BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

SEA WATER FOR MAKING CONCRETE

It is a common belief amongst engineers that sea water is not suitable for use in making concrete as it might lead to the impairment of strength and corrosion of reinforcement. But a number of R. C. C. structures built during and after the second World War, in the islands of Atlantic Oceans and along the sea coast of Los Angeles and Florida, bear testimony to the satisfactory use of sea water for mixing and curing concrete. In India, the reinforced concrete jetty at Kandla built around 1934 and now used for berthing tankers, and the present wharves built in concrete mixed with sea water, are all reported to be in satisfactory condition. On the other hand, there are also reports of cracking and spalling of concrete in structures in coastal areas because of corrosion of steel due to the use of sea water in the concrete mix. The poor performance of these structures is mostly due to the lack of control on quality of concrete and workmanship. It is also possible that the codes of practice for reinforced concrete under exposure to marine conditions were either not existing at that time or were not strictly followed.

The need for using sea water for construction arises in certain situations where no other source of water is available or where fresh water is costly to transport. Such conditions have often arisen at the construction sites along the sea coast and construction engineers in the field are then beset with doubts about the advisability of using sea water. This digest has been compiled to give guidance about the use of sea water for concrete based on laboratory investigations and field experiences gained abraod.

Sea water contains about 3.5 percent of dissolved salts. About 78 precent of the salt is sodium chloride and about 15 percent is chloride and sulphate of magnesium The other constituents are calcium sulphate, potassium sulphate etc. which are generally low and within the safe limits. The composition of sea water from some of the sources along with the average sea water composition is reported in Table 1. It appears

Table 1

Composition of Sea-Water (g/L)

Constituents	Mediterranean	Atlantic	Mean Sea water	Indian
Sodium (Na)	11.56	9.95	11.00	10.56
Potassium (K)	0.42	0.33	0.40	0.38
Magnesium (Mg)	1.78	1.50	1.33	1.27
Calcium (Ca)	0.47	0.41	0.43	0.40
Chloride (Cl)	21.38	17.83	19.80	19.00
Bromide (Br)	0.07	0.06	—	0.07
Sulphate (So_4)	3.06	2.54	2.76	3.65
Bicarbonate (HCo_3)	—	—	—	0.14
Total	38.74	32.62	35.72	35.47

that the composition of sea water of Indian origin is close to the average and hence the inferences drawn from the studies abroad on the use of sea water for RCC can be extended to our conditions.

Chloride and sulphates in sea water are the most important from the point of view of action on concrete and reinforcement. All chlorides accelerate the setting of cement (calcium chloride is a well known accelerator) and may improve the early strength to varying degrees. But they are known to cause corrosion of reinforcement. Sulphates, on the other hand, retard the setting and also the development of strength at early ages in some cases. Hence the effect of sea water which contains both chlorides and sulphates has been considered from the following two aspects,

(i) its effect on setting time and strength development of concrete

(ii) likelihood of corrosion of reinforcement.

Sea water has been found to a-ccelerate the setting of concrete by improving the hydration of major cement constituents i. e. alite and belite. But the effect is apparently not so pronounced as to cause any serious trouble in its casting and laying. Early strengths have invariably shown an improvement with sea water when compared with distilled water in the mix but later strength have been observed to fall by 8 to 15 percent. IS456-1964 'Code of Practice for plain and reinforced concrete' permits the use of any water with concrete provided the crushing strength is not lower than 90 percent of the strength of concrete mixed with distilled water. BS 3148-1958 "Specification on water for making concrete" allows concrete cube strength of even 80 percent of companion test specimens in which distilled water has been used. Hence it may be concluded that sea water is safe enough for use in concrete where strength fall is not more than 20 percent. Moreover, fall in strength can be easily corrected by small adjustment in water-cement ratio or cement content in the concrete.

