INVESTIGATION INTO THE EFFECTS OF TEMPERATURE ON STRENGTH CHARACTERISTICS OF CONCRETE PRODUCED IN ANAMBRA STATE

[*]C.B.N. Bert-Okonkwor[1];*K.C Okolie[1];*Okongwu M.I[1];
[*]Nzeneri Oluchukwu Precious-Favour [2]
[*]Department of Building, Nnamdi Azikiwe University, P.M.B 5025, Awka, Anambra State, Nigeria[1]
[*]Building Technology Department, School of Environmental Sciences, Federal University of Technology, Owerri, Nigeria[2]

Abstract:
The study investigated the effects of temperature on strength of concrete produced in Anambra State, Nigeria. The study is an experimental research. Concrete were produced at different temperature within the study area. Cement, aggregates (fine and coarse) and water were used in mixing concrete. Dangote Cement was used for all the concrete produced. The fine aggregates used was obtained from River Sand (Onitsha), coarse aggregate is crushed stones from Nkwelle Ezunaka and water used for the concrete mixing is fit for drinking. These concrete produced were tested in the laboratory (Anambra State Material Testing Laboratory) for workability and compressive strength and the result obtained were presented in simple tables and graphs. The study found out that there is great variation in strength of concrete produced at different temperatures. The average compressive strength at 27.6^0C is $14.83N/mm^2$. At temperatures above 30^0C, the strength of concrete tends to diminish/reduce. Compressive strength of concrete at 33.85^0C and 35.1^0C was $11.6N/mm^2$ and $11.1N/mm^2$ respectively. Also, the result of the slump value ranges from 48.4mm – 103.5mm (indicating that all the concrete mix is workable). The graph in Figure 3 indicates that concrete produced in early hours of the day yielded the highest compressive strength (28^{th} day) while as temperature increases, the compressive strength of concrete diminishes. The study was concluded by recommending that the best time for concrete production is in the morning when atmospheric temperature is still below 30^0C within the study area. From the results of the study, it can be clearly noticed that with increase in temperature, there is there is significant increase slump of concrete mix as well as decrease in crushing load and compressive strength of concrete.
Keywords: Concrete, Cement, Temperature, Compressive Strength.

INTRODUCTION

Concrete is a major component of infrastructural facilities in the 21st century because of its versatility in use. Concrete is used more than any other man-made material in the world [1]. Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slay cement, aggregates (overall coarse aggregate made of gravel or crushed rocks such as limestone, or granite plus fine aggregate such as sand), water, and chemical admixture [2]. The word concrete comes from the word "Concretus" (meaning compact and condensed); the perfect passive participle of "concrescere", from "con-"(together) and "crescere" (to grow). Concrete as a material has been known since before Roman times, but it is only since the introduction of Portland cement by Joseph Aspdin, an English Manson, that it becomes widely regarded as a structural material. It is one of the most versatile materials of great strength and durability, provided good control measures are maintained through all the stages of production. Ezeokonkwo [3], concrete can be described as any product or mass made by binding together particles of some inert materials by the use of cementing medium. Generally, the medium is the product of reaction between hydraulic cement and water. Also those inert materials are referred to as aggregates. The materials used as

aggregates include sand, crushed stones, gravels, expanded clay etc. Concrete is composed of cement, water, aggregates (fine and coarse) and admixture which enables it to achieve a set goal, and a wide variety of ratio mixes obtained from these ingredients [4, 5]

As widely used construction material in civil engineering structures, the properties of concrete have direct relationship with structural safety. Standard concrete specimens are usually cured and tested under ideal conditions according to specifications. However, concrete structures are exposed to external environment in service; the mechanical (static and dynamic) properties of concrete are complicated as they are affected by environmental/climatic conditions such as temperature and relative humidity [6, 7]. As with any material, concrete will expand and contract as the temperature rises and falls. The size of movement depends upon the change in temperature and the coefficient of thermal expansion o f concrete.

