Trends in Civil Engineering and its Architecture
DOI: 10.32474/TCEIA.2020.04.000179
ISSN: 2637-4668
Research article

Modeling Heterogeneous Grades of Aggregate on Partial Replacement of Metakaolin on Compressive Strength of Concrete

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Received: 📅 August 25, 2020 **Published:** 📅 September 11, 2020

Abstract

Aggregate in different size has been known to be one of the concrete properties in strength development of any grades. The study evaluates the sizes of aggregate in heterogeneous condition to determine their various rate of effect to the optimum required strength. These are determined on the design grade required based on the imposed loads evenly distributed, the study precisely monitored the impact of heterogeneity of aggregate size at different mixed proportion, the size and shapes of aggregate were considered in the study integrated with Metakaolin content at different dosage, the study observed linear growth to the optimum level recorded at twenty eight days of curing, various predictive values were generated to monitor the variationof developed strength influenced by heterogeneous aggregate size, it is observed that the larger the size, the lower surface for the development of the gel bonds, these were monitored and evaluated based on the developed modeling techniques, other observation shows that the bigger size of aggregate on heterogeneous level inconcrete mix prevent the uniformity of load distribution,when it experience stress. Compactions of the concrete were other parameter that displayed its effect on the variation of strength as it experienced the effect on this condition, while others include the cement-aggregate ratios and curing time. The predictive values were compared with experimental data for model validation, and both parameters developed best fits correlation, the study is imperative because the effect of aggregate size and shapes has be evaluated, there rate of impact on concrete strength partially replaced with Metakaolin has been determined.

Keywords: Modeling heterogeneous, Aggregate Metakaolin and compressive strength

Introduction

The pursue for high strength by experts to monitor the growth rate of high-performance concretes has definitely improved substantially in this current time; it has been observed that there high demands for high performance concrete nearly all construction industries. It has observed in the these last three decades, the level integration of cementitious materials, these includes such as fly ash, silica fume and ground granulated blast furnace slag, such modifiers are currently integrated fully, this materials are applied as partial cement replacement materials, more so studies has expressed it clearly that it has experienced meaningfully improvement on the strength and stability characteristics of concrete, comparing it with ordinary Portland cement (OPC) alone. Such examination has definitely provided adequate required curing [1-4]. More so in this current state of scientific approach, there is need for high strength concrete, addictive such as silica fume has been observed to be more useful [5,6].These types of additive's have created serious impact developed good particle packing based on its level of strong pozzolanic property, this implies that it has escalated the resistance of concrete in these aggressive environments, more so Metakaolin (MK) according to [7,8]. Furthermore, materials such as calcined kaolin, and other type of pozzolan, these materials are generated from calcinations; it has the capability to be applied as substitute silica fume material. In nation like India MK has generated a very elevated measure of quantities, these are procedures of generating kaolin mineral, these concepts are very wide spread that has proven it reserves availability in most nations [9-13]. Previously, numerous studies have shown high rate of interest in MK, because it has been observed to possess both pozzolanic and microfiller as its characteristics [4,13-15]. Such application has proven successfully development of high strength, including self-compacting concrete applying mathematical modeling [16,17].

Theoretical Background

$$\frac{d_{cd}}{dx}+V(y)c_d=\varnothing(y)c_d^n \qquad (1.0)$$

Dividing equation (1.0) all through by c_d^n we have

$$c_d^{-n}\frac{d_{cd}}{dx}+v(x)c_c^{1-n}=\varnothing(y) \qquad (1.1)$$

Let

$p=c_d^{1-n}$

$$\frac{dp}{dy}=(1-n)c_d^{1-n}\frac{d_{cd}}{dy} \qquad (1.2)$$

$$c_d^{-n}\frac{d_{cd}}{dy}=\frac{1}{1-n}\frac{dp}{dy}$$

Substituting equation (1.2) and (1.3) into equation (1.1) we have that

$$\frac{1}{1-n}\frac{dp}{dx}+V(y)p=\varnothing(y)$$

Integrating both sides we have $\int d\left[e^{V(y)(1-n)y}p\right]=\varnothing(y)(1-n)\int e^{V(1-n)y}dy$

$$p=\frac{\varnothing(y)}{vu(y)}+Ae^{-Vu(y)(1-n)y}$$

Substituting equation (1.2) into equation (1.13) we have

$$c_d^{1-n}=\frac{\varnothing(y)}{vu(y)}+Ae^{-Vu(y)(1-n)y} \qquad (1.6)$$

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-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

