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THE EFFECT OF HOT AIR CURING ON ULTRA-HIGH STRENGTH CONCRETE USING LOCALLY AVAILABLE MATERIAL

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Abstract

High and Ultra-high strength concrete are becoming popular for many applications, including critical infrastructure subjected to high strain rate loading such as blast and impact. A strain rate dependent material that is applicable to a

Keywords

Effects, Hot Air Curing, Ultra High Strength Concrete, Locally available materials.

INTRODUCTION

In time past there has been change in concrete technology. The use of supplementary material and revolutionary developments in admixtures has facilitated improvements in the mechanical properties and durability of concrete. Lea, (1988). Concrete is a composite construction material compose primarily of aggregate cement and water. The coarse aggregate is generally grave or crushed rock such as limestone, or granite, while the fine aggregate is material such as sand, cement, Ordinary Portland cement, or other cementitious material such as fly ash and

range of strengths, varying from normal strength to ultra-high strength concrete, is presented in this paper. The result from a comprehensive experimental study conducted to investigate the strength and deformation capacity of concrete cylinders udders high-velocity impact loading using a split. Unconfined 50 mm diameter cylinder with compressive strength varies from 32Mpa (4640 psi) to 160Mpa (23 200 psi) were tested to deprive the dynamic properties of concrete at strain rate up to 300 s-1 the SHPB test data were analyzed to obtain the stress-strain relationships and strength dynamic increase factors (DIFs) for these concrete specimens under dynamic compression.

slag cement, serve as a binder for the aggregates. Various chemical admixtures are also added to achieve varied properties. Water is required for hydration of the cement to produce chemical compound that bind the other components together, to produce concrete. Concrete has relatively high compressive strength, but much lower tensile strength (American concrete institute MI 2004).

The use mineral and chemical admixtures and other methods that are used to increase concrete density, in addition to high strength, the concrete should exhibit greater durability characteristics. This actually means that the concrete should be of high strength and high performance. Materials that are developed in recent year are ultra-high strength concrete (UHSC) also known as reactive powder concrete (RPC). Some researchers at Bouygues Laboratory in France (Dili and Santhanam 2004).

This new material as usually produced with cement, fine quartz sand, silica fume, steel fibers and high rang water reducing admixture (HRWRA). Very low water-to-cement material ratios are used to produce this kind of concrete. In a more accurate

Literature Review

Background study on concrete:

Concrete is the most widely used as a material in construction. It is obtained by mixing cement, aggregate, water and sometime admixture in require proportion. The strength and durability of other characteristics of the concrete depends on the properties of its ingredients, the proportion of mix and the method of compaction and other controls during placing and curing. The need to produce concrete from readily available materials has brought the use of laterite as fine aggregate. These could either be in form of full replacement of or combination with sand. (Ogunseye and Ogunsiji, 2002).

Concrete produce from using laterie as fine aggregate is usually called laterized concrete. It has been defined as concrete in which stable laterite replaces fine aggregate i.e., sand (Salau, 2008). There have been many investigation on laterzied concrete by different researchers.

The general observation has been that the strength of laterized concrete decreases with increase in percentage of laterite replacement considered optimum water/cement ratio of 0.5. They found that the compressive strength of laterized concrete ranges from 17- 34.2 N/mm^2 for the mixes considered. The concrete was found to be suitable for use in buildings, provided laterite content did not exceed 50%. Ukpata et al. (2012)

Normal Strength Concrete

Normal strength concrete is widely used material in the concrete construction industry. It is strong in compression and has unlimited structural applications in combination with steel reinforcement. Normal strength concrete considered to be concrete with a compressive strength of 20 Mpa to 4Mpa (3000 to 6000 psi). the strength for fully compacted of normal strength is affected by free water – cement ratio and the type of aggregate. (Black.1990)

The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement (Often referred to as OPC). Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common for Portland cement is in the production of concrete.

Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural load bearing element (Portland cement,2014)

Ultra High Strength Concrete and Method of Application

The use of ultra high strength concrete and their methods of applications, there is a close relationship between the construction material available and the type of structures we build today. In some types of structures they can only be built after we must have developed the appropriate material for construction. In some rare occasions, engineers may have dreamed of specific structural concepts hoping that one day we can develop and achieve the required materials to realize the construction (Graybeal, B. 2010).

Ultra-high strength concrete (UHSC) in its present state become commercially available in the United States in about 2000 (Graybeal, 2011). The Federal Highway Administration (FHWA) started to investigate the proper use of UHSC for highway infrastructure in 2001 and has been working with state transportation departments to deploy the technology since 2002.

This work has lead to the use of UHSC In several bridge application, including precast, prestressed girders, precast waffle panels for bridge decks, and as a jointing materials between precast concrete desk panel and girders. The first ultra-high strength concrete (UHSC) high bridge in the united state as a precast canopy components consist of half shells, columns, tie beams, structs, and troughs. (Lafarge North America inc.)

In Canada today, the first UHSC bridge was constructed in 1997 (Blaise and couture1999) this pedestrian bridge consist of a precast, post-tensioned space truss. At least 26 bridges have been built in Canada using UHSC in one or more components.

UHSC is a cementitious, component material composes of an optimized gradation of granular constituents, a water-to cementitious materials ratio less than 0.25, and of a high percentage of discontinuous internal fiber reinforcement. The new material is the result of important developments in the cementitious material technology that have taken place in the last decades, such as, the development of puzzolanic admixtures and superplastizicers. The idea was to develop concrete with a homogenous and dense. The excellent durability performance features and elevated mechanical properties of UHSC are base upon on the following principles is reduced water/ cements of approximately 0.14 to 0.27 that result in a dense structure with negligible capillary pores. (Schmidt and fehling 2005).