Numerous researches have been conducted to investigate the relationships between concrete performances and environmental conditions. Apipattanavis, Molenaar, Rajagopalan and Xi [8] proposed an integrated framework to identify the weather attributes that cause construction delays and to quantify weather threshold values. Winds speed and temperature will play an essential part on labour productivity in many different ways. Extreme temperatures can affect concrete. In particular, the influence on the design parameters such as compressive, tensile, and flexural strength is important. Okereke [9] believes that the development of good properties by concrete also depends upon the climatic conditions/curing environment to which a concrete is subjected to, especially during its early age. High temperature during the dry season is one of the important factors that adversely affect setting times, ultimate strength, rate of heat evolution etc., of cement concrete. High temperature causes rapid evaporation of water from the concrete surface, which is one of the worst conditions for a fresh concrete. According to Solatiyan, Asadi and Bozorgmehrasl [10], concrete pavements are generally exposed to temperatures of 20 degrees below zero, simulating a freeze-thaw situation. Freeze-thaw cycles can influence the properties of concrete significantly. In addition, the low temperature can cause cracks. In a cold climate, any water which permeates the concrete surface through the concrete's pores will be frozen. As the water freezes, it expands by the concrete surface through the concrete's pores will be frozen. As the water freezes, it expands by 9%, thereby increasing pressure in the concrete. If the resulting stress is greater than the intrinsic tensile strength of reinforced concrete, a crack will occur. Moreover, Bijen [11], opined that, if low temperature continues, the cracks will develop considerably.

High temperature also can have an influence on the performance of concrete. In order to highlight the influence, Ergün, Kürklü and Baspınar [12] conducted an experiment by using three concrete test series using different water cement ratios—concrete A (w/c = 0.73), concrete B (w/c = 0.60), and concrete C (w/c = 0.48). The experimental results pointed out clearly that, as the temperature increases from 20 to 100 degrees Celsius, there is a very small increase in compressive strength. Above the water boiling point of 100 degree Celsius, the value of compressive strength shows the decline with the temperature increase.

Additionally, the extreme temperature can influence the chemical reaction in concrete. An increase in temperature will result in higher corrosion rates when combined with CO2. Moreover, Ergün, Kürklü and Baspınar [12] argued that when reinforced concrete is exposed to a high-temperature situation, the physical and chemical changes have a significant effect on the concrete material rather than the reinforcing steel bar material. In other words, a high temperature affects the mechanical strength loss of concrete more significantly than that of a steel bar. It was also found that the extreme temperature can influence the chemical process during hydration (the setting and hardening of concrete). Climate change can modify the level of environmental humidity. The environmental humidity or moisture damping could also influence the internal water content of concrete. It is noted that the internal water content of concrete plays a significant role in the performance level on mechanical properties.

Also, high temperature can affect the flexural strength dramatically, resulting in a weakened performance of flexural capacity. Additionally, the extreme temperature can influence the

chemical reaction in concrete. An increase in temperature will result in higher corrosion rates when combined with CO_2. Moreover, Ergün, Kürklü and Baspınar [12], argue that when reinforced concrete is exposed to a high-temperature situation, the physical and chemical changes have a significant effect on the concrete material rather than the reinforcing steel bar material. In other words, a high temperature affects the mechanical strength loss of concrete more significantly than that of a steel bar. It was also found that the extreme temperature can influence the chemical process during hydration (the setting and hardening of concrete). Climate change can modify the level of environmental humidity. The environmental humidity or moisture damping could also influence the internal water content of concrete.

Shebab and Heba [13] present an experimental program to describe the effect of different temperature on concrete strength when Fibre Reinforced Polymer (FRP) is used to strengthen concrete structures. The following conclusions can be drawn from the experimental results: According to the different used temperatures the values of compressive strength are obtained of specimens confined with different shapes of CFRP and unconfined specimens. The values of compressive strength are plotted versus temperature as shown in figure. The result demonstrated that the higher the temperature the lower the values of compressive strength, this was probably caused by softening of the adhesive and as a result strain and stresses along the interface adhesive / concrete were more evenly distributed. Their result further revealed that when temperature increased from 0^oC to 200^oC the lowest value of decrease is obtained in case of wrapped with 3 strips and is estimated by about 20.52%. However, in general the highest values of compressive strength are obtained when the specimens are wrapped totally with CFRP followed by specimens wrapped with 3 strips then wrapped with 2 strips and in the rear these without CFRP, which represents the relationship between the values of compressive strength and CFRP wrapping.