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

Area of cross section of specimen (mm^2)

Results and Discussion

Table 1-7; Figures 1-7. The figures explained the behaviour of the gravel size and shape on the bond from variations of compressive strength at different water cement ratios and curing age. The trend at different figures experienced linear increase to optimum level recorded at twenty eight day of curing, but the compressive observed at different figures experienced the expected variation of strength that determined the effect of heterogeneous aggregate size, because decrease of the strength was experienced at different figures, even though linear trend was observed in all the figures, the impact of the heterogeneity on the concrete shows that larger maximum size aggregate gives lower surface area for developments of gel bonds, this is responsible for the lower strength of the concrete. Secondly bigger aggregate size causes a more heterogeneity in the concrete which will prevent the uniform distribution of load when stressed. The behaviour of the model concrete on Metakaolin as partial replacement for cement experience similar condition, but the developed model concrete grades are high strength, the study observed the effect from the aggregate heterogeneity impact on variation of compressive strength, but still maintained the influenced from the heterogeneous impact in all the figures. The predictive values in figure seven and eight explained the variation of water cement ratios against curing age, the graphical expression shows the rates of decrease in strength as the water cement ratios increase, such experience were determined in the study, numerical simulation shows results expected of the material based on the behaviour of the compressive strength, these experimental values for model validation maintained similar trend expressing best fit correlations.

Table 1: Predictive and experimental values of compressive strength at different curing age.

Curing age	Predictive values of compressive strength [W/C 0.40]	Experimental values of compressive strength [W/C 0.40]
7	29.47561688	27.628
8	31.29773568	29.472
9	33.11985448	31.316
10	34.94197328	33.16
11	36.76409208	35.004

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12	38.58621088	36.848
13	40.40832968	38.692
14	42.23044849	40.536
15	44.05256729	42.38
16	45.87468609	44.224
17	47.69680489	46.068
18	49.51892369	47.912
19	51.34104249	49.756
20	53.16316129	51.6
21	54.98528009	53.444
22	56.80739889	55.288
23	58.62951769	57.132
24	60.45163649	58.976
25	62.27375529	60.82
26	64.09587409	62.664
27	65.91799289	64.508
28	67.74011169	66.352

Table 2: Predictive and experimental values of compressive strength at different curing age.

Curing age	Predictive values of compressive strength [W/C 0.44]	Experimental values of compressive strength [W/C 0.44]
7	28.97549278	27.4
8	30.72616528	29.04
9	32.47683778	30.68
10	34.22751028	32.32
11	35.97818278	33.96
12	37.72885528	35.6
13	39.47952778	37.24
14	41.23020028	38.88
15	42.98087278	40.52
16	44.73154528	42.16
17	46.48221778	43.8
18	48.23289029	45.44
19	49.98356279	47.08
20	51.73423529	48.72
21	53.48490779	50.36
22	55.23558029	52
23	56.98625279	53.64
24	58.73692529	55.28
25	60.48759779	56.92
26	62.23827029	58.56
27	63.98894279	60.2
28	65.73961529	61.84

Table 3: Predictive and experimental values of compressive strength at different curing age.

Curing age	Predictive values of compressive strength [W/C 0.46]	Experimental values of compressive strength[W/C 0.46]
7	28.73283332	27.42
8	30.44884018	29.12
9	32.16484704	30.82
10	33.8808539	32.52
11	35.59686076	34.22
12	37.31286763	35.92
13	39.02887449	37.62
14	40.74488135	39.32
15	42.46088821	41.02
16	44.17689507	42.72
17	45.89290194	44.42
18	47.6089088	46.12
19	49.32491566	47.82
20	51.04092252	49.52
21	52.75692939	51.22
22	54.47293625	52.92
23	56.18894311	54.62
24	57.90494997	56.32
25	59.62095683	58.02
26	61.3369637	59.72
27	63.05297056	61.42
28	64.76897742	63.12

Table 4: Predictive and experimental values of compressive strength at different curing age.