A high packing density achieve by optimizing the granular size, eliminating coarse aggregate and addition of quartz. Use of high amount of super platizicers to regulate the workability. In addition of steel fiber to increase the strength and ductility of the UHSC can be also referred as reactive power concrete (RPC) or ultra high performance fiber reinforced concrete (UHPFRC) due to the fact that after the first plain RPC (without fibers) mixtures which shows a very high brittleness behavior, all researchers start to add short fibers to increase the ductility. If the previously mentioned basic principles are carried out all the performance that characterize UHSC should be attained. The optimum packing of particles initially used in the mixture design of plain RPC should probably be optimized in a different way due to the disturbance that the fibers causes on the granular skeleton (markovic 2006).

Primary Constituent

The main constituents of UHSC are cement, water, sand, silica fume, super plasticizer and fibers. The following points explain briefly these main ingredients (Denarie 2004). The amount of cement used, higher, UHSC is more than two times higher than that for NSC> in most cases, Portland Cement V is used due to its low tricalcium aluminate content, water as previously mentioned, one of characteristics of UHSC is its low water cement ratio. The amount of water used is the rigorously required to hydrate the cement thus the formation of pores is fairly reduced, avoiding the interconnection between them. Therefore, the absence of a capillary structure improve the strength and the impermeability of this material.

Sand

The sand used needs to have excellent qualities, both in strength and low absorption. The particle sizes have to be small, frequently lesser that 1mm, to achieve an adequate homogeneity in the mix. Quartz sand with a maximum size of 1mm is typically used. It is important that the aggregate used exhibit high strength and low adsorption (Roux et al. 1996)

Function of High Rang Water Admixtures

The classification of admixture is done according to the purpose of the admixtures. As far as chemical admixtures are concerned, there are five distinct kinds of admixture: air-entering, water-reducing, retarding, accelerating and plasticizers. There is another special category of admixtures into which all the other admixtures fall. The group has admixtures with a number of functions such as corrosion inhibition, reduction of shrinkage, workability enhancement, bonding, damp proofing and colouring (Portland Cement Association, 2013). They are capable of increasing the workability of concrete.

Silica fume

Silica fume is also known as condensed silica fume, micro silica or volatilized silica. It is a byproduct of the induction is furnaces in the silica metal and ferrosilicon ally industries. Compare to normal Portland cement and typical fly ashes, silica fume particles show particle size distribution of two order of magnitude finer, silica fume is high pozzolanic but its 17 major disadvantages is that it increase the water requirement of concrete appreciably if water reducing admixture are utilize in mitigation.

The addition of silica fume increases the mechanical strengths and gain the compactness and microstructure of UHSC. The optimum ratio between silica fume and cement is 25% (Danarie 2004; Richard and Cheyrezy 1995).

The term of micro silica, condensed silica fume, and silica fume are often used to describe by-products extracted from the exhaust gases of ferrosilicon, silicon, and other metal alloy smelting furnaces. However, the terms of silica fume and micro silica are used fro those condensed silica fumes that are of high quality for using in the cement and concrete industry. In the European standard, the term of silica fume has been used. (Schmidt and Fehling 2005)

Silica fume was first discovered in Norway in 1947 when the environmental controls stated the filtering of the exhaust gases from furnaces. The main portion of these fumes was a finely composed of a high percentage of silicon dioxide. As the pozzolanic reactivity for silicon dixide was well known, many studies have been done on it.

Silica fumes can be utilized as material for supplementary cementations to increases the strength and durability. According to the Florida Department of Transportation (2004), the quantity of cement replacement with silica fume should be between 7% and 9% by mass of cementation materials.

Silica fumes consists of the fine particles with specific surface about six time of cement because its particles are very finer than cement particles. Hence, it has been found that when silica fume mixes with concrete the minute pore spaces decreases. Silica fume is pozzolanic, because it is reactine, like volcanic ash. Its effects are related to the strength, modulus, ductility, sound absorption, vibration damping capacity, abrasion resistance, air void content, bonding strength with reinforcing steel, permeability, chemical attack resistance, alkali-silica reactivity reduction, creep rate, corrosion resistance of embedded steel reinforcement, freeze-thaw durability, coefficient of thermal expansion (CTE), specific heat, defect dynamics, thermal conductiving, dielectric constant, and degree of fiber dispersion in mixes containing short microfibers. Wu, C. et al (2009)

Also, addition of silica fume decreases the workability of the mix. Silica fume can solve problems, because of its very looses bulk density and fine particles. However, it causes other problem such as stickiness, bridging in storage silos, and clogging of the pneumatic transport equipment.

Silica Fume Source

It is very fine no crystalline silica manufactured by electric are furnaces as a by-product of the production of metallic silicon or ferrosilicon alloys. The raw materials are coal, quartz, and woodchips or saw dust. The smoke that produced from furnace operation is stored and sold as sold as silica fume rather than being land filled.(Wu, X.-G .Han, S.-M., 2010).

As the silica fume powder particles are hundred times finer than ordinary Portland cement, there might be problem arise when deals with silica fume such

As dispensing consideration, transportation, and storage that must be taking into account. To overcome some of these difficulties, the material is commercially divided in various forms. That difference between these forms is the size of the particle which do not significantly affect the chemical make-up or reaction of material. This difference has effect on the different purpose of use. Thus, careful consideration is needs when choosing the type of silica fume for specific application.

