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The Impact of Meteorological Conditions on the Value of Fresh and Hardened Concrete

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Authors' contributions

This work was carried out in collaboration between all authors. Author ECD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BOA and EVA managed the analyses of the study. Author EVA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The learning scrutinizes the influence of meteorological situations on fresh and case-hardened concrete formed in the South East, Nigeria. The variables considered in the research are temperature as well as relative humidity. The meteorological condition parameters were gained from Nigerian Metrological Agency in Lagos, Nigeria. The middling yearly temperature oscillated $26.39^{\circ}C$ to $32.49^{\circ}C$ was used as a control for the experiment. Slump and strength tests were conducted on concrete samples and results exposed that workability and compressive strength of the concrete was affected by temperature and relative humidity. It was discovered that concrete manufactured in the sunrise hours (9 am-12 noon) when the temperature and relative humidity were little have better quality than those manufactured in the late afternoon (2-4 pm) as portrayed by the results of the tests on the tables. However, the research acclaims that Professionals and other stakeholders in the construction practice should be aware that temperature and relative humidity partake to influence the quality of concrete during production on site. The research also inaugurates that the suitable time to produce high-quality concrete is between the hours of 9 am-2 pm and any other time will call

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for the use of admixture to produce concrete of similar quality although of a higher cost thus, affecting the budget of the project. In conclusion, professionals in practice are recommended to ensure effective supervision during concrete production.

Keywords: Meteorological conditions; quality; concrete; slump; crush Load; geographical region and crushing strength.

1. INTRODUCTION

Climate is meteorological conditions, including temperature, precipitation and wind that characterize a particular geographical region. These meteorological conditions subject materials used in construction to varying degrees of stress as a result of climatic variations. These conditions are usually other than ideal, and therefore affect the mechanical and chemical properties like its corrosion rate, yield strength, tensile strength and ductility of the materials to such an extent that they do or do not meet its specific service requirements.

These materials may encounter low or elevated temperatures, high or low humidity levels, acidic or alkaline precipitation, varying wind conditions including sandstorms, hurricanes, tornadoes etc. The resultant effect (that is the climatic effects on construction materials) of these conditions is of high significance to the construction professionals in whose hand lies the choice of material suitable for use. This is because different climatic conditions impose different requirements on the use and storage of construction materials [1].

Concrete as a synthetic construction material is made by mixing cement, fine aggregate (usually sand), coarse aggregate (usually gravel or crushed stone) and water in proper proportions is seen as possessing unique characteristics of workability, durability and strength [2]. This makes it the most common building materials in use in today's construction clime.

However, as with all materials, deterioration is inevitable. A major agent of deterioration is the aforementioned climate and its attendant climatic conditions. The essence, therefore, is to investigate if climatic conditions prevalent in the area of discussing adversely affects the quality of concrete produced.

The problem associated with concrete production is generally known, well documented and researched worldwide. These problems include poor quality of materials and low level of workmanship during concrete production. Other than these, other quality related problems in concrete production are in existence.

1.1 Climate Characteristics of South East Nigeria

The focus of this study is on South East Geo-Political zone of Nigeria. The study area lies within the tropical region with early rainfall and full commencement of the rainy year. The dry season lasts between four to five months. The highest rainfall is recorded from July to October (4 months) with a little break in August. The average highest annual rainfall is about 1952 millimeters [3].

The temperature pattern has a mean daily and annual temperature of 28°C and 27°C respectively [3]. The nature of climatic conditions variation associated with the weather in the study area is shown below in table one.

Prevailing climatic events, such as temperature, rainfall, high winds and humidity have some consequences in the production of (fresh) concrete work on construction sites. Planning for these weather-related emergencies, in the design and method of production will rely on knowledge of the frequency of these events [4].

The assessment of the precipitation is an important problem in hydrologic risk as far as fresh concrete production is concerned. This is why the evaluation of rainfall extremes, as embodied in the intensity-duration frequency (IDF) relationship, has been a major focus of both theoretical and applied hydrology [5]. defined rainfall IDF relationships as graphical representations of the amount of water that falls within a given period of time [6]. These graphs are used to determine when a certain rainfall rate or a specific volume of flow will reoccur in the future. Smith (1993), states that the precipitation frequency analysis problem computes the amount of precipitation Y falling over a given area in a duration of X minutes with a given probability of occurrence in any given year [7].

