National Council for Cement and Building Materials

CORROSION IN REINFORCED CONCRETE STRUCTURES

APRIL-MAY 1988

NCB TECHNOLOGY DIGEST

CORROSION IN REINFORCED CONCRETE STRUCTURES

INTRODUCTION

CONCRETE is the most widely used construction material. Under normal circumstances, concrete structures are durable and provide trouble-free service for many years. However, there are many instances of distress to RCC structures observed due to corrosion of reinforcements. This technology digest discusses the causes of corrosion of reinforcements and lays down guidelines for repair and rehabilitation and for making durable concrete in new construction.

CORROSION OF REINFORCEMENT

The high alkalinity of the chemical environment normally present in concrete (pH>12.5) protects the reinforcements by forming a protective oxide film on the iron. The integrity and protective quality of this film depend upon the alkalinity or the pH of the concrete. The higher the alkalinity, the greater is the protective quality of this film. The steel in concrete becomes potentially more susceptible to corrosion, as the alkalinity of concrete is reduced by leaching or carbonation, or when soluble chlorides are present at iron-concrete interface. Chlorides ion is a specific and unique destroyer of the protective oxide film.

At a pH less than 11.5, corrosion may occur even in the absence of chlorides. At a pH greater than 11.5, a measurable amount of chloride is required, and that amount increases as the pH at the iron-concrete interface increases. The pH-chloride relationship and the basic general requirements for the occurrence of corrosion of reinforcement in concrete, are shown in Fig 1(a) and 1(b).

Chloride associated corrosion can occur due to its entry either during the construction stage or during the usage. Addition of chloride-based admixtures or use of concrete-making materials having chloride causes its entry during the construction, while the exposure of concrete structures to chloride bearing environment causes the second type of situation. When the protection to steel is destroyed either by carbonation or by the presence of chlorides, rusting process starts. Rust formation is accompanied by

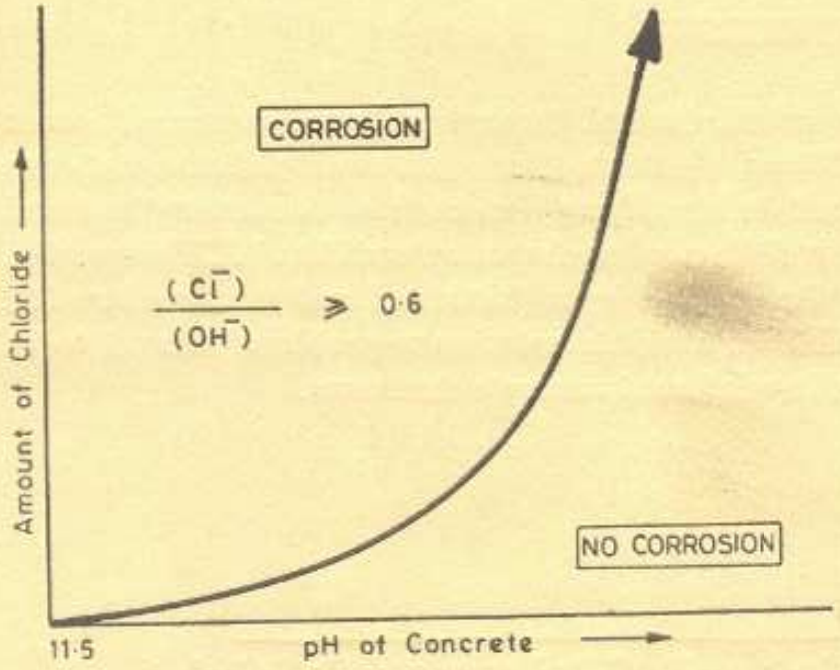

Fig. 1(a) Schematic Relationship of Chloride and pH in the Liquid Phase and Corrosion of Iron

