EFFECT OF SALT WATER ON CONCRETE USING BIDA NATURAL STONES AS COARSE AGGREGATE

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MEng/SEET/2017/7188

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE RQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER IN CIVIL ENGINEERING (STRUCTURAL)

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ABSTRACT

Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to arrive at a particular strength. The cement and water react together chemically to form a paste together with the aggregate particles. The mixture sets into a rock-like solid mass, which has considerable compressive strength but little resistance in tension. In this research, concrete was properly mixed using salt water at 35g/l and water only respectively with Bida natural stones as coarse aggregate in the production of concrete. The physical and mechanical properties of the aggregates were determined and the compressive strength of hardened concrete were determined at 7, 14, 21 and 28 days curing. A total of 144 cubes were cast and cured for 7, 14, 21 and 28 days. The mix ratio of 1: 2: 4 and w/c 0f 0.5 were used. The concrete developed in this work has slump ranging from 0 – 135 mm, compressive strength ranging from 8.94 N/mm^2 - 27.11 N/mm^2 and density ranging from 1757.04kg/m^3 to 2198.52kg/m^3 respectively. The use of salt water should be welcome and not feared for casting and curing of concrete during construction most especially in coastal environment if a mix ratio of 1:1.5:3 grade M20 is applied.

TABLE OF CONTENTS

Title	Page
Cover Page	i
Title Page	ii
Declaration	**Error! Bookmark not defined.**
Certification	**Error! Bookmark not defined.**
Dedication	**Error! Bookmark not defined.**
Acknowledgements	**Error! Bookmark not defined.**
Abstract	iii
List of TablesP	viii
CHAPTER ONE	**1**
1.0 INTRODUCTION	**1**
1.1 Background to the Study	1
1.2 Problem Statement	2
1.3 Aim and Objectives of the Study	2
1.4 Justification of the Study	3
1.5 Scope and Limitation of the study	3
CHAPTER TWO	
2.0 LITERATURE REVIEW	**4**
2.1 Concrete and its Constituents	4
2.1.1 Concrete	4
2.1.2 Strength of concrete	5
2.1.3 Aggregates	6
2.1.4Cement	10
2.3 Setting time	12

2.3.1 Compressive Strength of Concrete 12

2.3.2 Tensile Strength 13

2.4 Salt water (Sea water) 13

2.4.1 Chemical action of sea water on concrete. 14

2.4.3 Salinity measurement 16

2.4.6 Some Consequences of the use of saline water as mixing water or curing water 17

2.4.7 Salinity and compressive strength of concrete 18

2.5 Effects of Salt on Concrete 19

2.5.1 Physical Attack 19

2.5.2 Chemical Attack. 20

2.6 Mix Design 21

CHAPTER THREE

3.0 MATERIALS AND METHODS 22

3.1 Materials 22

3.1.1 Ordinary Portland cement 22

3.1.2 Sand 22

3.1.3 Water 23

3.1.4 Bida Natural Stones (BNS) 23

3.2 Methods 23

3.2.1 Specific gravity Test 24

3.2.3 Bulk density test 26

3.2.4 Moisture content 27

3.2.5 Aggregate impact value Test 28

3.3 Properties of Fresh Concrete 29

3.3.1 Workability of concrete 29

a) Slump test 29

3.4 Mean compressive strength 30

3.4.2 Cement content 30

3.4.5 Aggregate content 30

3.4.6 Fine aggregate content 31

3.4.7 Coarse aggregate content 31

3.5 Estimation of Quantity of Materials required for Compressive strength test 150 x 150 x 150 mm (Cubes) 31

3.5.1 Weight of Materials for Experiment for the different mix ratio used. 32

3.5.3 Weight of Materials for Experiment No 3 with Mix Ratio 1:3:6 32

3.7 Preparation of Concrete 33

3.8 Casting and Compaction of Concrete 33

3.9 Curing of Concrete 34

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION 35

4.1 Result of Preliminary Tests conducted on the Fine and Coarse Aggregates 35

4.2 Specific Gravity Test 37

4.5 Aggregate Impact Value (AIV) 40

4.6 Aggregate Characterization 40

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS 47

5.2 Recommendations 48

REFERENCES 49

APPENDICES 52

LIST OF TABLES

Table	Title	Page
2.4.2	Major ion composition of sea water.	15
2.4.4	Factors for connecting EC (1.5) to ECe	17
4.1	Sieve analysis result for Bida natural stones	35
4.2	Sieve analysis of fine aggregates	36
4.2.1	Specific gravity test on fine aggregates	37
4.2.2	Specific gravity test on BNS	38
4.3	Result of bulk density of fine aggregates, BNS	38
4.4.1	Moisture content test for fine aggregates	39
4.4.2	Moisture content test for Bida natural stones	39
4.5.1	Aggregate impact value test for BNS	40
4.7.1	Mechanical properties of fresh concrete	41
4.7.2	Chemical Analysis of fresh water and salt water	42
4.8.1	Mix ratio 1:1.5:3	43
4.8.2	Mix ratio 1:2 :4	43
4.8.3	Mix ratio 1:3:6	43

LIST OF FIGURES

Figure	Title	Page
4.9.1:	Compressive strength of sample at 7days curing	44
4.9.2:	Compressive strength of sample in 14days curing	44
4.9.3:	Comparison of compressive strength of sample at 21days curing	44
4.9.4:	Comparison of compressive strength of sample at 28days curing	44
4.9.5:	Compressive strength for mix ratio 1.1:5.3	45
4.9.6:	Compressive strength for mix ratio 1:2:4	45
4.9.7:	Compressive strength for mix ratio 1:3:6	45

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Concrete is a mixture of cement, water and aggregates in a given proportions. Aggregates represent some 60-80% of the concrete volume. They are inert grains bound together by means of a binder which is cement. Although inert, they introduce an important contribution to these major characteristics which make concrete the most favoured building material. Aggregates help to reduce shrinkage and heat dissipation during hardening and also contribute to the increase in the mechanical strength of concrete. Depending on the mix, cement generally represents about 12-14% of concrete weight. It plays an active part in the mixture by ensuring cohesion between aggregate grains and, in doing so, it introduces a decisive contribution to concrete mechanical strengths. During the hardening process, due to it heat dissipation it could lead to shrinkage and cracking (Malhotra, 1988). Water occupies 6-8% of the composition of fresh concrete also depending on the mix. It provides for cement hydration and for the workability of the fresh concrete mixture. When in excess, it determinately affects concrete porosity and mechanical strengths (Mbadike and Elinwa,2011).

On average, seawater in the world's oceans has a salinity of about 3.5% (35 g/L). This means that every kilogram (roughly one litre by volume) of seawater has approximately 35 grams of dissolved salts (predominantly sodium (Na^+) and chloride (Cl^-) ions). It was reported that the use of sea water for mixing concrete does not reduce the strength of concrete although it may lead to corrosion of reinforcement in certain cases. Research workers are unanimous in their opinion, that sea water can be used in un-reinforced concrete or mass concrete, sea water slightly accelerates the early strength of concrete (Fred, 2020).

Granite, limestone, sand stone, or basaltic rock re crushed for use principally as concrete aggregate or road stone. Thus, this research intends to determine the effect of 'salt water' on hardened concrete using Bida natural stones (BNS) as coarse aggregate.

1.2 Statement of the Research Problem

About 75 percent of the surface of the earth is covered by oceans; therefore, a large number of structures are exposed to Salt water with high salinity either directly, or indirectly. As a result, several coastal and offshore sea structures are exposed to the continuous action of physical and chemical deterioration processes (Modupeola and Olutoge,2014).

The planet earth is experiencing noticeable shortage of pure clean water sources for future construction work and the use of water containing salt to develop durable concrete of lasting performance will be greatly beneficial if looked into properly (Falah, 2010).

Only 2.5 Percent of the world's water bodies is said to be fresh water, the remaining constitute seawater (Adebakin, 2003). This challenge of building and maintaining durable concrete structures in coastal environs have long become a serious issue to the people living in this areas and this provides an excellent opportunity to understand the complexity of concrete durability problems in these areas.

1.3 Aim and Objectives of the Study

The aim of this research is to determine the effect of salt water on concrete made using Bida Natural Stones as coarse Aggregates.

The objectives of the research are to;

i. Determine the physical and mechanical properties of the Aggregates.
ii. Determine the effect of salt water at 35g/L on concrete

iii. Determine the workability of fresh concrete using fresh water and salt water for casting.
iv. Determine the Compressive strength of concrete produced using Bida Natural Stones, at 7, 14, 21 and 28 days of curing using salt water at 35g/L.

1.4 Justification of the Study

Crushed stones are available in some parts of Nigeria, like Abuja and are transported to other places like Bida and its environs. This increases haulage distance. Bida natural stones are abundantly available in Bida areas. These aggregates are cheaper than crushed granite and have been proved with laboratory evidence that the aggregate is suitable (Alhaji, 2016).

The planet earth is experiencing noticeable shortage of pure clean water sources for future construction work and the use of water containing salt to develop durable concrete of lasting performance will be greatly beneficial if looked into properly (Falah, 2010). Hence this research work seeks to determine the effect of salt water on concrete as substitute for ordinary water.