Table 1. Climatic conditions variation in the area

Climatic factor	Max	Min	Mean
Rainfall intensity (mm)	2600.71	1157.30	1879.00
Rainfall duration (days)	99.00	64.00	81.50
Relative Humidity (%)	86.90	70.25	78.57
Temperature (°C)	32.49	26.39	29.44

Edeh, Eboh and Mbam (2011)

Within the study area, temperature and humidity are high year-round [6]. There are two seasons in Nigeria, the wet season (March through November) and dry season December through February). The dry season starts with harmattan —a dry chilly spell with a dusty atmosphere brought about by the North East (NE) winds blowing from the Arabian Peninsula across the Desert. During the rainy season, a marked interruption in the rains occurs during the month of August, resulting in a short dry season often referred to as the "August break", though for 5 years now this has not been consistent in August due to climate change [4].

1.2 Climatic Influences in Concrete Production

Cement concrete is highly used in construction as a reinforced material in the universe. It gained a special influence in construction society. Durability, ultimate strength, rate of heat of hydration, impermeability, setting time, development, rate of strength and workability belong to the most significant features of fresh and hardened concrete [1]. Okereke (2003), explores the desired properties of fresh and hardened concrete which may sometimes be predictably attained through brainy selection of the basic concrete makeup materials, proper proportioning and mixing of components, curing and compacting [1].

Whan and Ullah (2004), shows that there are some instances where some particular properties of concrete like extended diminished setting times, increased resistance to alkali-aggregate reactions, early strength gain, lesser rate of heat of hydration are in need [8,9]. Often, it is more practical and economical to attain the desired properties in concrete by adding one or more additional materials to the elementary concrete making materials all through the process of concrete [10].

Okereke, (2003) examination revealed that the growth of good properties by concrete also be governed by the climatic conditions to which a concrete is subjected to, particularly during its initial stage of development [1]. High temperature during the dry season is one of the main factors that unsympathetically affect ultimate strength, rate of heat evolution, setting times etc., on cement aggregate mixture. High temperature causes rapid dehydration of H_2O from the concrete surface, which is the first worst conditions for a fresh concrete. Speedy dehydration of water from the concrete surface results to earlier setting of the concrete and no time is left accessible for concreting operations.

1.3 Precipitation, Wind and Humidity

Weather state of affairs at a job site-hot or cold, windy or cool, waterless or moist may be massively diverse from the best conditions anticipated at the time a concrete mix is identified, designed, or selected. Weather can adversely affect the properties and the serviceability of concrete unless certain practices are followed by the contractor and concrete producer [11]. Precipitation includes rain, snow or hail, which is formed by condensation of moisture in the atmosphere and fall to the ground. The location of this study has rainfall as its primary type of precipitation [12]. Cemex (2012), attests that rainfall during concrete placement presents a challenge to good quality concrete [13].

In general, overcoming the problems of cold weather involves protecting concrete. There are many ways of producing desired results but all of them have schedule and budget implications. The most important element for success in cold weather is a plan of action by contractors which is coordinated with the builder/architect/engineer, concrete supplier and owner/his representative. Planning can help provide a structure of the required durability and quality within minimal disruptions to the project schedule and budget.

2. METHODOLOGY

The study reviews the relevant available literature on the effect of climatic conditions on the quality of fresh and hardened concrete produced for construction work. The climatic conditions considered in this study will allow construction professionals and contractors to quantify and evaluate the effect of various controllable and uncontrollable variables that affect fresh and hardened concrete development in terms of workability and strength. Thus the study was carried out based on the following two stages of experimental data collection:

- Materials Characterization: The objective of this stage is to determine the effect of temperature, and relative humidity on the production of mixed fresh concrete without any admixture). Standard Aggregates both coarse and fine will be measured based on the ratio (1:2:4) of the mix with the volume of water kept constant.
- Experimental Phase: The data obtained from the mixing of concrete is used for the determination of the slump value and compressive strength. These were obtained by use of a truncated cone for the slump measurements and crushing of the concrete cubes using a crushing machine after seven days for compressive strength.

2.1 Test Location

The slump tests were conducted in situ within the civil engineering laboratory of Nnamdi Azikiwe University, Awka. The cube moulds were placed in curing tanks and taken out at 7days and taken to the test lab at Niger Cat Construction Company laboratories.

