
20fcu	24.6465	24.0025	23.3565	22.3885	20.7765	19.1645
21fcu	25.8882	25.212	24.5337	23.5173	21.8247	20.1321
22fcu	27.1299	26.4215	25.7109	24.6461	22.8729	21.0997
23fcu	28.3716	27.631	26.8881	25.7749	23.9211	22.0673
24fcu	29.6133	28.8405	28.0653	26.9037	24.9693	23.0349
25fcu	30.855	30.05	29.2425	28.0325	26.0175	24.0025
26fcu	32.0967	31.2595	30.4197	29.1613	27.0657	24.9701
27fcu	33.3384	32.469	31.5969	30.2901	28.1139	25.9377
28fcu	34.5801	33.6785	32.7741	31.4189	29.1621	26.9053
29fcu	35.8218	34.888	33.9513	32.5477	30.2103	27.8729
30fcu	37.0635	36.0975	35.1285	33.6765	31.2585	28.8405
31fcu	38.3052	37.307	36.3057	34.8053	32.3067	29.8081
32fcu	39.5469	38.5165	37.4829	35.9341	33.3549	30.7757
33fcu	40.7886	39.726	38.6601	37.0629	34.4031	31.7433
34fcu	42.0303	40.9355	39.8373	38.1917	35.4513	32.7109
35fcu	43.272	42.145	41.0145	39.3205	36.4995	33.6785
36fcu	44.5137	43.3545	42.1917	40.4493	37.5477	34.6461
37fcu	45.7554	44.564	43.3689	41.5781	38.5959	35.6137
38fcu	46.9971	45.7735	44.5461	42.7069	39.6441	36.5813
39fcu	48.2388	46.983	45.7233	43.8357	40.6923	37.5489
40fcu	49.4805	48.1925	46.9005	44.9645	41.7405	38.5165
41fcu	50.7222	49.402	48.0777	46.0933	42.7887	39.4841
42fcu	51.9639	50.6115	49.2549	47.2221	43.8369	40.4517
43fcu	53.2056	51.821	50.4321	48.3509	44.8851	41.4193
44fcu	54.4473	53.0305	51.6093	49.4797	45.9333	42.3869
45fcu	55.689	54.24	52.7865	50.6085	46.9815	43.3545
46fcu	56.9307	55.4495	53.9637	51.7373	48.0297	44.3221
47fcu	58.1724	56.659	55.1409	52.8661	49.0779	45.2897
48fcu	59.4141	57.8685	56.3181	53.9949	50.1261	46.2573
49fcu	60.6558	59.078	57.4953	55.1237	51.1743	47.2249

50fcu	61.8975	60.2875	58.6725	56.2525	52.2225	48.1925
51fcu	63.1392	61.497	59.8497	57.3813	53.2707	49.1601
52fcu	64.3809	62.7065	61.0269	58.5101	54.3189	50.1277
53fcu	65.6226	63.916	62.2041	59.6389	55.3671	51.0953
54fcu	66.8643	65.1255	63.3813	60.7677	56.4153	52.0629
55fcu	68.106	66.335	64.5585	61.8965	57.4635	53.0305
56fcu	69.3477	67.5445	65.7357	63.0253	58.5117	53.9981
57fcu	70.5894	68.754	66.9129	64.1541	59.5599	54.9657
58fcu	71.8311	69.9635	68.0901	65.2829	60.6081	55.9333
59fcu	73.0728	71.173	69.2673	66.4117	61.6563	56.9009
60fcu	74.3145	72.3825	70.4445	67.5405	62.7045	57.8685
61fcu	75.5562	73.592	71.6217	68.6693	63.7527	58.8361
62fcu	76.7979	74.8015	72.7989	69.7981	64.8009	59.8037
63fcu	78.0396	76.011	73.9761	70.9269	65.8491	60.7713
64fcu	79.2813	77.2205	75.1533	72.0557	66.8973	61.7389
65fcu	80.523	78.43	76.3305	73.1845	67.9455	62.7065
66fcu	81.7647	79.6395	77.5077	74.3133	68.9937	63.6741
67fcu	83.0064	80.849	78.6849	75.4421	70.0419	64.6417
68fcu	84.2481	82.0585	79.8621	76.5709	71.0901	65.6093
69fcu	85.4898	83.268	81.0393	77.6997	72.1383	66.5769
70fcu	86.7315	84.4775	82.2165	78.8285	73.1865	67.5445
71fcu	87.9732	85.687	83.3937	79.9573	74.2347	68.5121
72fcu	89.2149	86.8965	84.5709	81.0861	75.2829	69.4797
73fcu	90.4566	88.106	85.7481	82.2149	76.3311	70.4473
74fcu	91.6983	89.3155	86.9253	83.3437	77.3793	71.4149
75fcu	92.94	90.525	88.1025	84.4725	78.4275	72.3825
76fcu	94.1817	91.7345	89.2797	85.6013	79.4757	73.3501
77fcu	95.4234	92.944	90.4569	86.7301	80.5239	74.3177
78fcu	96.6651	94.1535	91.6341	87.8589	81.5721	75.2853
79fcu	97.9068	95.363	92.8113	88.9877	82.6203	76.2529
80fcu	99.1485	96.5725	93.9885	90.1165	83.6685	77.2205
81fcu	100.3902	97.782	95.1657	91.2453	84.7167	78.1881
82fcu	101.6319	98.9915	96.3429	92.3741	85.7649	79.1557
83fcu	102.8736	100.201	97.5201	93.5029	86.8131	80.1233
84fcu	104.1153	101.4105	98.6973	94.6317	87.8613	81.0909
85fcu	105.357	102.62	99.8745	95.7605	88.9095	82.0585
86fcu	106.5987	103.8295	101.0517	96.8893	89.9577	83.0261
87fcu	107.8404	105.039	102.2289	98.0181	91.0059	83.9937
88fcu	109.0821	106.2485	103.4061	99.1469	92.0541	84.9613
89fcu	110.3238	107.458	104.5833	100.2757	93.1023	85.9289
90 Fcu	111.5655	108.6675	105.7605	101.4045	94.1505	86.8965

