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Effects Of Salt Water On The Mechanical Properties Of Concrete: Nembe Salt Water, Case Study.

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Abstract
In this project, the Effects of Salt Water on the Mechanical Properties of Concrete was determined. For Compressive strength test, total number of concrete cubes cast was seventy two, that is, thirty six cubes using salt water and thirty six cubes using fresh water. Similarly, total number of beams cast for flexural strength test was the same as compressive strength test. Also, total numbers of concrete cylindrical cubes cast for Split tensile strength were the same too. Three mix ratios used were (1:1.51:3.2), water cement ratio (0.47), (1:2.06:4), water cement ratio (0.58), and (1:3.3:5.3), water cement ratio (0.78) respectively. The concrete cubes, beams and cylinders were cured at 7, 14, 21 and 28 days hydration period respectively before crushing. The results of the average compressive strength of concrete obtained using fresh water ranges from (43.26-47.90)N/mm2 ,(26.07-41.62)N/mm2 and (16.29-29.63) N/mm2 while that of its salt water ranges from (42.07-47.26)N/mm2 ,(25.92-38.96) N/mm2. ,and (16.15-27.71)N/mm2 for the mix ratios, (1:1.51:3.2), (1:2.06:4), and (1:1.51:3.2) respectively. The flexural strength of concrete obtained using fresh water ranges from (6.60-9.09)N/mm2 ,(6.55–8.24)N/mm2 and (6.18–9.07)N/mm2 while that of its salt water ranges from (5.98-8.08)N/mm2 ,(6.26-8.18)N/mm2 and (6.15-8.39)N/mm2 for the mix ratios, (1:1.51:3.2), (1:2.06:4), and (1:1.51:3.2) respectively. The split tensile strength of concrete obtained using fresh water ranges from (3.30–3.69)N/mm2 ,(2.00–3.20)N/mm2 ,and (1.25–2.28)N/mm2 while that of its salt water ranges from (3.24-3.64)N/mm2 ,(2.00-3.00)N/mm2 and (1.24-2.13)N/mm2 for the mix ratios, (1:1.51:3.2), (1:2.06:4), and (1:1.51:3.2) respectively. The initial and final setting time of cement using fresh water was 50 minutes and 586 minutes while that of salt water was 57 minutes and 607 minutes respectively. The water analysis result shows a high percentage content of salinity of 930mg/l as chlorine in salt water and 0.00mg/l in fresh water. The difference in the slump, compressive, flexural and split tensile Strength of concrete for fresh and salt water was as a result of the salinity content of the salt water sample used. I conclude that salt water has slight effect on the concrete and will corrode reinforcement if used in the construction hence I recommend the use of super sulphate cement which is resistance to sulphate attack.
Significance: *The significance of this study lies in its contribution to the understanding of the effects of salt water on concrete. The findings of this study will provide valuable insights for Engineers, Architects, and Construction professionals on how to protect concrete structures from exposure to salt water. Concrete is a widely used construction material, and its durability is critical to the safety and integrity of structures. Salt water is a common environmental factor that can cause concrete to deteriorate, leading to potential safety issues and costly repairs. By understanding the effects of salt water on concrete and providing recommendations on how to protect concrete from exposure to salt water, this study will contribute to the development of more durable and safer structures. Furthermore, the study focuses on the River Nun in Nembe in Bayelsa State as a case study, which can provide insights into the effects of salt water on concrete in similar environments. This can be particularly useful for construction projects located in coastal areas or near borders of salt water. Another significance of this project is that a paper will emerge that will be used as an academic tool to help students handle similar or related projects with confidence.*
Keywords*: Compressive Strength, Flexural Strength, Fresh water, Salt water, setting time, Split tensile Strength.*

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I. Introduction

Concrete is a composite material composed of cement, aggregates (fine and coarse) and water in a given percentage amounts that harden over time. Concrete is the second most used substance in the world after water. (Yassar, 1996). It is a known fact that concrete is widely used construction material due to its high compressive strength and durability, however, concrete is not resistant to the effects of the environment, and its exposure to different environmental conditions can cause it to deteriorate over time. One such environmental condition is exposure to salt water, which can cause concrete to degrade and lose its strength, leading to potential safety issues and costly repairs. According to a study by (Zhang *et al*., 2020), salt water exposure can cause significant damage to concrete structures.

The study found that salt water can cause the concrete to lose its strength and increase its permeability, leading to increased chloride ion penetration and corrosion of the reinforcing steel. The study also noted that the extent of the damage depends on various factors, including the salt water concentration, the duration of exposure, and the type of cement used. Another study by (Khan and Ullah, 2019) who investigated the effects of salt water on the compressive strength of concrete, found that, exposure to salt water can cause a significant reduction in the compressive strength of concrete, which can compromise the structural integrity of the concrete. In Nigeria, coastal regions and areas near bodies of salt water are susceptible to the effects of salt water on concrete structures. In Bayelsa state, the River Nun is a significant body of salt water that flows into the Atlantic Ocean. Concrete structures located near the River Nun are at risk of deteriorating due to exposure to salt water, highlighting the need for research on the effects of salt water on concrete in this area. Concrete is used for numerous purposes in construction such as construction of buildings, dams, foundations, highways, parking structures, pipes, poles among others (Matthias, 2010). Also, the use of concrete in offshore drilling platforms and oil storage tanks is already on the increase. Concrete piers, decks, break-water, and retaining walls are widely used in the construction of harbours and docks. Floating offshore platforms made of concrete are also being considered for location of airports, power plants, and waste disposal facilities in order to relieve land from pressures of urban congestion and pollution (Gopal, 2010). 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 as ions of Sodium, chloride, magnesium, calcium, Sulphate and potassium (Akinkurolere *et al*., 2007). Most seawater is fairly uniform in chemical composition, which is characterized by the presence of about 3.5 percent soluble salts by weight. The ionic concentrations of Na^+ and Cl^- are the highest, in Atlantic Ocean typically 11000 and 20000mg/litre respectively.

Water used in this Project work is brack water. Brack water is water that has more salinity than fresh water, but not as much as sea water. The word 'brack' comes from the Middle Dutch root "brack" meaning "Salten" or "Salty". Brackish water is also the primary waste product of the salinity gradient power. Salinity gradient or Osmotic power is the energy retrieved from the difference in salt concentration between sea water and river water.Water is said to be salty if it contains chloridesand sulphates.

The effect of Salt water on concrete was first discussed in 1840 by J. Smeaton and L. J. Vicat. Their two-year examination on the research topic titled "What is the trouble with concrete in Salt water" revealed that a large number of concrete structures in Salt water in the United States, Canada, Cuba and Parama are exposed to chemical deterioration (Tibbetts, 1968). Mehta (1980) reported after exposing concrete cylinder to Salt water that the section of concrete that always remain above high-tide lines would be vulnerable to cracking and spalling.

The results of Portland Cement Association (PCA on their 37-year study revealed that seawater had no damaging effect on submerged concrete specimens, regardless of their cementitious composition; whereas, concrete positioned above high tide suffered more corrosion damage than concrete placed at mean tide levels (Stark, 2010). Concrete in marine environment suffer deterioration which may be due to the effects of chemical reaction of seawater constituents with cement hydration products, alkali-aggregate expansion which occur when reactive aggregates are present, crystallization pressure of salts within concrete when one face of the structure is subject to wetting and others to drying conditions, frost action in cold climates, corrosion of embedded steel in reinforced or prestressed members, and physical erosion due to wave action and floating objects (Mokhtar and Swamy, 2008) or Gopal (2010). Mehta (1994) and (Akinkurolere *et al*., 2007) also noticed that concrete can deteriorate by stresses caused by crystallization of salts in the pores when one side of a slab or retaining wall of a permeable solid is in contact with a salt solution and the other sides are subjected to loss of moisture by evaporation.