Curing age	Predictivevalues ofcompressive strength [W/C 0.48]	Experimental values of compressive strength[W/C 0.48]
7	28.49497883	26.48
8	30.17700648	28.06
9	31.85903413	29.64
10	33.54106178	31.22
11	35.22308943	32.8
12	36.90511708	34.38
13	38.58714473	35.96
14	40.26917238	37.54
15	41.95120003	39.12
16	43.63322767	40.7
17	45.31525532	42.28
18	46.99728297	43.86
19	48.67931062	45.44
20	50.36133827	47.02
21	52.04336592	48.6
22	53.72539357	50.18
23	55.40742122	51.76
24	57.08944887	53.34
25	58.77147652	54.92
26	60.45350417	56.5

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27	62.13553182	58.08
28	63.81755947	59.66

Table 5: Predictive and experimental values of compressive strength at different curing age.

Curing age	Predictivevalues ofcompressive strength [W/C 0.49]	Experimental values of compressive strength[W/C 0.49]
7	28.37782364	26.55
8	30.04311484	28.14
9	31.70840603	29.73
10	33.37369723	31.32
11	35.03898842	32.91
12	36.70427962	34.5
13	38.36957081	36.09
14	40.03486201	37.68
15	41.7001532	39.27
16	43.3654444	40.86
17	45.03073559	42.45
18	46.69602679	44.04
19	48.36131798	45.63
20	50.02660918	47.22
21	51.69190037	48.81
22	53.35719157	50.4
23	55.02248276	51.99
24	56.68777396	53.58
25	58.35306515	55.17
26	60.01835635	56.76
27	61.68364754	58.35
28	63.34893874	59.94

Table 6: Variation of water cement ratios on experimental values of compressive strength at different curing age.

Variation ofW/C]on experimental values ofcompressive strength	0.4	0.44	0.46	0.48	0.49
7fcu	27.628	27.4	27.42	26.48	26.55
8fcu	29.472	29.04	29.12	28.06	28.14
9fcu	31.316	30.68	30.82	29.64	29.73
10fcu	33.16	32.32	32.52	31.22	31.32
11fcu	35.004	33.96	34.22	32.8	32.91
12fcu	36.848	35.6	35.92	34.38	34.5
13fcu	38.692	37.24	37.62	35.96	36.09
14fcu	40.536	38.88	39.32	37.54	37.68
15fcu	42.38	40.52	41.02	39.12	39.27
16fcu	44.224	42.16	42.72	40.7	40.86
17fcu	46.068	43.8	44.42	42.28	42.45
18fcu	47.912	45.44	46.12	43.86	44.04
19fcu	49.756	47.08	47.82	45.44	45.63
20fcu	51.6	48.72	49.52	47.02	47.22
21fcu	53.444	50.36	51.22	48.6	48.81
22fcu	55.288	52	52.92	50.18	50.4
23fcu	57.132	53.64	54.62	51.76	51.99
24fcu	58.976	55.28	56.32	53.34	53.58

25fcu	60.82	56.92	58.02	54.92	55.17
26fcu	62.664	58.56	59.72	56.5	56.76
27fcu	64.508	60.2	61.42	58.08	58.35
28fcu	66.352	61.84	63.12	59.66	59.94

Table 7: Variation of water cement ratios on experimental values of compressive strength at different curing age.

Variation of [W/C] on predictive values of compressive strength	0.4	0.44	0.46	0.48	0.49
7fcu	29.47562	28.97549	28.73283	28.49498	28.37782
8fcu	31.29774	30.72617	30.44884	30.17701	30.04311
9fcu	33.11985	32.47684	32.16485	31.85903	31.70841
10fcu	34.94197	34.22751	33.88085	33.54106	33.3737
11fcu	36.76409	35.97818	35.59686	35.22309	35.03899
12fcu	38.58621	37.72886	37.31287	36.90512	36.70428
13fcu	40.40833	39.47953	39.02887	38.58714	38.36957
14fcu	42.23045	41.2302	40.74488	40.26917	40.03486
15fcu	44.05257	42.98087	42.46089	41.9512	41.70015
16fcu	45.87469	44.73155	44.1769	43.63323	43.36544
17fcu	47.6968	46.48222	45.8929	45.31526	45.03074
18fcu	49.51892	48.23289	47.60891	46.99728	46.69603
19fcu	51.34104	49.98356	49.32492	48.67931	48.36132
20fcu	53.16316	51.73424	51.04092	50.36134	50.02661
21fcu	54.98528	53.48491	52.75693	52.04337	51.6919
22fcu	56.8074	55.23558	54.47294	53.72539	53.35719
23fcu	58.62952	56.98625	56.18894	55.40742	55.02248
24fcu	60.45164	58.73693	57.90495	57.08945	56.68777
25fcu	62.27376	60.4876	59.62096	58.77148	58.35307
26fcu	64.09587	62.23827	61.33696	60.4535	60.01836
27fcu	65.91799	63.98894	63.05297	62.13553	61.68365
28fcu	67.74011	65.73962	64.76898	63.81756	63.34894

