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EFFECT OF INCORPORATION OF ALUMINIUM WASTE IN CONCRETE MATRIX USING DIFFERENT MIX RATIO AND WATER CEMENT RATIO

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ABSTRACT

The research investigated the effect of incorporation of aluminum waste in concrete matrix using different mix ratio and water cement ratio. Aluminum waste which was obtained from Aluminum Extrusion Industry (ALEX) Inyishi in Ikeduru Local Government Area of Imo State, Nigeria was investigated. Concrete Cubes with different ingredient components, mix ratio and water cement ratio were used to cast cube samples. The cubes have a dimension of 150mm x 150mm x 150mm. The cube samples were tested for 7, 14 and 28days strength. The total of 216 concrete cubes were cast. The result showed that the addition of 5% Aluminum waste to a standard 1:2:4:0.55 mix caused the compression strength of the concrete to rise from 26.07N/mm^2 to 28.47N/mm^2 . This result represents an increase of 9.21% in compressive strength. The initial and final setting time of the Ordinary Portland Cement (OPC) used is 53mins and 587mins respectively. The slump test of aluminum waste concrete at different water cement ratio using 1:2:4 mix ranges from 4-20mm while that of 1:3:6 mix ranges from 7-14mm.

KEYWORDS: Aluminum waste; compressive strength; Slump; Setting time; Curing.

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INTRODUCTION

The incorporation of waste in concrete manufacture may provide a satisfactory solution to problems posed by waste management [1]. The building sector uses large quantities of natural materials, hence its capacity to recycle and upgrade waste is considerable [2]. Certain industrial byproducts have been used for a number of years as cement or concrete components [3]. Other waste products may also be recycled and upgraded in concrete [4]. However, the new materials thus formed must be usable as a building material and in particular have the necessary performance characteristics to satisfy the specifications determined by its application [5]. In addition, it should be inoffensive with regards to health and the environment.

Finally, the incorporation of the waste should not impair concrete durability. Traditional assessment methods must therefore be adapted to evaluate these new materials [6].

This study contributes to the development of a methodology for assessing concrete manufactured from waste. The methodology is based on the study of concrete containing experimental waste (Aluminum waste). The aluminum waste is considered as experimental waste because of, in particular, its high content of soluble salt [7].

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 agents into concrete [8]. The movement of chemical species within the material and the leaching of certain chemicals are also closely linked to concrete diffusivity [9].

Finally, the strength characteristics of concrete containing different percentage of aluminum waste at different water cement ratio and mix ratio were studied to identify their influence on concrete produced with them [10].

METHODOLOGY

MATERIALS AND METHODS

Materials

CEMENT: The Dangote Cement which is a brand of Ordinary Porland Cement was used in this work.

AGGREGATES: The fine aggregate used in this work is clean river sand which is free from deleterious materials. The fine aggregate used passes through 2.36mm sieve size.

The coarse aggregate used is also very clean and free from dirts. The coarse aggregates passes through 19mm sieve size. Both aggregates conforms to [11] and [12] for fine and coarse aggregates respectively.

WATER: The water used is potable water.

ALUMINUM WASTE: The aluminum waste which was obtained from Aluminum Extrusion Industry (ALEX) Inyishi in Ikeduru Local Government Area of Imo State, Nigeria is irregular in shape and black in colour. The waste was sieved with 150µm sieve size to obtain a finely divided (powdered) material which was used in this research work.

METHODS

Setting Time of Cement

This test was carried out in accordance with [13] using the Vicat apparatus. The Vicat apparatus uses initial and final setting pins for the determination of initial and final setting time respectively.

The carry out this experiment, 94g of water was added to 200g of cement to form cement paste. The paste was then placed on the Vicat apparatus using Vicat mould. Before the placement of the paste on the apparatus, the initial setting pin was fixed on the apparatus for initial setting time. The apparatus is calibrated in millimeters. For the initial setting time the initial setting pin was dropped on the paste to 5$\pm$1mm calibration mark on the apparatus. The initial setting time was then recorded starting from the time the water was added to the paste to the time the dropping of the pin on the paste was 5$\pm$1mm mark on the apparatus.

Similarly the final setting time was recorded using the final setting pin. The final setting pin has an inner and outer edge. The final setting time was taken when only the inner edge makes a mark on the paste when allowed to drop freely. The final setting time was recorded starting from the time the water was added to the paste to the time the inner edge of the final setting pin makes a mark on the paste.

COMPRESSIVE STRENGTH AND WATER CEMENT RATIO

Preliminary investigations were carried out to ascertain the behavior of aluminum waste concrete. A standard mix ratio of 1:2:4 and 1:3:6 were used to cast cubes of 150mm x 150mm x 1500mm. These ratios were kept constant but first at varying water cement ratio and then at varying aluminum waste content. Batching was carried out by weight.