(Akinkurolere *et al*., 2007) suggested that the compressive strength of concrete is shown to be increased by the presence of salt or ocean salt in the mixing & curing water. The rate of strength gain is also affected when the concrete is cast & cured with salt water & vice versa. Mixing concrete with salt water increases the compressive strength rapidly & the strength was still increasing at 28 days.

(Preeti *et al*., 2014) suggested that there was a marginal increase in the concrete cubes which were casted and cured with salt water as compared with the concrete cubes cast and cured with fresh water. The rate of the strength gain in fresh water cubes is slow as compared with the salt water cubes. At 28 days, the rate of strength gain is still increasing in all the concrete cubes. The fresh water cubes also recorded its maximum strength at 28 days. Although, the compressive strength of the salt water concrete cubes was slightly higher than that of the fresh water concrete cubes.

(Krishnam *et al*., 2014) suggested that there is no quantitative reduction in compressive strength compared to target strength when the concrete is exposed to both "potable water mixing and sea water curing" and "mixing and curing by sea water. There is an increase in 7 days split tensile strength of concrete for "Potable water mixing and sea water curing "in M30 and M35.

(Olutoge *et al*., 2014) suggested that it was observed that concrete cast and cured with sea water increases gradually for all curing days beyond the strength of control cast. The compressive strength of concrete batched and cured with fresh water agrees with the value of the compressive strength of 1:2:4 mix at 28days, of about 20N/mm^2. The strength of concrete batches cast with salt water and cured with fresh water was also observed to have increased even at 28 days and 90 days respectively.

(Swati, 2015) in his research work suggested that during mixing and curing on compressive strength of concrete, commonly water used for concreting is water from boreholes which contains number of salts and hence we are testing it for extreme case i.e. sea water case.

Thus this project aims to determine the effect of Salt water on the Mechanical Properties of concrete with a view of producing durable marine concrete structures. The study involved producing concrete samples with water from the river Nun and subjecting them to various tests after curing for 7, 14, 21 and 28 days and comparing them with concrete samples produced with fresh water subjected to the same tests under the same hydration period as to determine the effects of saltwater on their performance.

II. Objectives Of Study

The general objective of the study is to know the adverse effect the salt water may have on the mechanical properties of concrete using Nembe salt water as case study.

The Specific Objectives are:

i. Determine the compressive strength, the Flexural strength and the split tensile strength of concrete samples produced with salt water compared to those produced with fresh water.
ii. Determine the variation in workability of the concrete produced with salt water compared to those produced with fresh water (Slump test).
iii. Determine the variation on initial and final setting time of cement produced with salt water compared to those produced with fresh water.
iv. Analyze the data obtained from the tests and draw conclusions on the effects of saltwater on the performance of concrete.

III. Methodology

The materials used for this research work are ordinary Portland cement (OPC), salt water, fresh water, fine and coarse aggregates.

Collection Of Salt Water Samples

The salt water was collected from River Nun in Nembe Local Government Area of Bayelsa state. The salt water collected was used for both batching and curing of concrete cubes and beams.

Collection Of Fresh/Tap Water Sample

The tap water used was collected from a tap at Port Harcourt, Rivers State, Nigeria. The tap water was also collected in a quantity that will be enough for both batching and curing of the concrete cubes and beams. The typical water-cement ratio varies between 0.47 - 0.78 for different grades of concrete mix.

Collection And Grading Of Fine Aggregates

The fine aggregates used for batching of concrete was graded by use of 5.0 mm BS sieve. The sieved samples were washed and dried to remove impurities which could affect or reduce the concrete or cement strength.

The use of this sieve size is to conform the grading of (Seeley, 1976) for the grading of fine aggregate as zone 2. The percentage passing of 5.0 mm sieve is between 90-100%.

The fine aggregate (sand) used in this project is from a construction site at No. 1 Diobu Avenue in Aba, Abia State passing through 5.00 mm sieve. The grading zone of fine aggregate (sand) was zone 2 as per BS 882 standard specification. Fine aggregate content is usually 32% to 45% by mass or volume of the total aggregate content.

Collection And Grading Of Coarse Aggregates

The coarse aggregate used for the batching was first graded with 20 mm BS sieve. The passing sieve was first washed to remove impurities. After which the aggregates were dried before being used for batching. The passing sieve 20mm was used to conform to the BS 882 specifications and requirement according to (Seeley, 1976) for the grading of coarse aggregate. The passing sieve should be 95-100%. Crushed granite stone aggregate from Ebonyi State, Nigeria of maximum size 20mm conforming to BS 882 standard specification was used.

Collection Of Cement

The cement used was Dangote Cement. It was stored under dry condition, free of lumps and in conformity with BS 12.

Batching And Mixing Of Samples

The measured quantity of the fine aggregate was poured into the mixing tray and the required quantity of cement was added into it and mixed properly. Then, the required quantities of coarse aggregates were measured and mixed thoroughly with the mixture of fine aggregates and cement.

The required quantity of water was poured into the mixture and mix properly after which concrete is obtained. The initial setting time, workability, slumps, as well as placing the concrete into the concrete cubes/cylinder moulds and concrete beam moulds was carried out.

Slump Test:

Slump test was conducted to determine the consistency of plastic concrete and its suitability for detecting changes in workability.

Compressive Strength Test

Compressive strength is the capacity of concrete to withstand loads before failure. Of the many tests applied to the concrete, the compressive strength test is the most important, as it gives an idea about the characteristics of the concrete.

For the determination of the Compressive Strength, the concrete cube size measuring 150mm×150mm×150mm in dimension was used. The batching of the concrete moulds was by weight. The concrete was produced using salt water and fresh water respectively. When the concrete was properly mixed using the fresh water and the salt water respectively, the concrete cubes moulds were cleaned and oil was applied and the moulds were filled in layers approximately 50mm thick with the mixed concrete. Each layer of concrete was compacted with not less than 25 strokes using a tamping rod. The cubes were later filled to two third of their height and finally filled completely with the top surface levelled and smoothen with trowel and left for 24 hours to set before curing.

For the Compressive strength test, the total number of concrete cubes cast was seventy two (72), that is, thirty six (36) cubes using salt water and thirty six (36) cubes using fresh water.

After curing for a specific number of days, the cubes are brought out of water. The mass/weights of the cubes are measured and recorded. For each of the hydration period, three cubes were tested. The cubes are placed on the crushing machine and crushed to determine the failure load.

Then, the average compressive strength is determined using the formula stated below.

$$\sigma = \frac{P}{A}$$

Where σ =Compressive Strength (N/mm^2), P=Test load (N), A=Area (mm^2).

Flexural Strength Test:

The flexural strength test measures the force required to bend a beam under three point loading conditions. Therefore, flexural testing determines the bending properties of concrete. This is sometimes referred as a transverse beam test as it involves placing a sample between two points or supports and initiating a load using a third point. The flexural strength Test was determined using a beam mould of 150mm x 150mm x 700mm in dimension. The total number of beams cast was also seventy two (72) that is thirty six (36) beams using salt water and thirty six (36) beams using fresh water.

After curing for a specific number of days, the beams are brought out of water and kept moist. The top of the beam as moulded is turned to its side and marked as to help with centring in machine. The beams are loaded in the machine and centred on support blocks and loads are applied according to BS 1881 at a given rate of 400kg/minute until rapture occurs.

