ISSN: 2689-1204

Research Article

Journal of Applied Material Science & Engineering Research

Predictive to Monitor Modified Lightweight Concrete Density Influenced by Variation of Aggregate Size and Void Ratios

Eluozo SN[1]*and Dimkpa K[2]

[1]*Department of Civil Engineering, College of Engineering, Gregory University Uturu (GUU), Abia State of Nigeria*

[2]*Department of Architecture, Faculty of Environmental Science, Rivers State University, Nkpolu Oroworukwo, Port Harcourt*

[*]**Corresponding author**
Eluozo S.N., Department of Civil Engineering, College of Engineering, Gregory University Uturu (GUU), Abia State of Nigeria.

Submitted: 14 Dec 2019; **Accepted**: 08 Jan 2020; **Published**: 27 Jan 2020

Abstract
This paper predicts the rate of lightweight concrete density influenced by variation of heterogeneous aggregate deposition and void ratios. The study try to monitor the behaviour of this material under slight modification in concrete formations, variation of mixed designs output were observed to determined most concrete densities in structures, the basis for light weight concrete is to ensure imposed loads are reduced, this include other structural elements such column size, footings and other load bearing elements, such significant condition expressed the imperative of light weight concrete density in concrete structures, the study developed this element of concrete parameter to monitor the growth rate of the element under the slight modification from addictive material, such mixed design are applied to achieve all the required target parameters, such strength and other required characteristics in concrete structure are based on the these parameters, the study provided plate form for mechanical and durability performance that is required, the standard for efficient strength-to- weight ratio in structural element are achieved, this condition explained the advantage it has in the reduction of less reinforced steel including reduction of volume concrete. The study were developed to monitor light weight concrete density based on these factors, this were observed to determine the application of lightweight concrete density. This condition implies that the rate of lightweight concrete density modified will always attained such required status, the lightweight concrete simulation parameter are within the specification that can be achieved in such required rate. The study has express the significant of light weight concrete density based on the required level in other relevant area advantage of structural elements.

Keywords: Mathematical Model, Lightweight Concrete, Density and Void Ratios

Introduction
Concrete is defined as non-natural conglomerate stone made basically from Portland cement, water, and aggregate. Cement improves such binding characteristics of concrete. There is a development of chemical reaction known as hydration, this take takes place between the water and cement, and it is observed that concrete usually changes from plastic to a solid state [1, 2]. The procedures of curing endorse hydration of cement, it also consist the control of temperature including moisture movement from and into the concrete [3]. Appropriate application curing techniques has important impact on density and compressive strength of concrete [4]. The water-cement ratio (W/C) can be defined as the proportion by mass of free water to cementitious material in a concrete mix [5]. Normally, lightweight aggregate concrete has observed to absorb more impact energy compared to normal weight concrete [6, 7]. The density of normal weight concrete lies within the range of 2,200 to 2,600 Kg/m^3 [8]. The main purpose of lightweight concrete is to decrease dead load of structural concrete [9]. This type of concrete is applied to advance buoyancy of the structures [10].These concepts is done by introducing lightweight aggregate on development of concrete, it is observed that there is tendency of often results generating poor strength and durability performance of concrete, based on this factor it necessary note that there the tendency of improper quality control. So, instead of using lightweight aggregate, air entraining admixture can be used to reduce density of concrete [11, 12]. Applying this approach, concrete densities from 1,842 to 2,370 kg/m^3 can be generated through to meet exact project requirements [12]. There is uncertainties connected with the parameters influencing the density and compressive strength of cement paste makes it problematic to exactly approximation of such properties [13, 14]. Also, no definite conclusion can be drawn in terms of the effect of the density and surface texture of lightweight aggregate on the durability of concrete [15].