3. RESULTS

In order to capture the effects of the variables mentioned above on fresh and hardened concrete produced in the area of study, preliminary experiments were carried out as shown below.

3.1 Experimental Data used

Data for this study was obtained from Nigerian Meteorological Agency, Lagos. The annual temperature, relative humidity, rainfall and wind were obtained noting the maximum and minimum of these parameters listed above. These parameters were analyzed and the characteristics of the study area of Onitsha which represents Anambra State were used for the experiment.

With the ambient temperature of each test day measured, and relative humidity averaged from data for Onitsha based on the parameters obtained from the Nigerian Meteorological Agency, it becomes possible to carry out the experiment to see how these variables affect the results of the experiment.

3.2 Experimental Parameters

The experiment is to determine the slump and compressive strength of the fresh and hardened coarse concrete produced with the mix proportion of (1:2:4- 12 mm aggregate) with regards to the ambient atmospheric temperature prevalent. This experiment was repeated for three consecutive days in each case.

The slump test technique used in this study has been referred to as being simple, rugged, and an inexpensive field test to measure the fundamental rheological parameters of concrete [14,15]. They further allowed evidence that it has endured for nearly 90years of usage because of its simplicity and accuracy. The equipment for cube crushing was the universal testing machine.

3.2.1 Materials

Materials used for the experiment include the following:

Cement	: (Bua) Ordinary Portland cement BS12
Aggregates	: Coarse: (graded 12 mm)
Fine	: sharp sand
Water	: Drinkable water

3.3 Experimental Procedure

The test was carried out on a non-absorbent platform. The materials were weighed according to the ratio of 1:2:4-12 mm aggregate and these specifications were kept constant throughout the course of the experiment. Their equivalents are as follows;

Cement	- 1386 gm
Sharp Sand	- 2772 gm
Coarse Aggregate	- 5544.8 gm
Water	- 2000 mls

These quantities formed the basis on which the fresh concrete was produced and tested for the slump with temperature readings of the mix and ambient climatic conditions recorded before, during and after the mixture was made. The concrete cubes were made out of the mixture and placed when set in the curing tank.

3.4 Crushing of Cubes

The cubes were submerged in the curing tank for 12 hours and thereafter crushed after seven, fourteen, twenty-one and twenty-eight days.

3.5 Interpretation of Results

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed at true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. Very dry mixes, having a slump of 0-25 mm and are used in road construction. Low workability mixes having a slump of 10-40 mm are used for foundations with light reinforcement. Medium workability mixes of slump 50-90mm is for normal for reinforced concrete placed with vibration. The high workability concrete slump is greater than 100 mm.

3.6 Analysis of Result

The results of the experiments showed that climatic conditions have effect on the quality of concrete produced on construction sites. Hence the effects of temperature and relative humidity on the concrete are shown in the result of the experiment in tables 2-6. The tests conducted on concrete samples reveal that workability, curing, setting and compressive strength is affected by temperature and relative humidity.

The higher the temperature, the lower the quality and strength of the concrete. It shows that concrete cast between the hours 7 am-2 pm appears to be of better quality (workability) than the concrete produced from 2 pm to 4 pm which invariably show that concrete produced in the

Table 2. Test result for fresh concrete slump

Runs	Date	Time	Atmospheric temp 1°c1	Mix temp {°c}	Temp of water {°c)	Quantity of water {ml}	Slump {mm}
1	22/03/18	9.00	26.6	32	27	2000	45
2	>>	18.00	34	34.9	31.1	2000	82
3	>>	16.00	35	34	31.1	2000	90
4	23/03/18	9.00	27	31.9	27	2000	35
5	>>	18.00,	34.9	34.8	32.1	2000	90
6	>>	16.00	36	34.7	33	2000	94
7	26/03/18	9.00	30.1	31.4	31	2000	55
8	>>	18.00	33.8	34.1	30.5	2000	79
9	>>	16.00	35.5	34.7	31	2000	130