Then, the average Flexural strength or the Modulus of Rupture is determined using the formula stated below.

$$R = \frac{PL}{bd^2}$$

This is used when the fracture occurs within the middle third of the specimen. Here (a > 200mm) for 150mm beam size or

$$R = \frac{3Pa}{bd^2}.$$

This is used when (a < 200mm & a > 170mm) for 150mm beam size.
Where:
R = Modulus of Rupture (N/mm^2)
P = Maximum load applied that causes failure (N)
L = Supported length of beam (mm)
b = Width of specimen (beam) (mm)
d = Failure point depth of specimen (beam) (mm)
a = Line of fracture to the nearest support.

Split Tensile Strength Test

The split tensile test is an indirect way of evaluating the tensile test of concrete. In this test, a standard cylindrical specimen is laid horizontally, and the force is applied on the cylinder radially on the surface which causes the formation of a vertical crack in the specimen along its diameter. Therefore, this test is necessary to determine the load at which the concrete members may crack.

The Split tensile strength was determined using a cylindrical cube size of 300mm in length or height and 150mm in diameter. The total number of concrete cylinders cast was seventy two (72), that is thirty six (36) concrete cylinders using salt water and thirty six (36) concrete cylinders using fresh water.

After curing for a specific number of days, the concrete cylinders are brought out of water and kept moist. Before testing, a line is drawn on the specimen through the diameter of the specimen and the weight and dimensions of the specimen are recorded. The specimen is placed longitudinally on the Universal testing machine. A wooden sheet made of plywood is placed on both sides of the specimen before application of the load and must be aligned according to the marking. Loads are continuously applied in the range of 0.7 to 1.4 MPa/minute until the specimen fails by developing cracks.

Then, the Resultant Split Tensile strength is determined using the formula stated below.

$$T = \frac{2P}{\pi DL}.$$

Where:
T =Split Tensile Strength (N/mm^2).
P =Load at which the Specimen breaks (N).
$\pi = \frac{22}{7}$
D = Diameter of specimen (mm).
L = Length of specimen (mm)

IV. Setting Time Test Using Ordinary Portland Cement (Dangote)

Setting time tests are used to characterize how a particular cement paste sets. For construction purposes, the initial setting time must not be too soon and the final setting time must not be too late. It is important to note that initial setting time is the time to which the cement can be moulded in any desired shape without losing its strength. On the other hand, final setting time is the time taken to reach the stage when the cement paste becomes a hard mass and can take some minor load.

This test was carried out in accordance with the BS 12 (1978) using the Vicat apparatus, fresh and salt water samples respectively. The Vicat apparatus uses two pins, initial and final setting time pins for the determination of initial and final setting time of cement respectively.

To carry out this experiment, 80g of water was added to 200g of cement to form cement paste. The paste was then placed on the cup of the Vicat apparatus. Before the placement of the paste on the apparatus, the initial setting pin was fixed on the apparatus for initial setting time. The apparatus is calibrated in millimetres. For the initial setting time, the initial pin was dropped on the cement paste to 5mm calibration mark on the apparatus. The initial setting time was then recorded starting from the time the water was added to the cement to the time the pin penetrated up to 5mm on the apparatus.

Similarly, the final setting time was recorded using the final setting pin. The final setting pin has an inner and outer pin. The final setting pin time was taken when only the inner pin makes a mark on the paste

when allowed to drop freely. The final setting time was recorded starting from the time the water was added to the cement to the time the inner pin of the final setting pin makes a mark on the paste.
The result of the setting time of the Dangote Cement with fresh water and salt water are recorded.

Mix Design Proportions

Three mixture proportions were considered in this project work. Considerations were made on uncrushed maximum aggregate size of 20mm, slump range of 30-60mm, characteristics strength of 25N/mm^2 at 28 days, free water content of 180kg/m^3 and aggregate relative density of 2.6. The Free-water contents (kg/m^3) required to give various levels of consistence as measured by the slump according to the British Standard (BS 1881 Part 2, 1970) was considered. Wet density of concrete mix of 2375kg/m^3 corresponding to free water content of 180kg/m^3 used in all the mix design proportion calculations was obtained as seen in (https://staff.emu.edu.tr/ozgureren/en/Documents/CIVL284/BRE%20Mix%20Design%20Example%202.pdf)

The first, second and third mix ratios of 1: 2.06: 4, 1: 3.3: 5.3 and 1: 1.51: 3.2 had 34%, 38% and 32% proportion of fine aggregate corresponding to a free water/cement ratio of 0.58, 0.78 and 0.47 respectively. Standard deviation of 8N/mm^2 was used in all mix design proportions which correspond to Characteristic strength of 25N/mm^2.

The first mix design was proportioned for target cube strength of 39N/mm^2 and had a Cementitious material content of 310 kg/m^3, a fine aggregate content of 640.9 kg/m^3, a coarse aggregate content of 1244.1 kg/m^3 and a water cementitious ratio of 0.58.

The second mix design was proportioned for target cube strength of 39N/mm^2 and had a Cementitious material content of 230.8 kg/m^3, a fine aggregate content of 746.4 kg/m^3, a coarse aggregate content of 1217.8 kg/m^3 and a water cementitious ratio of 0.78.

The third mix design was proportioned for target cube strength of 39N/mm^2 and had a Cementitious material content of 383 kg/m^3, a fine aggregate content of 580 kg/m^3, a coarse aggregate content of 1232 kg/m^3 and a water cementitious ratio of 0.47.

Curing Of Concrete Cubes And Beams

The concrete cubes/cylinders and beams batched with the salt water are cured separately in a container containing the salt water. Also, the concrete cubes/cylinders and beams batched with the fresh water are cured in a container containing the fresh water.

The concrete cubes/cylinders and beams were cured for some days. Three of each of the concrete cubes/cylinder samples or beams samples were crushed at 7, 14, 21 and 28 days of curing.

Water Analysis

The collected samples were analysed raw without further treatment and compared with existing results obtained using Standard Distilled & Deionised water.

The method used was in line with American Society for Testing and Materials (ASTM) and Environmental Protection Agency (EPA) methods. National laboratory Water Analysis Water Test kit ‘ kit 1 & 2, Water safe WS 252 All-In-One water analysis kit and HANNA Portable Multi-parameter Water Testing meter were used in analysing water for Salinity, Turbidity, Total dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and other parameters as listed under “SUMMARY OF RESULTS”. Some specific subjective method such as odour and taste, as well as some individual instrumental analysis such as colour, conductivity and pH, in addition to results obtained were as indicated under “Water Analysis Test”

Colour Determination

Colour was determined by Spectrophotometric method using spectrum lab model 27A spectrophotometer. The colours of samples were compared with those of borehole water.

Odour Determination

Analysis of odour was carried out subjectively as reliable standard instrumental method was not available. A panel of six assessors were constituted for the purpose. 10-100 ml of sample was measured into six conical flasks and diluted to 200 ml with borehole water and stopped. This dilution and reference odour free borehole water were heated to 500ºC, the diluted samples and reference were then opened, shook and sniffed for odour. The (Threshold odour Number) which is the dilution factor that makes the odour just detectable was computed from table of results as follows;

$$TON = \frac{A+B}{A}$$

Where TON=Threshold Odour Number, A= ml of sample, B= ml of odour free reference sample.