Theoretical Background

$$\frac{dc}{dx} + A_{(x)}C_{(d)} = K_{(x)}C_d^{\ n};n \geq 2 \quad \text{.....................................(1)}$$

Where U($_X$) and K($_X$) are function of y

$$\frac{dc}{dX} + A_{(X)}C_{(d)} = B_{(X)}C_d^{\ n} \text{ ....(2a)}$$

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

$$C_d^{\ -n}\frac{dc}{dX} + A_{(X)}C_d^{\ 1-n} = B_{(X)} \text{ ....(3)}$$

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

$$(\left(\frac{1}{1-n}\right)\frac{dc}{dy} + U_{(X)}\beta = K_{(X)} \text{ ....(4)}$$

Multiplying Equation (4) through by (1- n) gives

$$(\frac{dc}{dy} + (1-n)U_{(X)}\beta = (1-n)K_{(X)} \text{ ....(5)}$$

Let $U_X = \frac{K_X}{2}$ ....(6)

Integrating both side of the equation gives:-

$$\int \frac{2}{2-\beta}d\beta = (1-n)\int K_{(X)}dx + \Phi \text{ ....(7)}$$

But $\beta = C_d^{\ 1-N}$

$$C_d^{\ 1-N} = D\exp[(2n-2)K_{(x)}X] \text{ ....(8)}$$

Materials and method

Density test

After 28 days curing, one set (3 cylinders) of concrete specimen were taken out from storage for density test according to ASTM C 642, for testing at particular day [16]. These specimens were turned to SSD (Saturated Surface Dry) condition by removing water from the surfaces. Then SSD weight of samples in air (C) was measured. Next the specimens were placed in oven at a temperature of 100 to 110°C for 24 h. After that weight of the specimen was measured. This is oven dry weight of samples in air (A). After that, the specimens were placed under water in a bucket and weight under water (D) was obtained. Temperature of water at test day (T) was also recorded and water density (ρ) was calculated for that temperature. Then from "Equation 1", density of concrete was calculated. Density test results are shown in Figure 2. From this test results, it can easily be said that density increases with days. But rate of density change is low. Concrete with SC shows more density values than concrete with BC (Shohana 2015).

$$\text{Compressive strength (N/mm}^2) = \frac{\text{Ultimate compressive load (N)}}{\text{Area of cross section of specimen (mm}^2)}$$

Dry density (bulk density), g1=…………………........ (1)
Here,
A= mass of oven-dried sample in air, (gram)
C= mass of saturated surface-dry sample in air, (gram)
D= mass of sample in water after immersion, (gram)

Results and Discussion

Table 1: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	268.45	264.46
8	306.8	305.84
9	345.15	347.15
10	383.5	385.53
11	421.85	424.85
12	460.2	463.23
13	498.55	495.55
14	536.9	533.93
15	575.25	575.25
16	613.6	614.62
17	651.95	654.95
18	690.3	693.34
19	728.65	725.65
20	767	764.23
21	805.35	806.35
22	843.7	846.73
23	882.05	884.15
24	920.4	922.42
25	958.75	955.75
26	997.1	995.12
27	1035.45	1035.45
28	1073.8	1075.81
29	1112.15	1113.15
30	1150.5	1152.52
31	1188.85	1186.85
32	1227.2	1228.23
33	1265.55	1266.55
34	1303.9	1305.93
35	1342.25	1344.25
36	1380.6	1385.64
37	1418.95	1419.95
38	1457.3	1458.32
39	1495.65	1495.65
40	1534	1534.32
41	1572.35	1572.35
42	1610.7	1612.72
43	1649.05	1649.05
44	1687.4	1687.43
45	1725.75	1726.75

46	1764.1	1766.13
47	1802.45	1805.45
48	1840.8	1840.84
49	1879.15	1879.15
50	1917.5	1917.62
51	1955.85	1955.75
52	1994.2	1995.34

Table 2: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	215.67	184.898
8	246.48	211.312
9	277.29	237.726
10	308.1	264.14
11	338.91	290.554
12	369.72	316.968
13	400.53	343.382
14	431.34	369.796
15	462.15	396.21
16	492.96	422.624
17	523.77	449.038
18	554.58	475.452
19	585.39	501.866
20	616.2	528.28
21	647.01	554.694
22	677.82	581.108
23	708.63	607.522
24	739.44	633.936
25	770.25	660.35
26	801.06	686.764
27	831.87	713.178
28	862.68	739.592
29	893.49	766.006
30	924.3	792.42
31	955.11	818.834
32	985.92	845.248
33	1016.73	871.662
34	1047.54	898.076
35	1078.35	924.49
36	1109.16	950.904
37	1139.97	977.318
38	1170.78	1003.732
39	1201.59	1030.146
40	1232.4	1056.56
41	1263.21	1082.974
42	1294.02	1109.388
43	1324.83	1135.802
44	1355.64	1162.216
45	1386.45	1188.63
46	1417.26	1215.044
47	1448.07	1241.458
48	1478.88	1267.872
49	1509.69	1294.286
50	1540.5	1320.7
51	1571.31	1347.114
52	1602.12	1373.528
53	1632.93	1399.942
54	1663.74	1426.356
55	1694.55	1452.77
56	1725.36	1479.184
57	1756.17	1505.598
58	1786.98	1532.012
59	1817.79	1558.426
60	1848.6	1584.84
61	1879.41	1611.254
62	1910.22	1637.668
63	1941.03	1664.082
64	1971.84	1690.496

