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The Effect of Sea Water on Compressive Strength of Concrete

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ABSTRACT : *This paper presents the experimental investigations on the effect of sea water on the compressive strength of concrete. Cement concrete cubes of 150mm x 150mm x 150mm were cast using fresh water and sea water with mix ratio 1:2:4. All the mixes were prepared using constant water cement ratio (w/c) of 0.6 by weight. A total of 140 concrete cubes were made in two batches; half of the cubes were made using fresh water and the other half using sea water. They were cured in fresh and sea water respectively. The curing was done for 7, 14, 21, 28 and 90days, then crushed using the Compressive Strength Test Apparatus at prescribed ages. The study shows an increase in the compressive strength of concrete for concrete specimens mixed and cured with sea water. Compressive strength of the concrete were also affected when the concrete was cast with fresh water and cured with salt water and vice-versa.*

KEYWORDS: *Concrete, Sea water, Compressive Strength*

I. INTRODUCTION

About 80 percent of the surface of the earth are covered by oceans; therefore, a large number of structures are exposed to sea water with high salinity either directly, or indirectly when winds carries sea 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.

Concrete is one of the major building materials use in modern day construction. It is a composite construction material composed of cement and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures (Akinkurolere et al, 2007; Neville and Brook, 2008; Matthias, 2010). 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 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. Sea water can be said to have a solution containing a great number of elements in different proportions. Primarily sea water contains some chemical constituent such ions of chloride, magnesium, calcium and potassium (Akinkurolere et al, 2007; Gopal, 2010). 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. Table 1 shows the concentration of major ions present in the world sea.

Table 1: Concentration of Major Ions in Some of the World Seas

Major Ions	Concentration (mg/l)								
	Black Sea	**Marmara Sea**	**Mediterranean Sea**	**North Sea**	**Atlantic Ocean**	**Baltic Sea**	**Arabian Gulf**	**BRE** Exposure**	**Red Sea**
Sodium	4,900	8,100	12,400	12,200	11,100	2,190	20,700	9,740	11,350
Magnesium	640	1,035	1,500	1,110	1,210	260	2,300	1,200	1,867
Chloride	9,500	14,390	21,270	16,550	20,000	3,960	36,900	18,200	22,660
Sulfate	1,362	2,034	2,596	2,220	2,180	580	5,120	2,600	3,050
TDS	17,085	26,409	38,795	33,060	35,370	7,110	66,650	32,540	40,960
TDS Ratio*	3.90	2.52	1.72	2.02	1.88	9.37	1.00	2.05	1.63

Source: Gopal (2010).

The effect of sea 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 sea water" revealed that a large number of concrete structures in sea water in the United States, Canada, Cuba and Parama are exposed to chemical deterioration (Tibbetts, 1968). Mehta (1980) reported after exposing concrete cylinder to sea water that the section of concrete that always remain above high-tide lines would be vulnerable to cracking and spalling as shown by the representation diagram in Figure 1. Another investigation recently carried out by Portland Cement Association (PCA) on long time study of cement performance in concrete (LTS) program provides key insights into the performance of concrete in seawater. The results of 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, 2001). 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; Gopal, 2010). Kumar Mehta and Monteiro, (2006) in 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.