Physical Properties

The properties of silica fume depend on the type of producing and the process used for its manufacture. It is in form of spherical particle shape. It is a power with particles having diameters 100 times smaller than Portland cement particles. Silica fume comes in three forms of power, condensed, and slurry. Its color varies from light to dark grey which depend on the process in the manufacture and is influenced by some parameter such as wood chip composition, furnace temperature, ratio of wood to the coal used, exhaust temperature, and type of metal produced. (Wipf, et al, 2011)

Chemical Properties

Faut K. et al 2009, summarizes properties of cement and silica fume. Silica fume is produced during a high-temperature reduction of quartz in an electric are furnace when the main product is silicon or ferrosilicon. Due to the large amount of electricity needed, these are furnaces are located in countries with well-provided electrical capacity including Scandinavia, Europe, Canada, USA, south Africa, and Australia.

The chemical process is complex and it depends on the temperature of the producing. The sic formed, initially intermediates roles.

At temperature >1520-c

Sio2+3c=sic+2co

At temperature>1800-c

3sio2+2sic= si+4sio+4sio2

The unstable gas diffuses in the furnaces where it react with react with oxygen to give the silicon dioxide 4sio+2O2=4sio2.

The application of silica fume in concrete mixtures has significantly increased and enhanced the properties of the concrete whether it is in wet stage or in harden condition.

The overall effects of silica fume on the concrete properties are as summarized.

1. Filling the voids between cement between cement grains (100 nm) since silica fume grains are smaller particles (8nm).
2. Improvement of rheological characteristics due to its perfect sphericity of the basic particles that produce lubrication effect.
3. Formation of hydration product by polozzolanic activity with the lime, producing an increase of the final strength.

Fibers.

Fibers are added to the concrete to increase the ductility and mechanical properties. The amount of fibers influences on the workability of the final product. The usual amount varies from 1% to 4% in volume.

Materials and Method

Materials

1. **Cement**: Dangote brand of ordinary Portland cement, which is gotten from the market at Ekiti is to be used. The cement was well covered and lumps are avoided.
2. **Fine aggregate**: are basically sands won from the land or the marine environment. **Fine aggregates** generally consist of natural sand with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from primary, secondary or Recycled

sources. The other fine aggregate used was well graded laterite having a uniformity coefficient (Cu) of 15.15 and specific gravity of 2.56. it was obtained from Landmark University Omu-Aran.

3. **Water**: Water used for mixing and curing was potable water, suitable for domestic consumption.
4. **Silica fumes, rice husk,** obtained from Landmark University Omu-Aran.
5. Quartz powder.
6. Rice husk ash: The ash is simply gotten from the burning of rice husk to ash for hours then sieved through a 600mm sieve.

Method

The method show the practical processes that was carried out and to show the processes and finally getting the required result.

Proportioning: the following recommendations for mix proportions were developed for use with commercially available constituent materials as shown and listed below.

Cement with moderate fineness and C3A content significantly lower than 8 percent.

Fig. (3.1) Dangote Portland Cement

Sand-to-cement ratio of 1.4 for a maximum grain size of 0.8mm (0.03 inches. This sand was gotten by sieving sand with sieve.

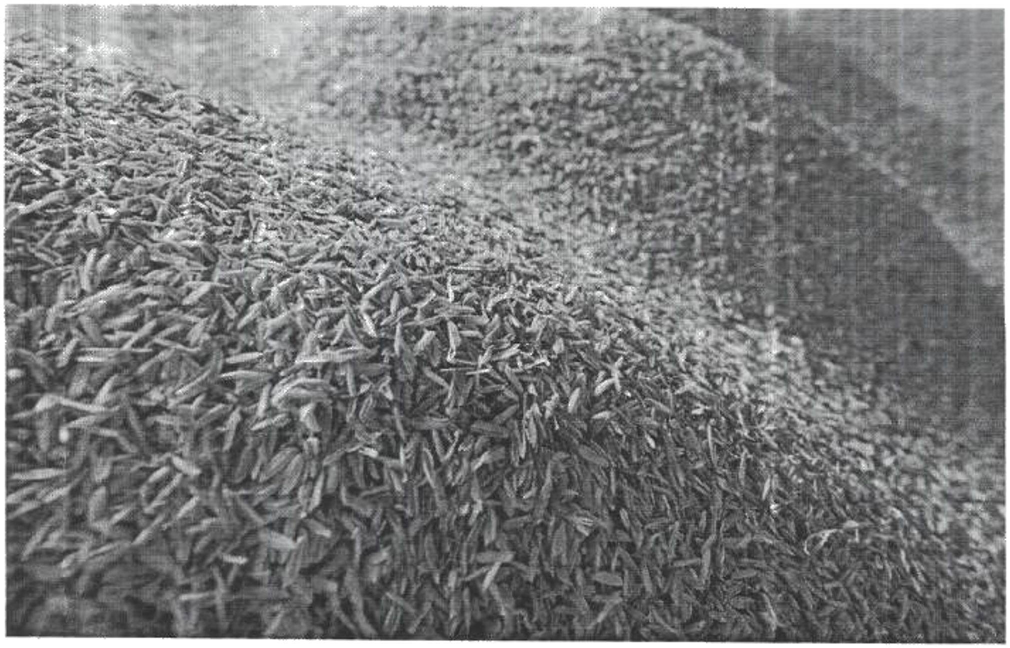

Fig (3.2) Fine sand

Silica fume with very low carbon content at 25 percent of the weight of cement

Fig. (3.3) Silica fumes

High-range water-reducing admixture about 0.01, also known as super plasticizer (5ltr)

