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The Effects of Delay in Hydrating Dry-mixed Aggregates on the Compressive Strength of Concrete.

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Abstract: *Most incidents of building collapse were due to concrete incompetencies caused by many technical factors. Thus, this paper evaluated the effects of delay in hydrating dry-mixed aggregates on the compressive strength of concrete. A total of eighty (80) concrete cubes of ratio 1:2:4 mix and size 150mm x 150mm x 150mm were cast and cured for the research. Four (4) sets of specimens were covered – Control, 2-hour delay, 3-hour delay and 4-hour delay before hydrating. For each of the specimens, twenty (20) cubes were cast, cured and crushed to determine the 7, 14, 21 and 28 day compressive strengths. The 28 day average compressive strength results obtained for Control, 2-hour delay, 3-hour delay and 4-hour delay were 20.60 N/mm^2, 16.00 N/mm^2, 12.60N/mm^2 and 10.92 N/mm^2 respectively. The compressive strength progressively decreased as the duration of the delay in hydrating the dry-mixed aggregates increased.*
Keywords: *Aggregates, Building collapse, Compressive Strength, Delay, Dry-mixed Concrete.*

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I. Introduction

Loss of lives, destruction of properties, traumatisation of families, property developers' loss of life investments, among others, are some of the consequencies of building collapse. All have their economic implications on the nation and the citizens.Concrete incompetence was identified by [1] as a major factor in building collapse. Cement, aggregates and water mixed in varied ratios are the constituents of concrete in attaining the desired strength. Water/cement ratio, grading, shape, strength and size of the aggregates are the dependencies of the compressive strength of the emerging concrete.It is a common sight on construction sites both in the urban and rural communities in Nigeria to dry-mix batched materials, especially through manual mixing method, and wait for the supply of water to hydrate the mix particularly during the dry season.

Therefore, this research is aimed at studying the effects of this waiting period for water supply to hydrate the dry-mixed materials on the average compressive strength of concrete.

II. Literature Review

The frequency of incidences of building failures and collapses in Nigeria has reached an alarming and embarrassing level. The magnitude of the losses incurred both in terms of lives and property is also colossal {[2],[3]}. Concrete essentially concerns the structural elements of buildings which make the study of the compressive strength of concrete significant in the evaluation of causative factors of building failures and collapses. Adequacy of compressive strength guarantees the capacity of the structure to withstand designed load while maintaining unruffled stability. Residential, public, commercial, educational, industrial buildings, even, on-going building projects do fail and collapse. Thus, [4] defined the characteristic strength of concrete as the value of compressive strength below which not more than a prescribed percentage of the test result should fall. The target mean strength or design strength exceed the characteristic strength by a margin.

Aggregates' redistribution and compaction create homogeneous materials called concrete with high strength. Concrete solidifies and hardens after mixing due to a chemical reaction known as hydration [5]. Water content affects the workability of fresh concrete. Particle surfaces will absorb water. Water fills the interstitial spaces too. Additional water will increase the fluidity and compaction. Indeed, [6] posited that, water content is the most important parameter governing consistency which is a parameter that is used to describe the aspect of workability that is related to the flow characteristics of fresh concrete. However, this activity of water addition is time-related. ASTM [7] provided that all water additions to concrete shall be completed within fifteen (15) minutes from the first water addition.

[8]listed the use of substandard building materials, incompetent professionals and society's disdain for professionalism within the industryas factors responsible for building collapse. Provision of specifications and adherence thereto are ethical professional responsibilities in quality building project delivery.

For this research, a mix ratio of 1:2:4(cement:stonedust:crushed granite) by weight was adopted. Standardised and constant mix ratio was recommended by [9] as poor mix ratio affects the quality of concrete therefrom.
Curing followed prescribed procedure. [10]defined curing of concrete as the process of maintaining satisfactory moisture content and a favourable temperature in concrete during the period immediately after the placement of concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements of service.