1.5 Scope of the study

The scope of this research covers the collection of materials, determination of physical and mechanical properties of the aggregate which includes, determination of Moisture content, Bulk density, Specific gravity, Sieve analysis, Aggregates Impact Value (AIV), Aggregates Crushing Value (ACV); mixing salt and water to form salt water (sea water)in the production of concrete specimen using 150mm x 150mm x 150mm cube. It also includes the determination of workability of fresh concrete and lastly, the determination of compressive strength of the concrete cubes after 7, 14, 21 and 28 days curing using salt water at 35g/L and ordinary water.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concrete and its Constituents

2.1.1 Concrete

Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to arrive at a particular strength. The cement and water react together chemically to form a paste, which binds the aggregate particles together. The mixture sets into a rock-like solid mass, which has considerable compressive strength but little resistance in tension.

Concrete has tremendous versatility because of its initial fluid state. It may be poured into a mould, and it is compacted by vibration or ramming to entrapped air. The mixture sets within a few hours for the mould or formwork to be removed. It is ideal for use in foundation where the load that is to be carried is wholly compressive. But in bending, tension could develop at low loads. The lack of resistance to overcome tensile strength is overcome by providing steel bars at appropriate places. The resulting composite structure is called reinforced concrete. In heterogeneous materials like concrete, quality of the constituent proportions in which they are mixed determine the strength and properties of the resulting products. A good knowledge of the properties of cement, aggregates and water is required in understanding the behaviour of concrete. In ordinary structural concrete, the aggregates occupy about 70% to 75% of the volume of the hardened mass (Olufemi and Manasseh, 2009).

Good quality concrete is a very durable material and should remain maintenance free for many years when it has been properly designed for the service conditions and properly placed through choice of aggregates or control of paste chemistry and microstructure.

Concrete can be made inherently resistant to physical attack, such as from cycles of freezing and thawing or from abrasion and from chemical attack, such as from dissolved sulfates or acids attacking the paste matrix or from highly alkaline pore solutions attacking certain aggregates. Judicious use of mineral admixtures greatly enhances the durability of concrete. Unlike structural steel, it does not require protective coatings except in very corrosive environments. It is also an excellent material for fire resistance. Although it can be severely damaged by exposure to high temperatures, it can maintain its structural integrity for a considerable period—long after steel buildings would have suffered irreparable damage. However, concrete does have weaknesses that limit its use in certain applications. Concrete is a brittle material with very low tensile strength. Thus, concrete is generally not loaded in tension and reinforcing steel (Osei, 2000).

2.1.2 Aggregates

According to Gambhir (1994), in his publication on evaluation of the effects of coarse aggregate sizes on concrete quality said the work was necessitated by the observations made at construction sites where artisans and craftsmen were left alone in concrete production. It was discovered that they used inadequate quantity and size of coarse aggregates due to difficulty associated in the mixing as if the coarse aggregates were not needed in concrete production. The research has established that the coarse aggregates and their sizes play critical roles in the development of adequate strength in concrete. It was observed that with proper mixing, the slump test results did not witness shear or collapse type of slump rather there were true slump in all cases of the test. The workability decreased with slight differences when the coarse aggregate size was increased. The increase in the coarse aggregates yielded appreciable increase in the compressive strength. It can therefore be inferred that the quality of concrete in terms of strength can be enhanced through an increase in the coarse aggregate size when proper

mix ratio, batching, mixing, transporting, placing and finishing's are employed in concrete productions.

2.1.3 Cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. There are two main forms of cement: Geopolymer cement and Portland cement. Cement is seldom used on its own, but rather to bind sand and gravel aggregate together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Cement is the most widely used material in existence and is only behind water as the planet's most-consumed resource. Cements used in construction are usually inorganic, often lime or calcium silicate based, and can be characterized as either; hydraulic or non-hydraulic, depending on the ability of the cement to set in the presence of water.

Non-hydraulic cement does not set in wet conditions or under water. Rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

Hydraulic cements (for Portland cement) set and become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet conditions or under water and further protects the hardened material from chemical attack. The chemical process for hydraulic cement found by ancient Romans used volcanic ash (pozzolana) with added lime (calcium oxide).

The word "cement" can be traced back to the Roman term opus caementicium, used to describe masonry resembling modern concrete that was made from crushed rock

with burnt lime as binder. The volcanic ash and pulverized brick supplements that were added to the burnt lime, to obtain a hydraulic binder, were later referred to as cementum, cimentum, cäment, and cement. In modern times, organic polymers are sometimes used as cements in concrete.

Hydraulic cement hardens by hydration of the clinker minerals when water is added. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main mineral phases of the clinker, abbreviated in the cement chemist notation (Shetty, 2009)

C3S: Alite ($3CaO \cdot SiO_2$);

C2S: Belite ($2CaO \cdot SiO_2$);

C3A:Tricalcium aluminate($3CaO \cdot Al_2O_3$)historically called 'celite';

C4AF: Brownmillerite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$).

The silicates are responsible for the cement's mechanical properties while the tricalcium aluminate and brownmillerite are essential for the formation of the liquid phase during the sintering (firing) process of clinker at high temperature in the kiln. The chemistry of these reactions is not completely clear and is still the object of research.

Torres *et al*, (2008) conducted a research on Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars.

Sugar cane bagasse ash (SCBA) was generated as a combustion by-product from boilers of sugar and alcohol factories. Composed mainly of silica, this by-product can be used as a mineral admixture in mortar and concrete. Several studies have shown that the use of SCBA as partial Portland cement replacement can improve some properties of cementitious materials. However, it is not yet clear if these improvements are associated

to physical or chemical effects. This work investigates the pozzolanic and filler effects of a residual SCBA in mortars.

The aim of their research is to verify the influence of secondary energy products and their relative proportions in the mixture (granular and fluid fly ashes produced by power plants, steel plant dust) to the resulting rheological properties of the mixture. The same time it was observed their effect on the development of tensile strength and compressive strength in different times and after freeze-thaw cycles (Torres *et al.,* 2014).

SCBA as cement replacement, the actual mechanisms that are responsible for these are not yet understood. It is not clear if the advantageous use of SCBA is due to physical or chemical effects. This difficulty is partially due to the fact that both effects are coupled to influence the results from most commonly used evaluation methods. For instance, if the particle size distribution of the SCBA is refined it can increase the packing density of the mixture as well as the chemical reactivity of the ash due to the increase in the specific surface area. The present study aims to evaluate the chemical and physical effects of a residual SCBA on the properties of cement mortars. At first, the influence of SCBA particle size distribution on the compressive strength, pozzolanic activity indices, Chapelle test result and packing density is investigated. In this case, the effect of cement dilution is maintained constant; however, the chemical and physical effects are distinct for different SCBAs. In the final part of the paper, the aim is to compare the performance of mortars containing SCBA and crushed quartz (CQ) – considered as an insoluble or low-reactivity material – with the same packing density. Under these conditions the physical effect of both mortars is approximately equalized and the actual pozzolanic activity of SCBA can be estimated (Papesch *et al*., 2017).

Grinding of SCBA was carried out in vibratory and tumbling mill, whereas CQ was processed by tumbling grinding. A mill manufactured by Aulmann and Beckschulte

Maschininfabrik (Germany) was used for vibratory grinding, which was carried out in batch mode, simulating continuous open circuit operation with grinding times varying from 8 to 240 min. Tumbling grinding simulating closed circuit operation with classification was performed for processing of SCBA and CQ with nearly identical particle size distributions. In this case, a tumbling mill was used with a bowl rotation speed of 70 rpm and 20% filling of steel balls as grinding media. The grinding products were classified by dry sieving (sieve size 45 lm) using a rotational and tapping shaker (Ro-Tap shaker). After sieving, the coarse material returned to the mill, which was filled with SCBA to maintain the constant feed. This set-up used in the grinding tests allowed a close control of product size distribution (Papesch *et al*., 2017).

The results from the investigation of the physical and pozzolanic effects of SCBA on the mortar properties were thus concluded as follows;

A direct relationship exists between the compressive strength of mortar containing SCBA and the Blaine fineness of the ash. On the other hand, the compressive strength of mortar containing SCBA is inversely proportional to SCBA's particle size. According to the investigation of the SCBAs produced by vibratory grinding, the finest SCBA provided the highest packing density of mortar, which generated a higher compressive strength and pozzolanic activity. Moreover, a clear correlation was observed between Chapelle reactivity and fineness of SCBA (Cordeiro *et al*, 2017).

The pozzolanic activity of SCBA was established from the comparison with an insoluble material at the same packing density. In that case, a different behavior was verified in relation to compressive strength of mortars produced with the mineral admixtures, SCBA and quartz. After 28 days of curing, the compressive strength of SCBA mortar was 31% higher than the strength of CQ-T mixture. This discrepancy was

also observed in pozzolanic activity, mechanical response, as well as in results from the modified Chapelle method. Thus, the results suggested that the SCBA presents physico-chemical properties appropriate for its use as mineral admixture and its reactivity was mainly dependent on particle size and fineness (Cordeiro *et al*, 2017).