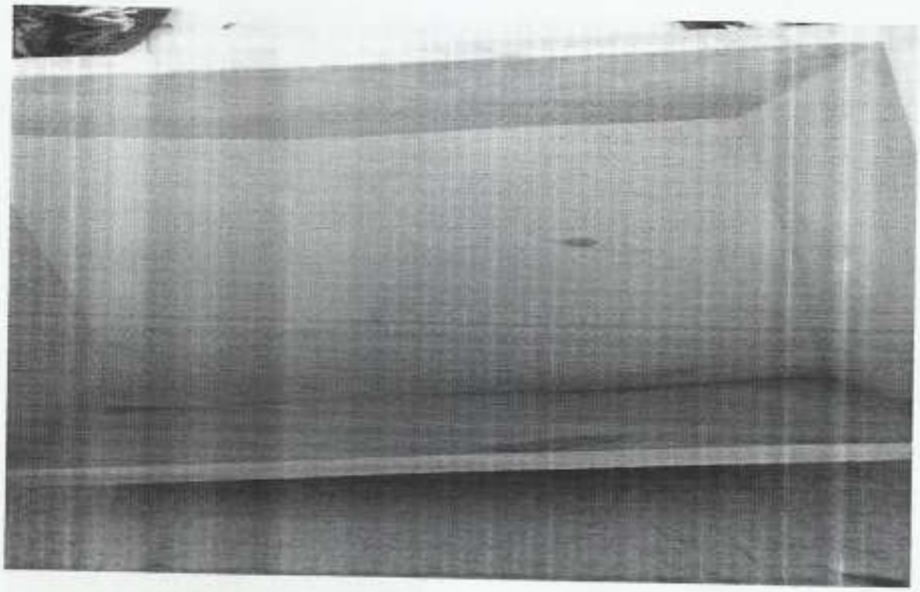

Fig (3.2). Fine sand.

Silica fume with very low carbon content at 25 percent of the weight of cement.

Fig (3.3). Silica fumes.

Fig. (3.4) Conplast 432ms (HRWAM)
Water-cement ratio of about 0.22
Quartz powder

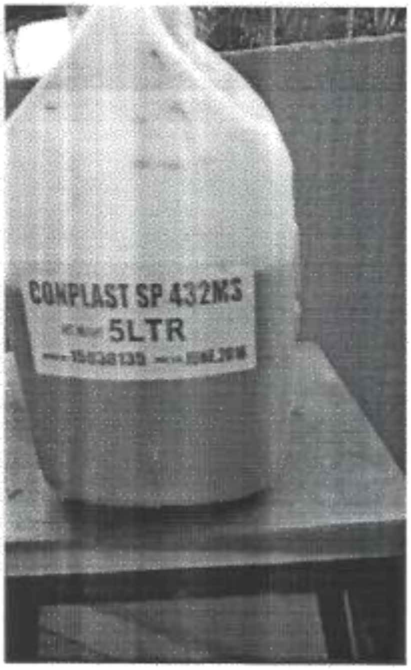

Fig (3.4). Conplast 432ms (HRWAM).

Water-cement ratio of about 0.22.

- Quartz powder.

Fig (3.5) Powder.

Fig (3.5) Powder

Steel fibers at 2.3 percent by volume length of 13mm, diameter 0.16mm with tensile strength of 2000mpa. Steel fibres were gotten from burning discarded tyres.

