Effect of Climatic Conditions on the Quality of Fresh and Hardened Concrete in the South East Nigeria

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Abstract: *This study investigates the effect of Climatic conditions on fresh and hardened concrete produced in the South East, Nigeria. The variables considered in this study are temperature and relative humidity. The Climatic condition parameters were obtained from Nigerian Metrological Agency in Lagos, Nigeria for this study. The average yearly temperature ranged 26.39°C to 32.49°C was used as control for the experiment. Slump and strength tests were conducted on concrete samples and results revealed that workability and compressive strength of the concrete were affected by temperature and relative humidity. It was discovered that concrete produced in the morning hours (9am-12 noon) when the temperature and relative humidity are low, have better quality than those produced in the late afternoon (2-4pm) as depicted by the results of the tests on the tables. The study therefore, recommends that Professionals and other stakeholders in the construction practice should be aware that temperature and relative humidity have effects on the quality of concrete during production on site. This study further establishes that the appropriate time to produce high quality concrete is between the hours of 9am-2pm and any other time will require the use of admixture to produce concrete of same quality although of a higher cost thereby affecting the cost of the project. Furthermore, professionals in practice are advised to ensure effective supervision during concrete production.*

Keywords: *Climatic conditions, Quality, Fresh and Hardened Concrete and Production.*

1. Introduction

Climate is seen as prevailing 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 properties of the materials to such an extent that they do or do not meet service requirements. These materials may encounter low or elevated temperatures, high or low humidity levels, acidic or alkaline precipitation, varying wind conditions including sand storms, hurricanes, tornadoes etc. The resultant effect 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 Okereke (2003). 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 by Heiserman (2007) as possessing unique characteristics of workability, durability and strength. 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 discuss 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. Climatic conditions equally posse quality issues during concrete production. American Concrete Institute (ACI, 305) itemizes hot weather concreting problem under the following headings;

- Potential problems for concrete in the freshly mixed states
- Potential problems for concrete in the hardened state, and
- Potential problems related to other factors

Similarly American Concrete Institute (ACI, 306) defines cold weather concreting problems as;

- Lack of required strength
- Improper curing procedures
- Rapid temperature changes, and Improper protection of the structure consistent with its serviceability.

These climatic conditions and their effect on the quality of concrete achieved during production are also well documented. Therefore, the principal concrete properties of durability, strength and economy must be attained in other to achieve good quality concrete irrespective of weather conditions. The varying effects of climatic conditions are of great concern to the practitioners in the construction industry. More so, problems, associated with achieving good quality concrete necessitate the need to understand prevailing climatic conditions in order to attain the concrete specification required during production. Climatic conditions in general are said to refer to the atmospheric conditions of a particular location over a long period of time (from one month to many millions of years, but generally 30years) Britannica Concise Encyclopedia, (2012). The US History Encyclopedia (2012) assesses that the climate of an area as the aggregate of weather conditions over time, based on data constructed from monthly, seasonal, and annual averages of weather elements, such as temperature and precipitation combined with statements about the frequency of extreme events such as droughts or tornadoes. From the foregoing, the area of discuss being the south east of Nigeria, has peculiar climatic conditions and a recent upsurge of construction activities which warrants an exploratory investigation as to the effect(s) of climatic conditions on concrete production.

Furthermore, given the fact that these effects have been noticed elsewhere, there is need to address this problem by providing a clear theoretical understanding of the basic requirements of concrete production in ideal climatic conditions and then, analyzing the prevalent climatic conditions to form an understanding of the requirements within the study area.

2. Justification

The effect of climatic conditions on the production of concrete is an area of study that has not received the required attention from researchers and construction practitioners in the south east Nigeria. There is therefore great need for an in-depth investigation by researchers to provide an objective analysis. of climatic condition and its effects on fresh and hardened concrete produced on projects sites in the South East Nigeria vis-a-vis the quality of concrete work. This then calls for a detailed experimental work in controlled conditions reflecting those climatic conditions prevalent in the area of study, including ambient temperature, relative humidity, wind, rainfall and harmattan.

Generally, as building projects get larger and more complex, clients are also increasingly demanding higher quality standards from the practitioners in the industry. South East Nigeria is a zone with active construction sites where most of the buildings are constructed without proper steps and care that are necessary in the production of fresh concrete. Consequently, the quality of concrete is affected. South East is a region within the geographical/climatic zone described as hot humid zone with an average annual temperature of 28°C--32°C and relative humidity of 50-70% (NIMEA, 2005; Okereke, 2003). From the literature review there have been relatively little or no detailed studies in this area. This provides the basis or rationale for the study and the findings will therefore increase the knowledge base of professionals and awareness of the effect of climatic conditions on fresh and hardened concrete produced in the South East Nigeria with respect to the quality and its control on project sites. Since the knowledge in this area of study is not yet known to the practitioners, the findings will provide the professionals, contractors, educational institutions with the information/skill needed in the field and thereby contribute to knowledge in this area of study. This research will try to discuss the range of problems that could be experienced during concrete mixing and placement in weather conditions experienced in the south east Nigeria. More background on the development of thermal or temperature effect (stresses) and other factors like precipitation, Relative humidity and wind are provided. Current and proposed techniques to mitigate the detrimental effects of these climatic conditions on fresh concrete are discussed.

3. Review of Literature

The work of some researchers regarding the subject matter is hereby presented.

3.1 Climate Characteristics of South East Nigeria

The focus of this study is on South East Geo-Political zone of Nigeria. According to Igbokwe (2007), the region is located between latitudes 04° 30'N and 07° 30'N and longitudes 06° 45'E and 08° 45'E. The study area comprises the geographical location of the following states: Abia, Anambra, Ebonyi, Enugu, and Imo. The region is bounded in the north-west by Kogi and Benue states, in the north east by Cross River State, in the South by Akwa Ibom and Rivers states and in the west by Delta state. The area is well drained. The notable rivers and streams that are found in the zone include the Niger, Imo, Nike Lake, Anambra, Idemili, Njaba, Oguta Lake, Nkisi, Ezu, Oji etc. These states have fairly good sub-soil strata except Ebonyi which shows clay stratification. Enugu State exhibits a coal sub stratum but with gravelly laterite to top soil up to a depth of about 5 meters. Anambra, Abia and Imo states exhibit quality sub-base foundation soil for buildings and other construction work. The study area lies within the tropical region with early rainfall usually in January/February 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. The temperature pattern has a mean daily and annual temperature of 28°C and 27°C respectively (Igbokwe, 2007). The nature of climatic conditions variation associated with the weather in the study area is shown below in Table 1.

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

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 (Okonkwo and Mbajiogu, 2010). 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 freqeuricy (IDF) relationship, has been a major focus of both theoretical and applied hydrology (Andreas and Venziano, 2006). (Dupont et. al, 2000) defined rainfall IDF relationships as graphical representations of the amount of water that falls within a given period of time. 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.

Within the study area, temperature and humidity are high year-round (Edeh, Eboh and Mbam, 2011). 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. (Okonkwo and Mbajiogu, 2010).