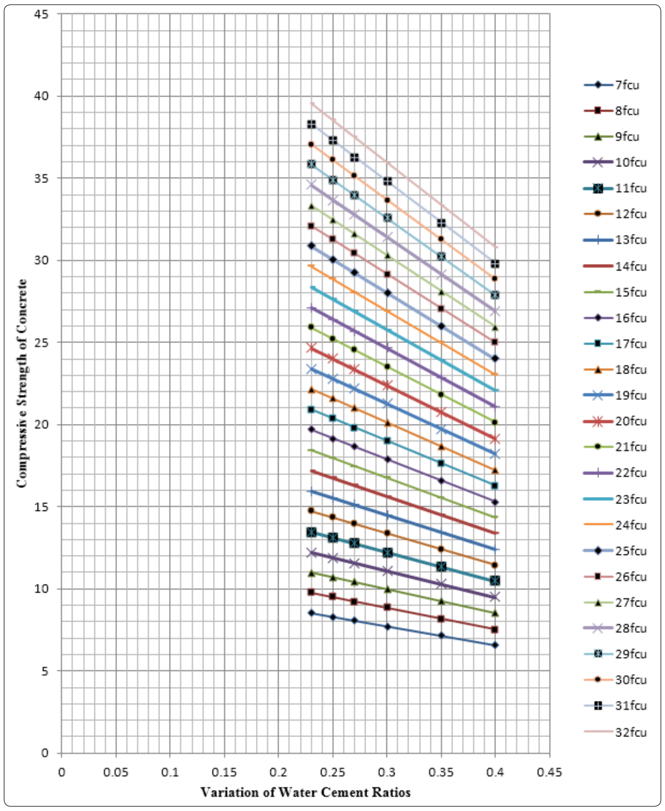

Figure 1a: Variation of Experimental Values of compressive strength at various Water Cement Ratios

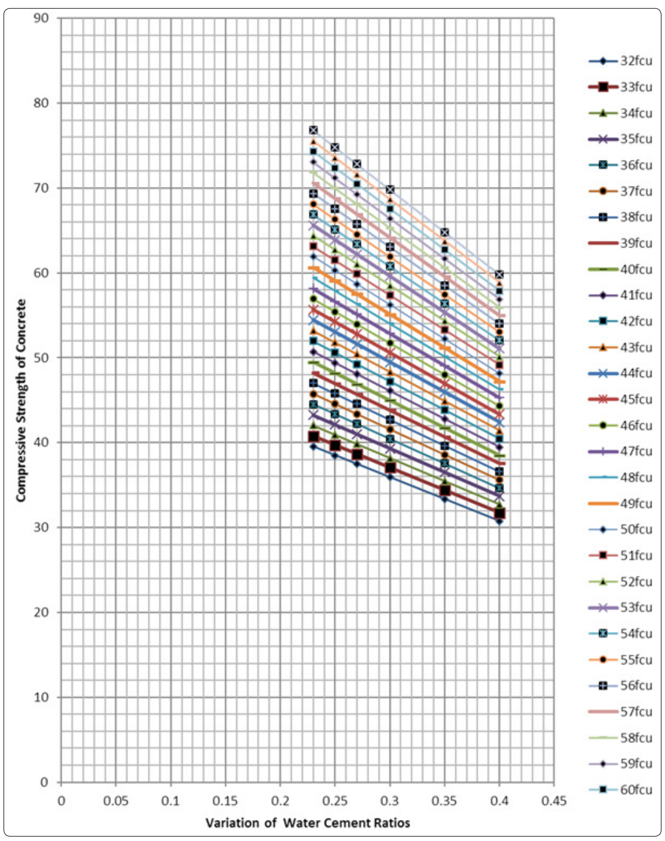

Figure 1b: Variation of Experimental Values of compressive strength at various Water Cement Ratios