Solatiyan, Asadi, and Bozorgmehrasl [10], investigate the Effect of Freeze-Thaw Cycles on Strength Properties of Concrete Pavements in Cold Climates. Their results reveal that, extreme temperatures can affect concrete. In particular, the influence on the design parameters such as compressive, tensile, and flexural strength is important. According to them, concrete pavements are gene. They added that, the low temperature can cause cracks. In a cold climate, any water which permeates the concrete surface through the concrete's pores will be frozen. As the water freezes, it expands by 9%, thereby increasing pressure in the concrete. They further stressed that, if the resulting stress is greater than the intrinsic tensile strength of reinforced concrete, a crack will occur. Moreover, if low temperature continues, the cracks will develop considerably. In addition, Bijen [11], opined that, high temperature also can have an influence on the performance of concrete. In order to highlight the influence,

Ergün, Kürklü and Baspınar [12], conducted an experiment by using three concrete test series using different water cement ratios - concrete A (w/c = 0.73), concrete B (w/c = 0.60), and concrete C (w/c = 0.48). The experimental results pointed out clearly that, as the temperature increases from 20 to 100 degrees Celsius, there is a very small increase in compressive strength. Above the water boiling point of 100 degree Celsius, the value of compressive strength shows the decline with the temperature increase.

In the study area, the temperature ranges between 27^0C – 36.9^0C, this will be shown clearly in Table 1.1 which is an extract from Nigeria Meteorological Agency. The table shows the mean monthly maximum temperature in the study area.

Table 1.1: Mean Monthly Maximum Temperature for Anambra State IN ^{0}C (2006-2015)
SOURCE: NIGERIA METEOROLOGICAL AGENCY

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2006	35.1	36.1	35.3	35.4	31.8	31.9	30.8	29.9	30	31.9	33.7	34.5
2007	35	36.8	36.9	34.4	32.7	31.5	30.4	29.6	30.1	31.5	32.3	33.8
2008	33.7	36.3	35.5	32.6	31.8	31	29.9	29.4	30.5	32.5	34.2	34.5
2009	33.9	34.6	35.8	33.9	33.1	31.9	30.2	30	30.5	31.3	33.5	35.7
2010	35.5	36	36.3	34.7	32.8	31.2	30.3	30.7	30.9	31.3	32.6	34.5
2011	35.3	36.4	35.7	33.6	32.8	30.2	29	29.3	30	31.8	33.8	33.7
2012	35.4	36.5	34.8	34	32.9	30.2	28.7	28.9	29.7	31.4	33.8	33.8
2013	35.4	36.4	34.9	34	33	30	28.3	29.4	30.2	30.9	33.9	33.8
2014	32.8	34.3	35.2	35.5	35.1	33.9	32.3	30.4	29.2	29.3	30.1	31.6
2015	33.5	34.9	34.7	33.6	32.0	30.5	29.5	29.6	30.2	31.2	32.6	32.9

In the present study, the main objective is to determine the effect of temperature on compressive strength of concrete produced at different temperature in the study area. The temperature changes and its effect on concrete is expected to guide professionals on the best time for concrete production in the study area.

Experimental Details
Materials Properties
A. Cement
The cement used throughout this work was Ordinary Portland Cement (OPC). The cement is tested and the test results satisfied the requirement of Nigerian Industrial Standards, NIS444-1: 2003 [15] and also in conformance with the requirements of BS 12: 1991 [16], the physical test results of the used cement are given in table 1.

Table 1: Properties of Ordinary Portland Cement (Dangote)

Tests	Results	NIS Requirements
Initial Setting Time (min)	156	75minimum
Final Setting Time(min)	260	NA
2day compressive Strength(N/mm^2)	14.55	$\geq$ 10.00
28day compressive Strength(N/mm^2)	38.8	32.5
Consistency (%)	28.8	NA
Soundness(mm)	0.24	10maximum
Insoluble Residue (IR) (%)	1.5	5.00 maximum
Sulphate Content (%)	2.3	3.5 maximum
Loss of Ignition (LOI) (%)	6.8	5.0 maximum

Source: Researchers work (2019)

B. Aggregates
Crushed stone with diameters ranging from 15 mm to 22 mm and natural sand with fineness modulus of 2.36 are adopted as coarse and fine aggregates respectively for concrete mixes of this investigation. The sieve analyses and particle size distribution of both coarse aggregates and natural sand are shown in table (2) ; plate (1) and (2) respectively.