4. Effects of the Climatic Conditions (Temperature, Rainfall, Relative Humidity and Wind) on Fresh Concrete

The weather condition in the South Eastern Nigeria has been explained in the weather condition trend in the region. From this, one sees the effect of climatic conditions on fresh and hardened concrete. These effects are in the area of temperature, rainfall, relative 4midity and wind. The effects of these climatic conditions are;

4.1 Thermal Temperature

Variations in temperature are often divided into two classifications-elevated temperatures which is above room temperature and low temperatures-below room temperature. According to Merritt (1984) this can be misleading because critical temperatures for the material itself may be high or low compared with room temperature. The researcher further stated that the lower limit of interest for all materials is absolute zero while the upper limit is the melting point for ceramics and metals, or melting or disintegration points for polymers and woods. The author opines that other critical temperatures include those for recrystallization in metals, softening and flow in thermosets, glass transition in thermoplastic, ductile brittle transitions and fictive temperature in glass. These temperatures mark the dividing lines between ranges in which materials behave in certain characteristics ways Merritt (1984), believes that the immediate effect of thermal changes on materials is reflected in their mechanical properties, such as yield strength, viscous flow, and ultimate strength. For most materials there is a general down ward trend of both yield and ultimate strength with increasing temperature. Sometimes, however, behavior irregularities in such materials are caused by structural changes (e.g. polymorphic transformations). Lower temperature behavior is usually defined on the basis of transition from ductile to brittle behavior. This phenomenon is particularly important in body-centered-cubic metals which show well defined transition temperatures. Porous materials exhibit a special low-temperature effect: freezing and thawing concrete for example, almost always contains water in its pores. Below 0°c (32°F), the water is transformed to ice, which has a larger volume. The resulting swelling causes cracking. Thus, repeated thawing and freezing have a wakening effect on concrete. Brick is another similar example (Merritt 1984, Okereke 2003). Schindler and McClough (2002) assert that relevant temperatures with reference to hot climates cause rapid setting. They believe that the higher the curing temperature is, the faster are the reactions between cement and water, and consequently the shorter becomes the setting time. The heat of hydration increases rapidly above curing temperatures of around 25 to 30°`. Schindler (2002), Merritt (1984) and Okereke (2003) shared the view that the compound which forms the major source of this temperature variation in concrete work is from tri-calcium silicate C_3S which contributes about 54% of the cement particle composition Gebhardt (1995). Concrete mixture proportions currently used in construction work may contain mineral and/or chemical admixtures, which could significantly change the rate of hydration and heat development. Komonen and Penthala (1997) in their experimental results have shown that a change in initial mixture temperature significantly affects the rate of heat development. The higher the temperature within the freshly mixed concrete, the higher and more rapid the rate of hydration. Thus, their conclusion is that "mixing temperature was the most significant variable considered in the experiment." The higher the mixing temperature the earlier the heat gain takes place and the faster the mix setting time". Concrete mixed, placed and cured at elevated temperature normally develop higher early strengths than concrete produced and cured at lower temperatures, but strengths are generally lower at 28 days and later ages (Emborg 1989, Nevitle 1996, and USBR 1975). It has also been shown from the studies carried out by many authors (researchers) that high curing temperatures will lead to a reduced later-age concrete strength as compared to sample cured at lower temperatures (Nevit 1996, and USBR 1975). Verbeck and Helmuth (1968) present an explanation for the reduced long-term strengths for concrete cured at high temperatures. They suggested that a higher initial temperature results in more than a proportional increase in the initial rate of hydration. Therefore, during the early stage of curing, when there is rapid strength development, the strength of concrete cured at the high temperature is greater than that of concrete cured at lower temperature. However, with rapid hydration, 'hydration products do not have time to become uniformly distributed within the pores of the hardening paste. In addition, "shells" made up of low permeability hydration products build up around cement grains. They believe that non-uniform distribution of hydration products leads to more large pores, which reduce strength, and the shell impedes hydration of the unreacted portion of the grains at later ages. Schindler and McCullough (2002) share the view that irrespective of the cause of the strength loss associated with concrete placed at high temperatures; this strength loss will directly affect the quality of concrete in use. Concrete used in heavy construction are usually designed in such way as to take care of fatigue failures, by ensuring that enough depth is provided for the concrete member to keep the stress to strength ratio to an acceptable level. When the long-term strength of the concrete is reduced, the capacity of the structure to withstand the intended fatigue life is reduced and the performance of the concrete is reduced.

4.2 Corrosion and Oxidation:

Okereke, (2003) defines corrosion as the systematic destruction of a material by chemical attack resulting from its environment. He further opines that for metals, corrosion involves gradual conversion into more stable state such as oxides, sulphate or carbonates. With oxygen, a metallic oxide is formed at normal temperature even in the absence of moisture. In high temperatures however, metals can combine with other gases to form chlorides, sulphides or carbonates. The presence of oxygen in humid environment coupled with high temperature is conducive for the growth and propagation of corrosion in metals. Merritt (1984) shared the view that corrosion is usually limited to metals and it involves some kind of chemical reaction. In more general terms, corrosion is the destruction of a metal by chemical or electro chemical reaction with its environment. The researcher also suggested other similar forms of degradation of materials; solvents attack, organic materials, sodium hydroxide dissolves glass, plastic may swell or crack, wood may split or decay, and Portland cement may leach away. With the above definitions corrosion could be broadened as the deterioration and loss of material due to chemical attack. Merritt (1984) opines that the simplest corrosion is by means of chemical solution; where construction material is dissolved by a strong solvent (for example when a rubber hose through which gasoline flows is in contact with hydrocarbon solvent). Wet corrosion occurs by mechanisms essentially electrochemical in nature. This process requires that the liquid in contact with the metallic mineral be an electrolyte. Also there exists a difference of potential either between two dissimilar metals or between different areas on the surface of a metal. Many variables modify the course and extent of the electrochemical reactions, but it is usually possible to explain the various forms of corrosion by referring to basic electrochemical mechanisms (Fontana et al, Merritt 1984, and Okereke 2003).

4.3 Concrete Deterioration:

Concrete deterioration is generally attributable as part of chemical reactions between alkali in the cement and mineral constituents of the concrete aggregates. Deterioration of concrete also results from contact with various chemical agents, which attack it in one of three forms:

- Corrosion resulting from the formation of soluble products that are removed by leaching.
- Chemical reactions producing products that disrupt the concrete because their volume is greater than that of the cement paste from which they were formed; and
- Surface deterioration by the crystallization of salts in the pores of the concrete under alternate wetting and drying.

These salts create pressure that can cause internal disruption (Okereke

2003, Greene, N.D. et al, Merritt 1984 and Uhlig 1984).

4.4 Corrosion Control and Prevention:

Proper selection of materials and sound engineering design are the best means of controlling and preventing corrosion. Merit in his contribution suggests that:

- Avoiding the use of dissimilar metals in contact where galvanic corrosion may result and also alloying can be used to improve chemical resistance.
- Modifying the environment may also control corrosion. Such techniques as dehumidification and purification of the atmosphere or the addition of alkalis to neutralize the acidic character of a corrosive environment are typical of the approach. Inhibitors that effectively decrease the corrosion rate when added in small amounts to a corrosive environment may be used to prevent or control the anodic and cathodic reactions in electro chemical cells.
- Application of protective coatings also furthers corrosion prevention and control. Three types of coatings are often employed: mechanical protection, separating the electrode from electrolyte (paints, grease, and fired enamels): galvanic protection by being anodic to the base metal (zinc coating on galvanized iron) Merrit and Uhlig (1984).