For each mix ratio with varying water cement ratio and aluminum waste content, three cubes were cast and cured at room temperature. The concrete cubes were filled and compacted in three layers i.e 1/3, 2/3, 3/3 respectively. Each layer was compacted 200 times using a tampering rod. At the end of each hydration period, the three cubes cast for each mix ratio and aluminum waste content were crushed and the average compressive strength recorded. The compressive strength is calculated by dividing the crushing load with the area of the concrete cube.

SLUMP TEST

A standard slump cone measuring 100mm x 200mm x 300mm was used. This test was performed on a non- absorbent platform. A sheet of metal plate was placed over a smooth and level surface in the absence of the platform. The inside of the cone was lubricated to facilitate easy lifting of the cone.

The cone was placed on the platform filled with concrete to one third of its height and compacted 25 times with a steel rod. The cone was later filled with concrete to two-third of its height and compacted 25 times. Finally the cone was filled completely and 25 times of compaction was also carried out. After compaction, the surface of the concrete in the cone was smoothened with trowel. At this stage, the cone was lifted and placed upside down with respect to its original position. A straigth edge was then placed on the reversed cone and the different between the cone and concrete was measured using a measuring rule. This difference in height between the cone and the concrete gives the slump of the concrete.

RESULT AND DISCUSSION

The result of the chemical analysis of aluminum waste is presented in table 1 and table 2 shows that of Ordinary Portland Cement. The result 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 enahces the complete hydration of OPC and consequently the development of high strength concrete.

The setting and constituent hardening of paste-water and cement was directly responsible for strength of the concrete. This was enhance 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. The two calcium silicates (C_3S and C_2S) are the main cementitious compounds in cement. From the result obtained aluminum waste behaved as a water reducer (Plasticizer) because it helped to achieve a higher strength by decreasing water cement ratio at the same workability when the admixture was not there. Table 1 also shows that aluminum waste contains 0.5% MgO of which 0.093% is present in OPC.

The improved workability of concrete which was observed during the work may be attributed to the presence of the trace elements. Table 3-16 shows the effects of aluminum waste on the compressive strength of concrete as the percentage of aluminum waste was increased in the standard 1:2:4 mix; while tables 17-26 described that for the standard 1:3:6 concrete mix.

The maximum compressive strength of $24.34N/m^2$ was attained by the addition of 5% of aluminum waste. This represents an increase of 6.64% in the compressive strength of the mix.

However, the increase in compressive strength of concrete by the use of aluminum waste was not too pronounced in the case of 1:3:6 mix. This behavior may be attributed to the reduction in the mass of OPC in 1:3:6 mix. It may therefore be concluded that the more the mass of cement in the mix, the better the effect of the aluminum waste. Tables 13-18 show the effect of variation of w/c ratio on aluminum waste. The results showed that the maximum compressive strength was attained at w/c ratio of 0.55 and 5% of aluminum waste ($28.47N/m^2$).

Table 27 shows the result of the initial and final setting time of OPC.

The result falls within the range of initial and final setting of OPC.

Table 1: Chemical Analysis of Aluminum Waste

PROPERTY	ALUMINUM WASTE
CaO(%)	18.2
MgO(%)	0.5
Fe_2O_3 (%)	0.26
Na_2O(%)	0.36
Al_2O_3(%)	15.89
SIO_2(%)	56.58
ZnO(%)	0.79
MnO(%)	0.56
L01(%)	6.4
$S0_4$(%)	Nil
CuO(%)	Trace
$T10_2$(%)	Trace
C_dO(%)	Trace

Table 2: Chemical Analysis of Dangote Cement

Oxide composition	Percentage by weight (%)
MgO	0.093
Fe_2O_3	6.405
CaO	11.30
Al_2O_3	20.60
$S10_2$	52.40
$T10_2$	0.52
Na_2O	2.10
K_2O	2.60
L01	3.90

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Table 3: Compressive Strength of Aluminum Waste =0 and w/c= 0.55 for 1:2:4 Mix

Slump: 15mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	350	470	400	460	430	460	600	570	590
Compressive Strength (N/mm^2)	15.60	20.90	17.80	20.40	19.10	20.40	26.70	25.30	26.20
Average Compressive strength (N/mm^2)	18.10			19.97			26.07		

Table 4: Compressive Strength of Aluminum Waste =2.5% and w/c= 0.55 for 1:2:4 Mix

Slump: 12mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	400	370	390	440	420	430	480	445	470
Compressive Strength (N/mm^2)	17.80	16.40	17.30	19.60	18.70	19.10	21.30	19.78	20.80
Average Compressive strength (N/mm^2)	17.17			19.13			20.63		