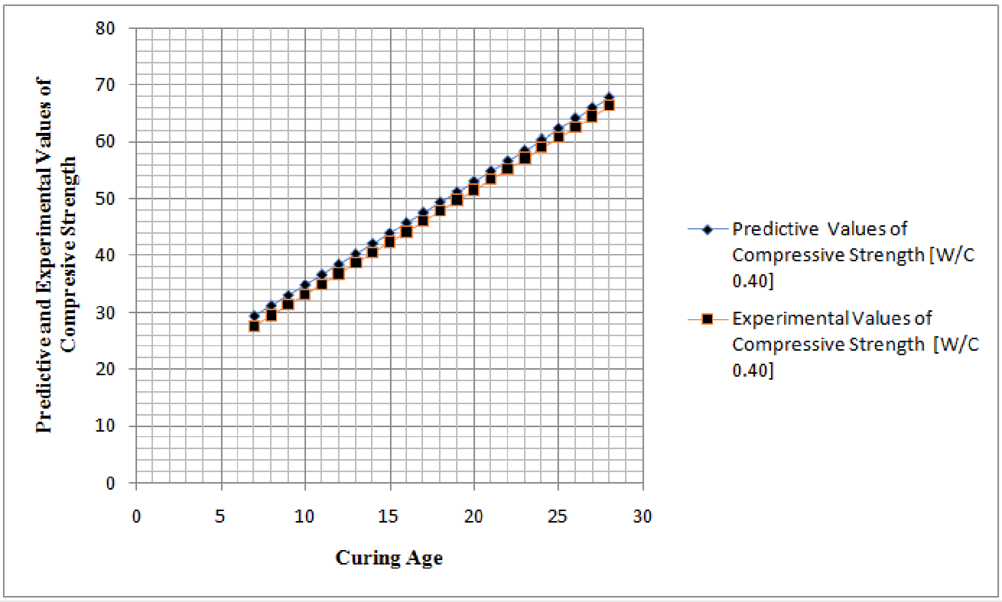

Figure 1: Predictive and Experimental Values of Compressive Strength at Different Curing Age.