4.5 Climatic Influences in Concrete Production:

Cement concrete is the most widely used construction material throughout the world and has gained a unique place in the construction industry. Workability, setting time, rate of heat of hydration, rate of strength development, ultimate strength, durability and impermeability are among the most important characteristics of fresh and hardened concrete (Okereke, 2003). He opines that the desired properties of fresh and hardened concrete can often be conventionally achieved through intelligent selection of the basic concrete making materials, proper proportioning and mixing of ingredients, placing, compacting, and curing. Whan and Ullah (2004), in their contribution believe that there may be many instances where some special properties of concrete such as extended reduced setting times, lower rate of heat of hydration, early strength gain, increased resistance to alkali-aggregate reactions etc. are needed. Sometimes it is more practical and economical to achieve such desired properties in concrete by adding one or more extra materials (such as mineral admixtures) to the basic concrete making materials during the process of concrete manufacturing. Okereke, (2003) 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. Rapid evaporation of water from the concrete surface causes it to set earlier and no time is left available for concreting operations.

4.6 Precipitation, Wind and Humidity:

Weather conditions at a job site-hot or cold, windy or calm, dry or humid may be vastly different from the optimum conditions assumed at the time a concrete mix is specified, 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 Mcpharlm (2012). Precipitation as defined by Encarta dictionaries (2009) 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. Cemex (2012) attests that rainfall during concrete placement presents a challenge to good quality concrete. They stipulate that the potential outcome could be a weakened non-durable concrete surface which may be visible immediately or become aperitif with time. This is as a result of concrete not able to allow its constituent water evaporates from the slab surface. This allows the slab surface to have a high water/cement ratio in the near surface of the concrete reducing its strength and therefore its durability. After finishing if the immature concrete surfaces have not protected from rain some of the cement paste may be washed out of the concrete, leaving a weakened surfaces and the possibility of related problems in the future. This may include dusting of the surface; an unsealed surface that will allow far more water to be absorbed. Damage to the concrete surface may be readily apparent, however, if the surface strength is only slightly affected, the long-term durability of the concrete may be reduced as may be indicated by surface deterioration in the form of crazing, scaling or erosion and a reduced ability to resist cracking due to freeze-thaw cycle. The most common consequences are normally surface scaling, resulting in a flaky layered concrete surface which may not become visible until the concrete slab surface is used this leads to the concrete breaking or crumbling. In general, rainfall during placement of concrete can present challenges in achieving a quality concrete. Potential outcomes range from no damage to a weakened non-durable surface, which may be visible immediately or may only become apparent with time.

5. Effects of Climatic Conditions on Concrete and Mitigating Techniques

From the earlier definition of climatic conditions as contained, in the background of the study, climatic condition is known to have variation in temperature, precipitation, wind and humidity. The mitigating technique required depends on the nature of the climatic weather. These climatic weather conditions will be considered under the following;

- Hot and Cold weather.
- Rain, Wind and Humidity.

Hot weather: Hot weather creates special challenges for pre-casters and technically, the problem they have to overcome when placing concrete in hot weather than in the cooler seasons.

This section will provide a general overview of current construction practices to mitigate the detrimental effects of different climatic conditions. To produce quality concrete in construction sites, a conceptual method to minimize the effects of climatic conditions on fresh concrete was discussed. As previously mentioned, the effects of climatic conditions on concrete production are classified under various conditions.

5.1 Hot-Weather Concreting

For Hot-weather concreting, the control of the prevailing temperature becomes very important. AS 1379 requires that concrete temperatures at the point of mixing and delivery to be within the range 5°C to 35°C for high ambient temperatures, precautions need to be taken by the producer to ensure that the concrete temperature at the point of delivery is within the allowable range. There are a number of options to control the temperature of concrete, including adjusting the temperature of the ingredients and/or cooling of the concrete mix. Australian Standard {AS 1379}, states that: the sensitivity of the temperature of a normal concrete mixture to that of its components can be demonstrated by the following formula.

$T = 0.1T, + 0.6Ta + 0.3Tw$

Where; T = Concrete temperature; Tc = Temperature of cement; T, = Temperature of the aggregate

Tw= Temperature of the water.

Source: Cement Concrete and Aggregates Australia (2004)

Aggregates make up the bulk of the concrete, and also have the highest heat capacity thus, have the greatest effect on the temperature of the freshly mixed concrete. Unfortunately, the temperature of the aggregates is also the most difficult to control. Some benefit can be gained from shading stockpiles of aggregates from the sun and/or keeping them moist with sprinklers. Storing them in bins (painted white) will also help/assist. The mix water offers the most potential for temperature reduction, particularly by adding crushed ice to it, as the latent heat of the ice is considerably higher than that of water. The temperature of the cement does not usually contribute significantly to the temperature of freshly mixed concrete because of its low specific heat and relatively small mass in the mix. Liquid nitrogen, injected into the concrete while mixing, may also be utilized. Latent thermal energy on vaporization to gas cools the concretes dramatically without any known deleterious effect. It should be noted that this process is only economical on major projects involving construction of large concrete elements. Another method with which to minimize the effect of hot weather is the use of Admixtures. Here various types of chemical admixture could be beneficial in hot conditions. Water reducers (plasticizers) can be used to reduce the water content or to aid the workability. Other factors that will have to be taken care of to avoid any adverse effect are;

- Cement type
- Cement content.

In summary concrete placed during the hot months of the year is subjected to conditions that can adversely affect the properties and serviceability of the harden concrete.

Some of the conditions that may be experienced are:

- Increased water demand
- Increased rate of slump loss
- Increased rate of setting.
- Increased tendency of plastic shrinkage cracking and drying shrinkage cracking.
- Lower ultimate strengths
- Decreased durability
- Undesirable surface appearance.

And again, American Concrete Institute (ACI) {1999} committee 305 defines Hot weather as any combination of the following conditions that tend to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise resulting in detrimental results.

- High ambient temperature
- High concrete temperature
- Low relative humidity
- Wind velocity.

5.2 Cold weather (Harmattan)

Weather conditions at a job site-hot or cold, windy or calm, dry or humid, may be vastly different-from the optimum conditions assumed at the time a concrete mix is specified, designed, or selected. Weather can adversely affect the properties and the serviceability of concrete unless certain practices are followed by the contractors and concrete producers (Mcpharlin 2012). Cold weather is defined by (American Concrete Institute, 1999) committee 306 as a period when for more than 3 successive days, the following conditions exist:

- The average daily air temperature is less than 40°f or 4°C and
- The air temperature is not greater than 50°f or 10°C for not more than one half of any 24 hour period.