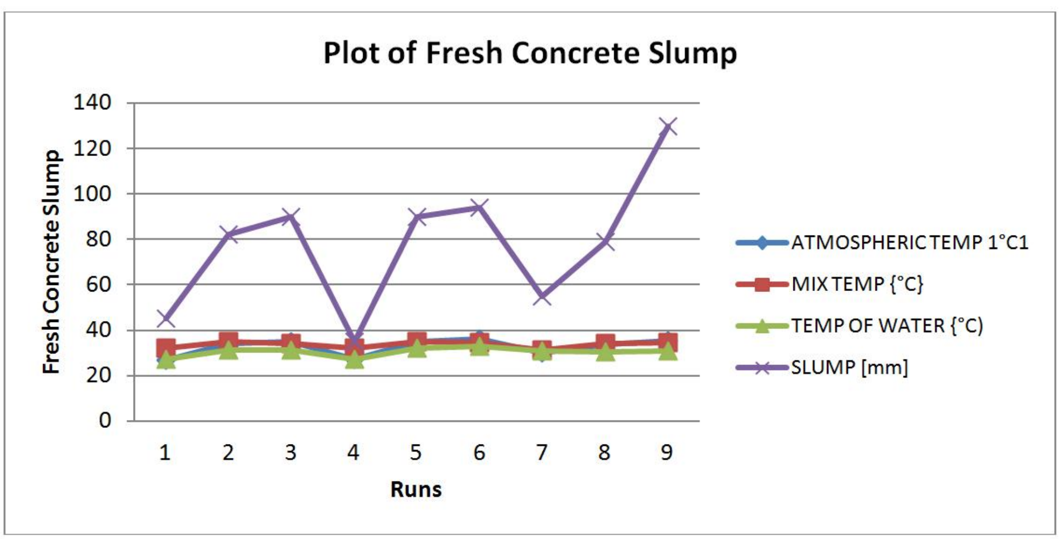

Fig. 1. Test result for fresh concrete slump

later afternoon are weaker. Relative humidity also exhibits some characteristics. The more humid the weather is, the less the quality of the concrete vis-a-viz. It will cost more to produce concrete of such quality by use of additive/admixture.

Table 3. Test result for crushed concrete cubes at seven days

Cube no.	Time of mixing	Date Cast	Age for testing [days]	Date tested	Weight of the cube	Density of the Cube kg/m^3	Crushing load [$kgms^{-2}$]	Crushing strength (n/mm^2)
1	9.00	22/03/18	7	29/03/18	7910	2. 34	340	15.2
2	18.00	D	7	29/03/18	7818	2. 25	318	14.1
3	16.00	>>	7	29/03/18	7436	2.14	280	18.4
1	9.00	23/03/18	7	30/03/18	7905	2.31	331	13.1
2	18.00	»	7	30/03/18	7301	2.18	260	11.6
3	16.00	»	7	30/03/18	7133	2.11	250	11.1
1	9.00	26/03/18	7	2/04/18	7919	2.35	365	16.2
2	18.00	»	7	2/04/18	7021	2.08	220	9.8
3	16.00	D	7	2/04/18	8110	2.40	310	13.8

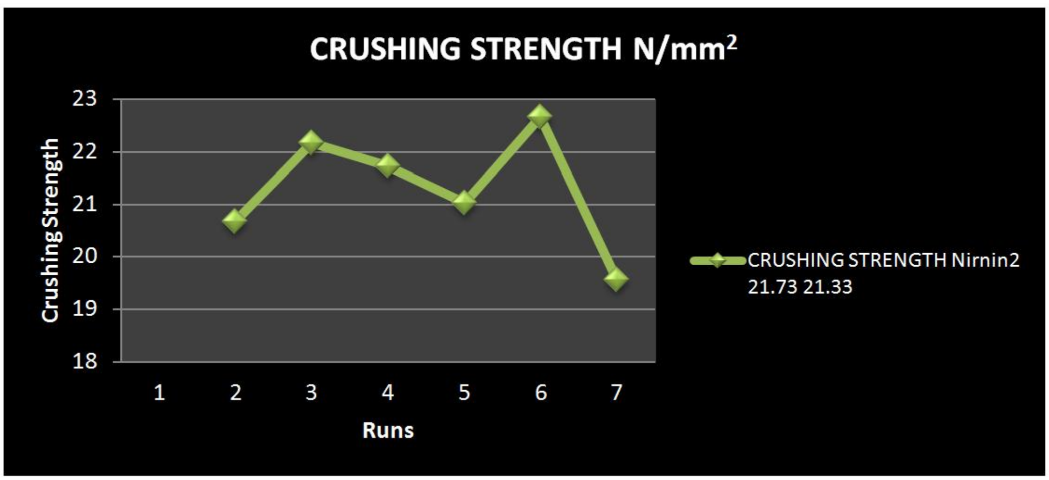

Fig. 2. Crushing strength (N/mm^2) result for crushed concrete cubes at seven days