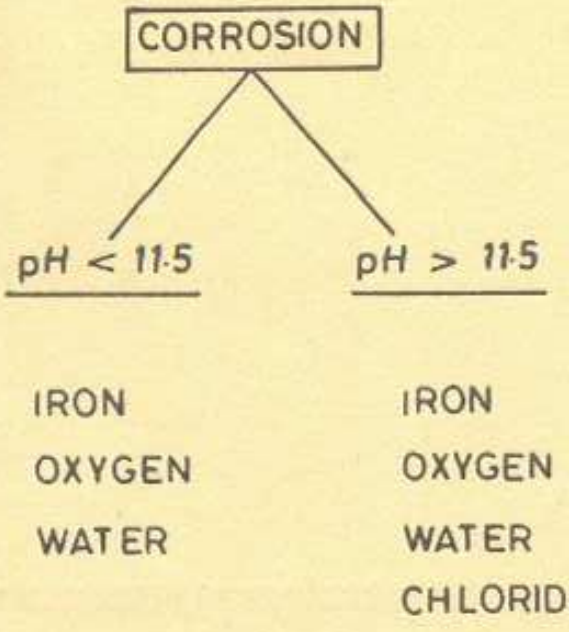

Fig. 1(b) Basic General Requirements if Corrosion is to Occur

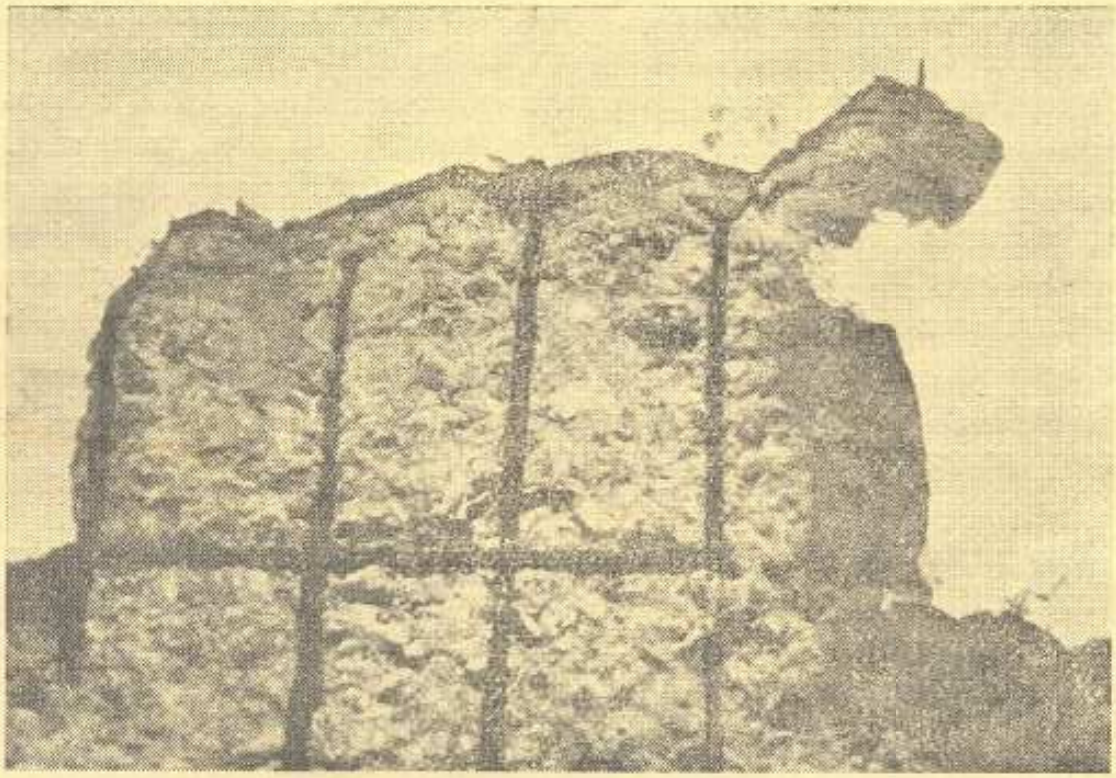

Fig. 2 Corrosion-Damaged RCC Roof Slab

development of large volumes which cause rupture to cover concrete in structures. Typical corrosion-damaged RCC roof slab is shown in Fig. 2.

NCB'S EXPERIENCE

During last 15 years, a number of cases showing distress due to corrosion of reinforcements have been investigated by NCB. It was found that the principal causes for reinforcement corrosion were material deficiencies and constructional inadequacies, summarised as follows:

a) Lower unit cement content and leaner mix proportions;
b) Inadequate concrete cover to reinforcement;
c) Presence of "pockets" or honeycombing in hardened concrete;
d) Ingress of moisture; and
e) Presence of high chloride content in hardened concrete

These investigations have clearly brought out the importance of quality of hardened concrete, mainly in terms of alkalinity (pH value). Whenever the pH value of cover concrete was below 10.0, either due to carbonation or inadequate cement content, corrosion of reinforcement has invariably taken place. This has been illustrated in Fig. 3, wherein the results of the