2.2 Setting time

Machado *et al*, (2010) postulated that researched on the Effect of additives on the compressive strength and setting time of a Portland cement and said, Improvements in strength and setting time of Portland cements (PC) are needed to enhance their performance as endodontic and load bearing materials. This study sought to enhance the compressive strength and setting time of a PC by adding one of the following additives: 20% and 30% poly-methylmethacrylate (PMMA), 20% and 30% irregular and spherical amalgam alloys, and 10% CaCl2. The control consisted of unreinforced PC specimens. Setting time was determined using a Gillmore apparatus according to standardized methods while compressive strength was measured using a universal testing machine after 21 hours or 60 days of water storage

Setting time experiments used a total of 72 specimens (n = 6) which were prepared by carefully pouring the cements into cylindrical metal molds (10 mm diameter x 1 mm) according to standardized procedures. Two glass plates were then positioned at top and bottom of the molds to prevent post-setting expansion. Initial setting time was determined with a Gillmore apparatus one minute after mixing by applying a vertical load (190 g) on the surface of the specimens for 5 seconds. This process was repeated every 30 seconds. Final setting represented the time required from the starting point of mixing to the point when the indenter failed to penetrate the material with a load of 455g (Akinkurolere *et al*., 2007).

In conclusion, all experimental groups – CaCl2, 20% and 30% PMMAs and 20% and 30% irregular and spherical amalgam alloys – significantly reduced the setting time of the PC. Only the 30% spherical amalgam alloy additive yielded a significant increase in the compressive strength of the reinforced cements. Therefore, the addition of 30% spherical amalgam alloy may be recommended to strengthen and reduce setting time of PCs in future clinical applications.

Bazid and Bulent, (2002) presented a research on The Effect of Sugar On Setting-Time of Various Types of Cements. They revealed that the objective of the research is to investigate the influence of sugar s of different origins (Beet & Cane) on the setting times of cement pastes. Sugar is incorporated with three different types of cements under three different curing conditions (Temp. and R.Humidity). The test results revealed that, under normal curing conditions (Temp. = 220^0C & R.H.≅ 60%), the efficiency of sugar in retarding cement setting becomes higher with increasing sugar-content up to a certain limit. However, with further increase in sugar content, its retarding efficiency started to decrease, until at certain higher content it showed reverse effects (i.e, it accelerated the cement setting). Furthermore, sugar causes higher retardation when added a few minutes after the mixing of water and cement. At the end of the research, the following conclusions where reached.

Setting of cement was retarded by incorporation of sugar in cement under all conditions of curing. Consequently, setting-times were extended. The extension in setting-time was increasing with an increase in sugar content up to a certain limit (≅0.15%) and then started to drop with further increase in sugar content. Sugar accelerated the cement-setting when a higher sugar content (≥0.3%) was used. Relatively low retarding tendency was shown by sugar under the second and third curing conditions. 0.15% sugar-content acted as an Optimum Sugar Content for retarding the setting.

2.3 Strength of Concrete

The maximum load or stress a concrete could withstand is referred to as its strength. The potential strength of concrete is determined by the properties and composition of its embedded material. The compressive strength of concrete is commonly used in the construction industry for the purpose of specification and quality control. A primary function of all structures is to carry load or resist applied forces of whatever nature, other functions such as retention of fluids, or exclusion of water or other destructive agents may be involved too in order to maintain sonority of structure without failure or cranking tensile strength of special, importance, although its actual magnitude is relatively low, usually steel, reinforcement is provided to resist tensile forces. The proportion of water to cement determines the strength, the age of the concrete, the quality as well as the mix and shape of the specimen tested. A specimen tested for compressive strength will have a higher indicated strength if the specimen is dry before testing whereas flexural strength will be lower in a dry specimen, strength must be carefully planned, designed and controlled (Osei, 2000).

2.3.1 Compressive strength of concrete

The compressive strength of concretes constitutes one of its most significant and useful properties and is the most easily determined. The compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. Concrete strength of up to 80N/mm^2 can be achieved by selective use of the type of cement, mix proportions, method of compaction and curing conditions. Since the compressive strength constitutes an important and useful properties, it is used as a measure of overall quality of the concrete and thus as an indication of other properties relating to determination of durability (Akinsola *et al.*, (2012).

2.3.2 Tensile Strength

An important factor often considered in constructing or designing concrete road is its tensile strength. For instance, its flexural strength or modulus of tensile strength in building is utilized for distributing the concentrated loads over a wider area of road pavement. Concrete members are also required to withdraw tensile stress resulting from any restraints to contraction due to drying or temperature variation. Unlike metals, it is quite uneasy to measure concrete strength and as such indirect methods have been introduced to assess this property. Of these methods is the “split cylinder test” being the simplest and most popularly used. The tensile strength of concrete is usually taken to be below its compressive strength. This may vary, however depending on the method used for measuring tensile strength and type of concrete (Neville and Brook, 2002).

2.4 Salt water (Sea water)

A popular yard-stick to the suitability of water for mixing concrete is that, if water is fit for drinking, it is fit for making concrete. This does not appear to be a true statement for all conditions. Some water containing imparities may be suitable for other purpose, but not for the mixture of concrete.

Some specification requires that if the water is not obtained from source that has proven satisfactory, the strength of concrete or mortar made with questionable water should be compared with similar concrete or mortar made with pure water. Sea water has a salinity of about 3.5percent; in that, about 78% is sodium chloride and 15% is chloride and sulphate of magnesium.It is reported that the use of sea water for mixing concrete does not appreciably reduce the strength of concrete although it may lead to corrosion of reinforcement in certain cases.The purpose of the experiment is to prove the doubt of people whether or not if salt water has an effect on concrete (Mbadike and Elinwa, 2011).

About 80 percent of the surface of the earth are covered by oceans; therefore, a large number of structures are exposed to Salt water with high salinity either directly, or indirectly when winds carries Salt water spray up to a few miles inland from the coast. As a result, several coastal and offshore sea structures are exposed to the continuous action of physical and chemical deterioration processes. This challenge of building and maintaining durable concrete structures in coastal environs have long become a serious issue to the people living in this areas and this provides an excellent opportunity to understand the complexity of concrete durability problems in these areas. The crust and interior of the earth constitutes the main source of seas. Salinity, which is measured in terms of, dissolved materials per kilogram of sea water or equivalently parts per thousand, represents the total quantity of dissolved salt in seawater.

Uneke *et al,* (2018) opine that the world seawater in most cases has salinity of the range (34-35)% though the properties of water to dissolved salts tend to vary within the ocean, the major component ions are evenly distributed in ocean water in relatively constant proportion that accounts for the defects and failures of buildings located in coastal areas.

2.4.1 Chemical action of sea water on concrete

According to Uneke *et al,* (2018) the chemical action of seawater on concrete is mainly due to attack by magnesium sulphate ($MgSO_4$). This is worsened by the chloride present in the seawater which retards the swelling that usually characterize the attack by sulphates in seawater which becomes whitish in appearance, more severe attack subjects the set concrete to expansion which leads to spalling and cracking. Finally, the concrete becomes liable and is reduced to soft mud. At first, the strength of the concrete tends to increase during the early stage of attack, but later followed by loss of strength that

preceded the resulted expansion. It is equally claimed that potassium and magnesium sulphates (KS, MgS) present in salt water can cause sulphate attack in concrete since they readily react with calcium hydroxide ($Ca(OH)_2$) present in the set cement through the hydration of C_3S and C_2S as depicted below (Bryant, 1964).

S + CH + 2H CSh_2 + KH

S + CH + 2H – CSH_2 + MH

Where K – KO and M – MgO

The attack by magnesium sulphate (MgS) is quite demanding as it forms sparing soluble magnesium hydroxide that forces the reaction to the right forming gypsum, MgS will equally react with the Calcium Sulphate (CSH) gel together with that produced by the reaction of magnesium sulphate while calcium hydroxide combine with silica hydrate (S^M) produced by the reaction with cementation gels to form non cementations product (M_4SH_8). Table 2.1 present major ion composition of sea water

Table 2.1 Major ion composition of sea water

	Common name	Ions	(g)
a)	Sodium	Na	10360
b)	Magnesium	Mg++	1.294
c)	Calcium	Ca++	0.413
d)	Potassium	K+	0.387
e)	Strontium	Sr++	0.008
f)	Chloride	Cl-	19.353
g)	Sulphate	SO42-	2.712
h)	Bromide	Br-	0.008
i)	Boron	N3B3	0.001
j)	Bicarbonate	HCO3-	0.142
k)	Fluoride	F-	0.001

Source: Laboratory analysis (2009)

2.4.3 Salinity measurement

Preeti *et al*. (2014) described fresh water as that purified expanse of water, which is devoid of any form of impurities, whereas, seawater is considered as water containing high percentage of Sodium chloride. Only 2.5 Percent of the world's water bodies is said to be fresh water, the remaining constitute seawater.

The electrical conductivity (EC) of the soil in decisiemens per meter (ds/m) is a measure of determining the salinity level at site. It is worthy to note that a salinity level of I ds/m is approximately equal to a total soluble salt level of 640ppm or 640mg/L. The technique involves measuring the current between two electrodes while allowing sufficient water to dissolve the salts.

The Table 2.2 gives a broad definition of salinity classes and their effects on vegetation I'C value of 4ds/m is assigned or regarded to be division between a non saline and saline soil. Thus, to give some perspective to the values, the maximum limit for human drinking water is a KC value of 2.5ds/m, while the I'C value of the Pacific Ocean is approximately 59ds/m. It is worthy to note that the classification in the tabular form below of salinity on agricultural crops is equally considered a reasonable classification for salinity in urban centres.