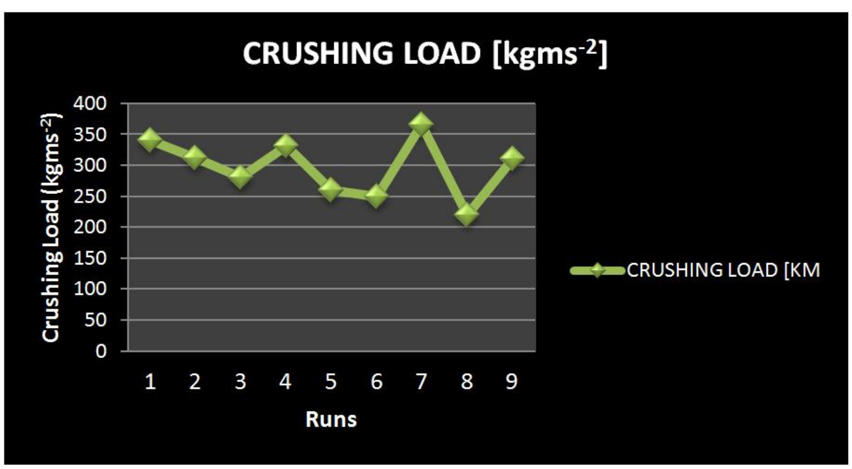

Fig. 3. Crushing load [$kgms^{-2}$] result for crushed concrete cubes at seven days

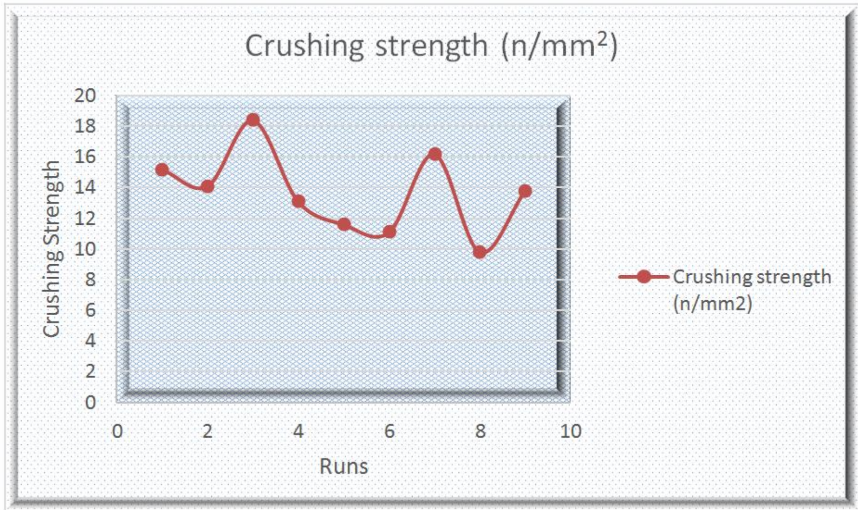

Fig. 4. Crushing strength [N/mm^2] result for crushed concrete cubes at seven days

Table 4. Test result for crushed concrete cubes at fourteen days

Cube no.	Time of mixing	Date cast	Age for testing [days]	Date-Tested	Crushing load [esn]	Crushing strength n/mm^2
1	9.00	22/03/18	14	4/04/18	452	20.09
2	18.00	>>	14	4/04/18	440	19.56
3	16.00	>>	14	4/04/18	425	18.89
1	9.00	23/03/18	14	5/04/18	415	18.44
2	18.00	>>	14	5/04/18	410	18.22
3	16.00		14	5/04/18	397	17.64
1	9.00	26/03/18	14	8/04/18	466	20.17
2	18.00		14	8/04/18	370	16.44
3	16.00	>>	14	8/04/18	417	18.53