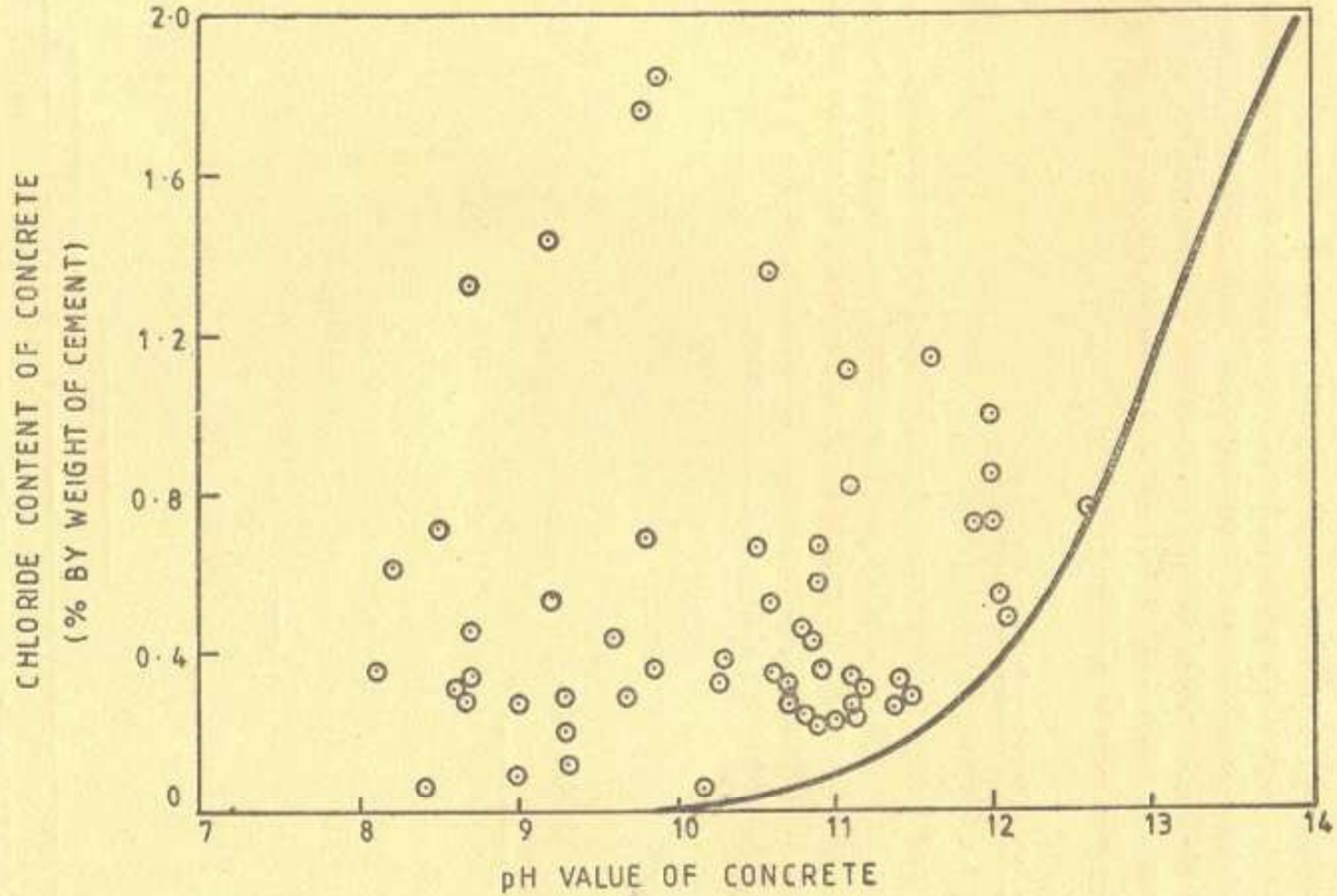

Fig. 3 Interaction Diagram of pH Value and Chloride Content in Corrosion-damaged Concrete

analysis of hardened concrete collected from the structures investigated so far, have been plotted. The envelope gives the limiting values on pH and chloride content of concrete. It can be seen from the plot that at pH less than about 10.0, corrosion occurred even in the absence of chlorides. About the amount of chlorides that can be permitted in concrete so far as the corrosion of reinforcement is concerned, a limiting chloride content of 0.15 percent by weight of cement recommended in IS : 456-1978 (Code of practice for plain and reinforced concrete) was found to be a safe limit. This has been illustrated in Fig. 4.

REPAIR AND REHABILITATION

In most of the cases, it may not be possible to stop the corrosion process altogether, but can be slowed down or contained, and thus the serviceable life of the structures can be enhanced. In some cases, it may be required to replace the structural components, if the designer finds it feasible without disturbing the stability of the structures.