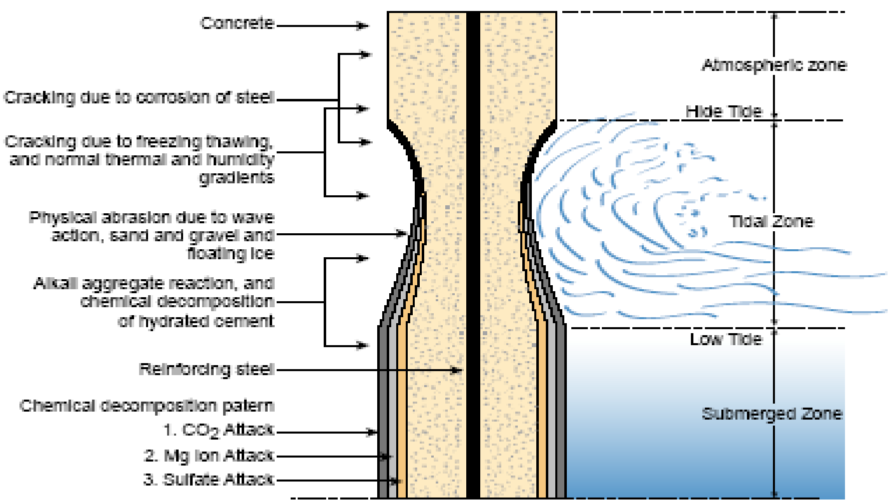

Figure 1: Concrete Cylinder Exposed to Seawater

Source: Mehta (1980)

Attack on concrete due to any of these reason tends to increase the permeability; not only would this make the material progressively more susceptible to further action by the same destructive agent but also to other types of attack. Thus mazes of interwoven chemical as well as physical cases of deterioration are found at work when a concrete structure exposed to seawater is in an advanced stage of degradation (Gopal, 2010).Therefore, marine concrete structures that will satiate the long term design requirements must follow a careful procedure in both design and construction stages. Suitable materials selection, good mix design, proper detailing of reinforcement, appropriate construction technique and a strict control program are the essential parameters to produce durable marine concrete structures. Thus this paper aims to determine the effect of sea water on the compressive strength of concrete with a view of producing durable marine concrete structures.

II. EXPERIMENTAL STUDIES

Materials

Cement : The cement used was Elephant Portland Cement. It was stored under dry condition, free of lumps and in conformity with BS 12. Table 2 gives the detail of the properties of cement.

Water : Fresh water and sea water were used. The water samples were clean and free from oil. The fresh water used was gotten from the tap at the Civil Engineering Department Laboratory, Moshood Abiola Polytechnic, Abeokuta, Ogun State and the sea water gotten from Eleko beach, Lagos State, Nigeria.

Aggregates : The fine aggregate was gotten from the stream, a washed sand deposit, free from organic matter. The coarse aggregate was granite a crushed rock of 3/4 inch size and of high quality. Both aggregates met the requirements of BS 882.

Methods

Preliminary Test : Some preliminary tests were carried out on the samples. The physico-chemical analyses were performed on fresh water and sea water in order to determine their chemical constituents as shown in figure 2. Setting time of the cement and sieve analyses of the aggregates were carried out as shown in figure 3 to determine the finess of materials used.

Fig 2: Physico-chemical analysis of water samples

Fig 3: Sieve Analysis of Aggregates

Specimen Preparation and Casting of Concrete Cubes : Batching was done by weighing the materials for the concrete specimen using a Manual Weighing Balance. Concrete mix ratio of 1:2:4 by weight of concrete 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) with the mould and it's based clamped together. The inside 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.

140 concrete cubes of 150x150x150(mm) were cast and cured in two batches. 70 cubes were made using fresh water and the remaining 70 cubes were made using sea water.

The cubes from the two batches were further divided into two; 35 cubes of the specimens from concrete cast with fresh water were cured in fresh water and the remaining 35 cube cured in sea water for 7, 14, 21, 28, and

90days respectively. The specimens were cured at room temperature in the curing tanks. Similar curing method was applied for concrete cast with sea water using the same curing days and environmental conditions. The details of the concrete specimen preparation are shown in Table 2.

Table 2: Details of Concrete Specimen

Curing Days	FF	FS	SF	SS
7	7	7	7	7
14	7	7	7	7
21	7	7	7	7
28	7	7	7	7
90	7	7	7	7
Total	35	35	35	35

- FF - Concrete cast and cured with fresh water
- FS - Concrete cast with fresh water and cured with seawater
- SF - Concrete cast with salt water and cured with fresh water
- SS – Concrete cast and cured with seawater.