Taste Determination

Like odour determination there is no reliable standard instrument for taste determination. Analysis was based on a panel of six (6) people who compared the test samples with those of borehole water.

pH Determination

This determination was carried out electrometrically using digital pH meter (corning model 2256) equipped with standard glass electrode. Calibration of meter was carried out using buffers 4 and 9. Values of samples were read.

Conductivity Measurement

Direct measurement with conductivity meter was made using borehole water as standard and deionised water for standardization. Instrument was powered for 15 minutes for electronic equilibration after which the equipment was zeroed with deionised water at 25°C. The measurements of standard sample and samples were taken directly in µs/cm.

V. Results And Discussion

Sieve Analysis Of Fine Aggregates

Table 4.1 shows the result of the sieve analysis of fine aggregate used. The result shows that the fine aggregate falls into zone 2 of calibration graph.

Table 4.1 Result of Sieve Analysis of Fine Aggregates:

Standard Sieve size	Mass of sample retained (g)	Mass of sample passing (g)	Percentage retained (g)	Percentage passing (g)
8mm	0.00	250	0.00	100
5mm	11.60	238.40	4.64	95.36
2.36mm	44.20	194.20	17.68	77.68
1.18mm	32.90	161.30	13.16	64.52
600µm	77.05	84.25	30.82	33.70
300µm	56.25	28.00	22.50	11.20
150µm	15.90	12.10	6.36	4.84
Pan	12.10	0.00	4.84	0.00

Slump Test Results

Tables 4.2a and 4.2b as shown below show the slump test results of the concrete batched with fresh water and that of salt water of different mix ratios respectively. It is observed that the salt water concrete slump of 1:1.51:3.2 mix ratio has the highest slump value of (52.8mm) while the fresh water concrete slump of the same 1:1.51:3.2 mix ratio has the slump value of (37.4mm). This is followed by the salt water concrete slump of 1:2.06:4 mix ratio with value of (49.2mm) while the fresh water concrete slump of 1:2.06:4 mix ratio was (33.8mm) and lastly the salt water concrete slump of 1:3.3:5.3 mix ratio was (47.1mm) while the fresh water concrete slump of 1:3.3:5.3 mix ratio was (32.3mm). It is, therefore, evident that salt water has effect on the concrete paste since there are differences between the slump of salt water concrete and that of fresh water.

Table 4.2a: Slump Test Result for Fresh Water Concrete of Different mix Ratios:

Mix Ratio	Water/Cement Ratio	Height of Slump cone (mm)	Height of Concrete after test (mm)	SLUMP (mm)
1 : 1.51 : 3.2	0.47	300	262.6	37.4
1 : 2.06 : 4	0.58	300	266.2	33.8
1 : 3.3 : 5.3	0.78	300	267.7	32.3

Table 4.2b: Slump Test Result for Salt Water Concrete of different mix Ratios:

Mix Ratio	Water/Cement Ratio	Height of Slump cone (mm)	Height of Concrete after test (mm)	SLUMP (mm)
1 : 1.51 : 3.2	0.47	300	247.2	52.8
1 : 2.06 : 4	0.58	300	250.8	49.2
1 : 3.3 : 5.3	0.78	300	252.9	47.1

Setting Time Test Result:

Table 4.3 below shows the result of the initial and final setting time of cement using fresh and salt water respectively. The initial setting time of cement using fresh water is 50 minutes while the final setting time is 586 minutes. The initial and final setting time of cement using salt water is 57 minutes and 607 minutes respectively. The higher the setting time, the lower the strength of concrete produced. This is because salt water increases the setting time of cement which indicates that the strength of concrete produced is reduced.

Table 4.3 Setting Time Test using Ordinary Portland Cement (Dangote):

For Fresh Water:

Initial setting time (minutes)	Final setting time (minutes)
50	586

For Salt Water

Initial setting time (minutes)	Final setting time (minutes)
57	607

Table 4.4 showed the Summary of Table of Results for Fresh water and Salt water Analysis Test compared with the known test According to ASTM/EPA Range /Limit for Standard Distilled & Deionised water.

Table 4.4 Summary of Table of Results for Fresh Water and Salt Water Analysis Test:

S/No	PARAMETER	**Standard for Distilled & Deionised water**	Fresh water sample	Salt water sample
1	Colour (A)	**0.00**	0.003	0.025
2	Odour	**Unobjectionable**	Unobjectionable	Unobjectionable
3	Taste	**Insipid**	Not Detected	Not Detected
4	pH	**7.00**	6.81	7.4
5	Temperature (ºC)	**26.5**	26.5	26.5
6	Conductivity (µS/cm)	**0.00**	0.23	326.05
7	Salinity as chloride (mg/l)	**0.00**	0.00	930
8	Total dissolved solid (TDS) (mg/l)	**0.00**	0.26	1250
9	Total suspended solids (TSS) (mg/l)	**0.00**	0.04	54.0
10	Turbidity (NTU)	**0.00**	0.02	44.9
11	Dissolved oxygen DO (mg/l)	**0.00**	0.09	4.8
12	Total Hardness (Mg/l $CaCO_3$)	**0.00**	4.70	21.0
13	Alkalinity as $CaCO_3$ ppm	**0.00**	1.01	3.86
14	Chemical oxygen demand COD (mg/l)	**0.00**	0.01	1.47
15	Total Petroleum hydrocarbon (mg/l)	**0.00**	0.00	1.4
16	Total hydrocarbon content (mg/l)	**0.00**	0.00	1.1
17	Biochemical Oxygen Demand (mg/l)	**0.00**	2.0	14.0
18	Nitrate ion (NO_3^-) mg/l	**0.00**	0.001	0.175
19	Phosphate (mg/l)	**0.00**	0.07	0.18
20	Phenols (mg/l)	**0.00**	0.00	0.46
21	Sulphate (mg/l)	**0.00**	6.5	0.175
22	Lead (mg/l)	**0.00**	<0.01	<0.01
23	Iron (mg/l)	**0.00**	0.05	0.21
24	Copper (mg/l)	**0.00**	0.21	0.58
25	Nickel (mg/l)	**0.00**	<0.001	0.85
26	Vanadium	**0.00**	0.85	<0.001
27	Zinc (mg/l)	**0.00**	<0.001	0.01
28	Cadmium	**0.00**	0.00	<0.001

Fig. 4.1 below showed the results of the average compressive strength of concrete produced using fresh and salt water respectively of mix ratio (1:1.51:3.2), and water cement ratio of 0.47. The result of the average compressive strength of concrete produced using fresh water ranges from (43.26N/mm^2 – 47.90 N/mm^2) while that of Salt water ranges from (42.07N/mm^2 – 47.26 N/mm^2). The result shows that the average compressive strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