III. Materials and Methods

3.1 Materials: the materials used were cement, aggregates and water.
Cement was Ordinary Portland Cement (Dangote brand) sourced at Ado-Ekiti. Ekiti state, Nigeria. The aggregates were fine and coarse. The fine aggregate was stone dust; the coarse aggregate was crushed granite. Both aggregate samples were sourced from The New Concept Quarry, along Ijan/Igbemo road at IgbemoEkitiin Irepodun/Ifelodun Local Government Area of Ekiti State. The crushed granite was of nominal size of 25mm in accordance with [11]. Potable water was obtained from the Blocklayingand Concreting Workshop of the Department of Building Technology, The Federal Polytechnic, Ado-Ekiti. The water used satisfied the BS [12] requirements.
3.2 Methods: standard 1:2:4 (Cement:Stonedust:Crushed granite) mix ratio by weight was used with a Water/Cement ratio of 0.7.
9.0Kg Cement : 18.0Kg Stonedust : 36.0Kg Crushed granite and 6.3Kg Water (0.7x9.0Kg) was used. After dry-mixing, four (4) samples were taken for investigation: control, 2-hour delay, 3-hour delay and 4-hour delay. The control specimen was immediately hydrated and twenty (20) cubes of concrete were cast. Twenty (20) cubes each were also cast for the test specimens upon hydration at the appropriate delayed hours. Therefore, a total of eighty (80) 150mmx150mmx150mm concrete cubes were cast in accordance with [13]. Curing started after twenty four (24) hours of production. Five (5) cubes each were crushed for the respective specimens for the determination of 7, 14, 21 and 28 day average compressive strengths.

IV. Tests

The tests carried out include particle size distribution, moisture content, water absorption and compressive strength.
4.1 Particle Size Distribution: Sieve analyses for fine aggregates and coarse aggregates were carried out. Sieve analysis is a gradation test used to determine Fineness Modulus (FM) which is a factor obtained by adding the percentages of material retained in each of the following sieves: #4.75mm, #2.36mm, #1.18mm, #0.60mm, #0.30mm, #0.15, #0.075mm for fine aggregates and #25mm, #20mm, #12.5mm, #10mm, #4.75mm and #2.36mm for coarse aggregates. The sum is divided by 100 to give the Fineness Modulus.
That is, for fine aggregates;

$$FM = \frac{\#4.75mm+\#2.36mm+\#1.18mm+\#0.60mm+\#0.30mm+0.15mm+\#0.075mm}{100}$$

And for the coarse aggregates;

$$FM = \frac{\#25mm+\#20mm+\#12.5mm+\#10mm+\#4.75mm+\#2.36mm}{100}$$

The test is carried out according to [14].
4.2 Moisture Content Test:This is to determine the percentage of water contained in the fine aggregate. It is determined as:

$$\%\ M.C. = \frac{(W_1 - W_2)}{(W_2 - W_3)} \times 100\%$$

Where,

M.C. = Moisture Content (%)
W_1 = Weight of Container + Wet Soil (g)
W_2 = Weight of Container + Dry Soil (after 24hours in the oven) (g)
W_3 = Weight of Container (g)
$(W_1 - W_2)$ = Weight of Moisture (g)
$(W_2 - W_3)$ = Weight of Dry Soil (g)

4.3 Water Absorption Test:This was used to determine the rate of absorption or retention of water. That is,

$$W.A. = \frac{W_2 - W_1}{W_1} \times 100\%$$

Where,

W.A. = Water Absorption (%)
W_1 = Initial weight (g)

W_2 = Final weight after treatment (g)
The test was carried out in accordance with [15].
4.4 Compressive Strength Test: This was conducted according to [16] at the curing ages of 7, 14, 21 and 28 days. It was determined as,

$$\text{Compressive Strength} = \frac{\text{Load at Failure (N)}}{\text{Bearing Area of Cube (mm}^2\text{)}}$$

V. Statistical Analysis of Data.

The data obtained from the tests were analyzed using Microsoft Excel and Statistical Packages for Social Sciences (SPSS).The analytical methods were descriptive statistical analysis and graphical analysis.
The descriptive statistical analysis summarized the obtained field data which were presented as tables. Charts andgraphs were also plotted to give visual presentations of the various factors.