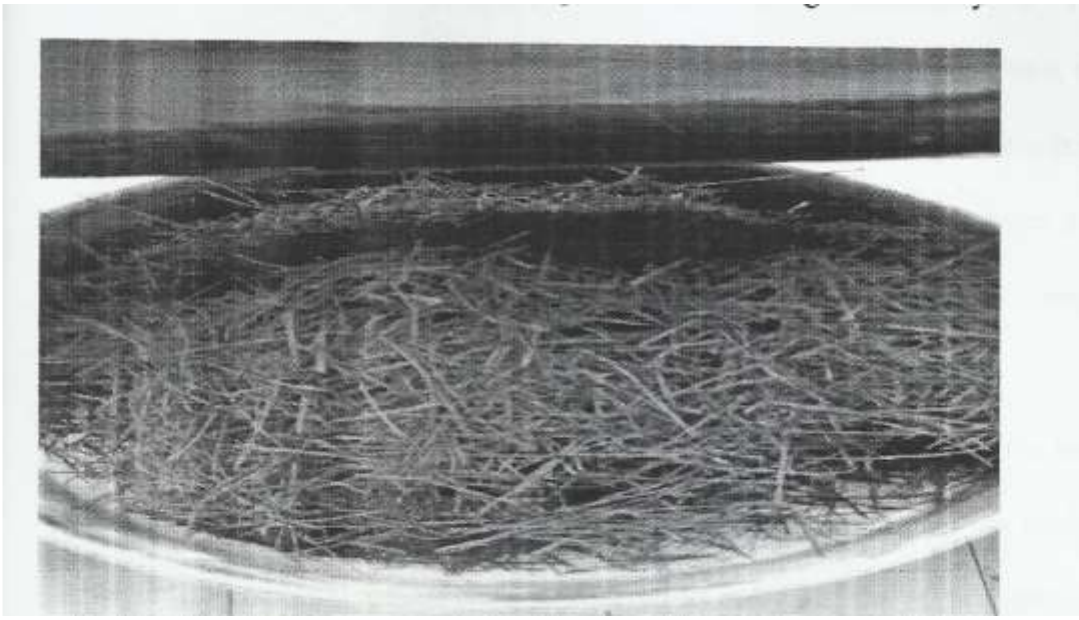

Fig (3.6) Steel fibers

Mixing and placing

Nearly any conventional concrete mixer will mix UHPC. However, it must be recognized that UHPC requires increased energy input compared to conventional concrete, so mixing time will be increased. This increased energy input, in combination with the reduced or eliminated coarse aggregate and low water content, necessitates the use of modified procedures to ensure that the UPHC does not overheat during mixing. This concern can be addressed through the use of a high-energy mixer or by lowering the temperatures of the constituents and partially or fully replacing the mix water with ice. These procedures have allowed UHPC to be mixed in conventional pan and drum mixers, including ready-mix trucks.

Mixing times for UHPC range from 7 to 18 minutes, which are much longer than those of conventional concretes. This impedes continuous production processes and reduces the capacity of concrete plants. Mixing time can be reduced by optimizing the particle size distribution, replacing cement and quartz flower by silica fume, matching the type of HRWR and cement, and increasing the speed of the mixer. The mixing time can also be reduced by dividing the mixing process into two stages. High-speed mixing for 40 seconds is followed by low-speed mixing for 70 seconds, for a total time of about 2 minutes.

So the mixing process was carried out by the use of mixer machine the reason for this was to achieve a good mixture the mixer machine was gotten from the concrete lab and connected the material which were to be

Fig (3.7) Weighing *balance*

used to carry out the mixing process were rice husk ash, fine sand, Portland cement, quartz stone, steel fibre, water, super plasticizer, note that this materials where weighed appropriately with the aid of a weighing balance as noted on the readings, so the powers are the first to be put inside the mixer to mix properly after this is done the complast is put to assist the powders mix properly then the steel fibre is put to mix with it.

Fig. (3.7) weighing balance

Fig. (3.8) concrete mixer (Electrical)

Then when the mixture is properly attained the ultra-concrete is been removed from the mixer by me then placed in the head pan then with the aid of a vibrating poker this concrete is been casted into the 500mm metal cube, depending on the run that was carried out it is then covered with polythene and then left dry.

Fig. (3.9). Concrete in head pan and casting cubes.

Design of experiment

The mixer proportion and the constituent of UHSC are in 4 while in the first 3 factors that are be varied are with Portland cement of 42.5. Other factors to be considered are quartz powder, high range water reducing admixture, steel fibre etc. each numerical factor is varied over (5) levels they are plus Alpha (+a), minus Alpha (-a), (axial/star points) +1 (high level), -1 (low level) (factorial point) and the center point (Mid-level).

1. Twelve runs: composed of eight factorial points (23), plus four center points.
2. Eight runs: composed of six star/axial points plus two more center points.

The three factors are represented as X1, X2 and X3 (independent variables), while R1, R2 and R3 represented the compressive strength (dependent variables).

Std	Runs	Block	type	Factors 1 X1: cement g	Factor 1 X2: RHA	Factor 1 X3: sand g	Compressive strength N/mm^2	
							R1	R2
9	1	Block 1	Centre	4	44.50	32.50		
10	2	Block 1	Centre	4	44.50	32.50		
12	3	Block 1	Centre	2	44.50	32.50		
1	4	Block 1	Factorial	4	19.00	22.50		
11	5	Block 1	Factorial	6	44.50	32.50		
2	6	Block 1	Factorial	6	19.00	22.50		
8	7	Block 1	Factorial	6	70.00	42.50		
4	8	Block 1	Factorial	2	70.00	22.50		
3	9	Block 1	Factorial	2	70.00	42.50		

7	10	Block 1	Factorial	6	70.00	22.50
6	11	Block 1	Factorial	2	19.00	22.50
5	12	Block 1	Factorial	4	19.00	42.50
18	13	Block 2	Centre	4	44.50	42.50
20	14	Block 2	Centre	4	44.50	42.50
17	15	Block 2	Axial	4	44.50	49.32
13	16	Block 2	Axial	0.64	44.50	32.50
14	17	Block 2	Axial	7.36	44.50	32.50
15	18	Block 2	Axial	4	1.61	32.50
19	19	Block 2	Centre	4	44.50	32.50
16	20	Block 2	Axial	4	87.39	32.50

When the cube gets dry we then remove the cubes and label them according to their various runs. The process is repeated continuously for the whole runs and the readings are taken where necessary. So the fig below is showing how the concrete were casted in cubes with the aid of a vibrating poker and before we casted this concrete we actually oiled the cubes to aid easy removal after it has dried properly.

