The Effect of Aluminum Waste on the Material Properties of Concrete

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ABSTRACT

The research investigated the density, Poisson ratio, young's modulus of Elasticity and modulus of Rigidity of aluminum waste concrete. Aluminum waste which was obtained from Aluminum Extrusion Industry (ALEX) Inyishi in Ikeduru local Government Area of State, Nigeria, was investigated. Concrete cubes with different ingredient components were cast and cured in water at room temperature for 28 days. Some selected mixes were used for the Poisson ratio test and control test respectively. A total of 66 concrete cubes were cast for the determination of density, Poisson ratio, young's modulus of elasticity and modulus of rigidity. The results of the density, poisson ratio, young's modulus of Elasticity and modulus of Rigidity ranges from 2.35-2.55kg/m^3, 0.38-153, 2.89 x 10^{-5} – 3.41 x 10$^{-5,}$ and o.56 x 10^{-5} -1.24x 10^{-5} respectively. The result of the control test of the density, Poisson ratio, young's modulus of Elasticity and modulus of Rigidity ranges from 2.41-2.56kg/m^3 0.53-2.01, 3.04 x 10^{-5} – 3.41 x 10^{-5} and 0.56 x 10^{-5} -1.38 x 10^{-5} respectively. Aluminum waste produces no significant effect on the density, Poisson ratio, young's modulus of Elasticity and modulus of Rigidity of the concrete.

Keywords: *Density, Poisson ratio, modulus of elasticity modulus of rigidity, aluminum waste.*

I. INTRODUCTION

Concrete is a mixture of cement, water, aggregates and admixtures (if any) in a given proportion. Aggregate represents some 60-80% of the concrete volume. They are inert grains bound by means of a blinder which is cement. Although inert, they introduce an important contribution to these major characteristics which make concrete the most favoured building materials [1]. Aggregates help to reduce shrinkage and heat dissipation during hardening and also contribute to the increase in the mechanical strength of concrete [2]. Cement generally represent 12-14% of concrete weight. During the hardening process, it generates shrinkage and heat dissipation phenomenon which leads to material cracking [3]. Water occupies 6-8% of the composition of fresh concrete. It provides for cement hydration and for the workability of fresh concrete mixture [4]. [5] reported that the standard workability tests are not suitable for aggregate concrete since they are sensitive to unit weight. [6] made similar observations when working with some materials. The incorporation of aluminum waste in concrete manufacture may provide a satisfactory solution to the problem posed by concrete production [7].

Finally the incorporation of aluminum waste in concrete should not impair concrete durability. Traditional assessment methods must therefore be adopted to evaluate this material [8]. This study contributes to the development of a methodology for assessing concrete manufactured from the aluminum waste. The methodology is based on the study of concrete containing this material. The durability and the environmental impact of concrete are closely connected to its transport properties which control the kinetics of the penetration of water and aggressive agent into concrete [9]. The movement of chemical species within the material and the leaching of certain chemicals are also closely linked to concrete to concrete diffusivity [10].

Finally, some selected mix ratios were used to determine density, poisson ratio, young's modulus of elasticity and modulus of rigidity of concrete produced with aluminum waste.

II. METHODOLOGY

Some selected mix ratios were used to cast concrete cubes for the determination of density, Poisson ratio, young's modulus of elasticity and moduluss of rigidity. Also, some selected mix ratios (control tests) were used to cast concrete cubes for the determination of the same properties. A total of forty five concrete cubes were cast and twenty one concrete cubes were also cast as control tests. The concrete cubes were cast and cured in water at room temperature for 28 days hydration period. At the end of the hydration period, the concrete cubes were tested for density, Poisson ratio, young's modulus of elasticity and modulus of rigidity.

The concrete cubes have the dimension of 150mm x 150mm x 150mm. The fine aggregate used was clean river sand, free from deleterious substances with a specific gravity of 2.62 and bulk density of 1533kg/m^3. The coarse aggregate was obtained from a local supplier with a maximum size of 20mm, specific gravity of 2.65 and bulk density of 1467kg/$m^{3.}$ Both aggregates conforms to [11] and. [12] respectively for coarse and fine aggregates. The cement used was Ordinary Portland Cement (Dangote) which conforms to [13]. The water used was a potable water. The aluminium waste used was obtained from Aluminum Extrusion industry (ALEX) Inyishi in Ikeduru Local Government Areas of Imo State, Nigeria. The waste was sieved with 150µm sieve size to obtain a finely divided material used for this work.

III. RESULT AND DISCUSSION

Table 1 shows the chemical analysis of aluminum waste while table 2 shows the chemical analysis of Ordinary Portland Cement used in this work.