VI. Results and Discussions

6.1 Particle Size Distribution:Sieve analysis was used to determine the particle size distribution. For the fine aggregates, stone dust having a fineness modulus of 4.12 was used while the maximum aggregate size for the coarse aggregate was 25mm. Table 1 below shows the results for fine aggregates.

Table 1: Particle size distribution for the fine aggregates.

Sieve size (mm)	Weight Retained (g)	Cumulative weight retained (g)	Cumulative (%) Weight Retained	Cumulative (%) weight Passed
4.75	7	7	1.88	100
2.36	75	82	22.04	77.96
1.18	77	159	42.74	57.26
0.60	69	228	61.29	38.71
0.30	94	322	86.60	13.40
0.15	40	362	97.31	2.69
0.075	10	372	100	0.00
TOTAL	411.86			

Fineness Modulus (FM) = 411.86/100 = 4.12

Fig. 1: Particle size distribution for fine aggregates

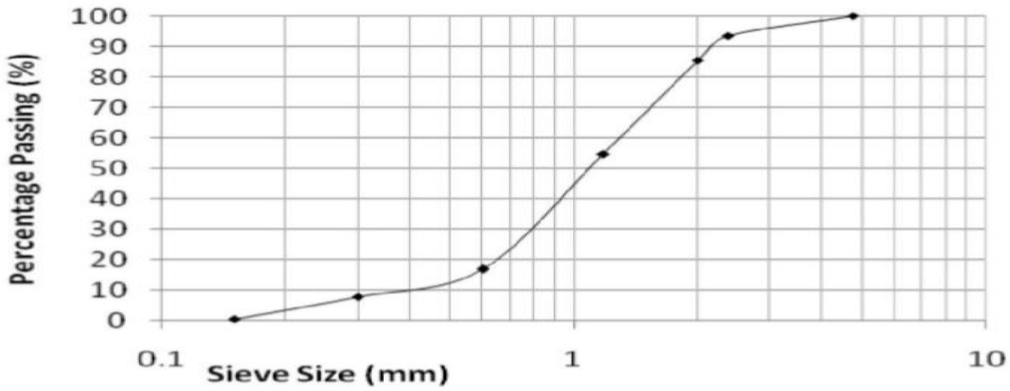

Table 2 shows the results of particle size distribution test for the coarse aggregates

Table 2: Particle size distribution for the coarse aggregates.

Sieve size (mm)	Weight Retained (g)	Cumulative weight retained (g)	Cumulative (%) Weight Retained	Cumulative (%) weight Passed
25	197	197	22.59	77.41
20	229	426	48.85	51.15
12.5	375	801	91.86	8.14
10	51	852	97.71	2.29
4.75	18	870	99.77	0.23
2.36	02	872	100	0.00

6.2 Moisture Content results:Three samples were considered in the determination of average moisture content of the stone dust used as fine aggregate. The results are shown in table 3 below:

Table 3: moisture Content Test results for the stonedust.

Container	W1 (g)	W2(g)	W3 (g)	W2-W3(g)	W1-W2(g)	%M.C.	Av. %M.C.
1	2.2	1.9	0.3	1.6	0.3	18.75	16.93
2	2.0	1.86	0.3	1.56	0.14	8.97	
3	1.1	0.96	0.3	0.65	0.15	23.07	

Average moisture content of 16.93% was obtained. Due to this, a water/cement ratio of 0.7 was used and deemed adequate.

6.3 Concrete compressive strength test results: The 7, 14, 21 and 28 days average crushing strength test results for the control, 2-hour, 3-hour and 4-hour delay concrete specimens are hereby presented in table 4 below.

Table 4: Summary of the average compressive strength results for the specified delay periods.