The average daily air temperature is the average of the highest and lowest temperatures occurring between the periods from midnight to midnight. Normal concrete practices can resume once the ambient temperature is above 50°f to 10°C for more than half the day. During cold weather-Harmattan-cold and dry and windy, preparations should be made to protect the concrete; enclosures, windbreaks, portable heaters, insulated forms and blankets should be ready to maintain the concrete temperature. Concrete gains very little strength at low temperatures. Freshly mixed concrete needs to be protected against the effects of Harmattan until a 'compressive strength of 710N/mm^2 or 500psi is attained. At normal temperatures this occurs in the first 24 hours. Up to 50% strength loss can occur the concrete temperature freezes within the first hours after placement or before the 710N/mm2 is attained. Temperature directly affects the rate at which hydration of the cement occurs. Low - concrete temperatures will retard the initial setting and strength gain. According to (Mcpharlin, 2012) cold concreting should be kept as close as possible to 10°C for at least 3 days. To shorten this time the concrete mix could be adjusted with the use of an accelerating admixture, the addition of an extra sack of cement, or the use of type III cement. These practices will increase the amount of heat generated in the mix to offset the effects of cold weather. According to ACI (American Concrete Institute (1999) 306 committee and Mcpharlin 2012), the following measures can be employed depending on the severity of the expected weather conditions (Harmattan for the area of study). Insulate the concrete to reduce heat loss. The heat generated from the internal chemical reactions will help to maintain favorable conditions for the development of early, strength. During cold weather the protection offered by forms, except those made of steel, is often of great significance. Forms will insulate the concrete and allow for favorable curing temperatures. Provide an additional heat source to maintain the concrete temperature. Combustion heating units must be equipped with heat exchangers that permit venting out the products of combustion (particularly carbon dioxide, Co2). Exposure of fresh concrete to Co2 can result in poor durability of the wearing surface and deterioration of the concrete. Modify the concrete mixture. Add accelerators, extra cement or use type Ill cement. Calcium chloride should be avoided in any structural concrete containing steel reinforcement. Calcium chloride will cause corrosion of the steel and lead to deterioration of the structure. 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.

6. 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 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.

7. Test Location

The slump tests were conducted in situ within the civil engineering laboratory of

Nnamdi Azikiwe University, Awka. The cube molds were placed in curing tanks and taken out at 7days and taken to the test lab at Niger Cat Construction Company laboratories.

8. 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.

9. 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.

10. 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- 12mm 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 for this study has been referred to as being simple, rugged, and an inexpensive field test to measure the fundamental rheological parameters of concrete (Koehler and Fowler, 2003). 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.

Materials:
Materials used for the experiment includes the following:
Cement: (Bua) Ordinary Portland Cement BS12
Aggregates: Coarse: (graded 12mm)
Fine: Sharp Sand
Water: Drinkable water

11. Experimental Procedure

The test was carried out on a non-absorbent platform. The materials were weighed according to the ratio of 1:2:4-12mm aggregate and these specifications were kept constant throughout the course of the experiment. Their equivalents are as follows;
Cement - 1386gm;
Sharp Sand - 2772gm;
Coarse Aggregate - 5544.8gm;
Water - 2000mls
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.

12. 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.

13. 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 to 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 slump of 0-25 mm and are used in road construction. Low workability mixes having slump of 10-40mm are used for foundations with light reinforcement. Medium workability mixes of slump 50-90mm is for normal for reinforced concrete placed with vibration. High workability concrete slump is greater than 100mm.

Table 2: Test Result for Fresh Concrete Slump

Exp. No.	Date	Time	Atmospheric Temp (°C)	Mix Temp (°C)	Temp Of Water (°C)	Quantity Of Water (ml)	Slump (mm)	Average Slump (mm)
1	22/03/12	9.00	26.6	32	27	2000	45	
2	>>	12.00	34	34.9	31.1	2000	82	
3	>>	16.00	35	34	31.1	2000	90	
4	23/03/12	9.00	27	31.9	27	2000	35	
5	>>	12.00,	34.9	34.8	32.1	2000	90	
6	>>	16.00	36	34.7	33	2000	94	
7	26/03/12	9.00	30.1	31.4	31	2000	55	
8	>>	12.00	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

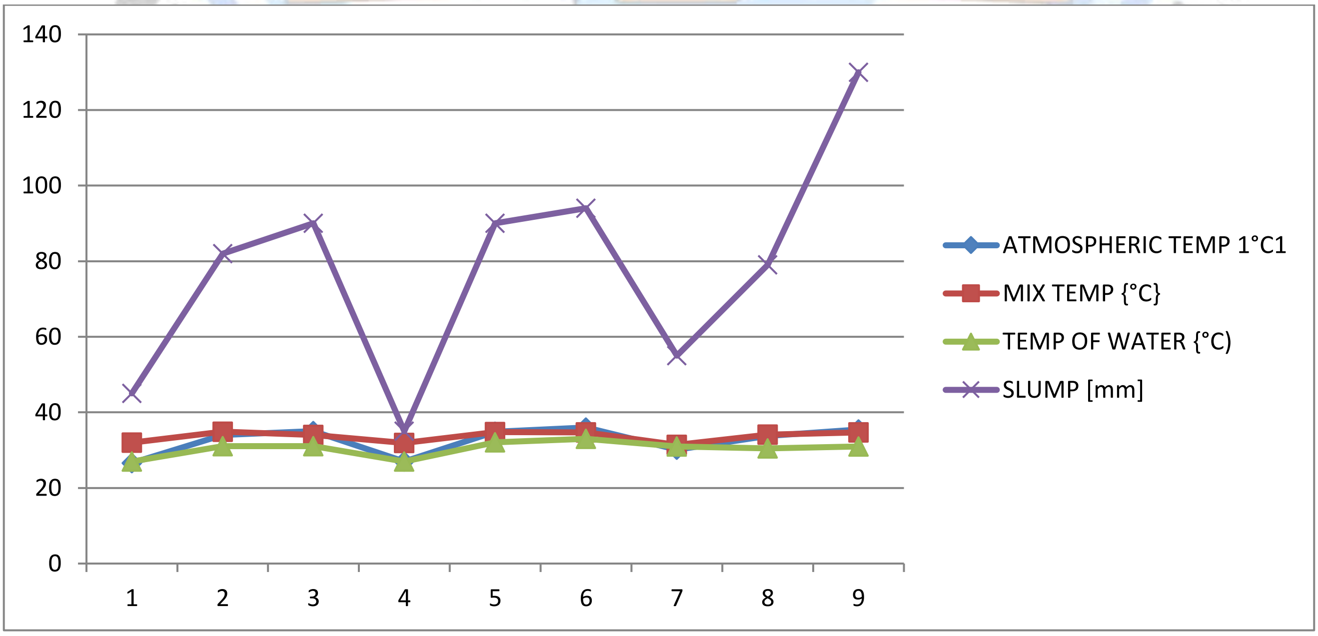


Table 3: Test Result For Crushed Concrete Cubes At Seven Days

Cube No.	Time Of Mixing	Date Cast	Age For Testing [Days]	Date Tested	Weight Of The Cube	Density Of the Cube Kg/M³	Crushing Load [Km	Crushing Strength N/Mm²	Remarks/ Observation
1	9.00	22/03/1	7	29/03/12	7910	2. 34	340	15.2	
2	12.00	D	7	29/03/12	7812	2. 25	312	14.1	
3	16.00	>>	7	29/03/12	7436	2.14	280	12.4	
1	9.00	23/03/1	7	30/03/12	7905	2.31	331	13.1	
2	12.00	»	7	30/03/12	7301	2.12	260	11.6	
3	16.00	»	7	'	7133	2.11	250	11.1	
1	9.00	26/03/1	7	2/04/12	7919	2.35	365	16.2	
2	12.00	»	7	2/04/12	7021	2.08	220	9.8	
3	16.00	D	7	2/04/12	8110	2.40	.	13.8	

