International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 03, March-2015

A Review on Strength of Concrete in Seawater

Akshat Dimri[1], Jay Kr. Varshney[1],
1- M.Tech Civil Engg
G.B.P.U.A&T, Pantnagar, India

V. K. Verma[2], Sandeep Gupta[2]
2- Assistant Professor, Civil Engg
G.B.P.U.A&T, Pantnagar, India

***Abstract*- Several billion tons of water is annually used as mixing, curing and cleaning around the world, in concrete industry. As there is a scarcity of fresh drinkable water around the world; so there is a need to save fresh water and hence possibilities of using seawater as mixing as well as curing water should be investigated seriously. Additionally, if use of seawater as concrete material is permitted, it will be very convenient and economical in the construction; especially in the coastal works. However; most of the reinforced concrete codes do not permit the use of seawater due to risk of early corrosion of reinforcement. The effect of seawater on concrete deserves special attention as the coastal and offshore structures are exposed to simultaneous action of a number of physical and chemical deterioration processes. Moreover, 80 percent of the earth is covered by seawater either directly or indirectly (e.g. winds can carry sea water spray up to a few miles in land from the coast). Concrete piers, decks, break-water, and retaining walls are widely used in the construction of harbors and docks. The use of concrete offshore drilling platforms and oil storage tanks is already on the increase. This paper illustrates the various research and their results that were carried out earlier on the experimental studies on the strength of concrete in seawater.**

Keywords: Seawater, compressive strength, flexural strength, sea salts

1. INTRODUCTION

The Concrete structures which are exposed to marine environment may deteriorate due to the result of combined effects of chemical action of seawater constituents on cement hydration products, alkali-aggregate expansion (when reactive aggregates are present), crystallization pressure of salts within concrete if 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. Attack on concrete due to any one of these causes tends to increase the permeability which would make the material progressively more susceptible to further action by the same destructive agents.

1.1 Concrete **:** Concrete is an artificial construction structural material made from the mixture of aggregates (coarse & fine), portland cement, water, admixtures & pozzolanic materials. Concrete is formed when portland cement hydrated and formed cement paste, which when mixed with aggregates hardens and binds the aggregates into solid mass. These constituents materials are a hardened binding medium or matrix, formed by a chemical reaction between cement and water, and aggregates to which the hardend cement adheres to greater or lesser degree (Murdock and Brook, 1979). The strength of concrete mainly depends on the proportion of its ingredient particles i.e. cement, sand, coarse aggregates etc. The strength of concrete is affected by the water-cement ratio,method of curing, physical properties of coarse & fine aggregates, cement etc.

1.2 Sea Water: Sea water has chemical constituent elements mainly : ions of chloride, sodium, magnesium, calcium and potassium. It has been analysed that sea water contains 78% NaCl, 7.86% $MgCl_2$, 3.74% $MgSO_4$, 2.34% $CaSO_4$, 1.8% K_2SO_4, 0.22% $CaCO_3$, 0.2% $MgBr_2$. NaCl2 & $MgCl_2$ has the highest concentration in comparison to other salts.

Sea water is an electrolyte and plays a major function in any electrolytic action between dissimilar metals and between salt concentration and steel (Bela,1989). Seawater has considerable varying PH value.

1.3 Concrete in seawater :The durability of concrete is regarded as its ability to resists the effects and influences of the environment while performing its desired functions(Hoff, 1991). Over the year it has become very necessary and imperative to ascertain the qualities of properties of coastal structures (oil platform, sea wall, buck head etc) in contact with sea water as they tend to perform their functions during the period of their design life. The properties of concrete structures such as strength, durability, stability,resistance to frost & thaw action etc require thorough investigation. The effect of seawater on concrete has remained a major problem associated with structures either built in sea water or cast or cured with sea water. According to Gani (1997), the presence of sodium chloride in sea water accelerates the attack on other compounds on the concrete. The chemical action of seawater on concrete is mainly due to attack by Magnesium sulphate ($MgSO_4$). This attack is by crystallization. It has been established that potassium and magnesium sulphates (K_2SO_4 & $MgSO_4$) present in seawater can cause sulphate attack in concrete as a result of initial reaction with calcium hydroxide ($Ca(OH)_2$) which present in set cement and form by hydration of C_3S & C_2S.

Seawater tends to increase the risk of corrosion of embedded steel reinforcement when the structure is duely exposed to air. The most damaging effect of seawater on concrete

structures arises from the attack of chlorides on the steel reinforcement and salt build up. The increase in the risk of corrosion of steel limit the use of seawater in steel reinforced structures, if prior preventive measures are not put in place. Preventive measures include the coating of reinforcement steel with cement slurry mixed with fresh water.