Some of the factors connecting EC to ECe and their multiplication factors and their soil texture group

Table 2.2 Factors for connecting EC (1.5) to ECe

	Soil texture group	Multiplication Factors
a)	Sands	17
b)	Sands loams	14
c)	Loams	10
d)	Clay loams	9
e)	Light clays	8.5
f)	Light Medium clays	8
g)	Medium clays	7
h)	Heavy clays	6

Source: (Lindohlm, 2009)

2.4.6 Some Consequences of the use of saline water as mixing water or curing water

Saline water actually increases the risk of corrosion of embedded reinforcing steel, if the structure is to be exposed to air service. Corrosion is promoted by the salt entering concrete through mixing or curing water. This chloride reduces the pH value and the salt collected in different concentrations in the free water contained in the concrete. Formation of self cells make it impossible to completely put an end to galvanic action because the anodes and cathodes may be switched in an attempts are made to repair the deteriorated concrete. However, seawater has been used on an installation in pacific island when fresh water was scarce. Its usage results in a gain in strength, lower values of water vapour transmission, and accelerated sets Akinsola *et al.* (2012).

2.4.7 Salinity and compressive strength of concrete

The most commonly considered valuable property of concrete is its compressive strength, although in many practical cases, other characteristics such as durability, impermeability, volume and stability may in fact be more important. Yet, the overall picture of the quality of concrete is usually provided by its compressive strength. Obviously, water satisfactorily used for mixing is as well suitable for curing purpose. However, there are some conditions of curing concrete for coastal structures that often occur and required special consideration. When concrete is cured with seawater it required maintaining moist environment by sealing materials, use of water, sprays, steam or saturated cover materials, all must be kept continuously wet. Indeed, salt water has been used for curing important structure in the past, recent research concerning salt-cell formation and galvanic corrosion of the reinforcing steel indicates that only fresh water is professionally used in curing concrete (Mbadike and Elinwa, 2011).

Previous investigations and researches carried out regarding the effect of salt water on the compressive strength of concrete either as mixing or curing water or even both, has over the time produced undependable outcomes which shows contradictions in the final result. The reports of the past studies revealed that when saline water is used as mixing water, the strength of concrete decrease, while recent studies indicated increasing strength. Even though the aggregate only undergoes little changes. There is the possibility that the changing chemistry and or the grinding of cement may be responsible so that the small differences in properties often observed could not be treated in a statistical fashion thus compounding the uncertainty of the action off salt.

Bryant (1964) carried out an experiment to determine the effect of ocean salts on compressive strength of concrete cast and cured with salt water. Hence they observed among other things that there were varying percentage increment in strength gained

after 28 days depending on the cement brand and possible sea salt (NaCl, $MgCl_2$, Na_2SO_4, or $CaCl_2$). They also observed that some chemical processes or reaction must have taken place. From this inconclusive experimental report, it was recommended that further test are needed. From the conclusion of the study, it was suggested that further research is needed to investigate the basic mechanism involve, and ascertain the influence and importance of such salts so as to monitor the strength at different ages and to investigate the effects of salt upon the other important characteristic of concrete such as shrinkage, creep etc and after the construction of building.

2.5 Effects of Salt on Concrete

As said earlier, the direct action of soluble salts results in salt attack, while the problems associated with salinity are often regarded to simply as salt damp, it is important to note that there exist many different salts that can be present, each possessing a different deterioration mechanism in terms of concrete. Since the usual test for salinity is the electrical total conductivity test which measures only the total soluble salt, it provides not an indication as to which types are present by knowing the composition of salts present, but precise assessment of the salt attack mechanism and durability requirements of concrete elements can be made and more effective salinity management strategies are implemented. Salt attacks on concrete can be in the following ways (Osei, 2000).

1. Physical attack
2. Chemical attack
3. Corrosion of reinforcement

2.5.1 Physical attack

Entrance of soil moisture into the concrete leads to rising damp and crystallization of salts (both chlorides and sulphates) as the water evaporates. Owing to the pressure

exerted by the crystallization process and the strength of the concrete, some disruption the concrete at the surface layer of the concrete may be softened and possibly fret away, exposing a fresh surface. Introduction of buried concrete elements prevents the exposure to attack of the fresh surfaces while the soften layer will typically slow down the rate at which further concrete will be attacked.

2.5.2 Chemical attack

Akinsola *et al.* (2012) stated that, alongside the chloride ions contained in saline ground water environments are naturally occurring sulphates of sodium, potassium, calcium or magnesium. At certain concentrations, these sulphates can chemically attack the concrete. The severity of the attack will depend on the types of sulphate present, their concentration, and movement of groundwater, pressure, temperature and the pressure of other ions, potential sources source include:

a) Groundwater containing dissolved sulphate

b) Dissolved sulphate formed from oxidation of sulphide minerals in the ground

c) Sulphate from back fills of coal ash or coal washers reject

Sulphate attack typically involves a reaction between the sulphate and constituents of the concrete to form products. The resulting swelling within the concrete leads to cracking which in turn allows easier access for further penetration of aggressive elements thus leading to further deteriorating. Attack from calcium, sodium and potassium sulphate is classified as “moderate’’ while magnesium and ammonium sulphate are potentially more severe in their action. This is because they attack a greater number of the concrete constituents.

2.6 Mix Design

The Department of Environment (DOE) method: This method of concrete design was first introduced in 1950, under the name " Road Note No 4", which was later replaced by "Design of Normal Concrete Mixes" in 1975 by the British Department of Environment (DOE). The design guidance was updated in 1988 to account for changes in the then current British Standard and is still used today, often being referred to as the British Standard concrete mix design.

The DOE method of concrete mix design works by calculating the values of eight (8) fundamental processes namely;

1. Mean target compressive strength
2. Water/Cement ratio
3. Water content using required slump value and aggregate size
4. Cement content
5. Concrete density
6. Aggregate content
7. Proportion of fine & coarse aggregates
8. Coarse aggregate.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The materials used for this research work are as follows;

3.1.1 Ordinary Portland cement

The cement was purchased from the cement stores at Gidan Kwano directly opposite the Federal University of Technology Minna, Niger State Nigeria School gate, where cement is kept on a raised platform and adequately protected from external damage by weather. The cement refer to in this work is the ordinary Portland cement (Dangote cement) produced in accordance with NIS 87: Part 1.(2004)

3.1.2 Sand

The sand was collected from Gidan mangoro, Minna, Niger state and was cleaned and sieved to be sure is free from dirt's or organic matters and also conforms to the grading requirement BS 882:(1987). Sand is a fine aggregate resulting from the natural disintegration of rocks. Where by fine aggregate means aggregate passing through sieve size 4.76mm BS 410 (2000). Aggregate should be hard and clean; it should be free from organic impurities. The presence of organic materials in aggregates results into poor concrete. In order to produce concrete of good quality, it is necessary that the sand should posses certain characteristics; firstly it is required that the compressive strength of the aggregate should at least equal to that developed by the cement paste which binds the particle together. In determining the performance characteristics of the aggregates as regards their suitability for concrete making, the major parameters considered are; particle size or grading, water content, texture distributions.

3.1.3 Water

Portable drinking water was used throughout this work; the water was clean, free from deleterious materials and fit for drinking as recommended by NIS 87: 2004. Water is necessary ingredient for concrete making because it is in it that all the other ingredients (cement, fine and quarry dust) are mixed together. The quality and quantity of water are of tremendous important both in the production process and in the development of strength in concrete.

3.1.4 Bida natural stones (BNS)

Natural Stones (NS) is reddish brown in color and predominantly round in shape. It also consists of pebbles and cross stratified sand stones. It was collected in Bida town, washed, dried and sieved to obtain maximum sizes of 20mm that was used for the experiment

3.2 Methods

The methodology employed for this research work includes the review of related relevant literatures that covers published materials especially journals and past thesis for historical data-based information and internet for new discoveries that have direct bearing on this study. The concrete specimen tested is 150mm x150mm x 150mm concrete cubes in accordance to specification (BS 1881: Part 108:1983).

The following tests were carried out on the aggregates used in order to determine their properties.

i. Specific gravity test
ii. Sieve analysis test
iii. Bulk density
iv. Moisture Content

v. Aggregate Impact Value

3.2.1 Specific gravity Test

Specific gravity is the ratio of mass of a unit volume of material to the mass of the same volume of water at the stated temperature. Equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume.

The specific gravity is tested in accordance to (ASTM:D7127-14). The whole reading was recorded and used in the specific gravity of the aggregate. The Equation (3.1) was used in determining the specific gravity of all other samples.

Specific Gravity = $W_2 - W_1 / (W_2 - W_1) - (W_3 - W_4)$ (3.1)

Where

W_1= Weight of cylinder

W_2= Weight of cylinder + sample

W_3= Weight of cylinder + sample + water

W_4= Weight of cylinder + water

3.2.2 Sieve analysis

In practice, each fraction contains particles between the openings of the standard test sieves. Test sieves used for concrete aggregates have square openings and described by the size of the openings in millimeter (mm) for larger size and by the number of openings per lineal centimeter (cm) for sieve smaller than 3.0mm. Coarser test sieves (4.0mm and larger) are made of wire cloth. The screening area in this case varies between 34-53% of the gross area of the sieve. The sieves used for concrete aggregate consist of a series in which the clear opening of any sieve is approximately one half of the opening of the next larger sieve sizes. Sieve analysis can simply be described in the process of dividing a sample of aggregate into fraction of same particle size. It is used in defining or determining aggregate grinding.