Fig 2: Crushing Strength (N/mm²) Result for Crushed Concrete Cubes at Seven Days

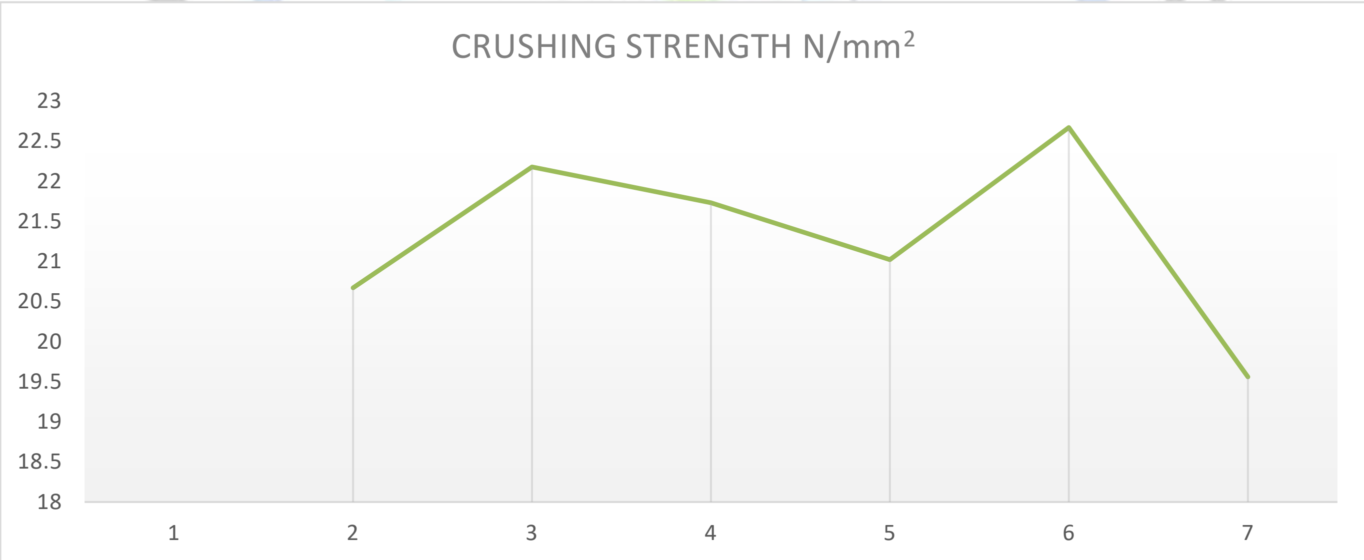


Fig 3: Crushing Load [I<N] Result for Crushed Concrete Cubes at Seven Days

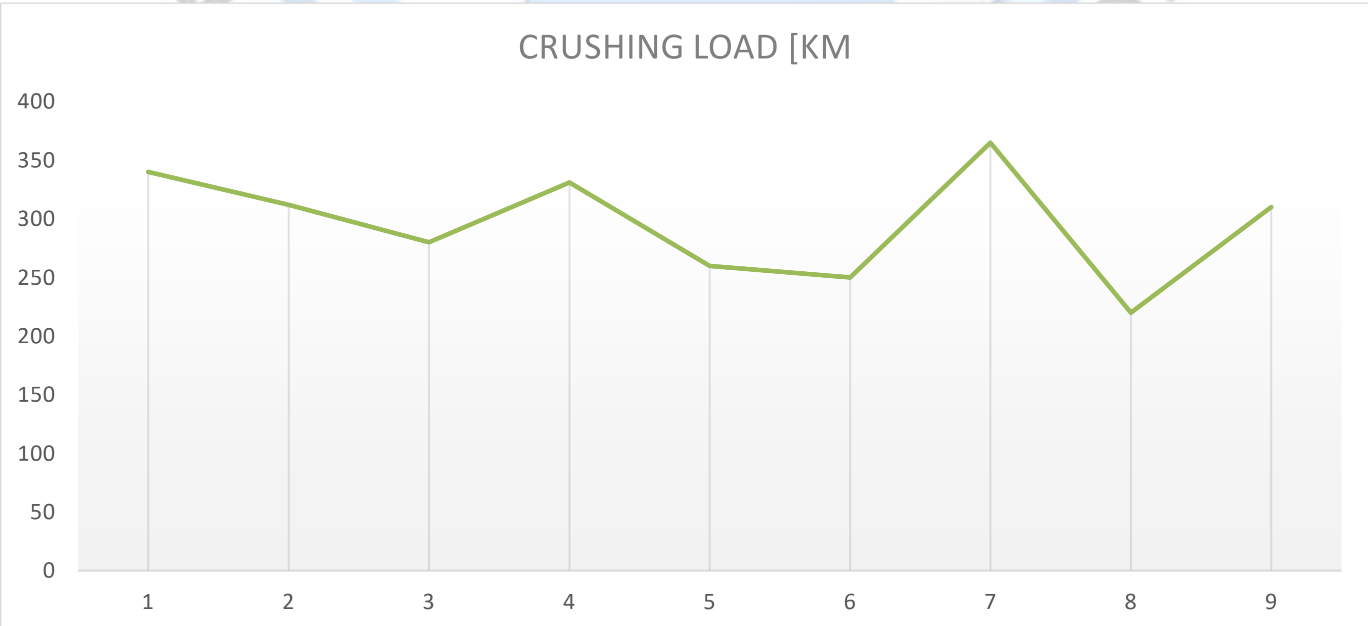


Fig 4: Crushing Load [kil] Result for Crushed Concrete Cubes at Seven Days

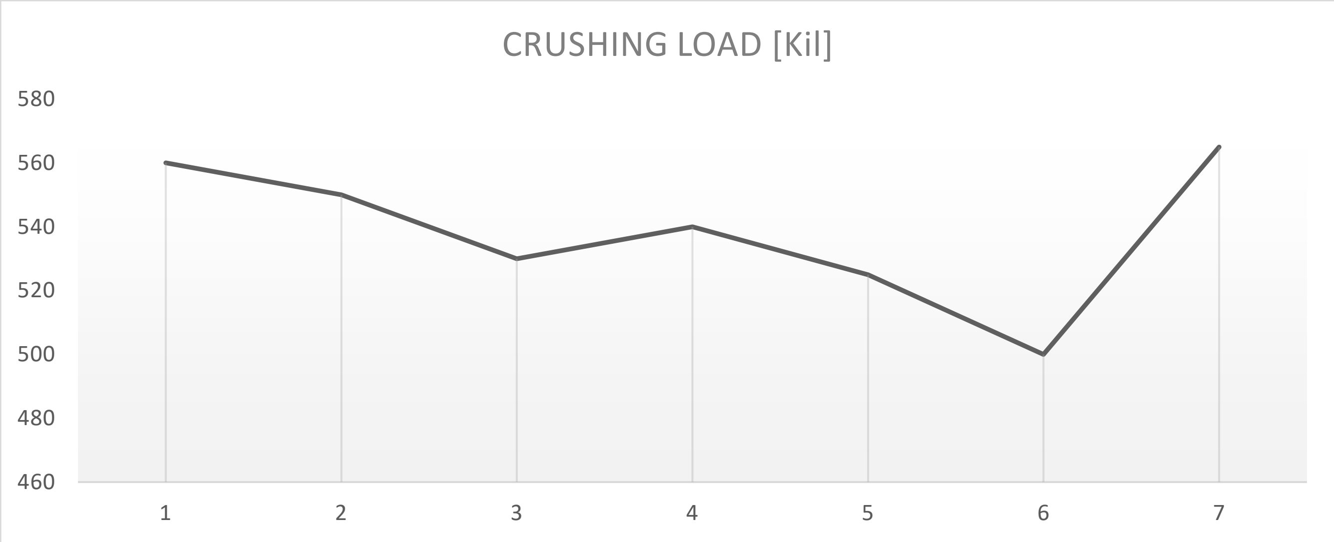


Fig 5: Crushing Strength [N/rnmz] Result for Crushed Concrete Cubes at Seven Days