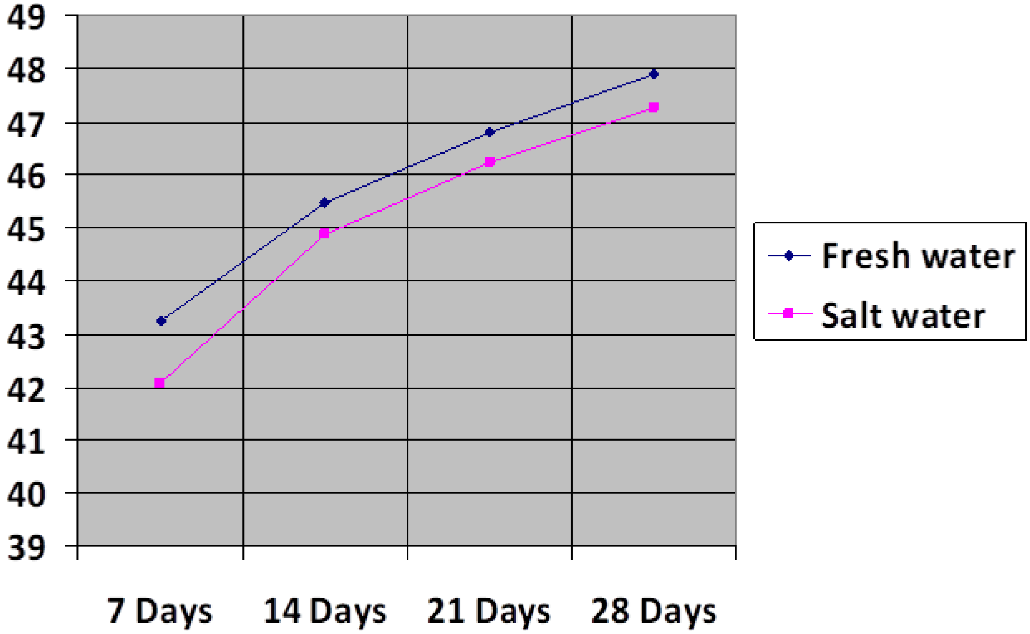

Fig. 4.1: Compressive Strength- Age Relationship for Fresh and Salt Water concrete (1:1.51:3.2/0.47)

Similarly, Fig. 4.2 below showed the results of the average compressive strength of concrete produced using fresh and salt water respectively of mix ratio (1:2.06:4), and water cement ratio of 0.58. The results of the average compressive strength of concrete produced using fresh water ranges from (26.07N/mm^2 – 41.62 N/mm^2) while that of Salt water ranges from (25.92N/mm^2 – 38.96 N/mm^2). In the same manner, it shows that the average compressive strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

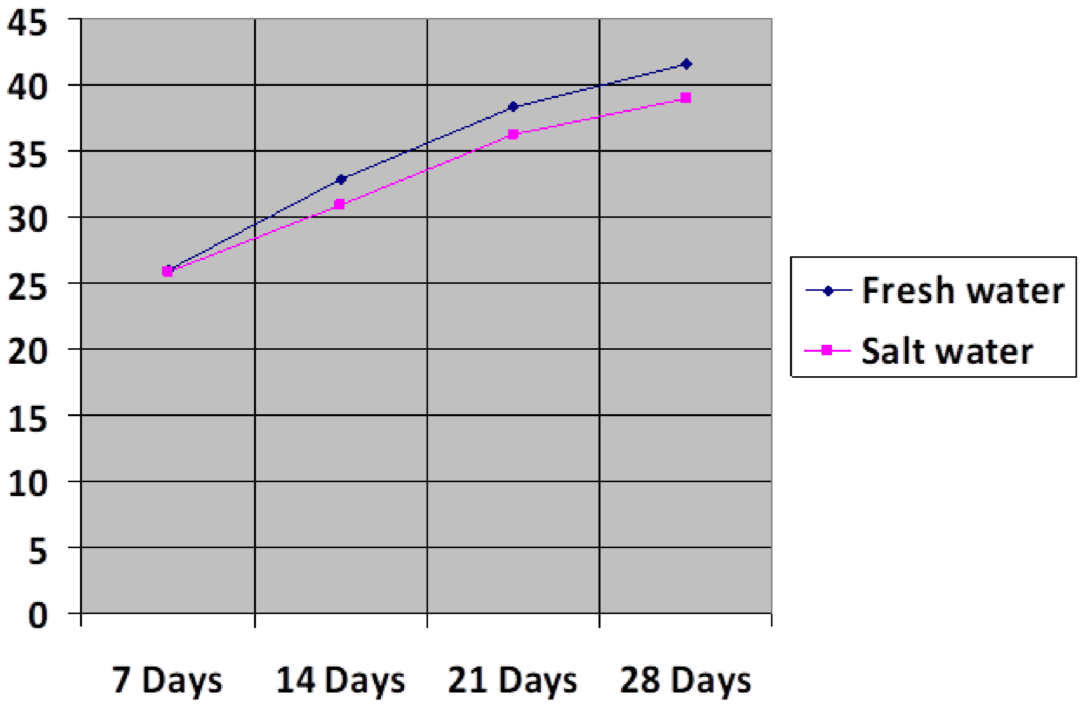

Fig. 4.2: Compressive Strength- Age Relationship for Fresh and Salt Water concrete (1:2.06:4/0.58)

Again, Fig. 4.3 below showed the results of the average compressive strength of concrete produced using fresh and salt water respectively of mix ratio (1:3.3:5.3), and water cement ratio of 0.78. The result of the average compressive strength of concrete produced using fresh water ranges from (16.29N/mm^2 – 29.63N/mm^2) while that of Salt water ranges from (16.15N/mm^2 – 27.71 N/mm^2). The result shows that the average compressive strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

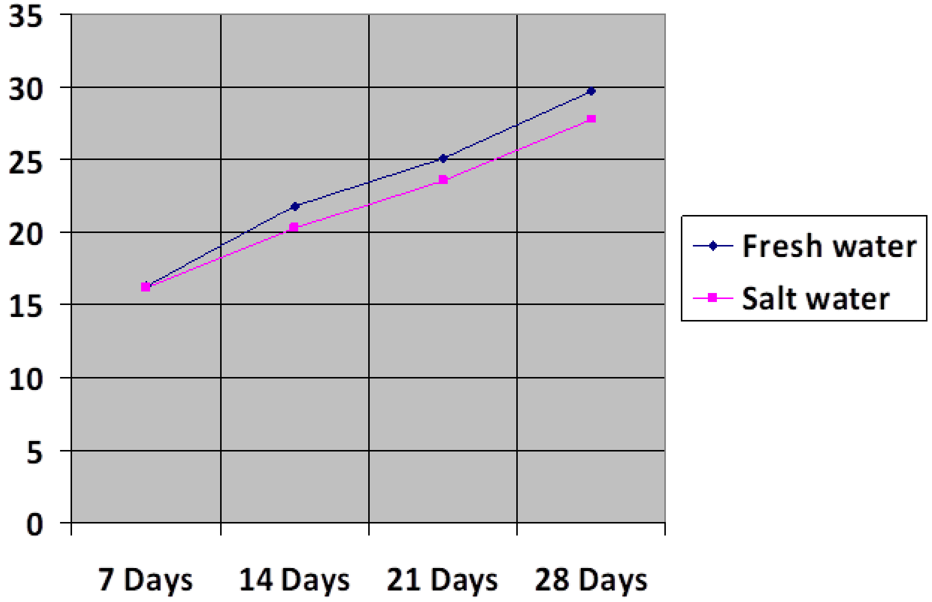

Fig. 4.3: Compressive Strength- Age Relationship for Fresh and Salt Water concrete (1:3.3:5.3/0.78)

Fig. 4.4 below showed the results of the average flexural strength of concrete produced using fresh and salt water respectively of mix ratio (1:1.51:3.2), and water cement ratio of 0.47. The result of the average flexural strength of concrete produced using fresh water ranges from (6.60N/mm^2 – 9.09 N/mm^2) while that of Salt water ranges from (5.98N/mm^2 – 8.08 N/mm^2). The result shows that the average flexural strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