ISSN 2348-6201

Table 5: compressive strength of Aluminum Waste =5% and w/c= 0.68 for 1:2:4 Mix

Slump: 10mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	280	300	350	310	330	340	352	370	430
Compressive									
Strength (N/mm^2)	12.44	13.33	15.56	13.78	14.67	15.11	15.64	16.44	19.11
Average Compressive strength (N/mm^2)	13.78			14.52			17.06		

Table 6: Compressive Strength of Aluminum Waste =7.5% and w/c= 0.55 for 1:2:4 Mix

Slump: 7mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	300	360	400	330	400	450	360	458	493
Compressive Strength (N/mm^2)	13.33	16.00	17.78	14.67	17.78	20.00	16.00	20.36	21.91
Average Compressive strength (N/mm^2)	15.70			17.48			19.42		

Table 7: Compressive Strength of Aluminum Waste

= 10% and w/c= 0.55 for 1:2:4 Mix

Slump: 7mm	**7 Days**			**14 Days**			**28Days**		
Samples	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Failure load (KN)	**560**	**320**	**350**	**430**	**400**	**410**	**650**	**420**	**450**
Compressive Strength (N/mm^2)	**24.89**	**14.22**	**15.56**	**19.11**	**17.78**	**18.22**	**28.89**	**18.67**	**20.00**
Average Compressive strength (N/mm^2)	**18.22**			**18.37**			**22.52**		

Table 8: Compressive Strength of Aluminum Waste

= 12.5% and w/c= 0.55 for 1:2:4 Mix

Slump: 6mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	460	300	320	380	400	390	460	580	470
Compressive Strength (N/mm^2)	20.44	13.33	14.22	16.89	17.78	17.33	20.44	25.78	20.89
Average Compressive strength (N/mm^2)	16.00			17.33			22.37		

ISSN 2348-6201

Table 9: Compressive Strength of Aluminum Waste

= 15% and w/c= 0.55 for 1:2:4 Mix

Slump: 5mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	320	270	330	310	340	370	430	410	390
Compressive Strength (N/mm^2)	14.22	12.00	14.67	13.78	15.11	16.44	19.11	18.22	17.33
Average Compressive strength (N/mm^2)	13.63			15.11			18.22		

Table 10: Compressive Strength of Aluminum Waste

= 20% and w/c= 0.55 for 1:2:4 Mix

Slump: 5mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	220	300	340	320	350	310	370	380	415
Compressive Strength (N/mm^2)	9.78	13.33	15.11	14.22	15.56	13.78	16.44	16.89	18.44
Average Compressive Strength (N/mm^2)	12.74			14.52			17.26		

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Table 11: Compressive Strength of Aluminum Waste = 25% and w/c= 0.55 for 1:2:4 Mix

Slump: 4mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	310	270	290	340	360	312	370	390	410
Compressive Strength (N/mm^2)	13.78	12.00	12.89	15.11	16.00	13.87	16.44	17.33	18.22
Average Compressive Strength (N/mm^2)	12.89			15.00			17.33		

Table 12: Compressive Strength of Aluminum Waste = 30% and w/c= 0.55 for 1:2:4 Mix

Slump: 4mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	400	420	390	450	440	458	490	520	540
Compressive Strength (N/mm^2)	17.78	18.67	17.33	20.00	19.56	20.36	21.78	23.11	24.00
Average Compressive Strength (N/mm^2)	17.93			19.97			22.96		

Table 13: Compressive Strength of Aluminum Waste

= 5% and w/c= 0.55 for 1:2:4 Mix

Slump: 5mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	410	419	380	540	530	508	610	630	682
Compressive Strength (N/mm^2)	18.22	18.62	16.89	24.00	23.56	22.58	27.11	28.00	30.31
Average Compressive Strength (N/mm^2)	17.91			23.38			28.47		

Table 14: Compressive Strength of Aluminum Waste

= 5% and w/c= 0.50 for 1:2:4 Mix

Slump: 5mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	390	440	410	530	450	493	650	600	510
Compressive Strength (N/mm^2)	17.33	19.56	18.22	23.56	20.00	29.91	28.89	26.67	22.67
Average Compressive Strength (N/mm^2)	18.37			24.49			26.08		

Table 15: Compressive Strength of Aluminum Waste = 5% and w/c= 0.65 for 1:2:4 Mix

Slump: 12mm	7 Days			14 Days			28Days		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	320	430	380	365	530	438	600	300	550
Compressive Strength (N/mm^2)	14.22	19.11	16.89	16.22	23.56	19.47	26.67	13.33	24.44
Average Compressive Strength (N/mm^2)	16.74			19.75			21.48		

Table 16: Compressive Strength of Aluminum Waste = 5% and w/c= 0.70 for 1:2:4 Mix

Slump: 20mm	7 Days			14 Days			28Days		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	280	450	320	470	399	306	400	620	384
Compressive Strength (N/mm^2)	12.44	20.00	14.22	20.89	17.73	13.60	17.78	27.56	17.07
Average Compressive Strength (N/mm^2)	15.55			17.41			20.80		