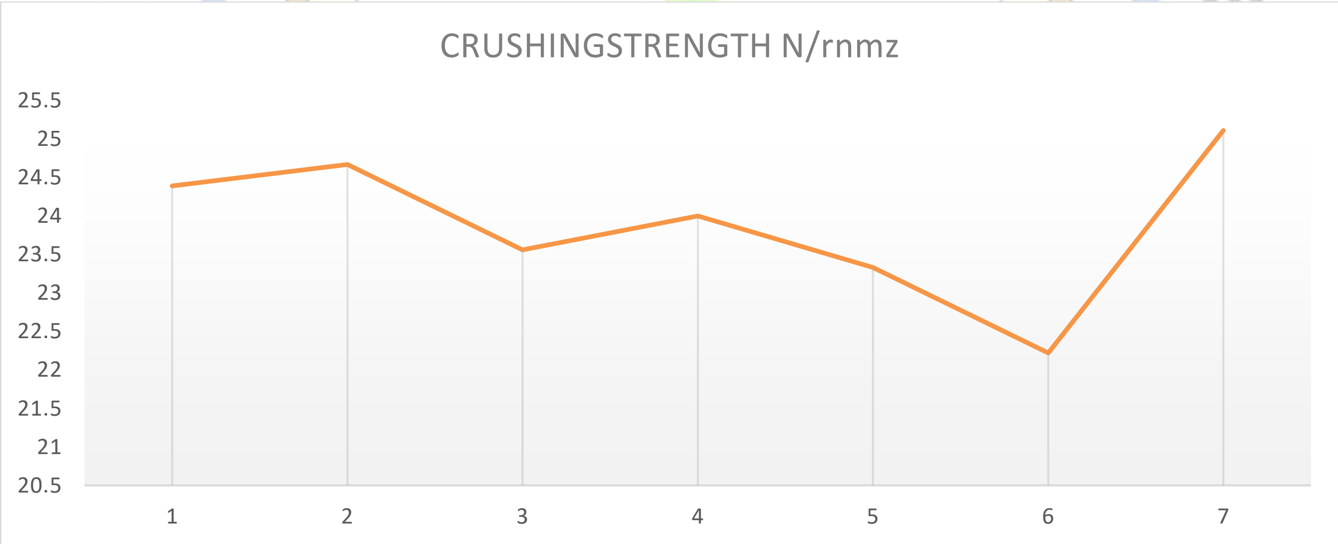


Table 4: Test Result for Crushed Concrete Cubes At Fourteen Days

Cube No.	Time Of Mixing	Date Cast	Age For Testing [Days]	Date-Tested	Crushing Load [kg]	Crushing Strength (N/mm²)	Remarks/ Observation
1	9.00	22/03/12	14	4/04/12	452	20.09	
2	12.00	>>	14	4/04/12	440	19.56	
	16.00	>>	14	4/04/12	425	18.89	
1	9.00	23/03/12	14	5/04/12	415	18.44	
2	12.00	>>	14	5/04/12	410	18.22	
	16.00		14	5/04/12	397	17.64	
1	9.00	26/03/12	14	8/04/12	466	20.17	
	12.00		14	8/04/12	370	16.44	
3	16.00	>>	14	8/04/12	417	18.53	

Fig 6:Crushing Strength [N/mr-n2] Result for Crushed Concrete Cubes at Fourteen Days