Table 1 shows that aluminum waste contain mainly $S10_2$ (56.58%), Al_2O_3 (15.89%), and CaO (18,2%). The presence of calcium oxide constitutes about 11.30% of Ordinary Portland Cement (OPC). The presence of calcium in aluminum waste enhances the complete hydration of OPC and consequently the development of higher strength concrete. The setting and constituent hardening of paste- water and cement was directly responsible for the strength of the concrete. This was enhanced by the presence of calcium in aluminum waste. The mechanism is that in the presence of water the silicates and aluminates of OPC form products of hydration or hydrates which in time produce a hard mass. Table 1 also shows that aluminum waste contains 0.5% M_gO, of which 0.093% is present in OPC. Tables 3 and 4 shows the selected mixes used for the Poisson ratio test and the control mixes used for the Poisson ratio test respectively. Tables 5-8 described the effect of aluminum waste on the material properties of concrete. The result showed that there was no significant change in the density, Poisson ratio, young's modulus of elasticity and modulus of rigidity.

The results of density, Poisson ratio, young's modulus of elasticity and modulus of rigidity ranges from 2.35 - 2.55 kg/m^3, 0.38 - 1.53, 2.89 x 10^{-5} - 3.41 x 10^{-5} and 0.56 x 10^{-5}- 1.24 x 10^{-5} respectively; while the results of the control test ranges from 2.41 - 2.56kg/m^3, 0.53 - 2.01, 3.04 x 10^{-5} – 3.41 x 10^{-5}, and 0.56 x 10^{-5} – 1.38 x 10^{-5} respectively.

Table 1: Chemical Analysis of Aluminum Waste

Property	**Aluminum waste**
C_aO(%)	18.2
M_gO(%)	0.5
Fe_2O_3(%)	0.26
Na_2O(%)	0.36
Al_2O_3(%)	15.89
$S1O_2$(%)	56.58
Z_nO(%)	0.79
M_nO(%)	0.56
LO1(%)	6.4
SO_4(%)	Nil
CuO(%)	Trace
$T1O_2$(%)	Trace
C_dO(%)	Trace

Table 2: Chemical Analysis of Dangote cement

Oxide composition	**Percentage by weight (%)**
M_gO	0.093
Fe_2O_3(%)	6.405
C_aO	11.30
Al_2O_3	20.60
$S1O_2$	52.40
$T1O_2$	0.52
Na_2O	2.10
K_2O	2.60
L01	3.90

Table 3: Selected Mixes Used for the Poisson Ratio Test

S/No	Z_1	Z_2	Z_3	Z_4	Z_5
1	0.55	1.00	0.00	1.50	3.00
2	0.55	0.95	0.10	2.00	4.00
3	0.55	0.88	0.16	2.50	4.00
4	0.55	0.83	0.20	2.00	5.00
5	0.55	0.92	0.80	2.50	4.50
6	0.55	0.96	0.70	2.25	4.00
7	0.55	0.85	0.75	1.85	3.70
8	0.55	0.80	0.50	2.25	4.75
9	0.55	0.78	0.13	2.25	4.75
10	0.55	0.80	0.25	2.20	4.40
11	0.55	0.78	0.23	2.25	5.00
12	0.55	0.88	0.15	1.75	3.50
13	0.55	0.76	0.60	2.25	4.75
14	0.55	0.78	0.78	2.00	3.50
14	0.55	0.79	0.65	2.00	4.25

Z_1 = Water cement ratio
Z_2 = Fraction of Ordinary Portland Cement
Z_3 = Fraction of Aluminum Waste
Z_4 = Fraction of Fine Aggregates
Z_5 = Fraction of Coarse Aggregates

Table 4: Selected Control Mixes for the Poisson Ratio Test

S/No	Z_1	Z_2	Z_3	Z_4	Z_5
1	0.55	0.97	0.09	2.15	4.30
2	0.55	0.90	0.08	2.13	4.10
3	0.55	0.89	0.08	2.19	4.44
4	0.55	0.83	0.10	2.00	4.13
5	0.55	0.81	0.13	2.04	3.88
6	0.55	1.00	0.09	2.10	3.83
7	0.55	0.96	0.07	2.25	4.38

Table 5: Results of the determination Poisson ratio

S/No	Replications	Failure load (KN)	dy ($x10^{-2}$mm)	dx ($x10^{-2}$mm)	Wet weight (kg)	Dry weight (kg)
1	A	800	192	87	8.50	8.71
	B	732	176	30	8.00	8.05
	C	776	210	108	8.66	8.54
2	A	750	130	410	8.41	8.44
	B	510	120	98	8.10	8.11
	C	558	121	76	7.92	8.30
3	A	630	250	110	8.80	8.84
	B	667	200	230	8.15	8.18
	C	791	216	58	8.05	8.00
	A	660	180	80	8.90	8.91
4	B	700	189	66	8.55	8.53
	C	600	183	93	8.67	8.67
5	A	410	114	120	7.90	8.56
	B	720	155	130	7.65	8.20
	C	598	162	99	8.63	7.95
6	A	655	100	90	8.11	7.15
	B	582	105	162	8.70	8.81
	C	707	176	155	8.30	8.26
7	A	490	108	102	8.25	8.34
	B	761	140	116	8.70	8.77
	C	713	115	100	8.65	8.60
8	A	680	263	88	8.48	8.39
	B	796	161	106	7.94	8.08
	C	722	237	94	8.02	8.00
9	A	715	112	46	8.55	8.52
	B	820	171	230	8.61	8.65
	C	631	102	152	8.15	7.95