Test procedure

By coarse aggregate, we mean an aggregate retained on a 12mm BS 812:Part103 (1989). They are mostly used in the production of normal dense concrete. For the purpose of this research work the coarse aggregate used is brick. By fine aggregate, we mean aggregate mainly passing 5mm square mesh. The fine aggregate used in this research work is sand. The sieves was thoroughly cleared and weighted individually on an electronic weighing balance, the set of sieve were arranged according to their size in descending order from maximum mesh opening to the minimum opening with a pan at the bottom. The sample used was weighted and then poured into the topmost sieve of the set of the sieves. The set of sieves with sample shaken manually with hand for fifteen minute because of absence of mechanical shaker in the lab, after which the sieve was removed from the shake and weighed. The weight of samples retained on them after the shaken was determined by subtracting the weight of sieves form the weight of sieve plus sample retained on the sieve.

3.2.3 Bulk density test

It is a property of a particular material. It is the mass of a particle of the material divided by the volume occupied. The volume included the space between the particles as well as the space inside the pores of individual particles. Bulk density can change depending on how the material is handled. For example, grain poured in a cylinder would have a particular bulk density, if the cylinder is disturbed, the grain particle will move and settle closer together resulting in a higher density.

Test Procedure

a) Compacted bulk density:

The sample divider was weighed and recorded as M_1. It was then filled to 1/4 of its volume and tamped 25 times by using a tamping rod. It was again filled with the same amount of aggregate and also tamped 25 times, the sample divider was filled with the same aggregate to the brim of the sample divider and tamped 25 times, the surplus aggregate was removed carefully.in accordance to IS 2386 : (Part 4) 1963

The weight of the divider with sample was weighed and the bulk density calculated, thus;

Bulk density; $\rho = \frac{M}{V}$ (3.2)

Where M is the weight of sample,

The weight of sample (M) is determined from Equation (3.2)

Where,

weight of sample divider = M_1

Weight of sample divider + sample =M_2

Then weight of sample = M = (M_2−M_1) (3.3)

b) Un-compacted bulk density:

The sample divider was weighed empty and recorded as M_1. The sample divider was filled using a scoop, the surface was then leveled with a straightedge, the sample divider

and aggregate was weighed and the bulk density calculated.

The volume of the sample divider = $(L\ x\ b\ x\ h)$ (3.4)

Where:

L = length of sample divider = 11.3cm

B= breadth of sample divider = 4.55cm

H = height of sample divide = 4.5cm

3.2.4 Moisture content

This is the process of determining the total, absorbed, and surface (free) moisture of aggregates to be used for internal curing of concrete. According to (Neville, 1987), moisture content is the amount of water in excess of the saturated and surface dry condition. Thus, the total water content of the moist aggregate is equal to the sum of absorption and moisture content. It is usually expressed in percentage. The moisture content is a very important index used for establishing the relationship between the soil behaviour and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil (Gupta, 2008)

Apparatus

a) Weighing Cans.

b) Electronic weighing balance.

c) Spatula

d) Electric oven (at 100^0C)

e) Tray

f) Gloves

Procedure

The weighing cans used were thoroughly cleaned with the aid of the brush. There initial weights were taken and recorded according to the label. The moist sample was placed in the weighing can with the aid of spatula. The corresponding weight of the can and moist sample was determined and recorded. The weighing can and moist sample was placed and left in the drying oven that is set at 105 °C overnight. The cans were carefully removed from the oven the following day with the help of the hand gloves and securely covered. It was allowed to cool to room temperature after which the weight of the can and dry sample was determined and recorded in accordance to BS 812-109:1990. This procedure was repeated two more times for the fine aggregates and three times each for the rest of the coarse aggregate sample (Gupta, 2008).

3.2.5 Aggregate impact value test

The aim of this test is to check the strength of aggregate and it's durability upon application of load, the following procedure was taken to realize this aim. The basic equipment here are the tamping rod, aggregate impact value machine, and sieves 10mm and 12.5mm.

Procedure

The aggregates are sieved through sieved using 12.5mm and retained at sieve 10mm; are taken and oven dried at 100-110^{o}c for 3-4hours. The aggregate impact cylindrical mould was weighed and then the mass was recorded as A. The mould was then filled with the coarse aggregate (crushed stone) in 3 consecutive layers, with each layer been subjected to tamping 25times before the subsequent one. After complete tamping, the mass of the mould + aggregate (crushed stone) was measured, B. then subtracting A from B yields C, which is weight of dry coarse aggregate (crushed stone) used. The sample was then placed on the aggregate impact value machine and hammered with 15blows. The cylinder is taken out and the crushed aggregates are sieved through IS

sieve 2.36mm and proportion that passed through it was weighed as mass of fraction passing sieve 2.36mm, D.

The aggregate impact value is estimated by (D/C * 100), as E.

This procedure was repeated again for second trial, after which an average was taken and evaluated as the aggregate impact value.In accordance to BS 812-112:1990

A= Mass of Cylinder

B= Mass of Cylinder + aggregate

C= Mass of Dry surface aggregate passing 12.5mm and retained on 10mm (B-A)

D= Mass of fraction passing sieve 2.36mm

E= Percentage Fines, which must be less than 45% for aggregates used for concrete for non-wearing surfaces and less than 25% for wearing surfaces like runways and roadways.

Note: the value is higher when more percentage of aggregates crush and break into smaller pieces which indicates the aggregates are of a lower quality.

3.3 Properties of Fresh Concrete

3.3.1 Workability of concrete

The slump test was used to estimate the degree of workability.

a) Slump test

This is a test that is used to determine the variations in the uniformity of a mix of given nominal proportions.

Test Procedure

The slump cone test should be cleaned and held firmly on a smooth surface with the small opening at the top. The slump cone test is filled with concrete in three layers and each layer tampered with 25 strokes with the 16mm tamping rod. The top surface of the slump cone was finished with the hand trowel and the cone was lifted gently. The

reduction in height of the unsupported concrete was then measure and recorded as the slump. In accordance to BS EN 12350-2:2019

3.4 Mean compressive strength

The target mean compressive strength was calculated using the following formulae

Fm = fc + (K x σ) where

Fc = characteristic strength

K = Risk Factor

Σ = Standard deviation

3.4.1 Water content

To calculate the required water content to achieve a suitable concrete workability, the following factors were used,

Slump Value (10mm – 30mm)

- Aggregate Size (20mm)

The values of these factors have been provided in the design requirements and can be found on table 3 of Appendix C.

3.4.2 Cement content

To calculate the amount of cement required, the following formula was used.

Cement content per m3 = Water Content per m3/ Free-water cement ratio

But the values of both water content and free-water cement ratio are known, so it is easily calculated

Cement content per m^3 = 190/0.58 = 328 kg/ m^3

3.4.5 Aggregate content

Using the fresh concrete density of 2440 kg/m^3, the aggregate content can be calculated using the following formula: Aggregate Content = Fresh Concrete density – (cement

content + Water content). These values have been obtained therefore, Aggregate Content = 2440 – (328 +190) = 1922 kg/m^3

3.4.6 Fine aggregate content

The proportion of fine aggregate in the concrete mix depends on the following

a)The grading of the sand

b)Maximum aggregate size

b)Workability of the concrete

d)Free-water/cement ratio

The proportion of the fine aggregate is obtained graphically as shown in figure 3 of Appendix E. By starting at 0.5, free-water/cement ratio axis and drawing a line vertically upwards to the percentage of fine aggregate passing through a 600μm sieve (57.1%). A horizontal line is then drawn to find the proportion of fine aggregate which is 28% as shown in figure 3 of Appendix E. Using the total aggregate content (1,922 kg/m^3), the proportion of fine aggregate can be calculated thus: 1,922 x 0.28 = 538 kg/m^3

3.4.7 Coarse aggregate content

Since the fine aggregate has been calculated, we simply deduct this value from the total aggregate content to determine the amount of coarse aggregate required. Given by

1922 – 538 = 1,384 kg/m^3

3.5 Estimation of Quantity of Materials required for Compressive strength test 150 x 150 x 150 mm (Cubes)

Number of Cubes required per experiment = 48 cubes

Volume of wet concrete per experiment = 0.15 x 0.15 x 0.15 x 48= 0.162m^3

Shrinkage Value = 1.54

Dry Volume of concrete = 1.54 x 0.04 = 0.06m^3

Mix ratio= 1: 2: 4, 1:3:6, 1:1.5:3

Density of Cement = 1440 Kg/m^3

Density of Fine Aggregate = 1662 Kg/m^3

Density of BNG = 1726 Kg/m^3

Weight of cement = 1/7 x 1440 x 0.06 = 12.34 Kg

Weight of Fine aggregate = 2/7 x 1662 x 0.06 = 28.49 Kg

Weight of BNS = 4/7 x 1726 x 0.06 = 59.18 Kg

3.5.1 Weight of Materials for Experiment for the different mix ratio used curing days 7,14,21 and 28 days for all mix ratio.