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Table 17: Compressive Strength of Aluminum Waste

= 0% and w/c= 0.80 for 1:3:6 Mix

Slump: 14mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	360	340	390	400	411	379	483	559	450
Compressive Strength (N/mm^2)	16.00	15.11	17.33	17.78	18.27	16.84	21.47	24.84	20.00
Average Compressive Strength (N/mm^2)	16.15			17.63			22.10		

Table 18: Compressive Strength of Aluminum Waste

= 2.5% and w/c= 0.80 for 1:3:6 Mix

Slump: 14mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	340	392	280	360	284	377	400	466	439
Compressive Strength (N/mm^2)	15.11	17.42	12.44	16.00	12.62	16.76	17.78	20.71	19.51
Average Compressive Strength (N/mm^2)	14.99			15.13			19.33		

Table 19: Compressive Strength of Aluminum Waste = 5% and w/c= 0.80 for 1:3:6 Mix

Slump: 13mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	310	290	330	320	342	378	510	650	483
Compressive Strength (N/mm^2)	13.78	12.89	14.67	14.22	15.20	16.80	22.67	28.89	21.87
Average Compressive Strength (N/mm^2)	13.78			15.41			24.34		

Table 20: Compressive Strength of Aluminum Waste = 7.5% and w/c= 0.80 for 1:3:6 Mix

Slump: 10mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	290	260	284	316	300	332	403	320	390
Compressive Strength (N/mm^2)	12.89	11.56	12.62	14.04	13.33	14.76	17.91	14.22	17.33
Average Compressive Strength (N/mm^2)	12.36			14.04			16.49		

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Table 21: Compressive Strength of Aluminum Waste

= 10% and w/c= 0.80 for 1:3:6 Mix

Slump: 9mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	260	251	273	299	308	250	331	347	380
Compressive Strength (N/mm^2)	11.56	11.16	12.13	13.29	13.69	11.11	14.71	15.42	16.89
Average Compressive Strength (N/mm^2)	11.62			12.70			15.67		

Table 22: Compressive Strength of Aluminum Waste

= 12.5% and w/c= 0.80 for 1:3:6 Mix

Slump: 12mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	240	270	212	264	294	249	318	272	340
Compressive Strength (N/mm^2)	10.67	12.00	9.42	11.73	13.07	11.07	14.13	12.09	15.11
Average Compressive Strength (N/mm^2)	10.70			11.96			13.78		

Table 23: Compressive Strength of Aluminum Waste = 15% and w/c= 0.80 for 1:3:6 Mix

Slump: 8mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	254	228	248	251	284	370	426	292	388
Compressive Strength (N/mm^2)	11.29	10.13	11.02	11.16	12.62	16.44	18.93	12.98	17.24
Average Compressive Strength (N/mm^2)	10.81			13.41			16.38		

Table 24: Compressive Strength of Aluminum Waste = 20% and w/c= 0.80 for 1:3:6 Mix

Slump: 7mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	200	420	331	228	285	270	338	460	373
Compressive Strength (N/mm^2)	8.89	18.67	10.27	10.13	17.11	12.00	15.02	20.44	16.58
Average Compressive Strength (N/mm^2)	12.61			13.08			17 .35		

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Table 25: Compressive Strength of Aluminum Waste = 25% and w/c= 0.80 for 1:3:6 Mix

Slump: 7mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	192	230	190	234	187	283	299	261	319
Compressive Strength (N/mm^2)	8.53	10.22	8.44	10.40	8.09	12.58	13.29	11.60	14.18
Average Compressive Strength (N/mm^2)	9.06			10.36			13.02		

Table 26: Compressive Strength of Aluminum Waste = 30% and w/c= 0.80 for 1:3:6 Mix

Slump: 7mm	**7 Days**			**14 Days**			**28Days**		
Samples	A	B	C	A	B	C	A	B	C
Failure load (KN)	166	214	273	280	255	260	268	438	416
Compressive Strength (N/mm^2)	7.78	9.51	12.13	12.44	11.33	11.56	11.91	19.47	18.49
Average Compressive Strength (N/mm^2)	9.81			11.78			16.62		

Table 27: Setting Time of Cement

Types of cement	**Dangote Portland cement**
Initial setting time (mins)	53
Final setting time (mins)	587

CONCLUSION

The conclusion of the study can be summarized as follows:

a) Aluminum waste can be used in construction as an additive in concrete

b) It can be used as a supplementary cementitious material in concrete production.

c) It can be used as a pozzolan.

d) Strength development in concrete increases with increase in hydration period.

e) The higher the workability, the lower the strength of concrete produced.

f) The maximum compressive strength was attained at w/c ratio of 0.55 and 5% of aluminum waste (28.47N/mm^2).

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