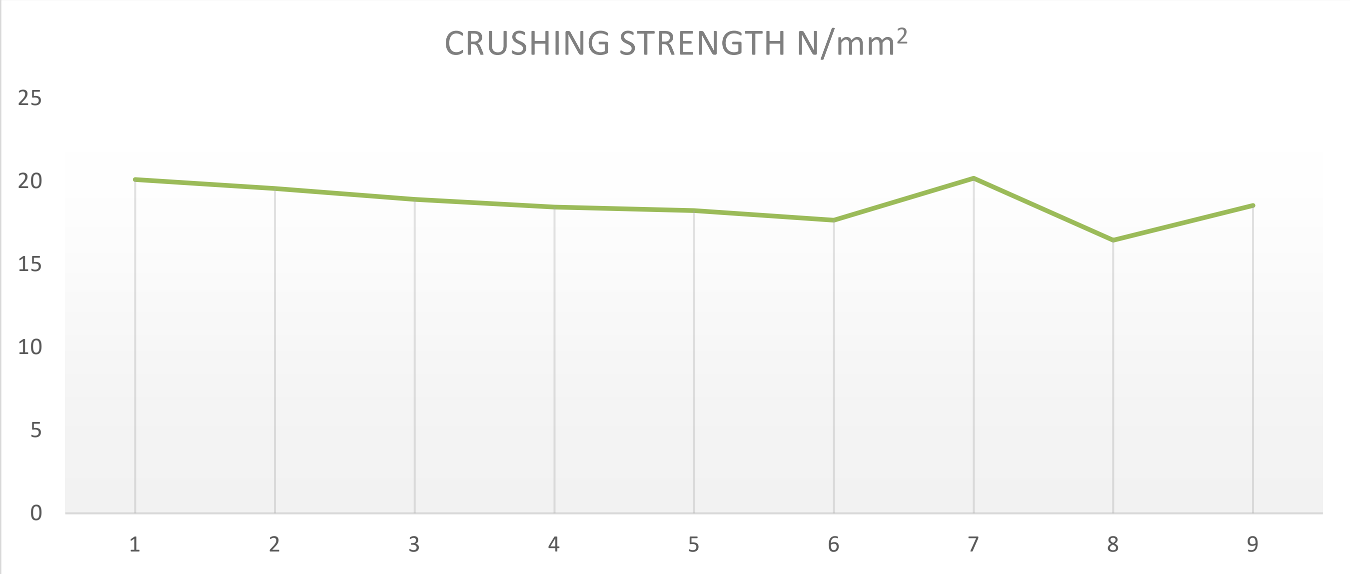


Fig 7:Crushing Load [ESN] Result for Crushed Concrete Cubes at Fourteen Days

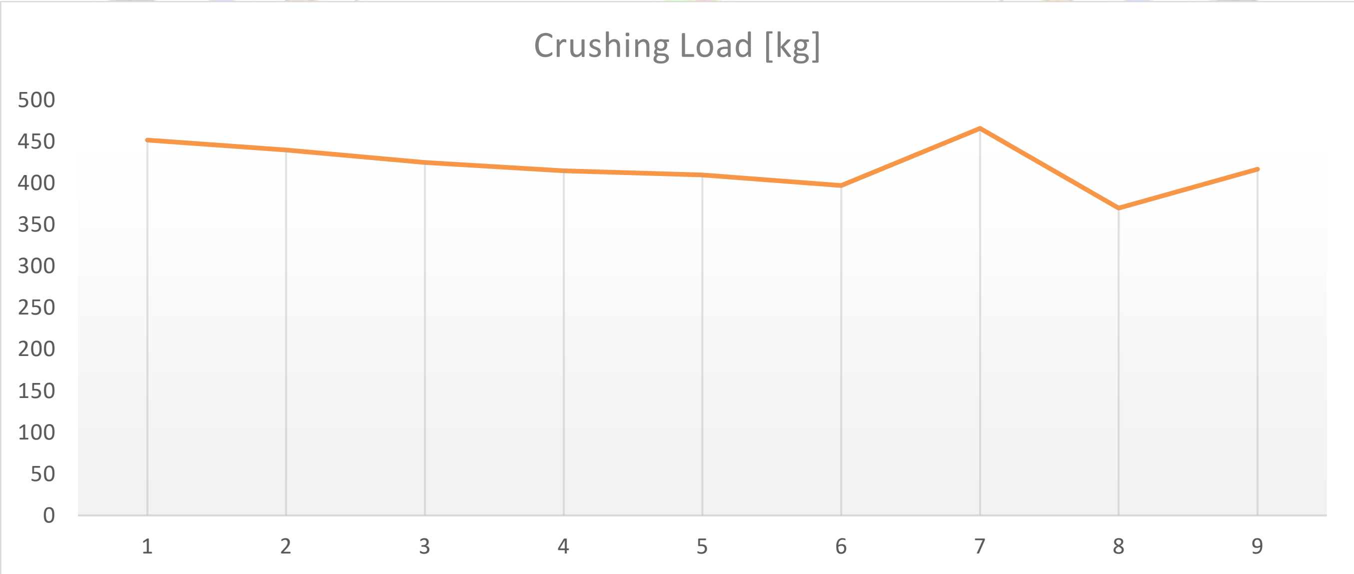


Table 5: Test Result For Crushed Concrete Cubes At Twenty One Days

Cube No. I	Time Of Mixing	Date Cast	Age For Testing [Days]	Date Tested	Crushing Load [kN]	Crushing Strength N/mm²	Remarks/ Observation
1	9.00	22/03/12	2 1	9/04/12	490	21.73	.
2	12.00	»	21	9/04/12	480	21.33	
3	16.00	»	21	9/04/12	465	20.67	
1	9.00	23/03/12	21	10/04/12	499	22.18	
2	12.00	»	21	10/04/12	490	21.73	
3	16.00	»	21	10/04/12	473	21.02	
1	9.00	26/03/12	21	13/04/12	510	22.67	
2	12.00	»	21	13/04/12	440	19.56	
3	16.00	»	21	13/04/12	470	20.39	

Fig 8:Crushing Strength [Nirnin²] Result for Crushed Concrete Cubes at Twenty one Days