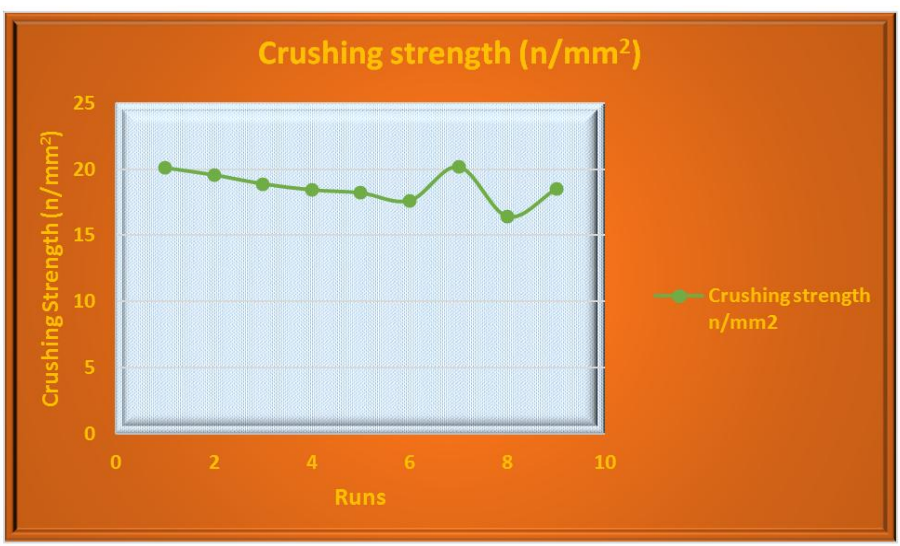

Fig. 5. Crushing strength [N/mm^2] result for crushed concrete cubes at fourteen days

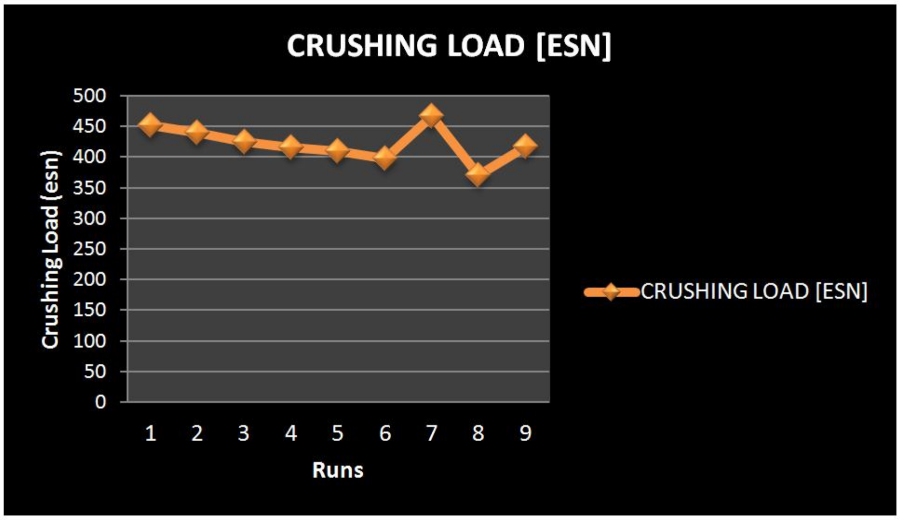

Fig. 6. Crushing load [ESN] result for crushed concrete cubes at fourteen days

Table 5. Test result for crushed concrete cubes at twenty one days

Cube no	Time of mixing	Date cast	Age for testing [days]	Date tested	Crushing Load [$kgms^{-2}$]	Crushing strength (N/mm^2)
1	9.00	22/03/18	2 1	9/04/18	490	21.73
2	18.00	»	21	9/04/18	480	21.33
3	16.00	»	21	9/04/18	465	20.67
1	9.00	23/03/18	21	10/04/18	499	22.18
2	18.00	»	21	10/04/18	490	21.73
3	16.00	»	21	10/04/18	473	21.02
1	9.00	26/03/18	21	13/04/18	510	22.67
2	18.00	»	21	13/04/18	440	19.56
3	16.00	»	21	13/04/18	470	20.39