C. Mix Proportion (M_{15} Mix Design - 1:2:4)
Dimension of mould = 15cm x 15cm x 15cm
Actual Concrete Weight for 1mould = 8650g

CEMENT- 1/7 * 8650g = 1.2kg
12moulds * 1.2kg= 14.4kg (cement)
SAND- 2/7 * 8650g = 2.47kg
12moulds * 2.47 = 29.66kg (sand)

AGGREGATE- 4/7 * 8650g = 4.9kg
12moulds * 4.9kg = 59.31kg
Aggregates comprises of both fine and coarse aggregate.
Thus for Coarse Aggregates (15/22mm) - 60% of 59.31kg
= 35.6kg (coarse aggregates)
Fine Aggregates (5/15mm) – 40% of 59.31kg
= 23.7kg (fine aggregates)

Table 2: Sieve Analysis for Coarse Aggregates

NNAMDI AZIKIWE UNIVERSITY AWKA. **SIEVE ANALYSIS** Operator:
CIVIL ENGINEERING Date:
Materials testing laboratory Material Ref: 15/22 mm AGG
Project: Crushed Rock Client
Sample Ref: Location: Nkwelle Ezunaka Appendix
Weight of Sample Wet Moisture Content % Weight of Sample Dry 1588.4 gms

SIEVES	WEIGHT RETAINED	PERCENTAGE RETAINED	PERCENTAGE COMMULATIVE	PERCENTAGE PASSING	SPECIFICATION
38.10					
31.75					
25.40				100.0	
19.05	254.6	16.0	16.0	84.0	
12.70	1289.9	81.2	97.2	2.8	
9.52	14.4	0.9	98.1	1.9	
4.75					
2.36					

Source: Researchers work (2019)

Plate 1: Sieve Analysis of Fine aggregate

PARTICLE SIZE DISTRIBUTION (SILT CONTENT) ON RIVER SAND (BS 1377:2:1990)

SAMPLE DESCRIPTION: LIGHT BROWN MEDIUM TO FINE SAND

TOTAL MASS OF DRY SAMPLE B: 100g

DATE TESTED: 16/10/2019

Wt Retained	Cumm. Wt Retained	% Retained	Cumm % Retained	Sieve Size	% Passing
0.00	0	0.00	0.00	75	
0.00	0	0.00	0.00	63	
0.00	0	0.00	0.00	50	100.00
0.00	0	0.00	0.00	37.5	100.00
0.00	0	0.00	0.00	28	100.00
0.00	0	0.00	0.00	20	100.00
0.00	0	0.00	0.00	14	100.00
0.00	0	0.00	0.00	10	100.00
0.00	0	0.00	0.00	6.3	100.00
0.00	0	0.00	0.00	5	100.00
0.00	0.00	0.00	0.00	3.35	100.00
0.85	0.85	0.85	0.85	2.36	99.15
8.87	9.72	8.87	9.72	1.18	90.28
26.93	36.65	26.93	36.65	0.6	63.35
19.25	55.90	19.25	55.90	0.425	44.10
18.09	73.99	18.09	73.99	0.3	26.01
15.32	89.31	15.32	89.31	0.212	10.69
7.32	96.63	7.32	96.63	0.15	3.37
2.23	98.86	2.23	98.86	0.063	1.14
1.14	100.00	1.14	100.00	Pan	
100.00		100			

Sand Analysis (%)	
Coarse Gravel -	
Fine Gravel -	0.00
Coarse Sand -	0.85
Medium Sand -	55.05
Fine Sand -	42.96
Fines -	1.14