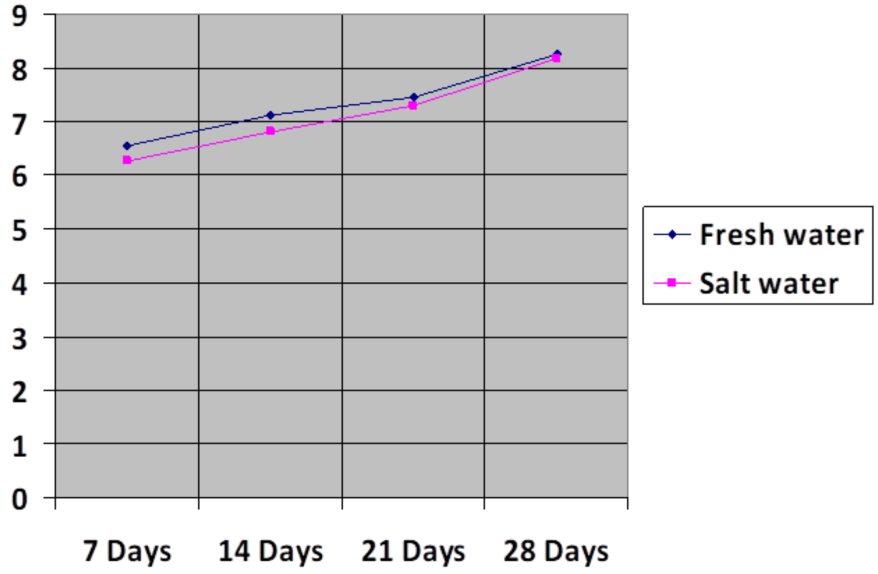

Fig. 4.4: Flexural Strength- Age Relationship for Fresh and Salt Water concrete (1:1.51:3.2/0.47)

Fig. 4.5 below showed the results of the average flexural strength of concrete produced using fresh and salt water respectively of mix ratio (1:2.06:4), and water cement ratio of 0.58. The result of the average flexural strength of concrete produced using fresh water ranges from (6.55N/mm^2 – 8.24N/mm^2) while that of Salt water ranges from (6.26N/mm^2 – 8.18N/mm^2). Equally, the result showed that the average flexural strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

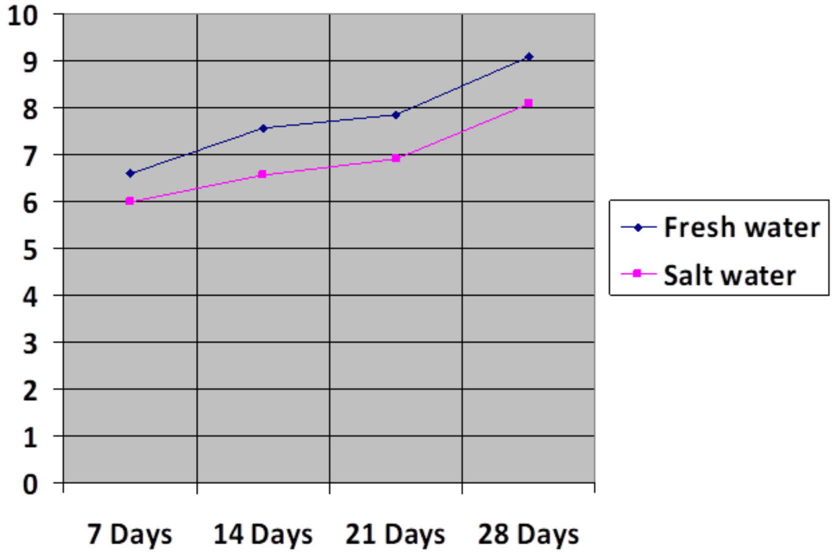

Fig. 4.5: Flexural Strength- Age Relationship for Fresh and Salt Water concrete (1:2.06:4/0.58)

Fig. 4.6 below showed the result of the average flexural strength of concrete produced using fresh and salt water respectively of mix ratio (1:3.3:5.3), and water cement ratio of 0.78. The result of the average flexural strength of concrete produced using fresh water ranges from (6.18N/mm^2 – 9.07N/mm^2) while that of Salt water ranges from (6.15N/mm^2 – 8.39N/mm^2). The result shows that the average flexural strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

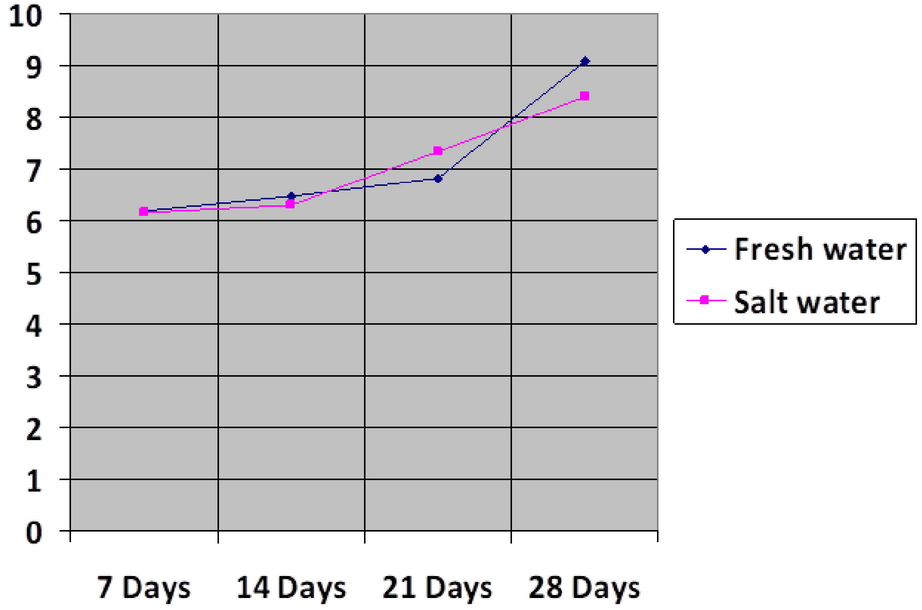

Fig. 4.6: Flexural Strength- Age Relationship for Fresh and Salt Water concrete (1:3.3:5.3/0.78)

Fig. 4.7 below showed the results of the average split tensile strength of concrete produced using fresh and salt water respectively of mix ratio (1:1.51:3.2), and water cement ratio of 0.47. The result of the average split tensile strength of concrete produced using fresh water ranges from (3.33N/mm^2 – 3.69 N/mm^2) while that of Salt water ranges from (3.24N/mm^2 – 3.64N/mm^2). The result shows that the average split tensile strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

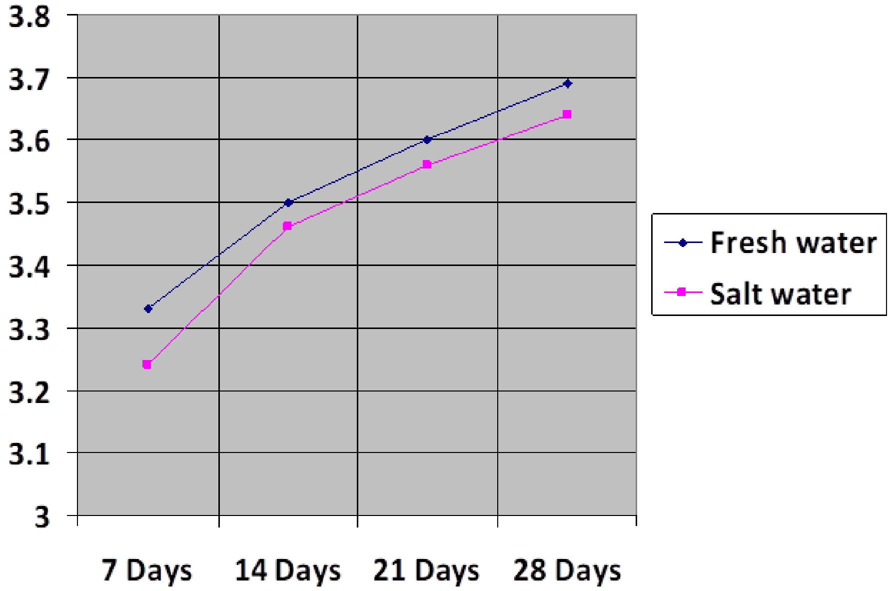

Fig. 4.7: Split Tensile Strength- Age Relationship for Fresh and Salt Water concrete (1:1.51:3.2/0.47)