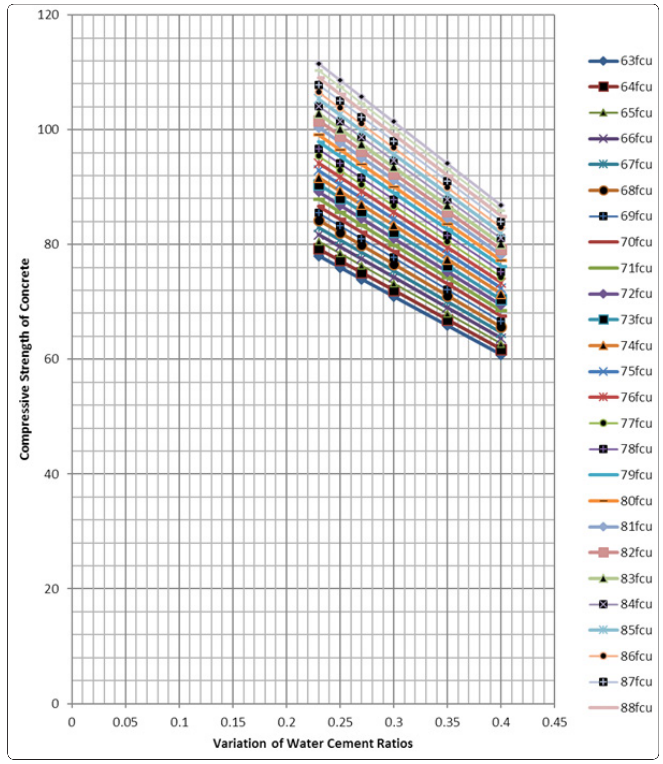

Figure 1c: Variation of Experimental Values of compressive strength at various Water Cement Ratios

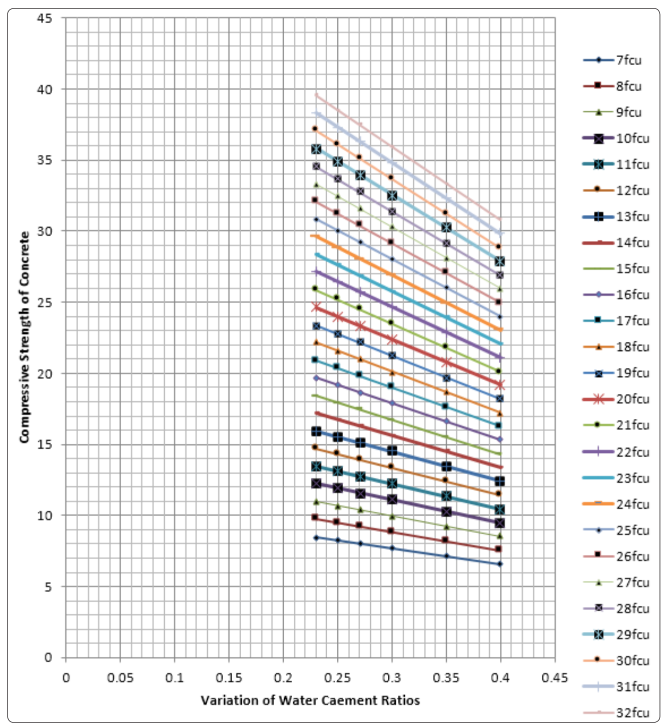

Figure 2a: Variation of Experimental Values of compressive strength at various Water Cement Ratios