Curing Method/Processes:

There were several curing processes that was used in the curing of this high Strength concrete which were the used of oven, water bath, normal water bath. The normal water bath we filled the water plastic container with water then placed the cubes inside. Then for the oven which heats at 200 degree Celsius we place the cubes inside to ensure its stay for 48hr of which the total number of cubes casted at a time was 36 cubes but depending on the run 12 cubes were caste at a time while in the curing aspect the cubes were cured for m28days respectively

Result and Discursion

As Mentioned the Input Independent Variables Were, HRWRA STEEL FIBRE And QUARTZ which are pointed out in analysis of variance with A, B and C respectively and the responses were compressive strength and compressive strength of UHSC concrete. In this stage, to evaluate the influence of these independent factors on correspond ding responses analysis of variance was done using Minitab software according to CCDE results are determine based on confident level at 95% (a=0.05). Significant terms was evaluated according to its probability value (P-value). Significant terms should have probability value more than 95% (a 6 0.05) and so the null hypothesis (HO) will be rejected and probability value if insignificant terms will b e less than 95% (PO.05) and these terms should be eliminated from final analysis and equations.

Anova analysis and regression models

Looking table 1 and 2 showing the ANOVA result in which we initial analyze the compressive strength. As seen on table 1 the probability value for term A was 0.0357 which is less than 0.05, so this term had effect on response trend while B and C were effective with probability value more than 99%. Squares of two A and C were effective with P-value 97% and >99% respectively but Square of B was not significant due to its probability value P=0.19. Interaction among B and C was not significant.

Looking at table 2 it can be seen that terms A, B and C were effective on compressive strength with then probability of 98%, 97% respectively. The square of factor A was significant with P-value less than 0.001 and Square of factor C was effectively with P-value 96% but it is obvious that square of factor B did not have any effect on compressive strength according to its P-value was about 0.1146. For component interaction it can be said that interaction among A and C was the most effective interaction with probability 97%. Interaction among B and C stood on second place with probability about 96% while interaction between A and B was not effective because of its P-value according to the table 4.

Generally comparing the two responses it can be observed that all of the linear terms were effective on compressive strength while the only two of three terms affected compressive strength. Finally about interaction according to the magnitude of P-value in the table of 1 and 2 it is obvious that interaction were more effective on compressive strength response 1 and 2. Moreover compressive strength responses with P-value 0.15 and 0.64 respectively, thus the specific model fitted the data satisfactorily.

Table 1 Response for compressive strength 1.

Response 1 Compressive Strength

ANOVA for response Surface Quadratic Model

Analysis of variance table [Partial sum of square- Type III]

Source	Sum of Square	df	Mean Square	F Value	p-value Prob>F	
Block	1.36	1	1.36			
Model	262.36	9	29.15	3.61	0.0348	Significant
A-HRWRA	49.24	1	49.24	6.09	0.0357	
B-Steel Fiber	2.12	1	2.12	0.26	0.6209	
C –Quatz	18.36	1	18.36	1.95	0.1660	
AB	9.78	1	9.78	1.21	0.2999	
AC	15.76	1	15.76	1.95	0.1960	
BC	3.024E-003	1	3.024E-003	3.744E-003	0.9850	
A^2	64.62	1	64.62	8.00	0.0198	
B^2	24.66	1	24.66	3.05	0.1146	
C^2	32.71	1	32.71	4.05	0.0751	
Residual 72.74		9	8.08			
Lack of fit	49.82	4	12.45	2.72	0.0751	not significant
Pure Error	22.93	5	4 .59			
Cor Total	336.46	19				

The model of 3.61 implies the model is significant. There is only a 3.48% chance that a model F-value this large due to noise values of ‘prob’) F” less than 0.500 indicate model terms significant the lack of fit F – value of 2.72 implies the lack of fit is not significant relative to the pure error. There is a 15.12% chance that a lack of fit f – value and could occur due to noise. Non-Significant lack of fit is good---we want the model to fit

Response for Compressive Strength

Response 2 Compressive Strength.

ANOVA for responses surface quadratic model

Analysis for variable table (partial sum of square – Type III)

Source	Sum of Square	df	Mean Square	F Value	p-value Prob>F
Block	1.23	1	1.23		
Model	144.47	9	16.05	2.01	0.1565 Not significant
A-HRWRA	41.80	1	41.80	5.23	0.0479
B-Steel Fiber	3.231	1	3.23	0.40	0.5404
C –Quatz	4.11	1	4.11	0.52	0.4912
AB	0.64	1	0.64	0.080	0.7838
AC	0.51	1	0.51	0.064	0.8062
BC	1.19	1	1.19	0.15	0.7082
A2	11.13	1	11.13	1.39	0.2681
B2	59.06	1	59.06	7.40	0.0236
C2	4.11	1	4.11	0.51	0.4913
Residual	71.86	9	7.98		
Lack of fit	25.06	4	6.26	0.67	0.6408 Not Significant n
Pure Error	46.80	5	9.36		
Cor Total	**217.55**	**19**			

The model F-value of 2.01 implies that the model is not significant relative to the noise. There is a 15.65% change that a "Model F-value" this large could have occurred due to noise. The lack of fit F-value of 0.67 implies the lack of fit is not significant relative to the pure error. There is a 64.08% change that a "lack of fit F-value" this large occurred due to noise. Non coefficients from first step of analysis for compressive strength are shown in table 3. According to these coefficients the second order polynomial model based on initial analysis which involves both significant and insignificant terms for compressive strength for both would be as following equations respectively:

Second Order Polynomial

4.1 Compressive Strength R1 = -43.26899 + 9.52898Xl + 0.31744X2 + 1.81771X3 – 0.020X2.X3

4.2 Compressive Strength R2 = -10.93881 + 2.68192Xl +0.36415X2 + 0. 56466X3 – 6.59725(Xl)2 + 0.015119(X2)2 – 1.81328(X3)2 -0.23795Xl.X2 – 3.3722Xl.X3 – 7.09746.X3

Table 4.1.2 Regression coefficients and percentage of R-square for both responses in first step of analysis of variance for compressive strength.