Total no of Cubes = 48

Mass of BNS = 113 Kg

Mass of Fine Aggregate = 58 Kg

Mass of Cement = 11 Kg

Mass of Water = 17 Kg

3.5.2 Weight of Materials for Experiment No 2 with Mix Ratio 1:2:4

Total no of Cubes = 48

Mass of BNS = 118 Kg

Mass of Fine Aggregate = 61 Kg

Mass of Cement = 26 Kg

Mass of Water = 13 Kg

3.5.3 Weight of Materials for Experiment No 3 with Mix Ratio 1:3:6

Total no of Cubes = 48

Mass of BNS = 124 Kg

Mass of Fine Aggregate = 64 Kg

Mass of Cement = 18 Kg

Mass of Water = 9 Kg

3.7 Preparation of Concrete

The concrete was prepared by mixing the various constituents manually. The aggregates was first spread in a uniform layer, Cement was then spread over the aggregates and the dry materials were mixed by turning it over and cutting with shovel until it appears uniform. The heaps of the dry material were then spread in a uniform layer; the required quantity of water was then added and mixed again thoroughly to achieve the final uniformity. Slump tests were carried out on the fresh concrete after the final uniformity was achieved and iron metal moulds were used for the casting of both cubes. The apparatus used includes; tray, iron metal moulds, hand towel, and shovel

3.8 Casting and Compaction of Concrete

Batching was done by weighing the materials for the concrete specimen using a manual Weighing Balance. Concrete mix ratio of 1:1.5:3,1:2:4 and 1:3:6 by weight of concrete and 0.6 water-cement ratio were used. Mixing was done manually on a clean concrete floor and the materials were thoroughly mixed in the dry state twice, after which water was added gradually while thoroughly mixing the concrete. Mixing of the concrete specimen continued by turning the mixture of cement, water and aggregates until the concrete was uniform in colour and consistency. The test cubes were cast inside steel mould of size 150x150x150(mm^3) with the mould and it's based clamped together. The inner part of the mould was smear with oil so as to enhance easy removal of the set concrete. The fresh concrete mix for each batch was fully compacted by tamping rods, to remove trapped air, which can reduce the strength of the concrete. A total of 144 concrete cubes of 150x150x150(mm^3) were cast and cured. The cubes from were

divided into 3 because of the 3 different mix ratios, 48 cubes for each mix ratio 1:1.5:3, 1:3:6 and 1:2:4 respectively. 24 cubes were cast in fresh water, 12 out of the 24 were cured in fresh water while the remaining cured with salt water for each of the mix ratios for 7, 14, 21 and 28 days respectively. The specimens were cured at room temperature in the curing tanks. Similar curing method was applied for concrete cast with Salt water using the same curing days and environmental conditions. The setting time was also determined using Vicat apparatus.

3.9 Curing of Concrete

The concrete cubes were de-molded after 24 hours of placing and transferred to the curing tank for a period of 7, 14, 21 and 28 days. The curing method adopted for the purpose of this research work is by placing the concrete cubes in hydration tank full of water to the brim, so as to keep the concrete cubes at saturated condition throughout the testing period.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Result of Preliminary Tests conducted on the Fine and Coarse Aggregates

The physico-chemical analyses were performed on fresh water and Salt water in order to determine their chemical constituents. Setting time of the cement and sieve analyses of the aggregates were carried out as well.

4.1.1 SIEVE ANALYSIS

The sieve analysis result conducted for the coarse and fine aggregates are presented in Tables 4.1 and 4.2

Table 4.1: Sieve Analysis Result for Bida Natural Stones (BNS)

Sieve sizes (mm)	Cumulative % Passing
20.00mm	100
14.00mm	73.56
10.00mm	41.19
6.30mm	7.16
5.00mm	1.82
3.35mm	0.33
Pan	0

Table 4.2: Sieve analysis of fine aggregates

Sieve sizes (mm)	Cumulative % Passing
5.00mm	99.74
3.35mm	98.94
2.36mm	97.06
2.00mm	95.12
1.18mm	85.68
850µm	75.56
600µm	57.14
425µm	34.9
300µm	24.1
150µm	2.94
75 µm	0.9
Pan	0

Finess Modulus = ∑ Cumulative % Retained/100 = 527.92/100 = 5.27

Sieve analysis result of coarse and fine Aggregate on Table 4.1 and 4.2 shows that percentage passing Seive 5.00mm, 3.35mm, 2.36mm, 2.00mm, 1.18mm, 850µm, 600µm, 425µm, 300µm, 150µm and 75µm was 99.74, 98.94, 97.06, 95.12, 85.68, 75.56, 57.14, 34.90, 24.10, 2.94 and 0.90 respectively. The Finess Modulus of 5.27 indicates that the average value of fine aggregate is in between the 5^{th} seive and the 6^{th} seive which shows that the average size of fine aggregate is in between 1.18mm and 850µm.

4.2 Specific Gravity Test

The specific gravity results conducted on the fine aggregate and coarse aggregate are presented in Tables 4.3 and 4.4

Table 4.3: Specific gravity test on fine aggregate

The specific gravity results conducted on the fine aggregate

Trial	Trial 1	Trial 2	Trial 3
Weight of cylinder (M_1)g	69.0	43.7	51.9
Weight of cylinder + sample (M_2)g	144.0	104.1	111.9
Weight of cylinder + water + sample (M_3)(g)	214.9	179.9	188.2
Weight of cylinder + water (M_4)(g)	168.2	142.3	150.7
Specific gravity = $\frac{m2-m1}{m4-m1)-(m3-m2)}$	2.65	2.60	2.67
Average specific gravity = $\frac{2.66+2.60+2.673}{3}$ = 2.64			

The specific gravity of an aggregate normally used in construction ranges from between 2.5 to 3.0 (Neville,2009). It is the mass cubic meter of the aggregate to the mass of the same volume of water. It depends on the mineral content of the aggregate and considered as an indication of strength. The average specific gravity obtain for the fine aggregate from Table 4.2.1 was 2.64 which is within the standard range of 2.5 – 3.0.tested according to BS EN 12620:Part 4 (2013).

Table 4.4: Specific gravity test on BNS

Trial	Trial 1	Trial 2	Trial 3
Weight of cylinder (M_1)g	155.4	116.6	148.8
Weight of cylinder + sample (M_2)g	342.6	293.0	363.2
Weight of cylinder + water + sample (M_3)(g)	588.1	462.9	617.3
Weight of cylinder + water (M_4)(g)	475.2	358.0	480.3
Specific gravity = $\frac{m2-m1}{(m4-m1)-(m3-m2)}$	1.05	1.56	1.87
Average specific gravity= $\frac{1.05+1.56+1.87}{3}$ =1.49			

The specific gravity results conducted on the coarse aggregate are presented in Tables 4.4 and 4.4 presents the result of specific gravity and average specific gravity of coarse aggregate (BNS) and fine aggregate

Table 4.5 shows the results of the Uncompacted and Compacted Bulk Density for Fine Aggregate, BNS

Table 4.5: Result of bulk density of fine aggregate, BNS

Materials Used	Uncompacted (kg/m^3)	Compacted (kg/m^3)	Ratio of uncompacted to compacted.
Fine Aggregate	1662	1754	0.95
Bida natural Stones	1726	1901	0.91

The ratios of uncompacted bulk density to compacted bulk density of Fine aggregate are 0.95, for BNS is 0.91. All the result obtained fell within the 0.87 and 0.96 standard as specified by Neville,(1990).

4.6 The moisture content results conducted on the fine aggregate and coarse aggregate are presented in Tables 4.6 and 4.7

Table 4.6: Moisture content test for fine aggregate

Trial		Trial 1	Trial 2	Trial 3
Weight of empty can	(M_1)g	29.8	24.3	25.7
Weight of can + sample	(M_2)g	161.7	167.4	155.9
Weight of can + dried sample	(M_3)g	135	140	130.3
		21.4	23.7	20.5

Moisture Content = $\frac{m2-m3}{m3-m1}$ x 100

Average moisture content = $\frac{21.4+23.4+20.5}{3}$ = 24.5%

Table 4.7: Moisture content test for bida natural stones.

		Trial 1	Trial 2	Trial 3
Weight of empty can	(M_1)g	50.1	60.9	51.2
Weight of can + sample	(M_2)g	287.2	327.5	306.3
Weight of can + dried sample	(M_3)g	283.9	319.9	300.3
		1.4	2.9	2.4

Moisture Content = $\frac{m2-m3}{m3-m1}$ x100

Table 4.6 and 4.7 presents the result of moisture content of coarse aggregate (BNS) and fine aggregate

4.1.5 Aggregate Impact Value (AIV)

The aggregate impact value(AIV) results conducted on the fine aggregate and coarse aggregate is presented in Table 4.8.

Table 4.8: Aggregate impact value test for BNS

Trial	Trial 1	Trial 2	Trial 3
Weight of aggregate impact mould (g)	2690	2690	2690
Weight of aggregate (g)	631	650	647
Weight of aggregate passing (2.36mm) (g)	96.5	89	92.2
Weight of aggregate retained (2.36mm) (g)	534.5	561	554.8
A.I.V = wt. Of aggregate passing / wt. Of aggregate × 100%	15.3	13.7	14.3
Average Aggregate Impact Value = (15.3 +13.7+ 14.3)/3 = 14.4%			

The aggregate impact value test is carried out to know the response of aggregates to different kinds of loads that the aggregates will be subjected to during their service life. It is the ability of aggregates that resist sudden impact or shock load on it.its in the required range.