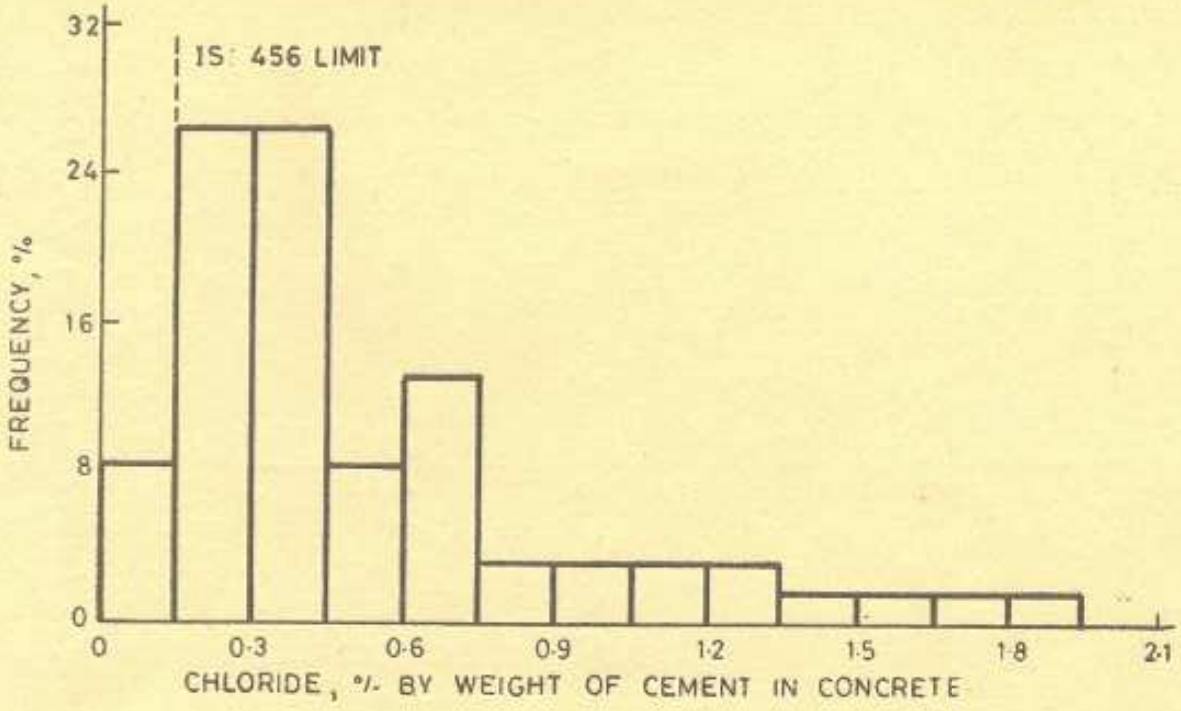

Fig. 4 Distribution of Chloride Content in Corrosion-Damaged Concretes (NCB Data 1976-1986)

Depending on the degree of distress, the repair method can be selected. For example, for structural members having areas with widespread high distress, all damaged concrete must be removed, the corroded reinforcement must be thoroughly cleaned, replaced if required, and suitable coatings to reinforcements must be provided. The prepared concrete surface must be treated with bonding agent, followed by dense concrete of say 1 : 1½ : 3 mix proportions and with maximum water-cement ratio of 0.40. Alternatively, the prepared concrete surface can be shotcreted with 1 : 3 cement mortar as per IS : 9012-1978 (Recommended practice for shotcreting), followed by 6mm thick 1 : 4 cement mortar rendering and cured properly.

For replacing the structural components, loads must be supported temporarily by adjustable props. The reinforcements must be thoroughly cleaned if corroded or replaced if required. Suitable coatings to reinforcements and dense concrete must be placed and properly cured.

RECOMMENDATIONS FOR NEW CONSTRUCTIONS

For new constructions to be durable, the following are the general recommendations:

a) Materials of construction should be selected to ensure concrete with good durability characteristics, satisfying the chloride content limit as per IS : 456.

b) Strict control on the maximum free water-cement ratio and minimum cement content should be ensured for the particular exposure condition for concrete, as per IS : 456.

c) Sound construction practices with adequate compaction and curing of concrete to achieve dense cover concrete should be adopted.

d) Adequate cover to reinforcements be provided.

e) Detailing practices for critical sections during construction should be adhered to.

f) Maintenance of the structures at regular intervals should be carried out.

NCB EXPERTISE

The experience gained through a large number of investigations has given NCB an insight into the problems of reinforcement corrosion. It has also helped in identifying the cardinal factors to be considered while designing buildings with adequate durability. NCB's expertise and consultancy services backed by sophisticated and most modern R&D facilities, are available for a viable solution to problems related to reinforcement corrosion in reinforced concrete structures.

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