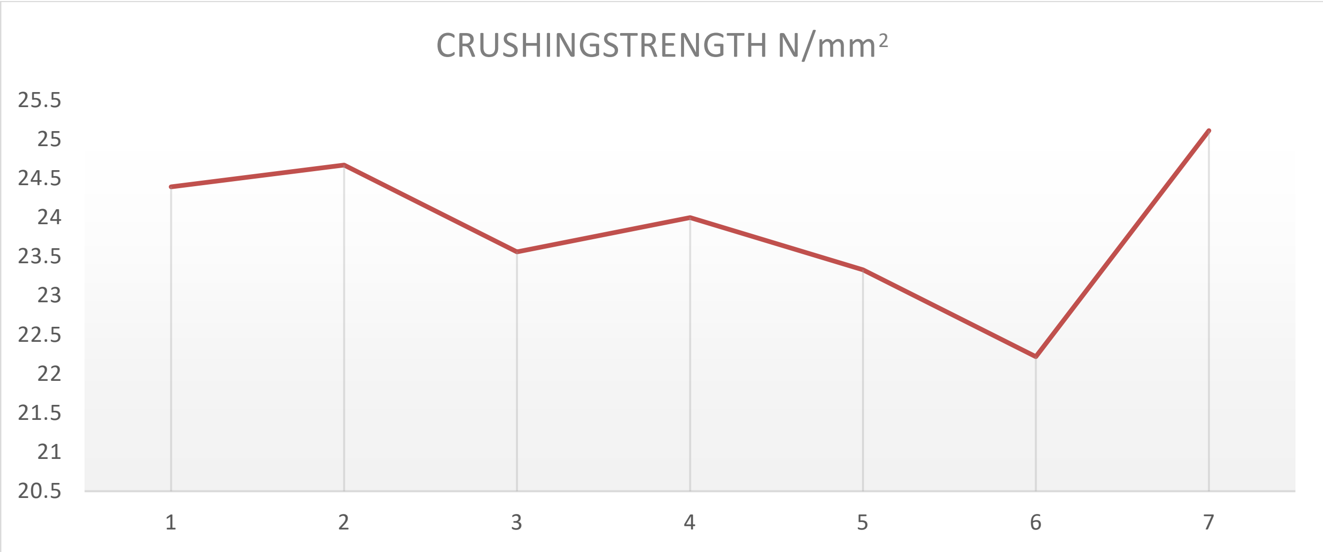


Fig 9:Crushing Load [kil] Result for Crushed Concrete Cubes at Twenty one Days

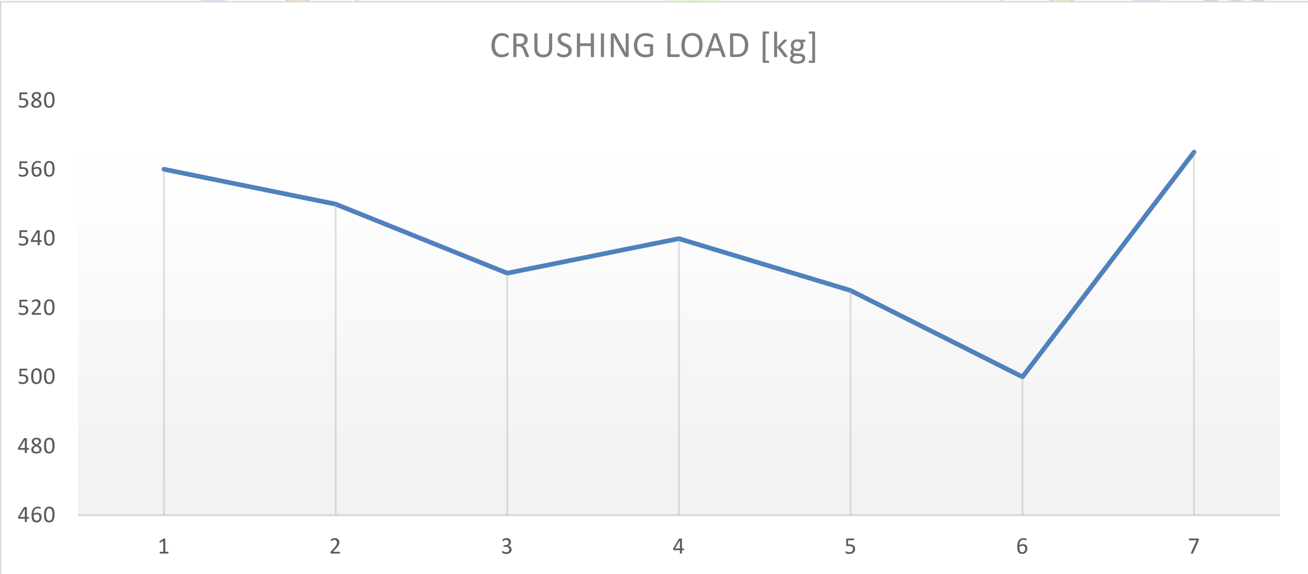


Table 6: Test Result For Crushed Concrete Cubes At Twenty Eight Days

Cube No.	Time Of Mixing	Date Cast	Age For Testing [Days]	Date Tested	Crushing Load- [Kil]	Crushing Strength (N/mm²)	Remarks/ Observation
1	9.00	22/03/12	2.8	16/04/12	560	24.39	
2	12.00		2.8	16/04/12	55	24.67	
	16.00	>>	28	16/04/12	530	23.56	
1	9.00	23/03/12	28	17/04/12	540	24.00	
2	12.00	>>	28	17/04/12	525	23.33	
	16.00	>>	28	17/04/12	500	22.22	
	9.00	26/03/12	28	20/04/12	565	25.11	
2	12.00		28	20/04/12	466	20.71	
3	16.00		28	20/04/12	470	20.89	

Fig 10: Crushing Strength [N/rnm²] Result for Crushed Concrete Cubes at Twenty Eight Days

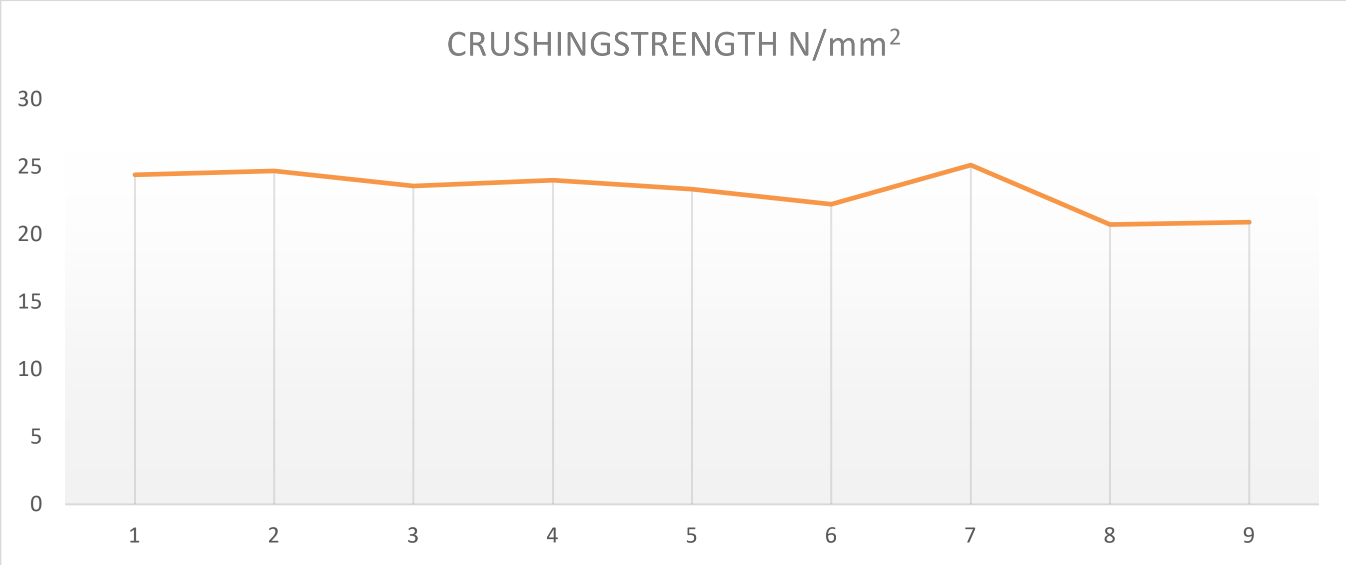
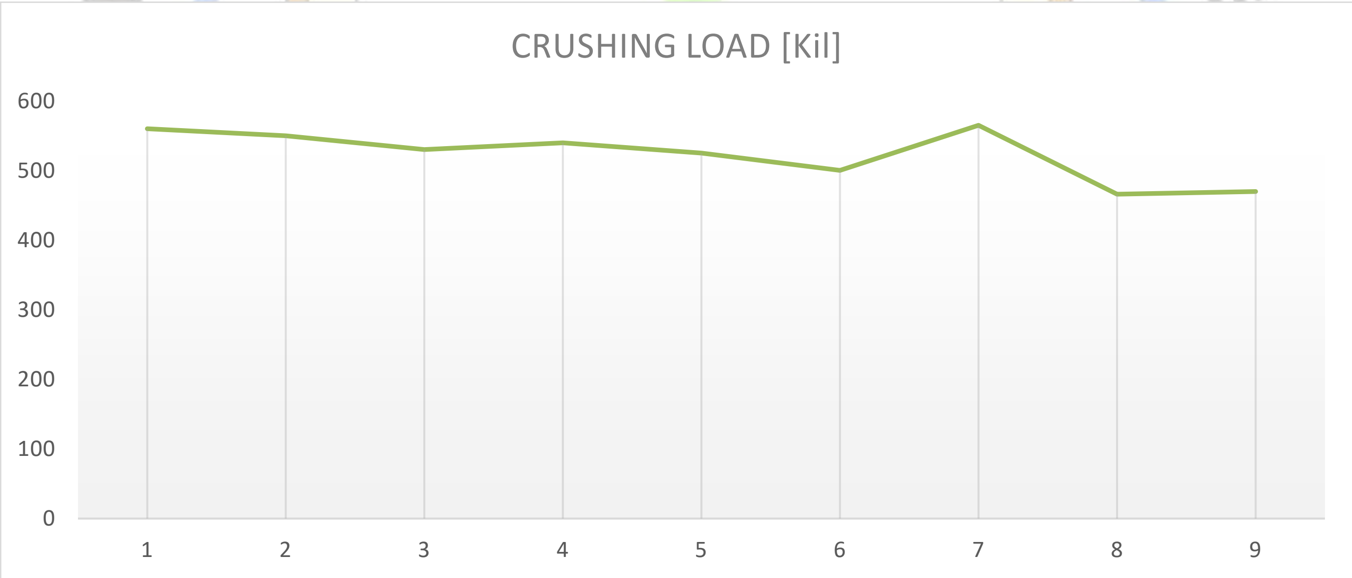


Fig 11: Crushing Load [kil] Result for Crushed Concrete Cubes at Twenty Eight Days



14. 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 Table 2. 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 7am-2pm appears to be of better quality (workability) than the concrete produced from 2pm to 4pm which invariably show that concrete produced in the 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 used of additive/admixture. 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.

15. Conclusion and Recommendation

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 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 Table 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 endeavor to produce their concrete between the hours of 7am to 2pm. Any other production outside this time will attract higher cost of production because of 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.

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