4.6 Aggregate Characterization

Adebakin (2012) described fresh water as that purified expanse of water, which is devoid of any form of impurities, whereas, seawater is considered as water containing high percentage of Sodium chloride. Only 2.5 Percent of the world's water bodies is said to be fresh water, the remaining constitute seawater (salt water) (Akinkurolere *et al.,*2007). Seawater is water gotten from sea, which is salty in taste. Salt water can be said to have a solution containing a great number of elements in different proportions.

Primarily Salt water contains some chemical constituent such ions of chloride, magnesium, calcium and potassium Most seawater is fairly uniform in chemical composition, which is characterized by the presence of about 3.5 percent soluble salts by weight. On average, seawater in the world's oceans has a salinity of about 3.5% (35 g/L).This means that every kilogram (roughly one litre by volume) of seawater has approximately 35 grams of dissolved salts (predominantly sodium (Na^+) and chloride (Cl^-) ions) which makes the salt water.

The mechanical properties of fresh concrete results conducted on the concrete mixed with fresh water and salt water are presented in Tables 4.9

Table 4.9: Mechanical properties of fresh concrete

TEST	CFW	CSW
Slump(mm)	75	80
Initial Setting Time (mins)	35	35
Final Setting Time (mins)	280	280

CFW – Concrete mixed with fresh water

CSW – Concrete mixed with salt water

Table 4.10 shows increase value of setting time, which implies that concrete mix with Salt water is not susceptible to the problem of flash and false set. Also slump value reveals that it falls into the normal range of concrete.

Some of the chemical analysis of fresh water and salt water are as follows:

Table 4.10: Chemical Analysis of Fresh water and Salt water

TEST	FRESH WATER	SALT WATER
PH	7.0	7.8
Electrical Conductivity	1053 micro s/cm	57.9 Micro s/cm
Total dissolve solid	1490 mg/l	31200 mg/l
Chloride	220 mg/l	6000 mg/l
Nitrate	-	-
Hardness	246 mg/l	-
Calcium	62 mg/l	210.6 mg/l
Magnesium	28 mg/l	1644 mg/l
Acidity	-	-
Alkalinity	-	0.8 mg/l
Iron	-	0.14 mg/l
Sulphate	110 mg/l	1400 mg/l
Potassium	-	475 mg/l
Chromium	-	0.03 mg/l
Phosphate	-	1.10 mg/l
Salinity	-	32. 6 g/l
Total suspended solid	-	-
Total solid	-	-
Colour	-	Blue
Temperature	20 OC	32.6 OC

4.5 Compressive Strength Variation

4.8.1 The compressive strength of three different mix ratios, 1:1.5:3 ; 1.2.4 ; 1.3.6 in 7,14,21 and 28 days curing.

Table 4.11: Mix ratio 1:1.5:3

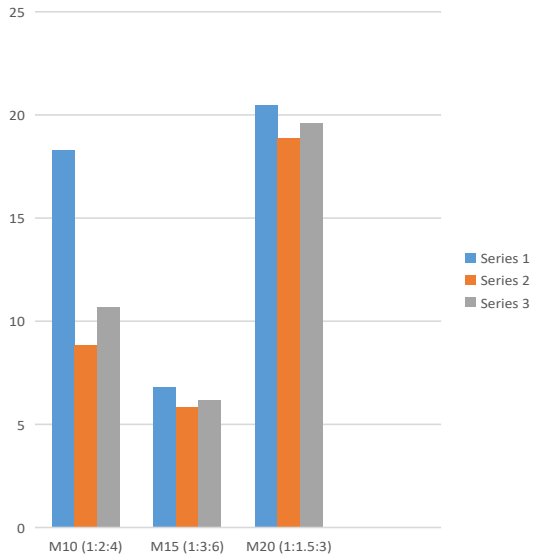
Concrete designation	7 days	14 days	21 days	28 days
Freshwater-freshwater (FF)	18.97	20.5	25.5	29.2
Freshwater-saltwater (FS)	20.47	23.8	23.7	28.0
Saltwater-freshwater (SF)	18.9	21.5	24.5	29.2
saltwater-saltwater (SS)	19.63	22.67	26.8	30.1

Table 4.12: Mix ratio 1:2:4

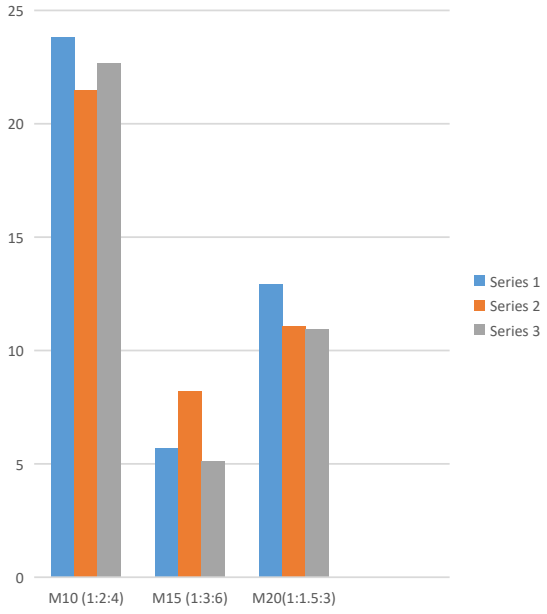
Concrete designation	7 days	14 days	21 days	28 days
Freshwater-freshwater (FF)	6.9	5.3	6.5	8.4
Freshwater-saltwater (FS)	6.8	5.7	6.1	8.6
Saltwater-freshwater (SF)	5.84	8.2	7.5	7.9
saltwater-saltwater (SS)	6.2	5.1	6.0	6.9

Table 4.13: Mix ratio 1:3:6

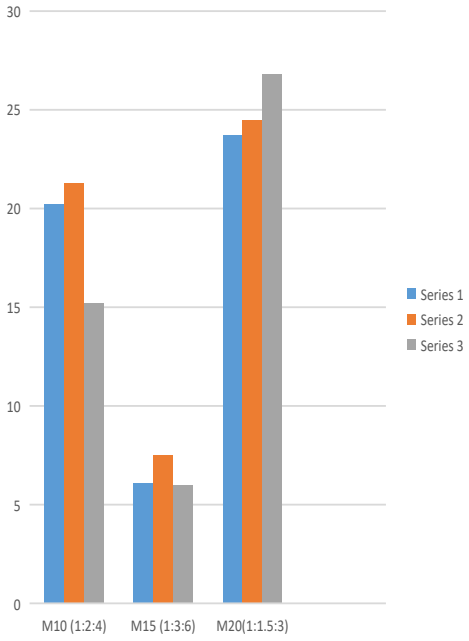
Concrete designation	7 days	14 days	21 days	28 days
Freshwater-freshwater (FF)	18.27	17.8	18.0	21.2
Freshwater-saltwater (FS)	18.3	12.9	20.2	23.0
Saltwater-freshwater (SF)	8.87	11.06	21.3	22.7
saltwater-saltwater (SS)	10.7	10.93	15.2	17.2



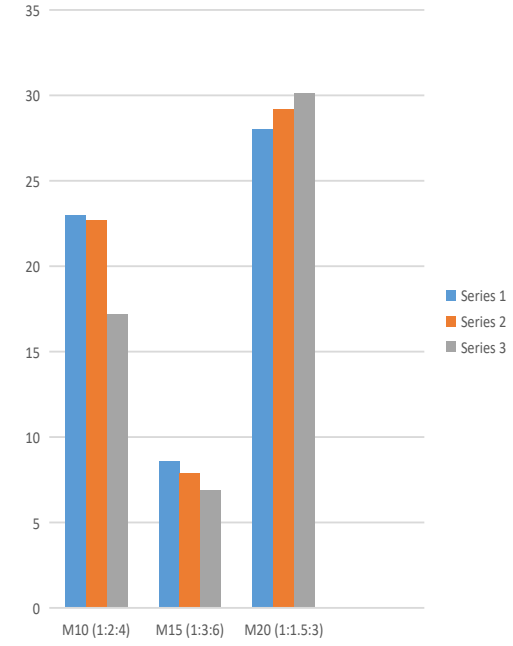
a) 7days curing



b) 14days curing



c) 21days curing



d) 28days curing

Compressive strength of sample for mix ratio 1.1:5.3 ,1.2.4 ,1.3.6 and curing in 7,14,21,28 days.