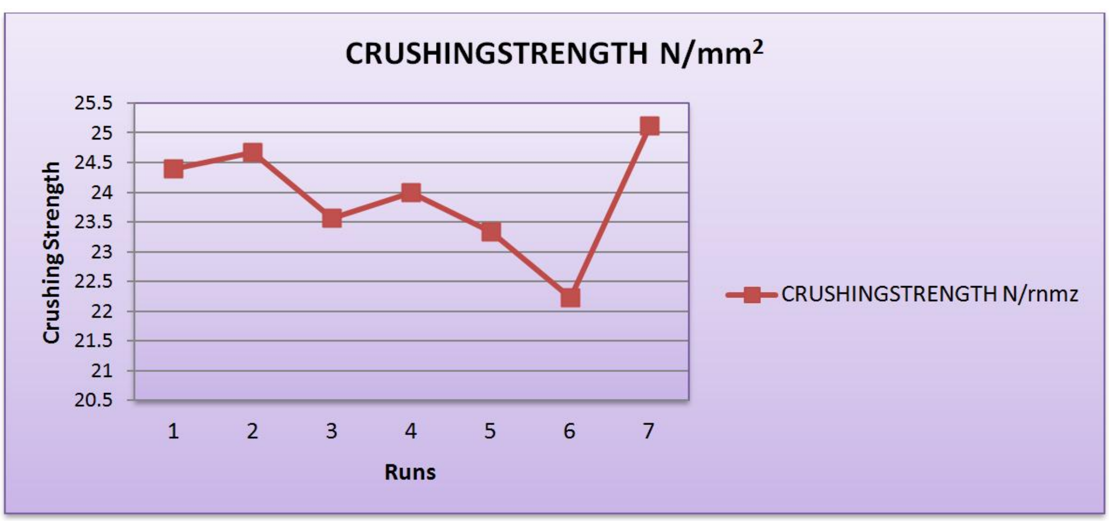

Fig. 7. Crushing strength [N/mm^2] result for crushed concrete cubes at twenty one days

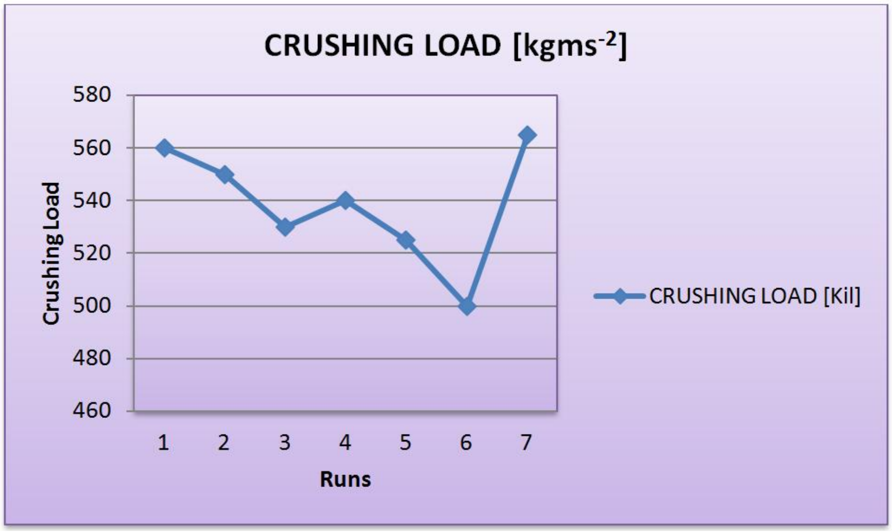

Fig. 8. Crushing load [kgms^{-2}] result for crushed concrete cubes at twenty one days

Table 6. Test result for crushed concrete cubes at twenty eight days

Cube no.	Time of mixing	Date cast	Age for testing [days]	Date tested	Crushing load [kgms^{-2}]	Crushing strength (n/mm^2)
1	9.00	22/03/18	2.8	16/04/18	560	24.39
2	18.00		2.8	16/04/18	55	24.67
	16.00	>>	28	16/04/18	530	23.56
1	9.00	23/03/18	28	17/04/18	540	24.00
2	18.00	>>	28	17/04/18	525,	23.33
	16.00	>>	28	17/04/18	500	22.22
	9.00	26/03/18	28	20/04/18	565	25.11
2	18.00		28	20/04/18	466	20.71
3	16.00		28	20/04/18	470	20.89