Table 3: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	167.65	176.4917
8	191.6	201.7048
9	215.55	226.9179
10	239.5	252.131
11	263.45	277.3441
12	287.4	302.5572
13	311.35	327.7703
14	335.3	352.9834
15	359.25	378.1965
16	383.2	403.4096
17	407.15	428.6227
18	431.1	453.8358
19	455.05	479.0489
20	479	504.262
21	502.95	529.4751
22	526.9	554.6882
23	550.85	579.9013

24	574.8	605.1144
25	598.75	630.3275
26	622.7	655.5406
27	646.65	680.7537
28	670.6	705.9668
29	694.55	731.1799
30	718.5	756.393
31	742.45	781.6061
32	766.4	806.8192
33	790.35	832.0323
34	814.3	857.2454
35	838.25	882.4585
36	862.2	907.6716
37	886.15	932.8847
38	910.1	958.0978
39	934.05	983.3109
40	958	1008.524
41	981.95	1033.7371
42	1005.9	1058.9502
43	1029.85	1084.1633
44	1053.8	1109.3764
45	1077.75	1134.5895
46	1101.7	1159.8026
47	1125.65	1185.0157
48	1149.6	1210.2288
49	1173.55	1235.4419
50	1197.5	1260.655
51	1221.45	1285.8681
52	1245.4	1311.0812
53	1269.35	1336.2943
54	1293.3	1361.5074
55	1317.25	1386.7205
56	1341.2	1411.9336
57	1365.15	1437.1467
58	1389.1	1462.3598
59	1413.05	1487.5729
60	1437	1512.786
61	1460.95	1537.9991
62	1484.9	1563.2122
63	1508.85	1588.4253
64	1532.8	1613.6384
65	1556.75	1638.8515
66	1580.7	1664.0646
67	1604.65	1689.2777
68	1628.6	1714.4908
69	1652.55	1739.7039
70	1676.5	1764.917
71	1700.45	1790.1301
72	1724.4	1815.3432
73	1748.35	1840.5563
74	1772.3	1865.7694
75	1796.25	1890.9825
76	1820.2	1916.1956
77	1844.15	1941.4087
78	1868.1	1966.6218
79	1892.05	1991.8349
80	1916	2017.048

Table 4: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	162.75	162.05
8	186	185.2
9	209.25	208.35
10	232.5	231.5
11	255.75	254.65
12	279	277.8
13	302.25	300.95
14	325.5	324.1
15	348.75	347.25
16	372	370.4
17	395.25	393.55
18	418.5	416.7
19	441.75	439.85
20	465	463
21	488.25	486.15
22	511.5	509.3
23	534.75	532.45
24	558	555.6
25	581.25	578.75
26	604.5	601.9
27	627.75	625.05
28	651	648.2
29	674.25	671.35
30	697.5	694.5
31	720.75	717.65
32	744	740.8
33	767.25	763.95
34	790.5	787.1
35	813.75	810.25
36	837	833.4
37	860.25	856.55

38	883.5	879.7
39	906.75	902.85
40	930	926
41	953.25	949.15
42	976.5	972.3
43	999.75	995.45
44	1023	1018.6
45	1046.25	1041.75
46	1069.5	1064.9
47	1092.75	1088.05
48	1116	1111.2
49	1139.25	1134.35
50	1162.5	1157.5
51	1185.75	1180.65
52	1209	1203.8
53	1232.25	1226.95
54	1255.5	1250.1
55	1278.75	1273.25
56	1302	1296.4
57	1325.25	1319.55
58	1348.5	1342.7
59	1371.75	1365.85
60	1395	1389
61	1418.25	1412.15
62	1441.5	1435.3
63	1464.75	1458.45
64	1488	1481.6
65	1511.25	1504.75
66	1534.5	1527.9
67	1557.75	1551.05
68	1581	1574.2
69	1604.25	1597.35
70	1627.5	1620.5
71	1650.75	1643.65
72	1674	1666.8
73	1697.25	1689.95
74	1720.5	1713.1
75	1743.75	1736.25
76	1767	1759.4
77	1790.25	1782.55
78	1813.5	1805.7
79	1836.75	1828.85
80	1860	1852
81	1883.25	1875.15
82	1906.5	1898.3
83	1929.75	1921.45
84	1953	1944.6
85	1976.25	1967.75
86	1999.5	1990.9
87	2022.75	2014.05
88	2046	2037.2
89	2069.25	2060.35
90	2092.5	2083.5