As per IS 456-1954 permissible limits of alkali chlorides and sulphates in mix water are 1000 and 500 mg/L respectively. Salts present in sea water exceed these limits. Although they do not affect the strength adversely, their presence may lead to persistent dampness in concrete and the formation of efflorescence. Sea water is therefore considered to be only satisfactory for all plain concrete work where persistent dampeness is of no consequence and finishing characteristics are not important.

Steel in concrete is normally protected against corrosion by the alkaline environment around it. Corrosion is caused by the neutralisation of alkalinity by carbon dioxide, oxygen and presence of chlorides. Most of the chloride ions present in mix water react with the tricalcium aluminate and calcium alumino ferrite phases present in the cement, forming calcium chloroaluminate and calcium chloroferrite. They get chemically combined and about 80 percent of the chlorides present thus get fixed up. It is only the free chloride ions which, when present in excess, may cause corrosion if they find access to the embedded steel. It has been shown by long time exposure tests that the use of 2 percent calcium chloride (by weight of cement) in a dense, well compacted concrete has little effect on the degree of corrosion of reinforcement Considering a m^3 of concrete containing cement content of 380 kg/m^3 and having water cement ratio of 0.55, the chloride introduced in concrete through the use of sea water as mix water has been calculated to be 1.04 percent (on the weight of the cement). This amount which is almost equal to the amount of chloride present in 2 percent calcium chlotide (content 0.96 percent) normally used should be considered within safe limits. Thus it may be concluded that sea water used as mix water has no ill effect on the reinforcement embedded in dense concrete.

The incidence of corrosion of reinforcement due to chlorides in the mixing water assumes secondary importance when it is considered that the curing water for marine structures can also be sea water which may provide excess of chloride ions to the embedded steel by diffusion if the concrete is permeable or if the the thickness of the cover is insufficient, Hence the ultimate governing factors are the quality of concrete and the thickness of the cover over the reinforcement.

The concrete structure may also be fully submerged in sea water. As per field experience gained so far, no corrosion has been observed under such condition on account of the virtual exculsion of oxygen and carbon dioxide. Under certain other situations concrete may be partially submerged between tidal zones. It may lead to corrosion due to alternate wetting and drying and capillary rise of sea water in the concrete, or the structure may be exposed to salt laden winds near the sea shore. Under these conditions low permeability of concrete assumes greatest importance since it would inhibit diffusion of chlorides and prevent corrosion. Permeability is mainly a function of the water-cement ratio and cement content of the concrete mix. It has been found that in good quality concrete when the W/C is below 0.55, diffusion of chloride ions is not significant at depth of 5 cm. or more. A cover of 7.5 cm over the reinforcement is considered adequate. For concrete permanantly under sea water and for concrete between tide levels minimum cement contents of 300 and 380 kg/m^3 respectively are necessary.

Use of sea water for making prestressed concrete is not recommended because the risk of corrosion is aggravated on account of the smaller diameter of the reinforcement which is already in a stressed state.

Recommendations

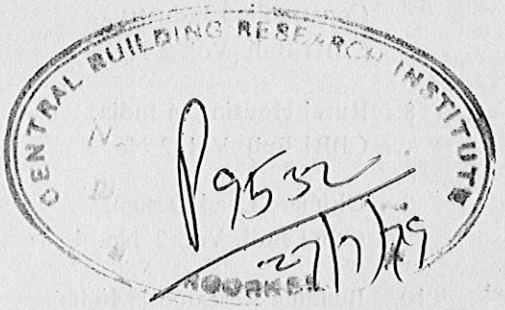
1. Use of sea water in making plain concrete does not pose any special problem. However, concrete strength test at 28 days should be used as a guide for the suitability of sea water.

2. With proper mix design, quality and workmanship it may be apprapriate to use sea water for making reinforced concrete. Here again concrete strength test and exposure conditions should be carefully considered for guidance.

3. Since sea water tends to cause dampness and efflorescence, it may be used either for foundation concrete or for buildings where finishing characteristics are not very important.

4. Use of sea water for prestressed concrete is not recommended.

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need, this Institute is bringing out a series of Building Digests from time to time and the present one is the 69th in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.



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