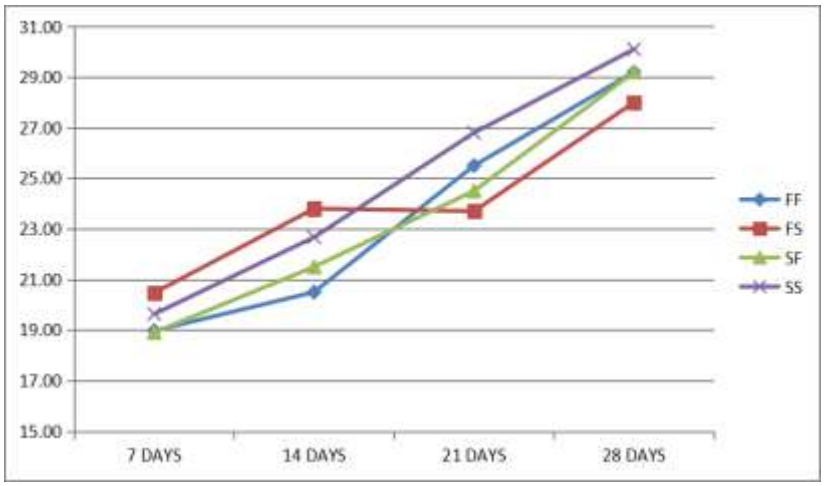


Figure 4.2: Mix ratio 1.1:5.3

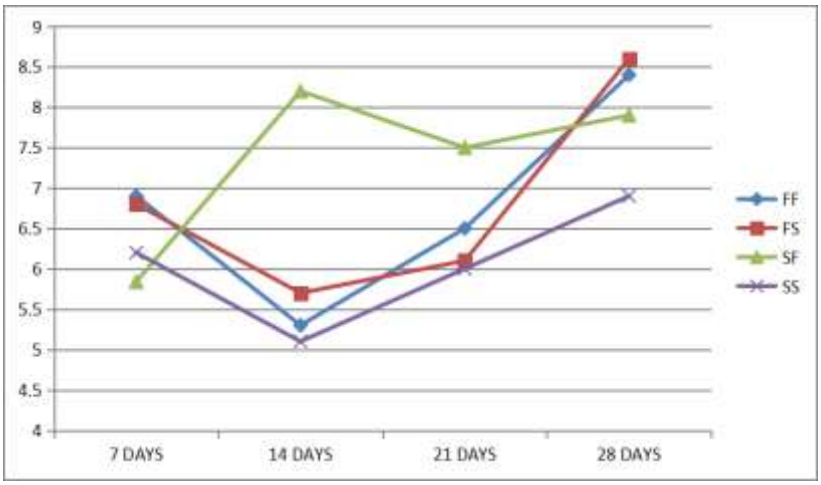


Figure 4.3: Mix ratio 1.2.4

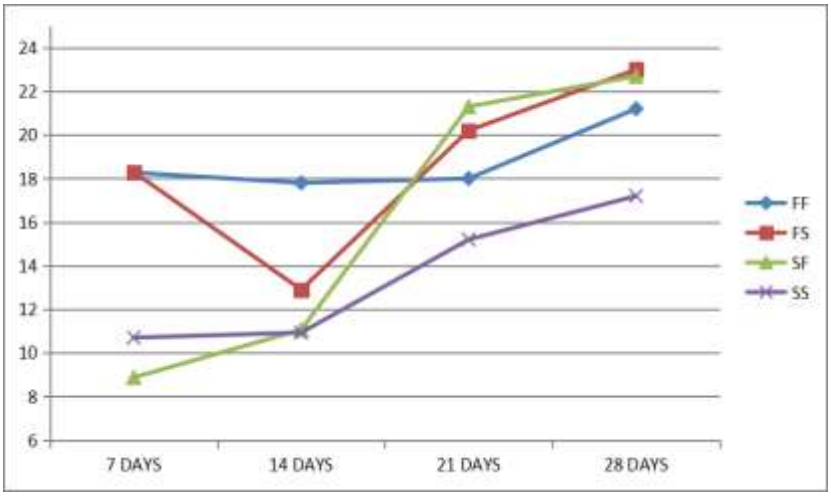


Figure 4.4: Mix ratio 1.3.6

Compressive strength of sample of mix ratio 1.1:5.3 ,1.2.4 ,1.3.6 and curing in 7,14,21,28 days.

The various compressive strength of mix ratio 1.1:5.3 ,1.2.4 ,1.3.6 are represented in bar chart and line graph (4.9.1) ,(4.9.2) ,(4.9.3) ,(4.9.4) ,(4.9.5) ,(4.9.6) ,(4.9.7) shows the variation and comparison of the compressive strength attained in 7,14,21,28 days curing. Also, there is an appreciable increase in strength at 7 days for concrete designations SF, FS and SS respectively which when compared with the FF control batches which has a lower strength at the early stage. Also, at 14th days all batches recorded an increase in strength, while the rate of the increase in FF, SS, SF batches higher than that of FS batches. At 21 days the rate of strength gained was also increasing proportionally as compared with control batches, but with a slight decrease in strength gain in FS batches. At 28 days, the rate of strength gain increased for all batches; while the compressive strength of SS batches was more than the control i.e. FF batches at 28 days. The batches recorded its maximum strength with more than 90% of the strength reached at 28 days.

It was observed that concrete cast and cured with saltwater increases gradually for all curing days beyond the strength of control cast (FF). The compressive strength of concrete batches FF agrees with the value of the compressive strength of 1:2:4 mix at 28 days, of about 20 N/mm^{2}.The strength of concrete batches cast with salt water and cured with fresh water (SF) was also observed to have increased even at 21days and 28 days respectively.

In practice, the fresh-fresh water situations occur in building constructed on interlands and main lands while the fresh-salt water situations are mainly in structures or building close to lagoon or sea. The salt-fresh water situations are very rare in practice, but are well pronounced in areas where there is scarcity of fresh water or the available surface water is salty. The salt-salt water situations are visible mostly in structures built in ocean or sea. Finally, in case of reinforced or pre-stressed members, corrosion of embedded steel can be prevented by painting or coating the steel with cement slurry made with fresh water. In addition, higher concrete cover can be provided when designing the member (Neville, 2008).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Having carried out the investigation into effect of salt water on concrete made with BNS as coarse aggregate, the following conclusions were made based on the results obtained.

The mechanical and physical properties of material were tested to ascertain that it meet certain requirements and specific engineering properties, sieve analysis was found to be in the range 34-53, bulk density fell within 0.87 and 0.97, moisture content is about 24.5%, aggregate impact value (AIV) is 14.4%.

The effect of salt water at 35g/l was determined by the compressive strength of each mix ratio at different curing days. The strength of concrete cubes cast and cured in fresh water for all mix ratio at 7,14 ,21 and 28 days was found at an average of 22.97 N/mm^2, this agrees with characteristics of compressive strength.

The compressive strength of concrete cubes cast and cured in salt water for all mix ratio at 21 and 28 days was found to reduce by an average of 17.87 N/mm^2, which mean the strength of concrete has reduced approximately by 8%.

The workability of concrete decreases in concrete cast with salt water and was seen that the higher the setting time, the lower the strength of concrete produced.

5.2 Recommendations

Based on the findings from this research, the following suggestions are made:

Not all material can be used as a building material, depending on what the project material is intended for, it must meet certain requirements and specific engineering standards, testing the physical and mechanical properties will help engineers determine if a material is suitable for its purpose.

This work indicate that ordinary concrete has good compressive strength performance when used with salt water, the use of salt water should be welcome and not feared for casting and curing of concrete during construction.

Water/Cement ratio that will give the minimum value of slump with adequate workability as well as minimum cement content should be used with maximum aggregate size in order to minimize the shrinkage cracking.

Curing is very necessary in concrete in order to ensure the complete hydration of cement

5.3 Contribution to Knowledge

This Research investigates the effect of salt water on concrete using Bida Natural Stones as coarse aggregate.

The physical and mechanical properties of the aggregates indicate that they are suitable for concrete production.

The values of Compressive strength of the concrete produced in mix ratio 1:1.5:3 ranges between 18.0N/mm2 – 30.0 N/mm2 even after 21 days, the mix ratio 1:1.5:3 grade M30 is recommended in coastal regions and suitable for construction.

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APPENDICES

Table 4.1: Sieve Analysis Result for Bida Natural Stones (BNS)

Sieve sizes (mm)	Mass of sieve (g)	Mass of sieve + sample (g)	Mass retained (g)	% Mass retained	Cumulative % Retained	Cumulative % Passing
20.00mm	1433.3	1433.3	0	0	0	100
14.00mm	1371.1	1635.5	264.4	26.44	26.44	73.56
10.00mm	1324.4	1648.1	323.7	32.37	58.81	41.19
6.30mm	1310.8	1651.1	340.3	34.03	92.84	7.16
5.00mm	1447.7	1501.1	53.4	5.34	98.18	1.82
3.35mm	1296.8	1311.7	14.9	1.49	99.67	0.33
Pan	804	807.3	3.3	0.33	100	0
Total			1000	100	475.94	

Table 4.2: Sieve Analysis of Fine Aggregates

Sieve sizes (mm)	Mass of sieve (g)	Mass of sieve + sample (g)	Mass retained (g)	% Mass retained	Cumulative % Retained	Cumulative % Passing
5.00mm	477.2	478.5	1.3	0.26	0.26	99.74
3.35mm	467.9	471.9	4	0.8	1.06	98.94
2.36mm	433.8	443.2	9.4	1.88	2.94	97.06
2.00mm	417.6	427.3	9.7	1.94	4.88	95.12
1.18mm	384.6	431.8	47.2	9.44	14.32	85.68
850µm	351.7	402.3	50.6	10.12	24.44	75.56
600µm	467.8	559.9	92.1	18.42	42.86	57.14
425µm	435	546.2	111.2	22.24	65.1	34.9
300µm	382.4	436.4	54	10.8	75.9	24.1
150µm	420.4	526.2	105.8	21.16	97.06	2.94
75 µm	400.1	410.3	10.2	2.04	99.1	0.9
Pan	297.1	301.6	4.5	0.9	100	0
Total			500	100	527.92	