2. LITERATURE REVIEW:

2.1: Strength of concrete mixed or cured with sea water

Liu et al. (2002) showed that composites have ever proved to be resistant to marine environment, and that the level of fine aggregate replacement by ground blast furnace slag and ground basaltic pumice had a beneficial effect on the compressive strength loss due to sea water attack and abrasion value.

M.I Retno Susilorini et al (2005) conducted experimental and analytical method. Through experimental method they investigated the compressive strength of concrete cylinders, with 7 days and 14 days with seawater curing and plain water curing. After 7 days and 14 days of curing, the concrete cylinders were tested by compressive testing machine.

The experimental results of this research showed that the compressive strength of 7 days and 14 days concrete specimens with seawater curing is higher than those cured by plain-water, about 2.56-5.25% for 7 days old specimens and 3.39-11.87% for 14 days old specimens. The result also showed that the lower water cement ratio, the higher concrete compressive strength would be. They found by analytical calculation that the specimens cured by seawater has higher compressive strength, about 0.06-0.39% for 7 days old specimens and 0.11- 0.33% for 14 days old specimens. The higher strength compressive of concrete specimens with seawater curing is provided by the existence of calcium chloride in seawater and by high temperature of seawater. This research concludes that both experimentally and analytically, the compressive strength of 7 days and 14 days old concrete specimens cured by seawater are higher than those cured by plain water.

Naghoj et al (2005) reported that adding loam to concrete mix can increase the compressive strength of concrete under normal conditions and enhance the performance of hardened concrete to resist the aggressive medium of salty sea water.

O. O. Akinkurolere et al (2007), examined the influence of salt water on the compressive strength of concrete. This research presents the results and findings of an experimental program on the influence of salt water from Lagos lagoon, in Nigeria on concrete compressive strength. In this research, concrete cubes of size 150x150x150 mm were cast with fresh & salt water using a mix ratio of 1:2:4 by weight of concrete. Water-cement ratio of 0.6 were used. They cast a total of 132 concrete cubes out of which half of the cubes were made using fresh water and remaining half were made using salt water. They were cured in fresh & sea water respectively. The concrete cubes were tested for compressive strength at 7, 14, 21, 28 days. They reported that the compressive strength of concrete is increased due to the presence of salt or ocean salt in the mixing & curing water.

Falah M. Wegian (2010) investigated the effects of mixing & curing of concrete with sea water on the compressive, tensile, flexural, and bond strengths and showed that there were increase of strengths of concrete when mixed & cured in sea water at early ages and a decrease for ages more than 28 days and up to 90 days.

Nobuaki Otsuk et al (2011) found that sea water may be used for mixing with concrete with some considerations. The countermeasures of using sea water as mixing water are as follows;

1) Use BFS cement or other blended cement instead of OPC

2) Use corrosion inhibitor.

3) Reinforced with stainless steel or corrosion resistant reinforcement.

Akinsola Olufemi Emmanuel et al (2012) conducted laboratory experiments to see the effects of lagoon and ocean water on R.C.C. They adopted a mix ratio of 1:3:6 for their research work. They cast Reinforced concrete specimens using both lagoon and ocean water and some specimens with fresh water. They buried the specimens at a depth of 1.5m below the ocean and lagoon for a period of 150 days. They found that specimens under ocean and lagoon showed an increment in compressive strength from 10.65N/mm2 and 10.57N/mm2 on 7th day to 17.05N/mm2 and 18.04N/mm2 on the 21st day respectively as against the 14.20N/mm2 on 7th day to 17.05N/mm2 and 18.04N/mm2 fresh water sample.

Tiwari Preeti et al (2014), found that there was a marginal increase in the strength of 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. They concluded that the compressive strength of the salt water concrete cubes was slightly higher than that of the fresh water concrete cubes.

P. Krishnam Raju et al (2014) studied the effect of seawater on compressive and flexural strength of ordinary Portland cement (OPC) of 53 grade. The mixes were prepared with “Potable water mixing & Sea water curing”, and “sea water mixing & sea water curing”. They casted a total of 54 cubes, 54 cylinders, 54 beams including specimens for reference concrete for the M30 & M35 mixes and exposed them for 7 days, 28 days and 90 days period of curing. They investigated the compressive strength behavior, modulus of rupture and flexural strengths. The reference concrete was prepared with opc using only potable water both for mixing

and curing. They observed that there is no considerable reduction in compressive strength due to mixing of sea water and also due to mixing and curing with sea water compared to its target strength.

2.2 Effect of salt concentration and its suitability on concrete

According to Vicat (1812), Prascal et al. (2006) 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, M., 1964).

S + CH + 2H -CSh2 + KH
S + CH + 2H – CSH2 + 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 produced by the reaction with cementation gels to form non cementations product (M_4SH_8).