Table 5: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	156.38	154.084
8	178.72	176.096
9	201.06	198.108
10	223.4	220.12
11	245.74	242.132
12	268.08	264.144
13	290.42	286.156
14	312.76	308.168
15	335.1	330.18
16	357.44	352.192
17	379.78	374.204
18	402.12	396.216
19	424.46	418.228
20	446.8	440.24
21	469.14	462.252
22	491.48	484.264
23	513.82	506.276
24	536.16	528.288
25	558.5	550.3
26	580.84	572.312
27	603.18	594.324
28	625.52	616.336
29	647.86	638.348
30	670.2	660.36
31	692.54	682.372
32	714.88	704.384
33	737.22	726.396
34	759.56	748.408
35	781.9	770.42
36	804.24	792.432
37	826.58	814.444
38	848.92	836.456
39	871.26	858.468
40	893.6	880.48
41	915.94	902.492

42	938.28	924.504
43	960.62	946.516
44	982.96	968.528
45	1005.3	990.54
46	1027.64	1012.552
47	1049.98	1034.564
48	1072.32	1056.576
49	1094.66	1078.588
50	1117	1100.6
51	1139.34	1122.612
52	1161.68	1144.624
53	1184.02	1166.636
54	1206.36	1188.648
55	1228.7	1210.66
56	1251.04	1232.672
57	1273.38	1254.684
58	1295.72	1276.696
59	1318.06	1298.708
60	1340.4	1320.72
61	1362.74	1342.732
62	1385.08	1364.744
63	1407.42	1386.756
64	1429.76	1408.768
65	1452.1	1430.78
66	1474.44	1452.792
67	1496.78	1474.804
68	1519.12	1496.816
69	1541.46	1518.828
70	1563.8	1540.84
71	1586.14	1562.852
72	1608.48	1584.864
73	1630.82	1606.876
74	1653.16	1628.888
75	1675.5	1650.9
76	1697.84	1672.912
77	1720.18	1694.924
78	1742.52	1716.936
79	1764.86	1738.948
80	1787.2	1760.96
81	1809.54	1782.972
82	1831.88	1804.984
83	1854.22	1826.996
84	1876.56	1849.008
85	1898.9	1871.02
86	1921.24	1893.032
87	1943.58	1915.044
88	1965.92	1937.056
89	1988.26	1959.068
90	2010.6	1981.08

Table 6: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	473.72	462.919
14	875.42	889.828
21	1313.13	1316.737
28	1750.84	1743.646

Table 7: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	262.64	262.1021
14	525.28	524.2171
21	787.92	786.3321
28	1043.11	1048.4471
35	1313.21	1310.5621
42	1568.48	1572.6771
49	1838.48	1834.7921

Table 8: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Curing Age	Predictive Values of Lightweight Concrete Density [Kg]	Experimental Values of Lightweight Concrete Density Kg
7	346.64	387.958
14	693.28	698.576
21	1046.85	1009.194
28	1395.81	1319.812
35	1593.21	1630.43
42	1911.21	1941.048

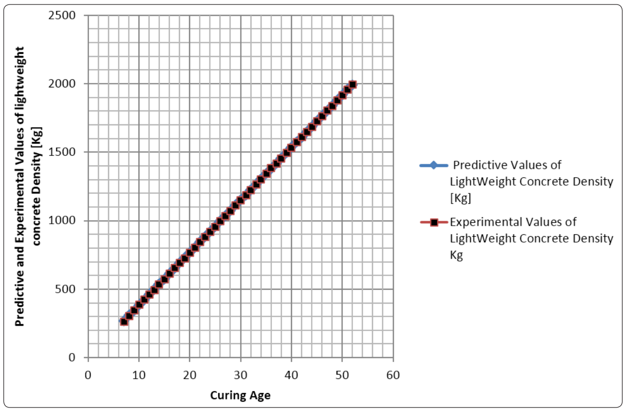

Figure 1: Predictive and Experimental Values of lightweight concrete Density at different curing Age