Testing Compressive Strength : The compressive strength test was performed on the concrete cubes, tested at the curing age of 7, 14, 21, 28 and 90days using the compression testing machine. The cube was placed between the compressive plates parallel to the surface and then compressed at uniform rate (without shock) until failure occurred. The maxi load at failure and the compressive strength were read through of the screen at the top of the machine. The compressive strength was calculated by dividing the maximum load in Newtons (N) by the average cross sectional area of the specimen in square millimetre (mm^2). The reported result is the average of seven samples. The test was carried out according to BS 1881: part 3. The representations are shown in Fig. 4 and Fig.5

Fig 4: Weighing of Cube

Fig 5: Cube after loading

III. RESULTS AND DISCUSSIONS

The results obtained from preliminary tests carried out on concrete and water are presented and discussed here as:

Table 3: 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 3; shows increase value of setting time, which implies that concrete mix with sea 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.

Table 4: Chemical Analysis of Fresh water and Sea water

TEST	FRESH WATER	SEA 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	-	-
Odour	Unobjectionable	Unobjectionable
Colour	-	Blue
Temperature	20 ^{O}C	32.6 ^{O}C

Table 5: Sieve Analysis of Fine Aggregate

Sieve Size (mm)	Percentage Passing (%)
10	100
3.35	96
2.36	95
1.70	81
0.212	2.5
0.125	0.8
0.063	0.2
Receiver	-

Table 6: Sieve Analysis of Coarse Aggregate

Sieve Size (mm)	Percentage Passing (%)
30.0	100
26.5	78
25.0	47
20.0	16
14.0	2.9
10.0	0.2
3.35	0
Receiver	-