Bryant, M. (1964), Taylor and Kuwari (1978) carried out an experiment to determine the effect of ocean salts on compressive strength of concrete cast and cured with salt water. They took alternate concentrations of sea salt (NaCl, $MgCl_2$, Na_2SO_4, or $CaCl_2$) and observed that some chemical processes or reaction must have taken place. They recommended that further test are needed to 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.

Mori et al. (1981) reported that the difference of strength between concrete mixed with seawater and fresh water is relatively small after 10 years of exposure test. Additionally, according to Yamamoto (1980), the concrete mixed with seawater may show higher strength compared with fresh water mixing under the environment below 15 ºC.

Novokshchenov (1995) reported the deterioration of reinforced concrete structure in marine environment constructed in the Arabian Gulf in 1977. They found that structure was seriously deteriorated due to steel corrosion. According to him, this deterioration was not due to chloride (Cl) derived from mixing water only, but also to the sever environment, especially sulphate attack. Besides, the water-cement ratio of concrete was relatively high (0.52-0.74) and ordinary Portland cement was used as cement. In the case of the low water-cement ratio such as 0.27 (Gayner, 1979) or the use of proper mineral admixture such as BFS (Ozaki, 1984), the steel corrosion in concrete mixed with seawater can be avoided even in the existing reinforced concrete structures.

Neville (2001) recommend that the seawater should not be used as mixing water for concrete reinforced by steel bars because of the high risk of corrosion. However the results of the long term exposure tests conducted by Port and Airport Research Institute in Japan indicated that the amount of Cl measured in concrete after 20 years of exposure is not affected by the mixing water (Fukute, 1990) and the negative influence of seawater used as mixing water is relatively decreasing with age (Otsuki, 1985).

Stark (2002) affirms the importance of controlling the water cement ratio and permeability of concrete in maximizing concrete durability. The study confirmed the importance of proper ratio of water to total cementitious materials and the resulting permeability as the primary factors determining performance in outdoor exposures. Furthermore, the use of low water cement ratio provides the greatest resistance to sulphate attack on concrete, and the composition of Portland cement is less important as it relates to performance in sulphate solutions.

Person (2003) studied the sulphate resistance of self-compacting concrete at ages of 28 & 90 days. The investigation shows that the concrete cured in a solution with sodium sulphate suffer from a larger loss of concrete mass due to limestone filler content in the concrete mixes.

Lateef Ige Raimi (2010) carried out research work to investigate the effect of seawater concentration, as mixing or curing, on the compressive strength of concrete. They found the result of the action of salt water from Lagos Bar-beach, in Nigeria, on concrete compressive strength. They took a total of 144 concrete cubes of 150 X 150 X 150 mm size, mixing ratio of 1:2:4 and a water cement ratio of 0.6, were cast with seawater, fresh water and blending of seawater.

The cubes were divided in two and cured in seawater and fresh water respectively. The compressive strength of the cubes determined through crushing at 7, 14, 21 and 28 days respectively. The weekly pH and temperature readings of curing seawater and fresh water were taken at interval of time, including the pH and temperature of unused seawater. They observed the pH value and percentage composition by mass of compounds: NaCl, $CaS0_4$, KBr, K_2S0_4 and $MgS0_4$. They found that compressive strength of concrete cast with seawater showed an increase in strength at 7, 14, 21 & 28 days. A remarkable rapid increase was noted in concrete cubes cast and cured with seawater at 7, 14, 21& 28 days respectively. Also, concrete cubes cast with fresh water and cured with seawater have their strength increased at 7, 14, 21 & 28 days as well. At 7days of curing, concrete cast with seawater and cured with seawater has attained strength of about 79% of the 28days compressive strength of the control

test. So that at 28days, SS (cubes cast with seawater and cured with seawater) has attained strength of about 114% of 28days compressive strength of control.

Md. Moinul Islam et al (2012), examined the suitability of sea water for mixing and curing of concrete. They studied the effect of sea water on compressive strength of concrete when used as mixing & curing water. Different mix ratios of concrete were prepared with different water cement ratios. Test specimens were cured under sea water of varying normality i.e.1N, 3N, and 5N, as well as plain water up to 180 days. (1N sea water means normal sea water made by mixing tap water with exact amount and proportion of principal salts found in natural sea water.) . They concluded that concrete specimen made & cured with sea water exhibits compressive strength loss of about 10% compared to plain water mixed and cured concrete. Also, their result showed that compressive strength is reduced with increase in seawater concentrations (i.e. increase in normality) and the nature of variation of strength is not proportional.