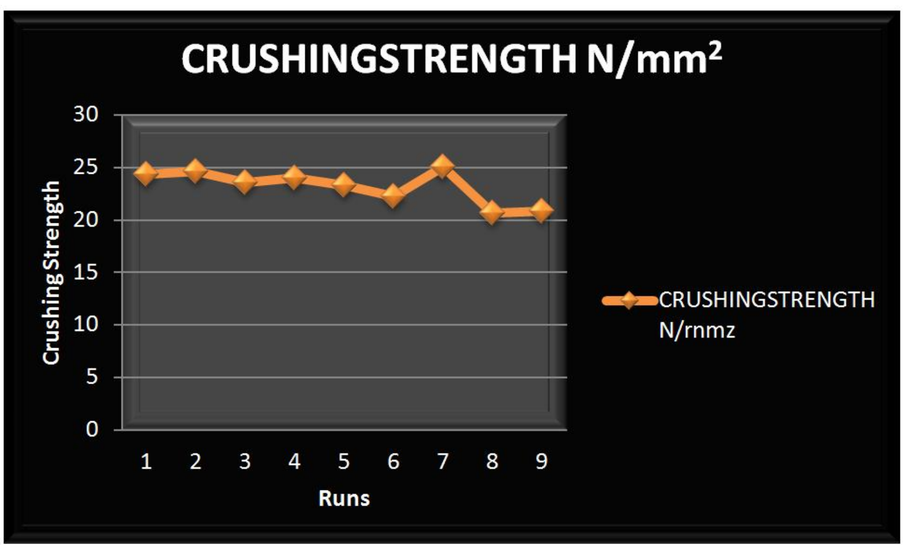

Fig. 9. Crushing strength [N/mm^2] result for crushed concrete cubes at twenty eight days

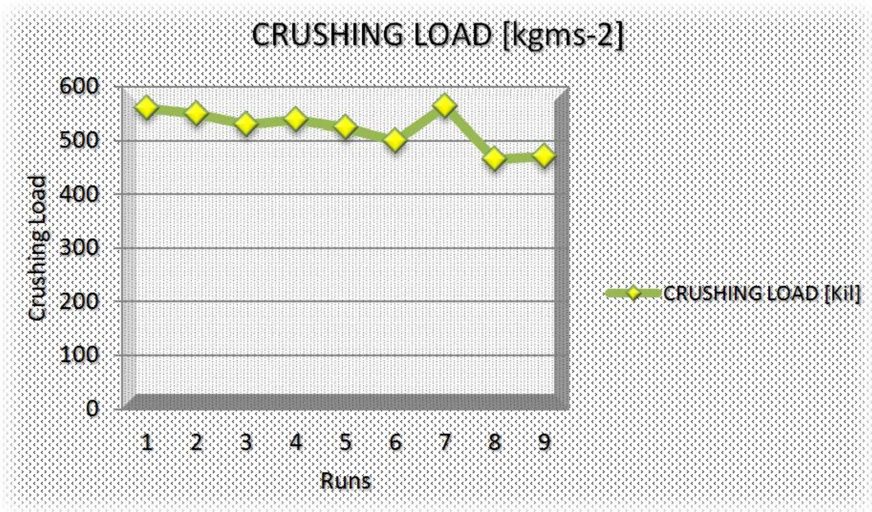

Fig. 10. Crushing load [kgms^{-2}] result for crushed concrete cubes at twenty eight days

This study, therefore, recommends that professionals and other stakeholders including educational institutions, in construction practice should be aware that temperature and relative humidity of any particular day affect the quality of the concrete produced.

4. CONCLUSION AND RECOMMENDA-TION

If is therefore pertinent to note that the quality of concrete produced during construction should be effectively monitored through regular quality control to eliminate those causes for poor quality work on the concrete production. The variables considered in this study are temperature and relative humidity. The climatic conditions parameters were obtained from Nigerian Meteorological Agency for a period of five years. The variables were found to affect the fresh hardened concrete produced before they are placed. From the results of the experiment conducted, it is observed that the concrete produced during the morning hours are stronger than those produced in the late afternoon as seen in tables 2 to 6 above.

This paper, therefore, recommends that professionals and other stakeholders in the construction practice should be aware that temperature and relative humidity of any particular day affects the quality of the fresh concrete produced. Professionals and stakeholders on construction sites should endeavour to produce their concrete between the hours of 7 am to 2 pm. Any other production outside this time will attract a higher cost of production because of the cost of additives added to maintain the same acceptable quality. Furthermore, professionals in practice are also advised to be sure of proper supervision during concrete production with respect to time of production. It will provide an insight for researchers who may want to delve into this area that has not been touched in this part of the world as earlier stated in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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