Conclusion

In conclusion and based of the findings of the study;

1. Generally comparing the two responses both response 1 and response 2 it can be observed that all of the linear terms were effective on compressive strength.
2. The lack of fit for response one was non-significant which implies that for response 1 the model is good

Also lack of fit for response 2 which also showed that the model was non-significant, from this we can say that the model is also good high range water admixture for both was non-significant this that HRWRA is good for the model likewise regression coefficients from first step of analysis for compressive strengths are shown in table 3. Significant terms with the P-value more than 0.05 are pointed out with one star and those with probability more than 99%. Generally looking at the experiment the model is said to be good.

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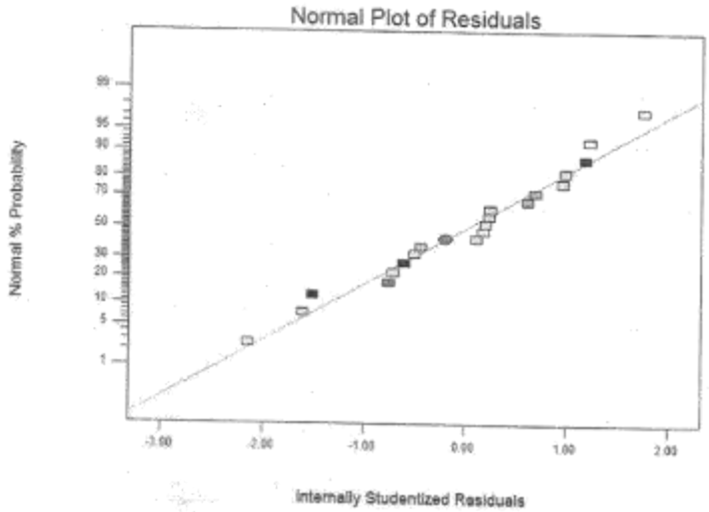


Fig (4.2) Normal plot of residual graph for compressive strength response 2

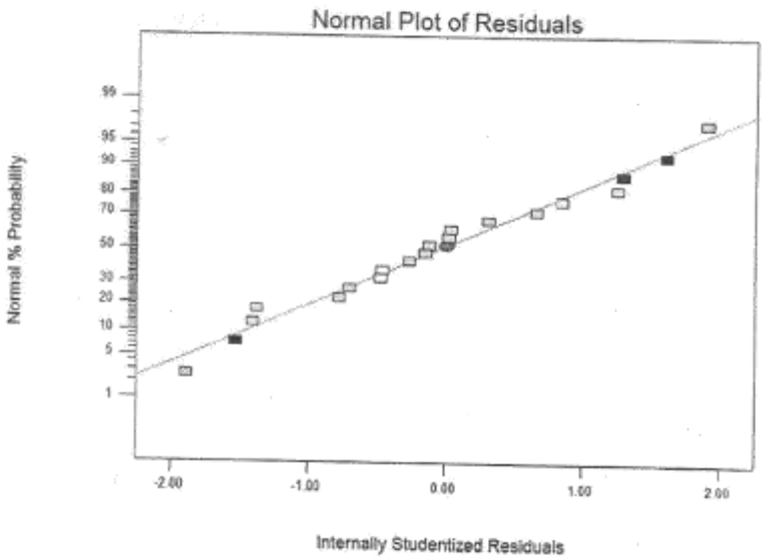


Fig (4.3) Normal plot of residual graph for compressive strength response 1

Final analysis of variance compressive strength Response 1 and 2 Graph.

Final analysis of variance compressive strength Response 1 and 2 Graph.

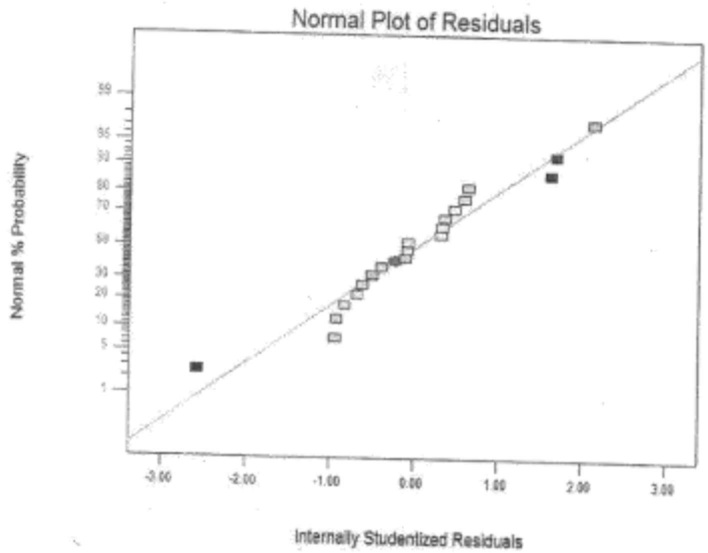


Fig (4.4) Normal plot of residual graph for final compressive strength response 1.