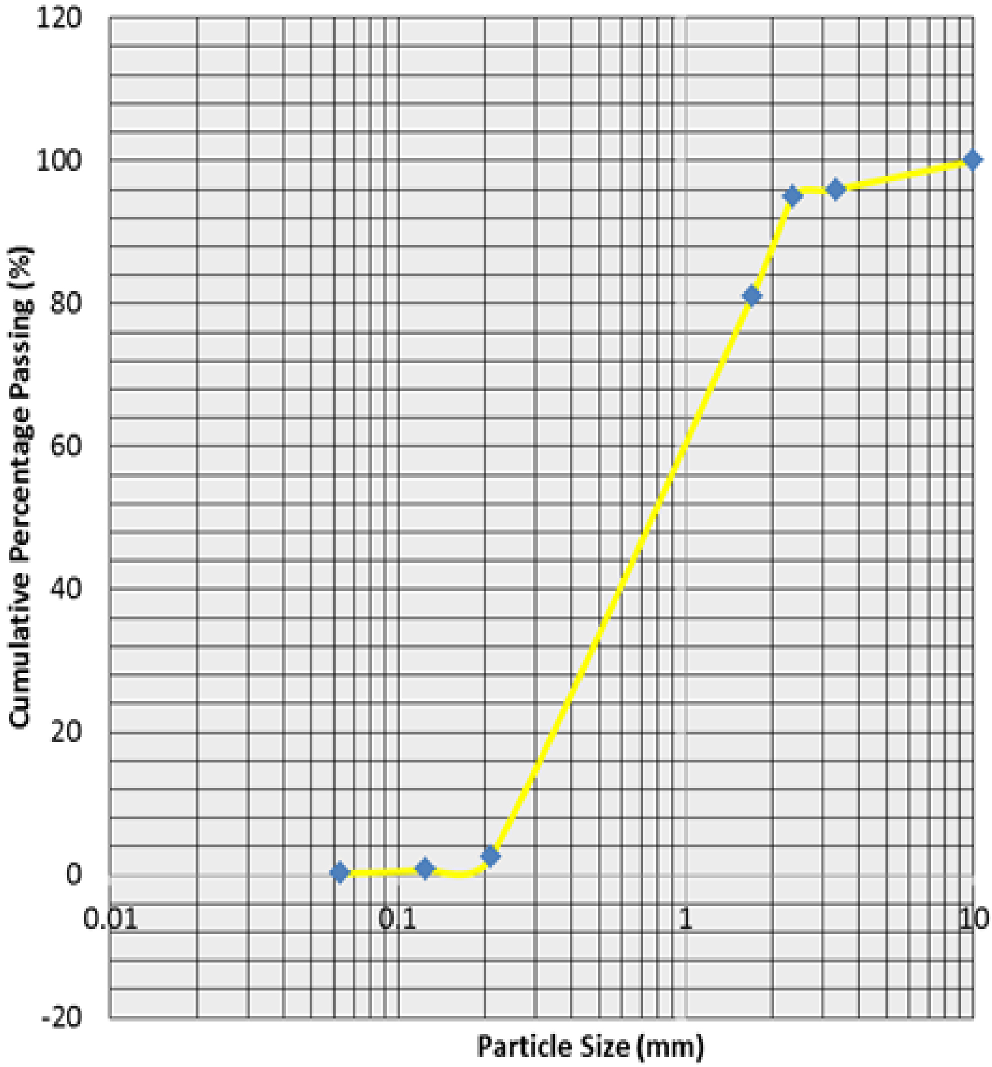

Figure 6: Particle Size Distribution of Fine Aggregate

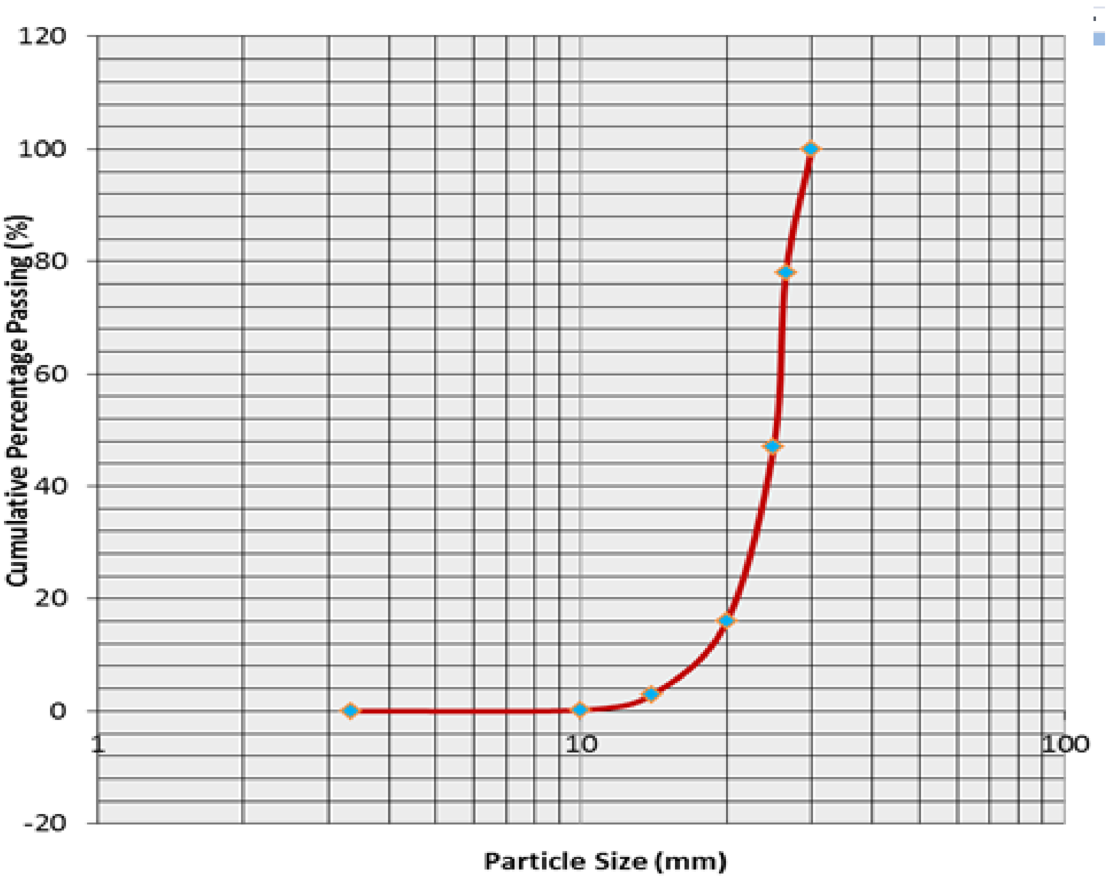

Figure 7: Particle Size Distribution of Coarse Aggregate

Table 7: Variation of Compressive Strength

CONCRETE DESIGNATION	CURING DAYS	AVERAGE WEIGTH OF CUBE (Kg)	AVERAGE CRUSHING LOAD (kN)	STRENGTH (N/mm^2)
FF	7 14 21 28 90	8.45 8.53 8.80 9.05 9.04	275.5 335 355.5 449.5 475	12.24 14.89 15.80 19.98 21.11
FS	7 14 21 28 90	8.43 8.70 8.75 8.87 9.02	290 330 300 422 450.5	12.89 14.66 13.33 18.75 20.22
SF	7 14 21 28 90	8.50 8.77 8.60 8.84 9.20	322 370 385.5 453.5 491.6	14.31 16.44 17.13 20.16 21.85
SS	7 14 21 28 90	8.55 8.80 9.08 9.35 9.40	310 405 448 493.5 520.7	13.78 18.00 19.91 21.93 23.14

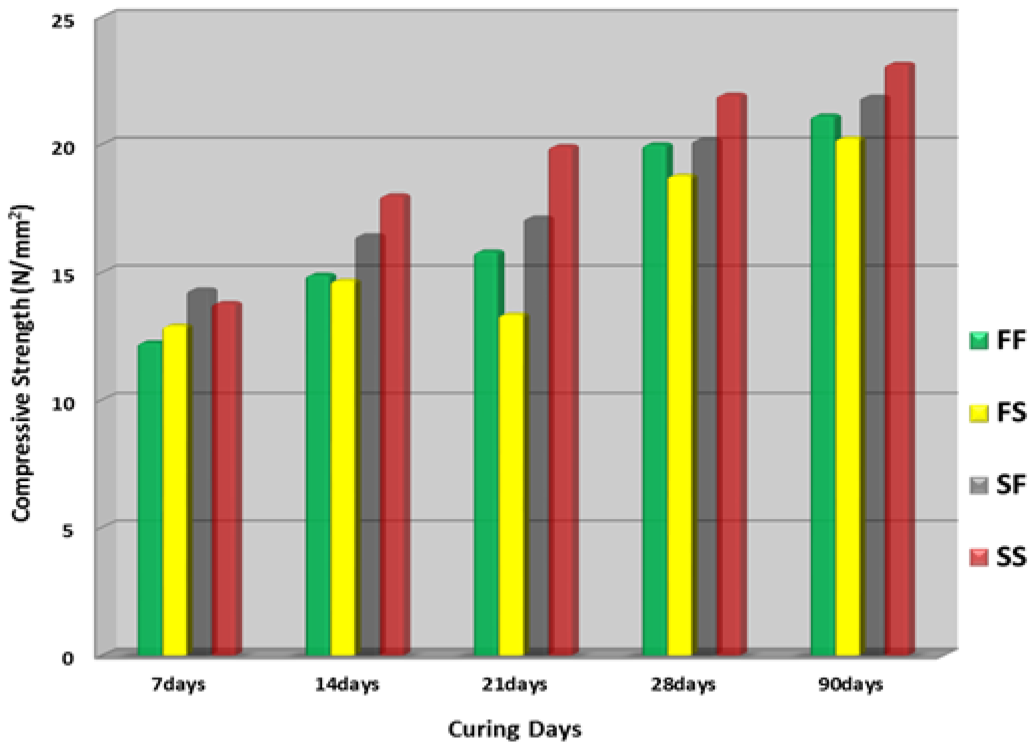

Figure 8: Variation of Compressive Strength

The results in Table 7 and Figure 8 above shows an appreciable increase in strength at 7days 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 at 90 days, but with more than 90% of the strength reached at 28 days.

IV. CONCLUSION

It was observed that concrete cast and cured with seawater 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 28days, of about 20N/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 28 days and 90days respectively. In practice, the fresh-fresh water situations occur in building constructed on interlands and main lands. 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 prestressed 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 and Brooks, 2008; Biczok, 1967).

Recommendation

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

[1] The use of salt water should be welcome and not feared for casting and curing of concrete during construction most especially in coastal environment.

[2] 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.

[3] Further study should be made on prevention of reinforcement from sulphate attack in order to avoid the fear of reinforcement from being easily corroded and on the effect of salt water on other important characteristics of concrete.

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