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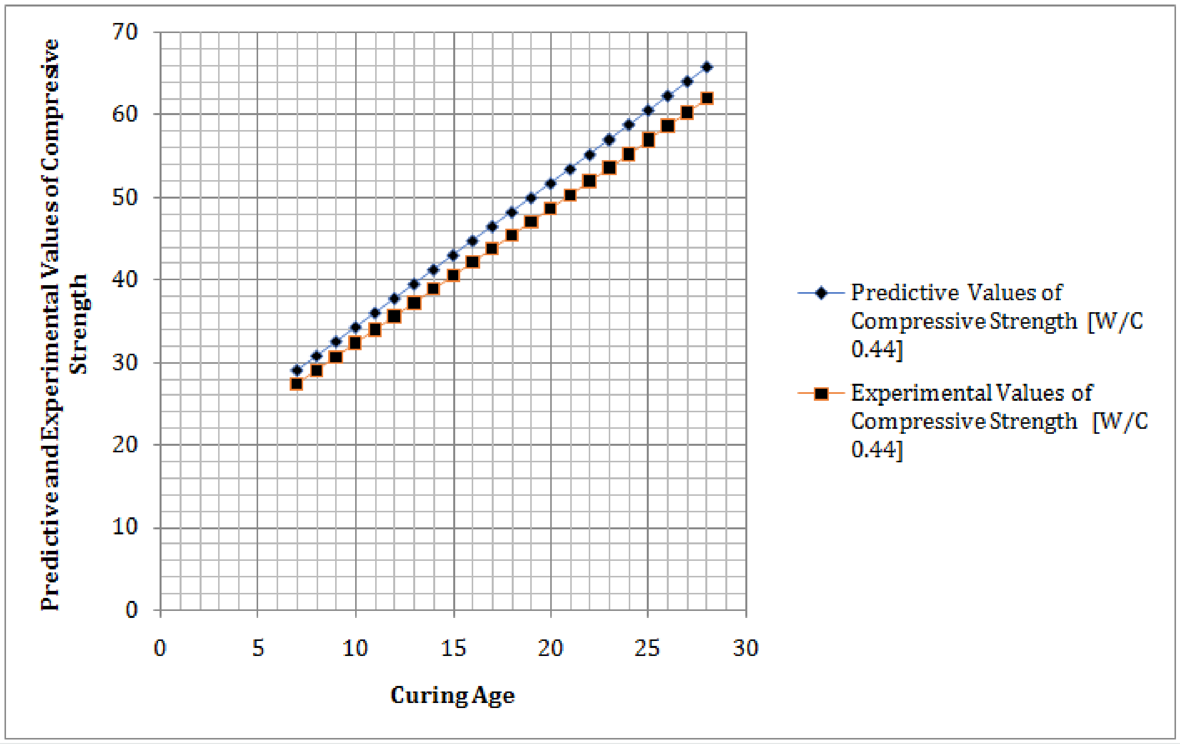
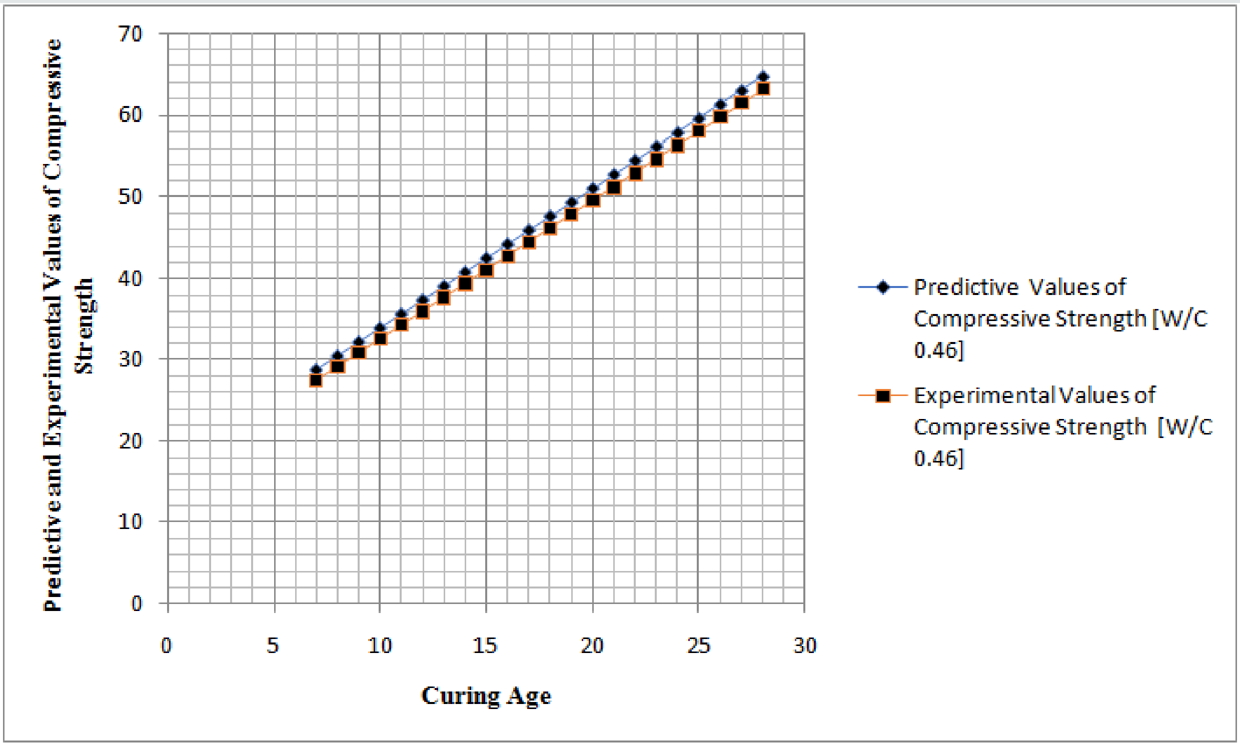


Figure 2: Predictive and Experimental Values of Compressive Strength at Different Curing Age.