Fig. 4.8 below showed the results of the average split tensile strength of concrete produced using fresh and salt water respectively of mix ratio (1:2.06:4), and water cement ratio of 0.58. The result of the average split tensile strength of concrete produced using fresh water ranges from (2.00N/mm^2 – 3.20N/mm^2) while that of Salt water ranges from (2.00N/mm^2 – 3.00N/mm^2). In the same manner, it shows that the average split tensile strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

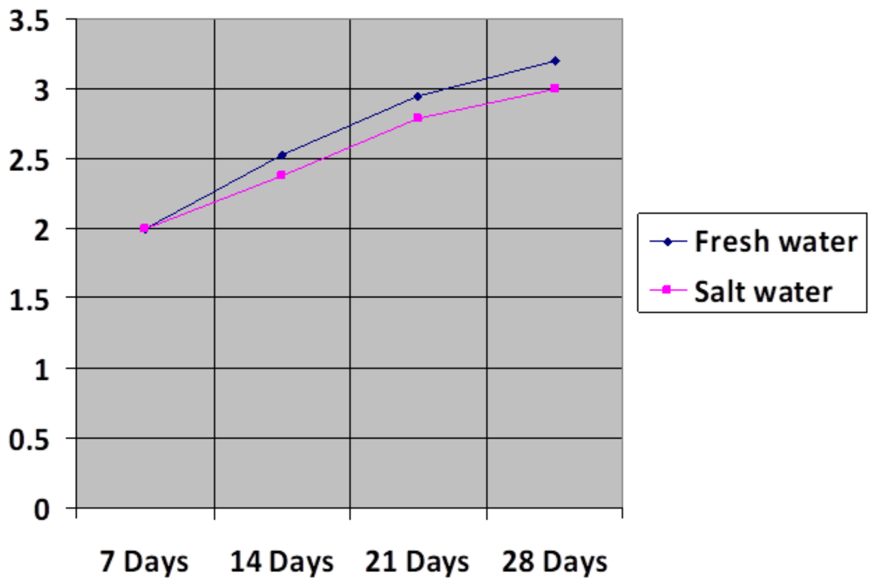

Fig. 4.8: Split Tensile Strength- Age Relationship for Fresh and Salt Water concrete (1:2.06:4/0.58)

Fig. 4.9 below showed the results of the average split tensile strength of concrete produced using fresh and salt water respectively of mix ratio (1:3.3:5.3), and water cement ratio of 0.78. The result of the average split tensile strength of concrete produced using fresh water ranges from (1.25N/mm^2 – 2.28N/mm^2) while that of Salt water ranges from (1.24N/mm^2 – 2.13N/mm^2). The result shows that the average split tensile strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

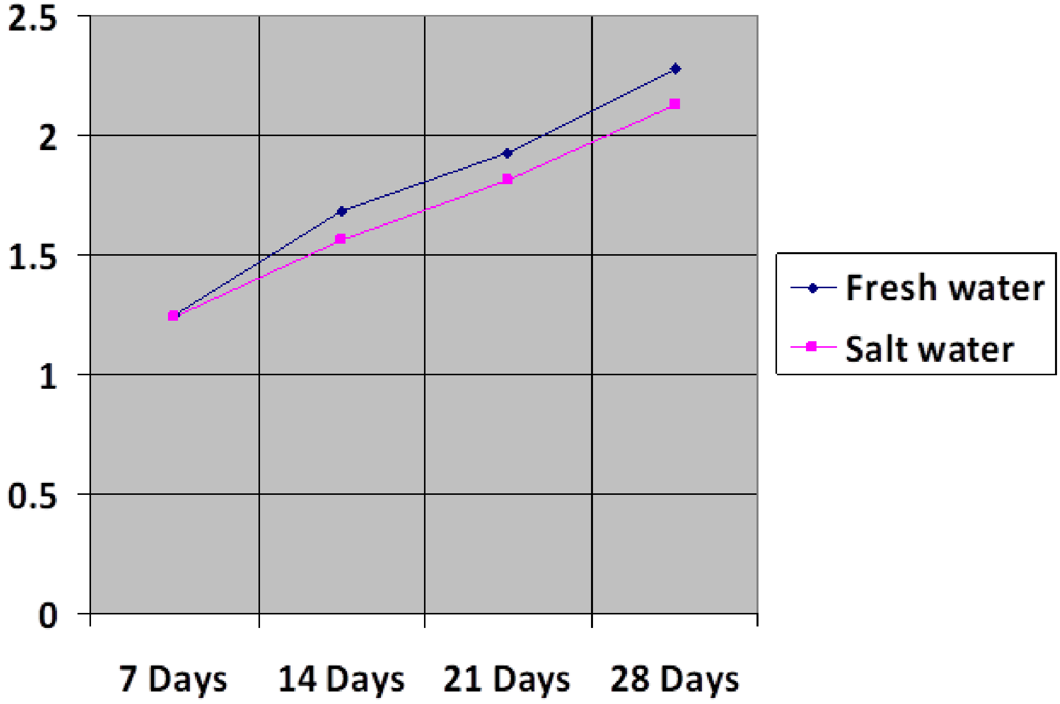

Fig. 4.9: Split Tensile Strength- Age Relationship for Fresh and Salt Water concrete (1:3.3:5.3/0.78)

VI. Discussion Of Results

From the slump test results, it is observed that the salt water concrete slump of 1:1.51:3.2 mix ratio has the highest slump value of (52.8mm) and (37.4mm) for its fresh water, followed by 1:2.06:4 mix ratio of (49.2mm) and (33.8mm) for its fresh water and lastly 1:3.3:5.3 mix ratio of (47.1mm) and (32.3mm) for its fresh water.

From the above stated results of slump, there are differences between the slump of salt water concrete and that of fresh water showing that salt water has effect on the concrete paste.

From the compressive test results, it is observed that the strength of the cubes produced with fresh water has greater strength than that of the salt water. The compressive strength of fresh water ranges from (16.29N/mm^2 – 47.90 N/mm^2) which is greater than salt water concrete with (16.15 N/mm^2 – 47.26 N/mm^2) for 1:1.51:3.2, 1:2.06:4, 1:3.3:5.3 mix ratios respectively.

Similarly, from the flexural strength test results, it is also observed that the strength of the beams produced with fresh water has greater strength than that of the salt water. The Flexural strength of fresh water ranges from (6.18N/mm^2 – 9.09N/mm^2) which is greater than salt water beams with (5.98 N/mm^2 – 8.39N/mm^2) for 1:1.51:3.2, 1:2.06:4, 1:3.3:5.3 mix ratios respectively.

In the same manner, the split tensile strength results showed that the fresh water has greater split tensile strength than the salt water. The Split tensile strength of fresh water ranges from (1.25N/mm^2 – 3.69N/mm^2) which is greater than salt water split tensile strength with (1.24N/mm^2 – 3.00N/mm^2) for 1:1.51:3.2, 1:2.06:4, 1:3.3:5.3 mix ratios respectively.