Age (days)	Average Compressive Strength (N/mm^2)			
	Control	2-Hour Delay	3-Hour Delay	4-Hour Delay
7	9.84	10.70	10.70	8.12
14	13.34	11.40	13.50	11.32
21	16.64	15.20	11.80	10.38
28	20.60	16.00	12.60	10.92

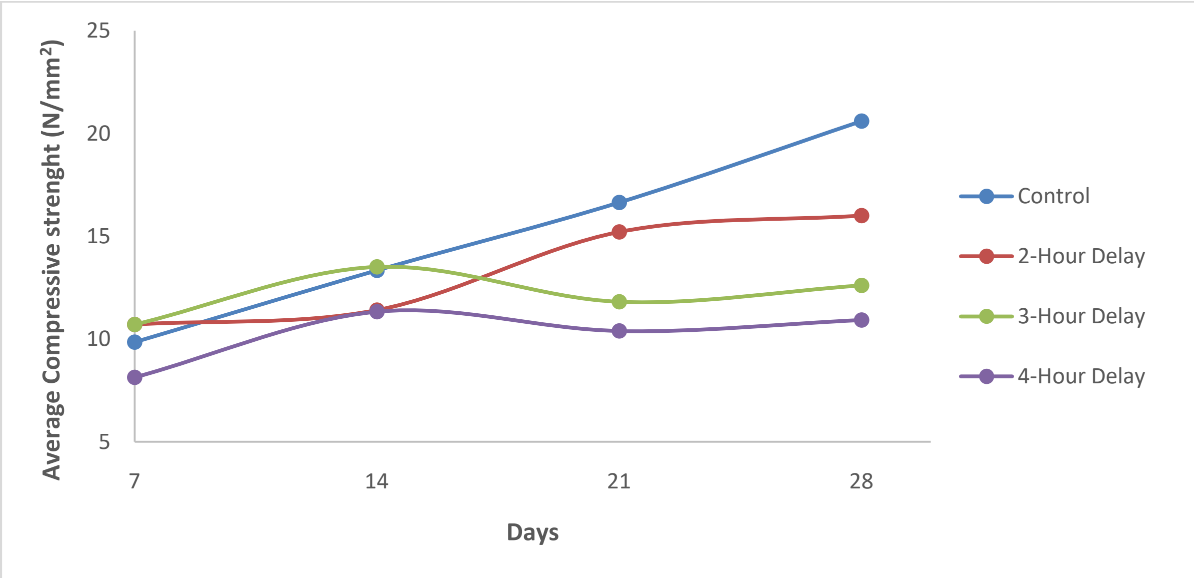

Figure 2: Hydrating time effects on the compressive strength of concrete.

The figure reveals a consistency in the increase in average compressive strength of the control mix from 9.84 N/mm^2 on day 7 to 20.60 N/mm^{2}on day 28. The 2-hour delayed mix specimen showed a marginal consistency in the strength attainment from day 7 to day 28 rising from 10.70 N/mm^2 to 16.00 N/mm^2 respectively. The 3-hour and 4-hour delayed specimens showed a hapharzard behaviour in the results. Appreciable marginal differences were noticed between the control specimen and the test specimens reducing in strength in direct proportion to the increase of the delayed time. That is, the test mixes have considerably lower compressive strengths than the B.S. requirements for the 28 day strength of a 1:2:4 mix ratio.

VII. Conclusions

Concrete produced after delay in the hydration of the dry-mixed aggregates is weak. The severity of the weakness proportionally varies with the duration of the delay. The binding quality of cement diminishes on exposure to the atmospheric condition during the period of delay and, thus, resulting in the low value of the concrete test specimens' compressive strengths. Weak concrete for in-situ construction makes structural components vulnerable in the future. This vulnerability will be manifested as structural defects in the future in buildings followed by failures and ultimate building collapse.

VIII. Recommendations

1. Seminars and Workshops should be organised for the masons by the Local Governments to train and retrain them on the fundamentals of good practices in building construction.
2. Project Monitoring Unit (PMU), should be established in the Work's Department of every Local Government and empowered though legislation to enforce compliance through monitoring and control of the activities of all Craftsmen involved in on-going projects within their domain.

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