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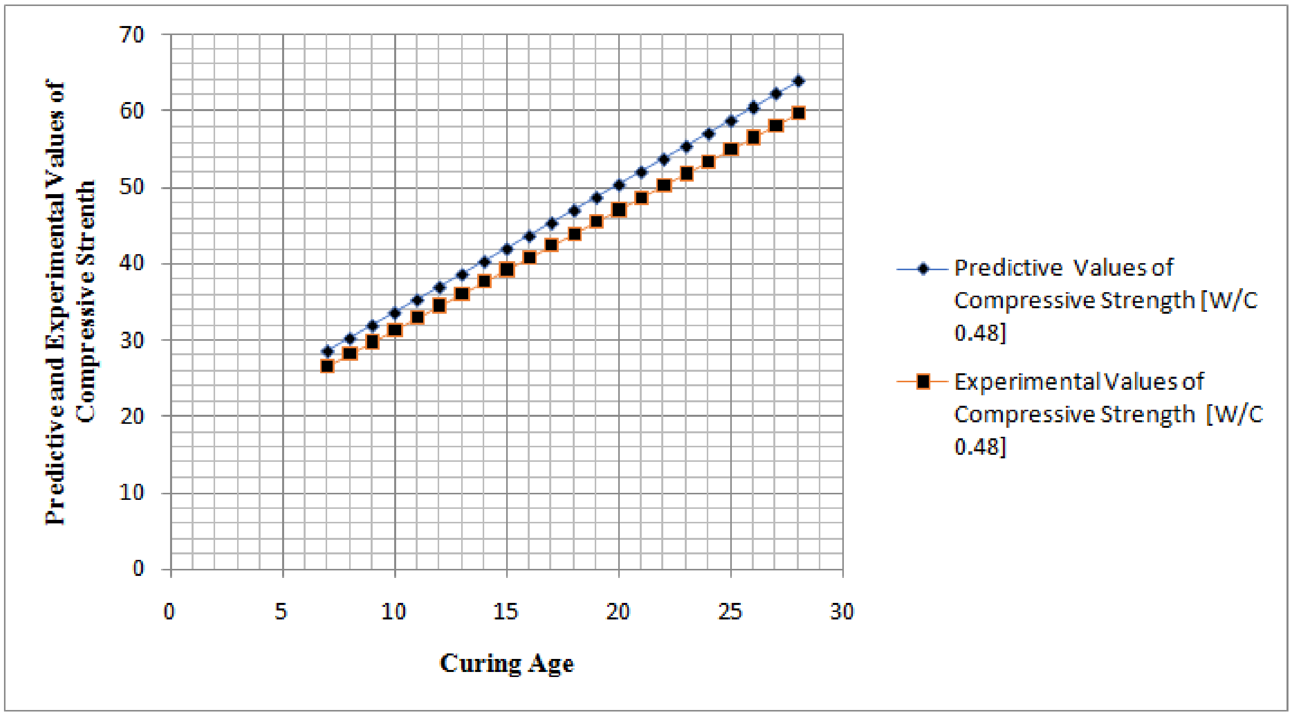

Figure 4: Predictive and Experimental Values of Compressive Strength at Different Curing Age.