10	A	861	208	100	7.66	8.13
	B	743	183	75	8.00	8.15
	C	666	126	192	8.80	8.84
11	A	620	180	115	8.14	7.75
	B	688	174	68	8.45	8.57
	C	606	128	91	8.11	8.14
12	A	525	145	290	7.98	6.94
	B	766	107	161	8.44	8.43
	C	748	131	167	8.31	8.38
13	A	600	171	84	8.80	8.83
	B	630	133	105	8.42	8.46
	C	690	130	217	8.25	8.22
14	A	592	158	53	7.75	8.04
	B	618	141	98	8.13	8.15
	C	498	148	130	8.62	8.58
15	A	730	150	295	8.55	9.21
	B	695	157	109	8.66	8.70
	C	610	177	76	7.97	7.88

Table 6: Results of the Determination of Poisson Ratio (Control)

S/No	Replications	Facture load (KN)	dy ($x10^{-2}$mm)	dx ($x10^{-2}$mm)	Wet weight (kg)	Dry weight (kg)
1	A	702	110	60	8.12	8.16
	B	776	202	140	7.62	8.04
	C	615	210	91	8.00	8.20
2	A	535	150	10	8.77	8.81
	B	708	158	30	8.61	8.68
	C	762	140	66	8.30	8.41
3	A	697	176	84	8.33	8.42
	B	620	131	52	8.10	8.11
	C	609	157	112	8.46	8.55
4	A	598	196	280	8.22	8.25
	B	701	182	38	8.18	8.19
	C	646	128	74	8.00	8.08
5	A	750	163	100	7.60	8.01
	B	800	177	600	8.82	8.70
	C	708	93	190	8.70	8.55
6	A	724	149	58	8.65	8.66
	B	521	137	121	8.35	8.27
	C	689	132	97	8.41	8.58
7	A	664	98	200	8.20	8.30
	B	840	116	133	8.00	8.67
	C	780	103	109	8.70	8.08

Table 7: Results of the Determination of Density, Poisson Ratio, Young's Modulus of Elasticity and Modulus of Rigidity

S/No	Replications	Fc	Average Fc	ℓ	μ	E ($x10^{-5}$)	G ($x10^{-5}$)
1	A	35.56	34.19	2.50	0.38	3.41	1.24
	B	32.53					
	C	34.49					
2	A	33.33	26.93	2.45	1.53	3.03	0.60
	B	22.67					
	C	24.80					
3	A	28.00	30.93	2.47	0.62	3.22	0.99
	B	29.64					
	C	35.16					
4	A	29.33	29.04	2.55	0.43	3.15	1.10
	B	31.11					
	C	26.67					
5	A	18.22	25.60	2.44	0.83	2.95	0.81
	B	32.00					
	C	26.58					
6	A	29.11	28.80	2.39	1.11	2.94	0.70
	B	25.87					
	C	26.58					

7	A B C	21.78 33.82 31.69	29.09	2.54	0.88	2.95	0.78
8	A B C	30.22 35.38 32.09	32.56	2.42	0.46	3.14	1.08
9	A B C	31.78 36.44 28.04	32.09	2.48	1.08	3.28	0.79
10	A B C	38.27 33.02 29.60	33.63	2.48	0.47	3.34	1.44
11	A B C	27.56 30.58 26.93	28.36	2.42	0.58	3.00	0.95
12	A B C	23.33 34.04 33.24	30.19	2.35	1.59	2.89	0.56
13	A B C	26.67 28.00 30.67	28.45	2.52	0.98	3.26	0.82
14	A B C	26.31 27.47 22.13	25.30	2.45	0.64	2.96	0.90
15	A B C	32.44 30.89 27.11	30.15	2.55	1.04	3.40	0.83

Table 8: Results of the Determination of Density, Poisson Ratio, Young's Modulus of elasticity and Modulus of Rigidity (Control)

S/No	Replications	Fc	Average Fc	ℓ	μ	E (x10^{-5})	G (x10^{-5})
1	A B C	31.20 34.49 27.33	31.01	2.41	0.55	3.07	0.99
2	A B C	23.76 31.47 33.87	29.70	2.56	0.24	3.41	1.38
3	A B	30.97 27.56	28.53	2.48	0.53	3.16	1.03
	C	27.06					
4	A B C	26.58 31.16 28.71	28.82	2.43	0.74	3.04	0.87
5	A B C	33.33 35.56 31.47	33.45	2.49	2.01	3.36	0.56
6	A B C	32.18 23.16 30.62	28.65	2.52	0.67	3.27	0.98
7	A B C	29.51 37.33 34.67	33.84	2.47	1.42	3.32	0.69

CONCLUSION

The conclusion of the study can be summarized as follows:

a) Aluminum waste can be used as an admixture in concretes production.

b) Aluminum waste has no significant effect on the density, Poisson ratio, young's modulus of elasticity and modulus of rigidity of concrete.

c) Aluminum waste can also be used as a supplementary cementitious material in concrete production.

d) Curing is very necessary in concrete in order to ensure the complete hydration of cement.

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