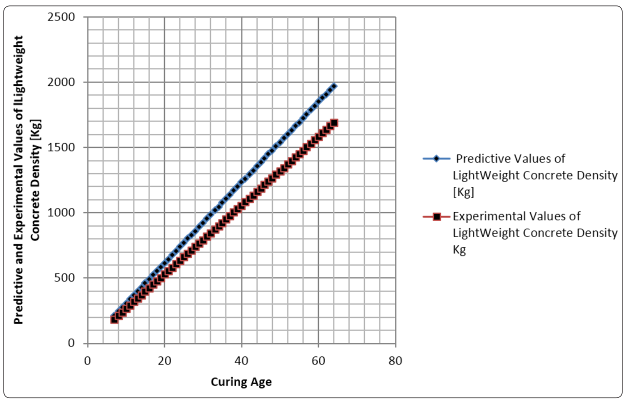

Figure 2: Predictive and Experimental Values of lightweight concrete Density at different curing Age

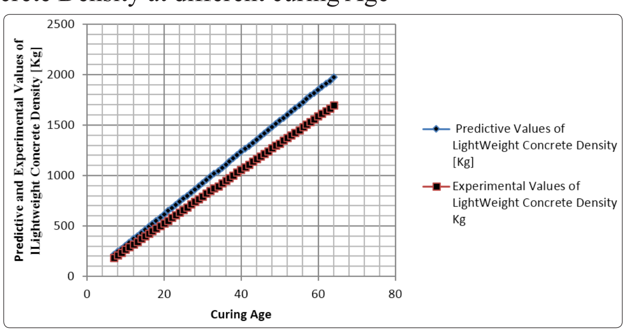

Figure 3: Predictive and Experimental Values of lightweight concrete Density at different curing Age

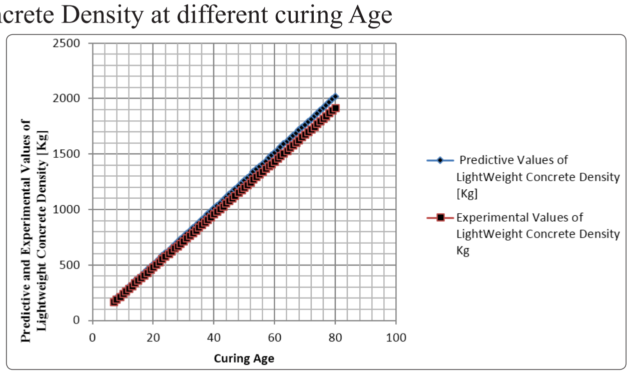

Figure 4: Predictive and Experimental Values of lightweight concrete Density at different curing Age

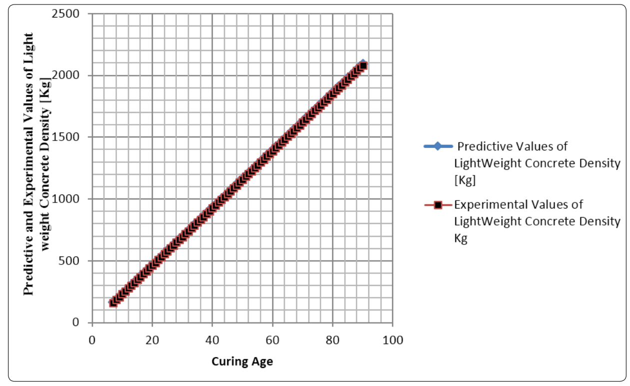

Figure 5: Predictive and Experimental Values of lightweight concrete Density at different curing Age

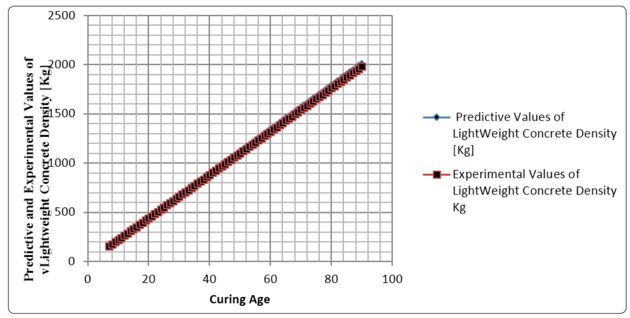

Figure 6: Predictive and Experimental Values of lightweight concrete Density at different curing Age