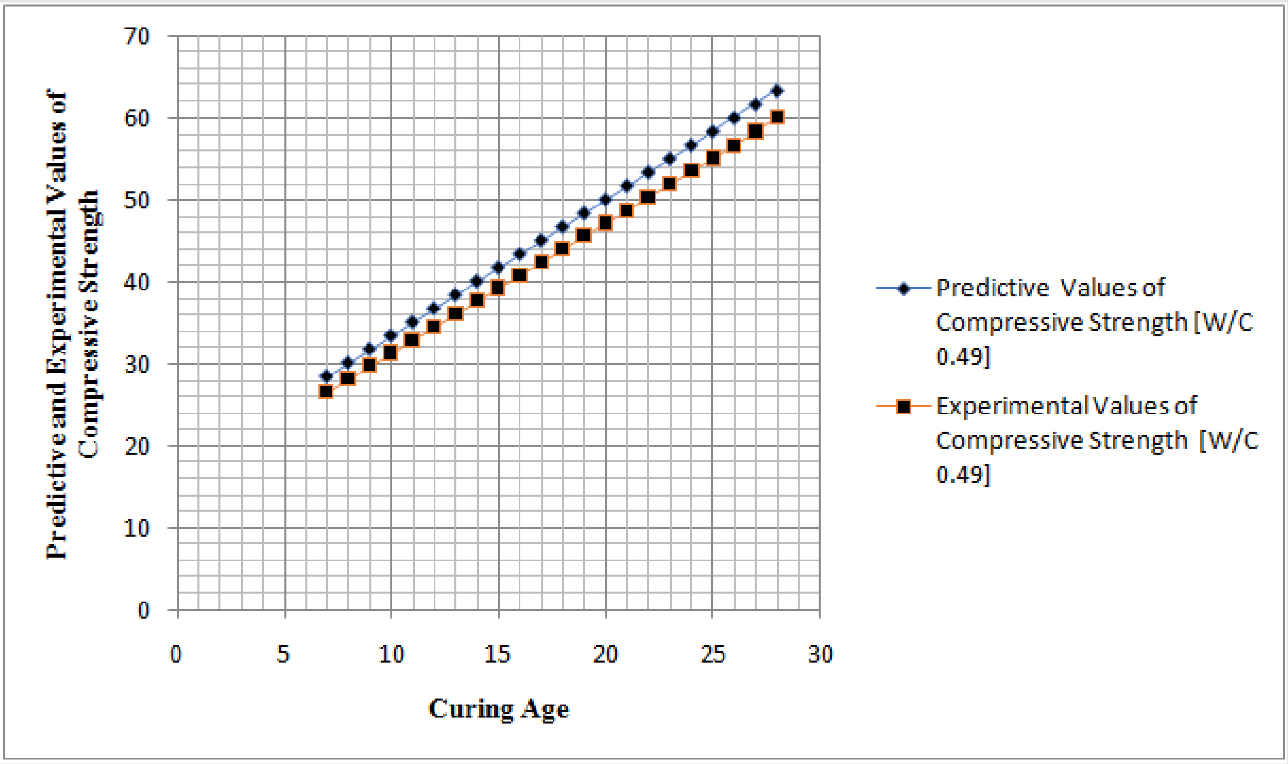

Figure 5: Predictive and Experimental Values of Compressive Strength at Different Curing Age.

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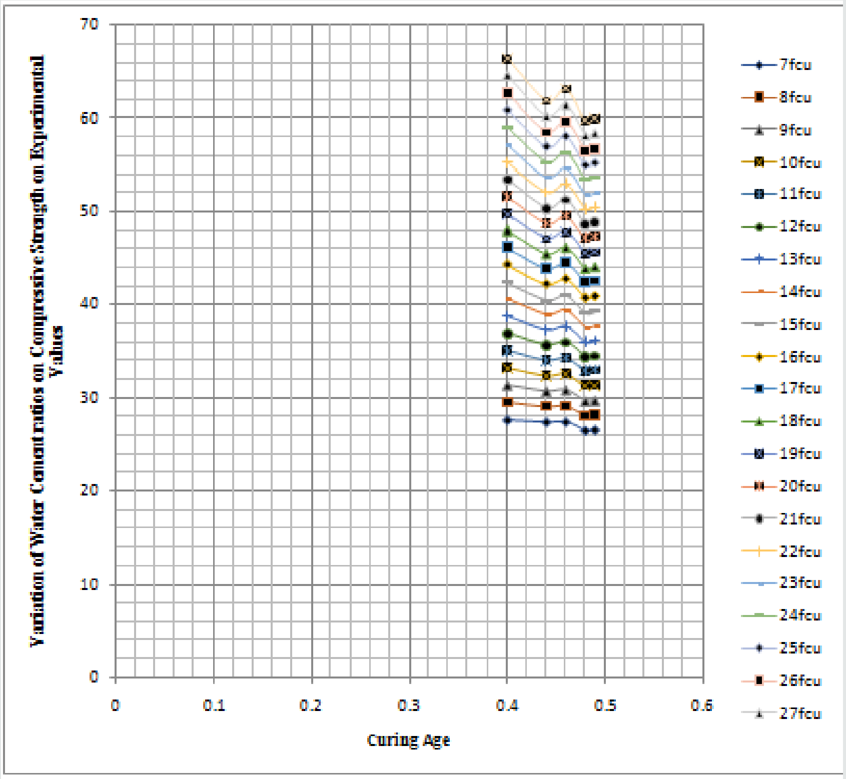