It was also observed that the Strength development in the concrete produced increases with the increase in the hydration period. The higher the setting time, the lower the strength of concrete produced.

From the curing, it was observed that a white powder is deposited on the body of the cubes/beams batched and cured with salt water each time the cube/beam is brought out of water for crushing while no such observation was made in those of fresh water batched and cured concrete. The white powder can be described as Efflorescence which is a crystalline, salty deposit on the body of the cubes/beams. Efflorescence alone does not create a major problem, but it can be an indication of moisture intrusion, which may compromise the structural material.

It is also important to mention based on our observation that curing is very necessary in concrete production in order to ensure the complete hydration of cement.

The water analysis test shows that there is high percentage content of salinity of chloride and high conductivity in salt water sample.

VII. Conclusion And Recommendations

Conclusion

In conclusion, by comparing the results of concrete cubes and beams produced with fresh water with those produced with salt water, based on the practical that have been carried out which includes the grading of aggregates, production of concrete (with both fresh water and salt water), slump test, curing of concrete cubes/beams and crushing of concrete cubes/beams, setting time test and water analysis, there are variations in the results which could be summarized as follows:

i. The strength development in the concrete produced increases with the increase in the hydration period.
ii. The use of salt water in the production of concrete will reduce the strength of concrete to approximately 7%. The variations in the results could be as a result of the 93% content of chloride in the salt water sample according to the water analysis results which could be responsible for the reduction of compressive strength, delay in setting time and slump of the concrete.
iii. The higher the setting time, the lower the strength of concrete produced.
iv. Curing is very important in concrete so as to ensure the complete hydration of cement.
v. The strength development in concrete depends on the percentage chemical composition of cement.
vi. The presence of chlorides and sulphates in salt water reduces the strength of concrete.
vii. We, therefore, confirm that salt water has effect on the concrete paste since there are differences between the slump of salt water concrete and that of fresh water.
viii. The result shows that the average compressive strength, average flexural strength and average split tensile strength of concrete produced using fresh water is higher than that of the salt water. The decrease is due to the presence of chlorides and sulphates in the salt water.

Based on the results so far, I conclude that salt water has slight effect on the concrete and will corrode reinforcement if used in the construction.

Recommendation

From the results of the practical test carried out, it is observed that the salt water actually have effects on the concrete. The use of salt water should be welcomed and not feared for casting and curing of concrete during construction most especially in coastal environments.

i. Since the effects of salt water will be more transparent in reinforced concrete as the steel will be subjected to rust by salt attack and this could lead to structural collapse, we, therefore, recommend the use of super sulphate cement because of its good properties of resistance to attack by sulphates since it can withstand attack from acids having pH values as low as 3.5.
ii. It is a known fact that Chlorides present in salt water breaks the passive layers around the reinforcing bars inside the concrete thereby exposing the reinforcements to rust, hence, we recommend that the concrete covers for structures in coastal locations should be minimum of 75mm as this will increase the time the chlorides can reach the passive layers, hence, the extent of damage by the Chlorides will be reduced or eliminated.
iii. We also recommend the use of Coatings on the surface of Concrete or coatings on the surface of steel on construction works in coastal areas which will make it hard for chlorides to penetrate hence will prevent rusting of the reinforcement.
iv. We recommend the use of corrosion inhibitors in construction works in coastal environments as they are admixtures which can either extend the time to corrosion initiation or significantly reduce the corrosion rate of embedded reinforcement or both in concrete containing chloride.
v. We recommend the use of Supplementary Cementitious Materials being added to concrete mixtures being used in coastal areas which will improve durability and decrease permeability, aiding in mitigating or diminishing alkali reactivity and improving the overall hardened properties of Concrete.
vi. Finally, the Engineer should be very careful when using Admixtures in construction works within or outside coastal areas to avoid using those with high content of Chlorides as this will affect the reinforcements.

References

[1] Akinkurolere, O. O., Jiang, C And Shobola O. M. (2007). The Influence Of Salt Water On The Compressive Strength Of Concrete. Journal Of Engineering And Applied Sciences, 2: 412 - 415.

[2] Chatterji A. K. (2016): Effect Of Salt Water On The Flexural Strength Of Concrete. Journal Of Scientific Industrial Research, Vol. 18, 2000, Pp. 301-340 *Encyclopaedia Britannica*. Retrieved 17 July 2013.

[3] Gopal, M. (2010). Concrete In Seawater. Retrieved From. Http://Www. Theconstructor.Org/Concrete/Concrete-In-Seawater/843/. Https://Staff.Emu.Edu.Tr/Ozgureren/En/Documents/CIVL284/BRE%20Mix%20Design%20Example%202.Pdf

[4] Khan, M. I., And Ullah, I. (2019). Effects Of Salt Water On The Compressive Strength Of Concrete. Journal Of Engineering And Applied Sciences, 38: 123-129.

[5] Krishnam Raju P, Lakshmi V And Pravallika S. Bhanu (2014). An Investigation On Fly Ash Blended Cement Concrete Using Sea Water. International Journal Of Advanced Scientific And Technical Research, 2(4).

[6] Matthias D. (2010). Properties Of Concrete. Retrieved From Http://En.Wikipedia.Org/Wiki/Concrete

[7] Mehta, P. K. (1980). Performance Of Concrete In Marine Environment. ACI. Pub. SP.

[8] Mehta, P. K. (1994). Mineral Admixtures For Concrete - An Overview Of Recent Developments Advances In Cement And Concrete. Proceedings Of Engineering Foundation Conference, (Ed.) MW Gutzeck, SL Sarkar, Pp: 243-256.

[9] Mokhtar M. A. And Swarmy, R.N. (2008). Influence Of Salt Weathering On The Properities Of Concrete. Arabian Journal For Science And Engineering , Volume 33, Number 1BPp. 501.

[10] Olutoge, F. Adeyemi And Amusan, G. Modupeola (2014). The Effect Of Sea Water On Compressive Strength Of Concrete. International Journal Of Engineering Science Invention, 3(7).

[11] Preeti Tiwari, Rajiv Chandak, R. K. Yadav (2014). Effect Of Salt Water On Compressive Strength Of Mortar. International Journal Of Emerging Trends In Engineering And Development, 2(4).

[12] Seeley Ivor (1976). Civil Engineering Specification. Fourth Edition By UBS Publisher's Distributor PVT Ltd, New Delhi.

[13] Stark, D. C. (2010). Long Term Performance Of Plain And Reinforced Concrete In Seawater Environments. Portland Cement Association, RD 119. Retrieved From. Http://Www.Cement.Org/Tech/Cct_Pca_Research_Tech.Asp.

[14] Swati Maniyal (2015). Experiment Review Of Effect Of Sea Water On Compressive Strength Of Concrete. International Journal Of Emerging Technology And Advanced Engineering, 5(3).

[15] Tibbetts, D. C. (1968). Performance Of Concrete In Sea Water. Canadian Building Series, 2: 159 – 180.

[16] Yassar M. H (1996). Composition Action Of Foamed And Lightweight Aggregate Concrete. Journal Of Materials In Civil Engineering, 8, No 3:111-118.

[17] Zhang, Z., Dai, Q., Yang, Y., Xie, Y., And Liu, Y. (2020). Experimental Study On The Effects Of Seawater On The Properties Of Concrete. Construction And Building Materials, 232, 117233. 10.1016