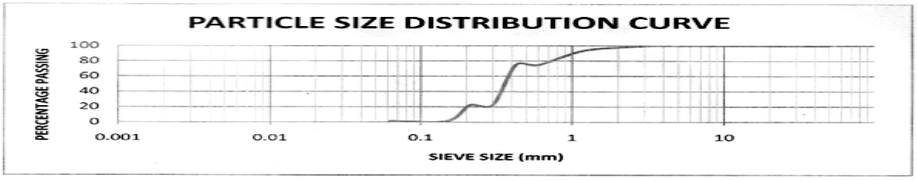


Plate 2: Particle distribution Curve of Fine Aggregate

Specimens

Concrete specimens are 150 mm cubes (produced for testing cube compressive strength) which are casted horizontally in steel moulds. The samples are collected and filled in a clean concrete cube. When the cube is half filled, the concrete is compacted by tapping with rod 25times. This is also repeated when the cube is filled. After compacting, the cube is put in a cool dry place to set for at least 24 h. All specimens are removed from the moulds 24 h after casting and cured in a curing room (°C and 95% RH (relative humidity)) for 28 days (BS2058: 1968) [17].

Laboratory Test

Two major laboratory tests are carried out in the course of this investigation. They include:

(a) **Slump test**: to determine the workability of the concrete used.

(b) **Compressive Strength test**: To determine the compressive strength (that is load on failure) of concrete cubes from different brands of cement.

The Slump Test

Objective: Slump test is used to determine the workability of concrete.

Procedures: The apparatus for this test consists of a hollow frustum of a cone which has a diameter at the top 100mn and at the bottom 200mm and a vertical height of 300mm; the cone is fitted with two handle on the sides for lifting. This equipment is also available in a more elaborate design. This has the same basic conic shape which is held in a steel frame and allowed to side freely up and down. The whole of the apparatus rests on a steel base. The tapping bar is a 16mm diameter rod, 600mm long, with a bullet nosed end as shown in Plate 3. The test is carried out by placing the metal plate on a level surface. The cone is held down by placing the feet on the metal plate and the cone is filled in form of district layers. Compaction is achieved by tapping each layer of the concrete 25times. When the cone is filled, the top is smoothened off with the rod and lifted the cone with a clean upward sweep. Then the cone is placed alongside the concrete and the reduction in height is measured. If the range of the slump is between 70mm-140mm (plate 4), the concrete is said to be good and okay in consistency but beyond that range, it is not okay.

Compressive Strength Test.

Objective: This is aimed at determining the compressive strength of concrete made from different brands of cement. Procedure is as discussed in Section 2.2

Results and Discussions

In order to understand the effects of temperature on the strength characteristics of concrete with all specimens are tested as mentioned above until failure and the results are discussed as follows:

Compressive strength of concrete-mix produced at different temperature and time of the day was also recorded to ascertain if variations in climatic conditions has any effect on the quality and strength characteristics of concrete. The results are presented in Table 3.1-3.3;

Table 3.1: Results of Experiments of Fresh Concrete Showing Slump and Crushing Strength Performed at Different Temperature (Time: 9:00am)

Exp. No	Atmospheric Temp ^{0}C	Mix Temp ^{0}C	Temp of Water ^{0}C	Slump(mm)	Crushing Load KN	Crushing Strength N/mm^2
1	26.6	32	27	45	340	15.1
2	27	31.9	27	35	331	13.1
3	30.1	31.4	31	55	365	16.1
4	26	31.4	27	42	338	15
5	27	31	31.2	38	330	14.7
6	27	32	27	53	326	14.5
7	29.6	31.5	29	58	328	14.6
8	27	32	27.5	50	339	15.1
9	28.5	30.1	28	56	342	15.2
10	27	31.5	27	52	335	14.9
Average	**27.6**	**31.48**	**28.2**	**48.4**	**337.4**	**14.83**

Source: Field Survey (2019)

Table 3.2: Results of Experiments of Fresh Concrete Showing Slump and Crushing Strength Performed at Different Temperature (Time: 12noon)