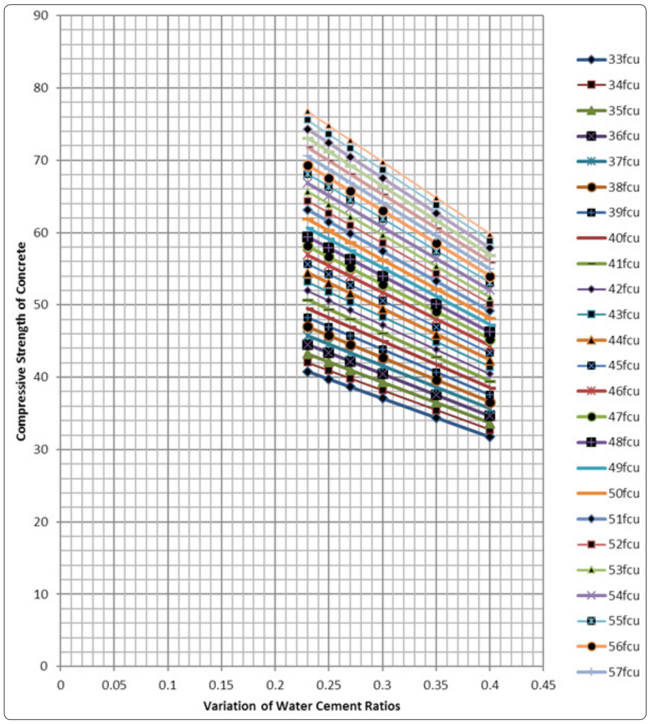

Figure 2b: Variation of Experimental Values of compressive strength at various Water Cement Ratios

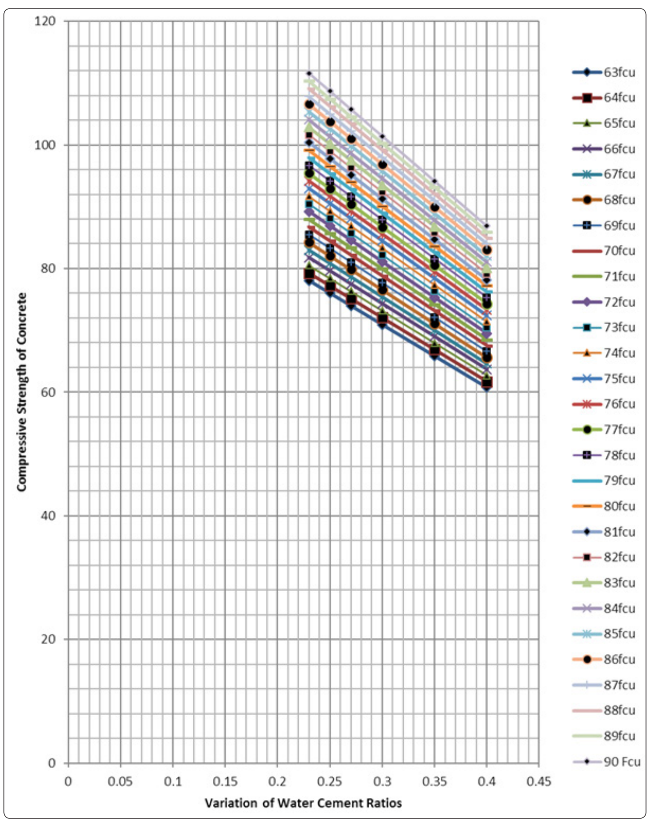

Figure 2c: Variation of Experimental Values of compressive strength at various Water Cement Ratios

The figures express the behavior of micro-silica as partial replacement of cement at different dosage of the addictives, the dosage applied at different mixed proportion based on the developed mixed design output, it generated homogeneous growth rate of compressive strength to the optimum level recorded at ninety days of curing age. Meanwhile, variation of mixed designed using different water cement ratios also generated compressive strength at different curing age, the strength development explained the reaction of micro-silica at different dosage or percentage applied in different mixed proportions. The results has definitely explained some significant factors, these are the pozzolanic reaction which occurs between silica fume and CH producing additional CSH in many of the voids around hydrated cement particles. This is due to high surface area of silica fume that normally affect the mobility of water within concrete segregation and bleeding of concrete that are virtually eliminated. The figures has also express the improvement of micro silica strength and its durability, the provision of uniform distribution and great volume of hydration was observed from the trends, these was archived from decrease in average size of pores in the cement paste. The study has detailed the variation strength development from the mixed proportion of high strength concrete generated at ninety days of curing, the behavior of the concrete properties such as voids ratios and permeability's of the concrete reflected of the concrete strength from the mixed designed concrete model. Numerical simulation applied in various concrete strength developments express the variation of strength at every twenty four hours of curing age. Increase in water cement ratios reflected decrease in compressive strength as observed in the trend, while decrease in water cement ratios reflected increase the strength, this also reflected lower concrete void ratios and permeability influencing the growth rate of concrete strength.

Conclusion

The study has developed the reflections from variation of water cement ratios on concrete strength development, this was carried out applying derived analytical concept. The output from various mixed design was integrated to the development model for high concrete strength and it rates of performance, from these parameters express their various significant on the growth rate of high strength concrete model, the variation of water cement ration signifies the rate of strength development generated from different mixed proportion and design, the reaction of micro-silica in various dosage of application has express the influential factors from the addictives including the mechanical properties, such as permeability and void ratios variations also reflects the influential characteristics of the material to maintained homogeneous growth rates to ninety days of curing. The study monitoring the detailed influential of micro-silica has express the detailed variation of the compressive strength.

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