3. RESULTS & CONCLUSIONS:

From all the earlier studies it can be concluded that the early 7 days strength doesn't affect when concrete is casted with plane water and cured in marine environment, but strength (compressive, tensile, flexural) decrease with respect to time (28 & 90 days). Also, the strength increases up to several days when concrete is casted as well as cured with seawater but decreases with passage of time. There is a need of higher research to be carried out to study the effect of seawater curing in concretes. Also seawater changes its normality in billions of years, so this effect due to change in normality should also be checked experimentally. Further, there is need to check the curing effect of seawater in high strength concrete. The factors which affect the strength of concrete in marine environment are- Corrosion of the metallic bars caused by chloride ions, damage of the cement paste carried out by sulphate attack, and swelling disruption of concrete if alkali-reactive aggregates are present in the concrete.

4. FURTHER SCOPE OF WORK:

(a).Anti-chloride admixtures can be used in concrete production to avoid the sea water effect on concrete

(b).Investigation can be extended for higher strength concrete (M40, M50 etc.).

(c) Outer covering of unplasticized poly vinyl chloride (upvc) tube may also be used to safe guard concrete column against seawater.

5. 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, Vol. 2 No. 2, pp. 412 - 415.
2. Akinsola Olufemi Emmanuel., Fatokun Ajibola Oladipo & Ogunsanmi Olabode E., (2012) "Investigation of salinity effect on compressive strength of reinforced Concrete", Journal of Sustainable Development; Vol. 5, No. 6; Published by Canadian Center of Science and Education.
3. Bella, M., & Fabuss, T. (1989). Properties of Seawater. 1st Edition Academic Press Boston.
4. Bryant, M. (1964). *Effects of Seawater on Concrete*. Miscellaneous paper no 6-690, U.S. Army Engineers, Waterways experiment station, Corps of Engineers, Vicks berg, Mississippi.
5. E. M. Mbadike (2011),"Effect of salt water in the production of concrete", Nigerian Journal of Technology, Vol. 30, No. 2
6. Falah M. Wegian; (2010), "Effects of sea water for mixing and curing on structural concrete Studies", The IES Journal Part A: Civil & Structural Engineering, Vol .3, No.4, pp 235 – 243.
7. Gani, S.J. (1997). Cement and concrete (1st Ed) Chapman & Halls. Pp:149-169.
8. Gayner. J.F.C. (1979) "Concrete in hot climates". Precast concrete Vol.10,No.4,pp.169-172.
9. Hoff, G.C. (1991). Durability of offshore and marine concrete structures; 2nd international conference, 1991 pp.33-64.
10. Kaushik, S. K. and Islam S. (1995), "Suitability of seawater for mixing structural concrete exposed to a marine environment", Cement & concrete composites, Vol.17, No.3, pp.177-185.
11. Lee, C. and Lee M. G. (1997). "Effect of fly ash and corrosion inhibitor on reinforced concrete in marine environments", Special publication of American concrete institute, No.SP-170 Vol.1, pp.141-156.
12. Liu, H., Tai, N., and Lee, W., 2002 Effect of seawater on compressive strength of concrete cylinder reinforced by non-adhesive wound hybrid polymer composites. Composites Science and Technology, 62(16), 2131-2141.
13. M. I. Retno Susilorini. Kristina Retno Dewi W, Tri Wibowo , (2005), "The performance of early – age concrete with sea water curing", Journal of Coastal Department, Vol. 8, No. 2, 85 – 95.
14. Md. Moinual Islam, Md. Saiful Islam, Md. Al-Amin and Md. Mydul Islam (2007) "Suitability of sea water on curing and compressive strength of structural concrete",Journal of Civil Engineering (IEB), 40 (I) (2012) 37 – 45.
15. Mehta, P. K. (1980) "Performance of Concrete in Marine Environment", ACI. Pub. SP.
16. Mori, Y. et. al. (1981). "10 years exposure test of concrete mixed with seawater under marine environment", *Journal of cement association*, Vo.35, pp.341-344 (in Japanese).
17. Murdock, L.J and K.M. (1979) concrete materials and practice 5th (Edn), Edward Amold (publishers) Ltd, London.
18. Neville, A. M. and Brooks, J. J. (2008) Concrete Technology, 3rd Edition, India, Dorling Kindersley.
19. Novokshchenov, V. (1995). "Deterioration of reinforced concrete in the marine industrial environment of the Arabian Gulf- A case study", *Materials and Structures*, Vol.28, pp392-400.
20. P. Krishnam Raju, V. Ravindra & M. Bhanusingh (2014), "An Investigation on Strengths of Concrete for Marine Works Using OPC and Sea Water", SSRG-IJCE, Vol.1.
21. Shetty, M. S. (2002). Concrete Technology, Theory and Practice, Fifths Revised Edition, S. Chand & Company Ltd, New Delhi.