Exp. No	Atmospheric Temp ^{0}C	Mix Temp ^{0}C	Temp of Water ^{0}C	Slump(mm)	Crushing Load KN	Crushing Strength N/mm^2
1	34	34.9	31.1	82	312	14.1
2	34.9	34.8	32.1	90	260	11.6
3	33.8	34.1	30.5	79	220	9.8
4	32.2	34.5	31	81	280	11.2
5	31	33.5	31.3	87	255	10.0
6	34	34.7	31	93	264	11.7
7	35.8	34.8	31.3	93	270	12.0
8	33.8	34	31	88	255	10.0
9	35	34.7	32.1	97	270	12.0
10	34	34.5	31.3	96	306	13.6
Average	**33.85**	**31.1**	**31.3**	**88.6**	**269.2**	**11.6**

Source: Field Survey (2019)

Table 3.3: Results of Experiments of Fresh Concrete Showing Slump and Crushing Strength Performed at Different Temperature (Time: 4:00pm)

Exp. No	**Atmospheric Temp ^{0}C**	**Mix Temp ^{0}C**	**Temp of Water ^{0}C**	**Slump(mm)**	**Crushing Load KN**	**Crushing Strength N/mm^2**
1	35	34	31.5	90	280	11.2
2	36	34.7	33	94	250	10.0
3	35.5	34.7	31.5	130	310	12.4
4	35.0	34.1	31.5	95	306	13.6
5	35.8	34.7	32	105	266	10.6
6	35	34	31	108	270	12.0
7	35	34	32.1	97	230	9.2
8	35	34.7	31.8	115	240	9.2
9	34	34.3	31	103	261	11.6
10	35	34	31	98	272	10.9
Average	**35.1**	**34.3**	**31.6**	**103.5**	**268.5**	**11.1**

Source: Field Survey (2019)

The values in Table 3.1 – 3.3 was also summarized and represented graphically. The graph is shown in Fig 1-3;