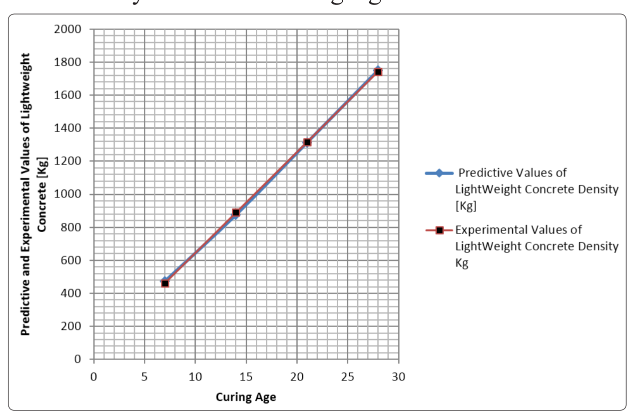

Figure 7: Predictive and Experimental Values of lightweight concrete Density at different curing Age

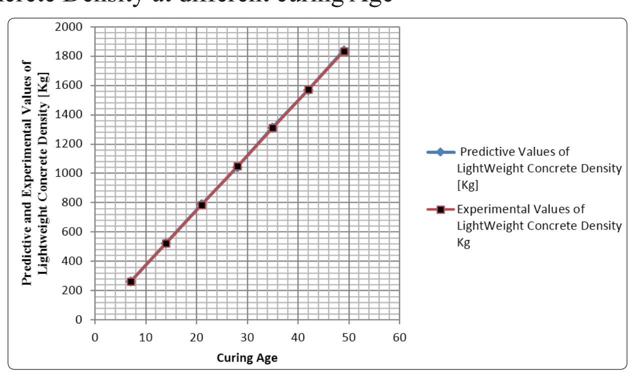

Figure 8: Predictive and Experimental Values of lightweight concrete Density at different curing Age

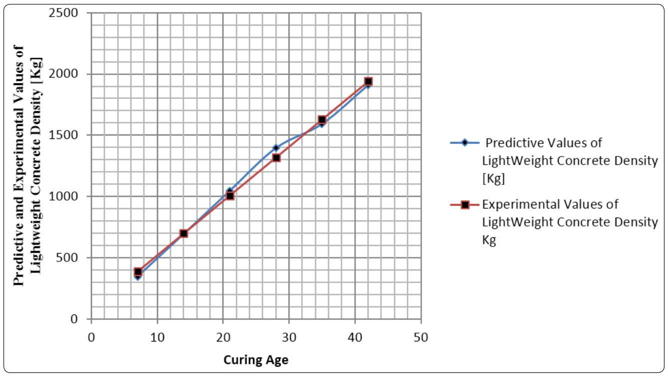

Figure 9: Predictive and Experimental Values of lightweight concrete Density at different curing Age

Figure 1-9 explained the behavior of concrete density made from light weight concrete, since it is made from less dense material, it is observed from its formation that such characteristics are reflected on the growth rate of its density, the figure from 1-9 experienced linear trend, but variations of density were observed, the density variation can be attributed to the characteristic of the concrete, the variation mixed proportion and design express the reflection of aggregate characteristics which definitely affect the strength, thus the size, shape, surface texture, grading and mineralogy are reflection of concrete strength in varying degrees of temperature and water cement ratios, it is also observed from studies that the aggregate strength is usually not a factor except in lightweight and high strength concrete. This condition on light weight condition experienced this reaction in the output of the density; these were experienced on the concrete density generated from the predictive values. The behaviour of aggregate as concrete characteristic express that aggregate occupies maximum volume of the concrete. It is the stuff that the cement paste experienced coats and binds together. The composition, shape, and size of the aggregate all have important influence on the workability, durability, strength, weight, and shrinkage of the concrete. More so, other effect on the study can also be sand and gravel in concrete as it serve several purposes. Because they act as filler, they also add more volume to the concrete. More volume means less air and a stronger product. The size of the gravel also helps to determine the concrete's strength. Other condition that may not affect the material, since it is light weight structure of concrete includes the tensile strength of the concrete, it is severely affected by increasing the size of the aggregate. On increasing the maximum grain size to 120–180 mm, the reduction in tensile strength is 30–50% as compared with concretes with maximum aggregate size of 20 mm. These properties include shape and texture, size gradation, moisture content, specific gravity, reactivity, soundness and bulk unit weight. The shape and texture of aggregate affects the properties of fresh concrete more than hardened concrete. The material having such status in it characteristics implies that it has definitely reflected parameters in light weight concrete density. The predictive values validated with experimental data has express it from the figures showing best fits correlations.