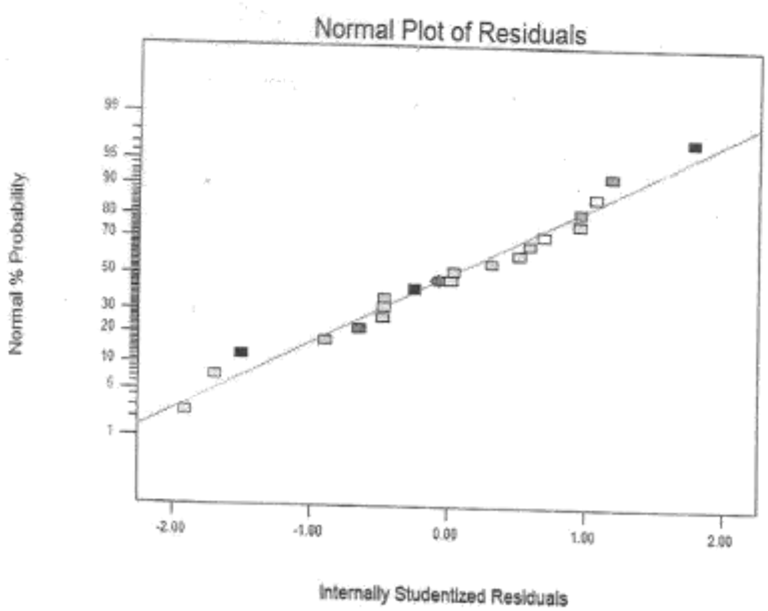
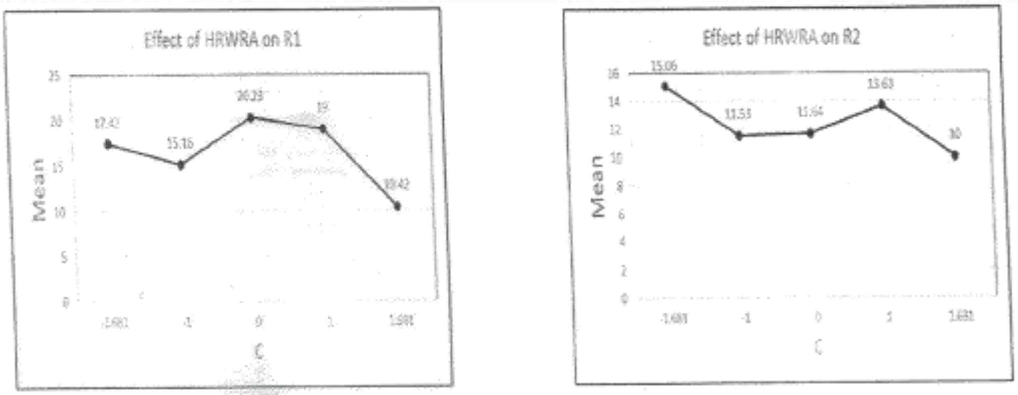
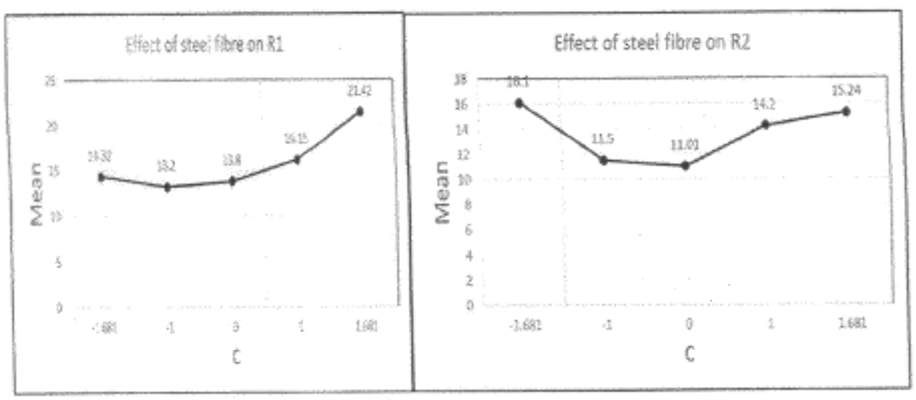


Fig (4.5) Normal plot of residual graph for final compressive strength response 2.



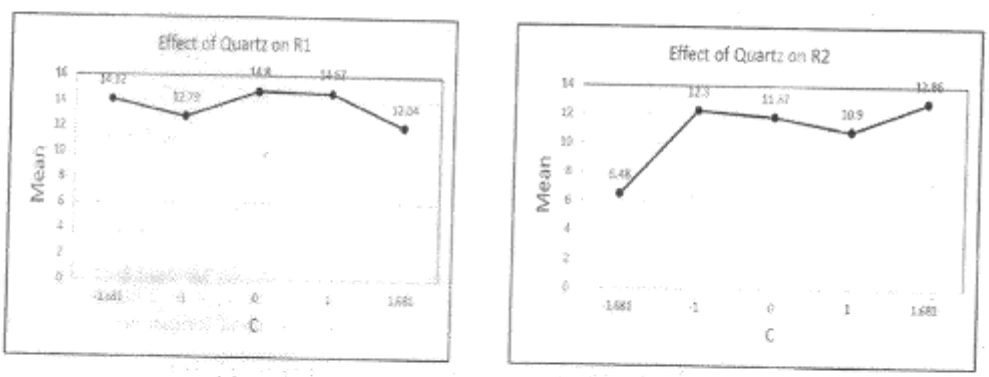
(a) (b)

Fig(4.6) Main effect plots of factor HRWRA on Response 1 and Response 2.



(a) (b)

Fig(4.7) Main effect plots of factor STEEL FIBRE on Response 1 and Response 2.



(a) (b)

Fig (4.8) Main effect plots of factor QUARTZ on Response 1 and Response 2.