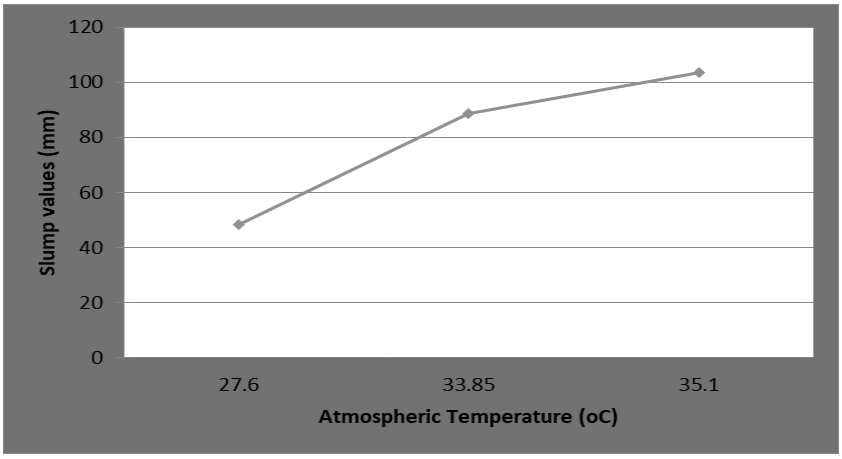


Fig 1: Graph of Atmospheric Temperature against Slump Values of Concrete mix

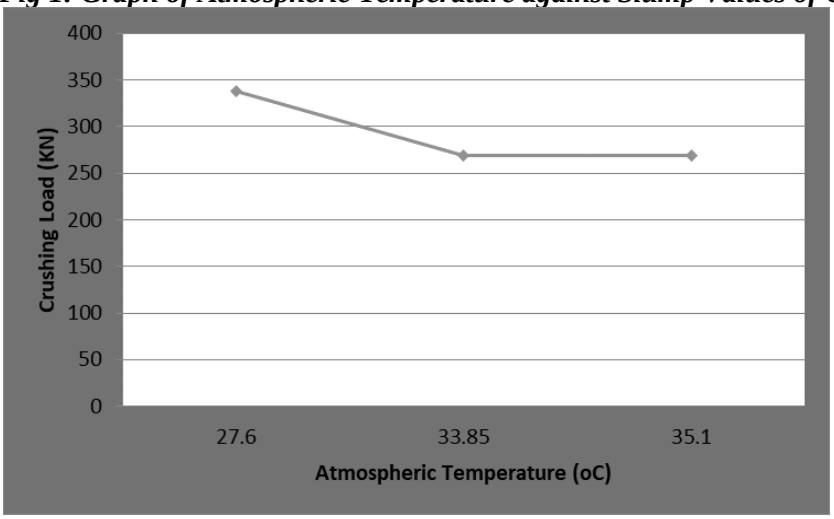


Fig 2: Graph of Atmospheric Temperature against Crushing Load of Concrete

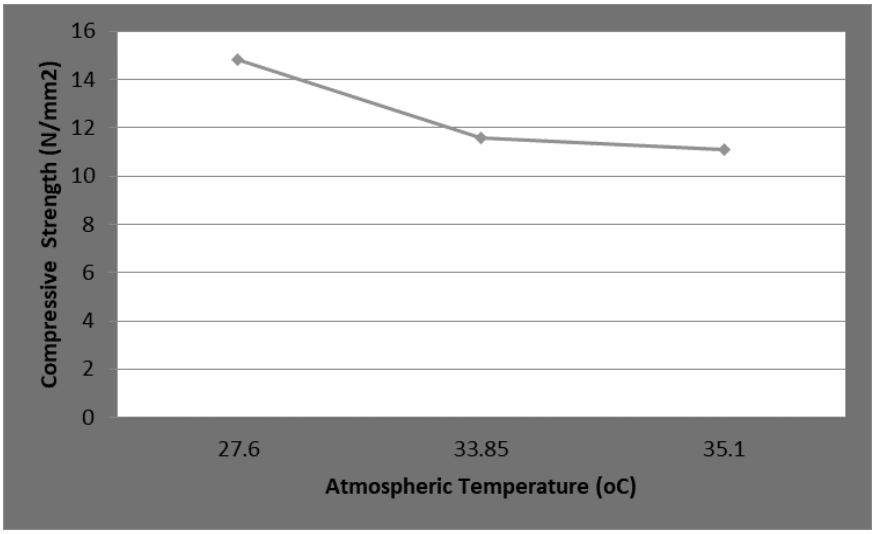


Fig 3: Graph of Atmospheric Temperature against Slump Compressive Strength of Concrete.

From Table 3.1 - 3.3, it can be deduced that there is great variations in strength of concrete produced at different temperature (climatic conditions). It can also be noticed that the best time for concrete-mix production is in the morning when temperature is still below 30^0C. The average compressive strength at 27.6^0C is 14.83N/mm^2. At temperatures above 30^0C, the strength of concrete tends to diminish/reduce. Compressive strength of concrete at 33.85^0C and 35.1^0C was 11.6N/mm^2 and 11.1N/mm^2 respectively. Figures 1-3 also summarized the table values

graphically and it can be seen in Fig 1 that increase in atmospheric temperature leads to increase in slump values of concrete. On the other hand, Fig 2 shows that increase in atmospheric temperature decreases the crushing load of concrete and increase in atmospheric temperature decreases the compressive strength of concrete (Fig 3).

Conclusion and Recommendation

According to Okereke [9], development of good properties by concrete does not depend solely on material selection. It also depends upon the climatic conditions/curing environment to which the concrete is subjected to, especially during its early age. In this study, the strength a characteristic of concrete was investigated to observe the variations among concrete strength produced at different temperatures within the study area. From the findings of this research the following conclusions and recommendations were drawn:

1. The average temperature within the study area ranges from 27^0C – 36.9^0C. This temperature is dependent on the time of the day and time of the year (season). [Table 1.1]
2. The concrete produced in the early hours of the day (atmospheric temperature = 27.6^0C) has the highest compressive strength. The average compressive strength at 27.6^0C is 14.83N/mm^2.[Table 3.1]
3. The lowest compressive strength which is 11.1N/mm^2 was produced at an atmospheric temperature of 35.1^0C [Table 3.3]
4. Increase in atmospheric temperature leads to increase in slump values of concrete-mix. [Figure 1]
5. It can also be concluded that provided all other factors affecting concrete production remains constant, increase in temperature results to decrease in crushing load of concrete as well as its compressive strength. [Figure 2 & 3]

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