Conclusion

The study has expressed the behaviour of modified concrete density, since light aggregates are used for structural lightweight concrete such as expanded shale, clay or slate, such material of its type are fire in rotary kiln, it normally develop porous structure, it has been observed that other non-structural materials with lower density are produced from other aggregates materials. There are other classes of non-structural lightweight concretes with lower density made with other aggregate materials, these are with higher air voids in the cement paste matrix, such as in cellular concrete, the study are developed on this basis as the density results reflected it from the predictive values. The research study developed its basis from this direction to determine concrete density slightly modified with other material, these were experienced in some of the results generated from simulation, linearization observed in all the graphical representation explain the growth rate of light weight density slightly modified with additives, such linear increase can be attributed to the reaction from the modifier, it send signal to increase of it compressive strength in the concrete mixed design. Experimental application has been the generator of results at seven day interval, but with modifier results are generated within 3-7 days of curing age. Empirical solution are applied to develop experimental models, but for this study analytical solutions were applied to developed model simulating it numerical and analytical, this expression was applied to monitor the results at every twenty four hours and seven days intervals. Correlation between experimental values and predictive parameters generated best fits; these expressions validated the derived model simulation parameters.

References

1. Lecture Notes on "Introduction to Concrete", University of Memphis, USA.
2. Rasa E, Ketabchi H and Afshar MH (2009) "Predicting Density and Compressive Strength of Concrete Cement Paste Containing Silica Fume Using Articial Neural Networks", Transaction A: Civil Engineering 16: 33.
3. Neville AM (1996) Properties of Concrete, 4th ed., USA, New York: John Wiley and Sons.
4. Akeem Ayinde Raheem, Aliu Adebayo Soyingbe, Amaka John Emenike (2013) "Effect of Curing Methods on Density and Compressive Strength of Concrete", International Journal of Applied Science and Technology 3: 55-64.
5. "Final Report: Field Measurement of Water-Cement Ratio for Portland Cement Concrete –Phase II Field Evaluation and Development" (2002) Wisconsin Highway Research Program #0092-45-16, Wisconsin Department of Transportation.
6. Celik Ozyildirim (2009) "Durability of Structural Lightweight Concrete" LWC Bridges Workshop, IBC.
7. Sri Ravindrarajah R & Lyte MC (2003) "Properties of adjusted density high-performance concrete", ADVANCES IN STRUCTURES: Steel, Concrete, Composite and Aluminium, ASSCCA '2003 Conference Sydney, Australia.
8. Neville AM (2000) Properties of Concrete, 4th ed., England: Longman.
9. "Technical Bulletin-CIP-36, Structural Lightweight Concrete" (2003) National Ready Mix Concrete Association.
10. Thomas A. Holm and John P. Ries, "Specified Density Concrete A Transition", Expanded Shale, Clay & Slate Institute (ESCSI)-United States.
11. High-Strength Structural Lightweight Concrete (2003) Light Concrete LLC, California, USA.
12. George C. Hoff (2002) "Guide for the Use of Low-Density Concrete in Civil Works Projects", Innovations for Navigation Projects Research Program, U.S. Army Corps of Engineers Washington, DC.
13. Neville AM and Brooks JJ (1987) Concrete Technology, Longman Scientific & Technical.

14. Haykin S (1994) Neural Networks: A Comprehensive Foundation, MacMillan, New York.
15. Chen Chung Kho (2003) "Water Permeability and Chloride Penetrability of Lightweight Aggregate Concrete", Proceedings of 9th NUROP Congress, Nanyang Technological University, Singapore.
16. ASTM C136–06 (2006) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, ASTM International, West Conshohocken, PA.
17. ASTM C128–12 (2012) Standard Test Method for Density, Relative Density (Specific Gravity),and Absorption of Fine Aggregate, ASTM International, West Conshohocken, PA.