Figure 6: Variation of Water Cement Ratios on Experimental Values of Compressive Strength at Different Curing Age.

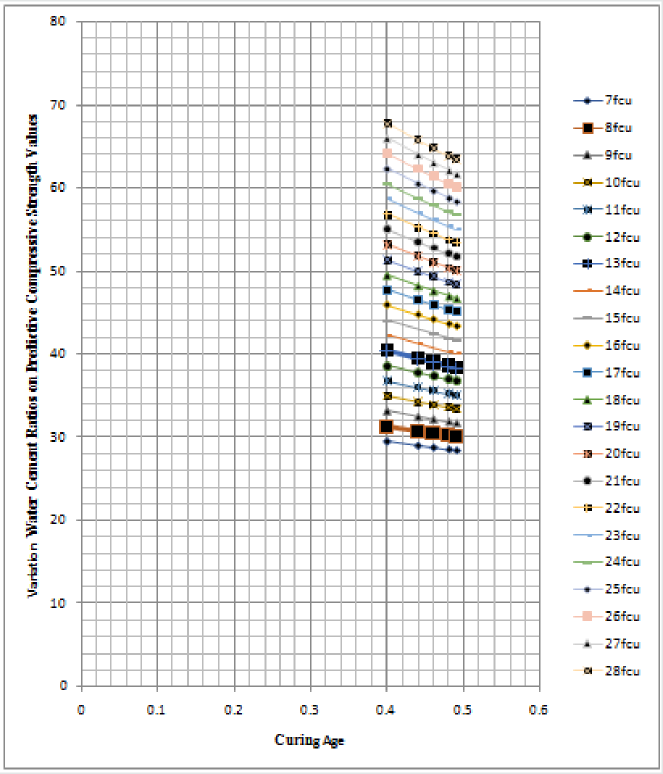

Figure 7: Variation of Water Cement Ratios on Predictive Values of Compressive Strength at Different Curing Age.

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Conclusion

The study monitors the behaviour of Metakaolin content as partial replacement on strength development influence by heterogeneous aggregate within curing age of [18,19]. Mixed design of concrete grades were carried out integrating Metakaolin content to monitor the behaviour of the material in terms of its bond compared to other addictives, but the major study carried out were to monitor the variation of strength development from heterogeneity of aggregate since, it is one of concrete properties. Metakaolin substance partially replaced cement that react with the concrete properties to generate these strength at different curing time, the study expressed graphically in linear trend at various water mixed ratios proportions, but the strength development were observed to vary compared to different mixed proportion, aggregate as concrete property were influenced on the mixed design to monitor the effect of strength growth, this were observed based on the shapes and variation of size, the application of this concrete property were experienced to determine its rate of effect on concrete strength development from variation of aggregate size. It is observed that the larger the size, the lower the surface for the development of the gel bonds, these were monitored and it was observed that the lower strength of concrete were experienced based on the effect of the aggregate heterogeneous size, other observation shows that the bigger size of aggregate on heterogeneous level in concrete mix prevent the uniformity of load distribution, when it experience stress. Compactions of the concrete were other parameter that displayed its effect on the variation of strength development, while other includes the cement-aggregate ratio and curing time. The application of modeling and simulations express details on the other parameters that played roles in the variations of concrete strength, Metakaolin as partial replacement expressed it strength as expected on its rate as a parameter, but the aggregate size at different grades in mixed design were the detail and precise study were carried out, the variations are influenced on the strength development that has been determined.

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