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CRI TECHNOLOGY DIGEST

CHEMICAL ATTACK OF REINFORCED CONCRETE STRUCTURES —CRI EXPERTISE FOR DIAGNOSIS AND PREVENTION/ PROTECTION

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CHEMICAL ATTACK OF REINFORCED CONCRETE STRUCTURES – CRI EXPERTISE FOR DIAGNOSIS AND PREVENTION/PROTECTION

This Technology Digest briefly places in perspective the problem of chemical attack of reinforced concrete structures vis-a-vis the methodology evolved by the Cement Research Institute of India (CRI) for investigating such cases as a means to formulate measures for protection and repair of the structures. An illustrative case study made by CRI is also outlined.

THE PROBLEM

Concrete structures, plain or reinforced, exposed to certain chemical agents, are bound to premature deterioration in the absence of proper protective and/or preventive measures. Reinforced concrete structures in chemical process industries are a case in point, they being constantly exposed to corrosive fumes and sprays of acids and alkalies as also air-borne particulate matter consisting of these and other salts. Apart from such general exposure, the floors and walls of the structures may come into contact with corrosive fluids through spillage and splashing. The effect of the aggressive agents is further aggravated by the particular environmental conditions maintained inside the plant premises, which include high/low temperature, humidity, draught, etc; for instance, some of the compounds absorb moisture. In all, the rate of deterioration will depend upon the nature of the chemical, its concentration, persistence of its contact with the structure, the type of reaction and the nature of the product formed and so on.

TYPICAL MANIFESTATIONS

Many a time, the effect of the reaction may not be immediately evident, though there may be occasional tell-tale signs, such as surface discolouration (Fig 1), spots and efflorescence on finishes (Fig. 2), and failure of external renderings and finishes (Fig. 3). This is because the reaction is generally slow. However, eventually the effect becomes harmful when the hydration products of cement get converted to products without any binding and strength property. Thus evading detection, the reaction proceeds insidiously and the reinforcement is affected, too. In worse cases, the result is premature structural failure and collapse of the plant building with inevitable risk of damage and disaster to plant, machinery and working personnel. Hence, protective measures become imperative to prolong the overall life of concrete structures and other building components in such environments and to make the structures safe to work under.

CASE STUDY

CRI made detailed investigations on the damage suffered by the reinforced concrete structural members and building components in a fertilizer plant manufacturing nitro-limestone. The chemicals present in the plant environment included nitric acid, vapour ammonia, ammonium nitrate and calcium ammonium nitrate. As a result of the exposure, all components of the building, i e walls and their finishes, structural beams and columns, floor and roof slabs and staircases had been affec-

Fig. 1 Exterior walls with discoloured patches

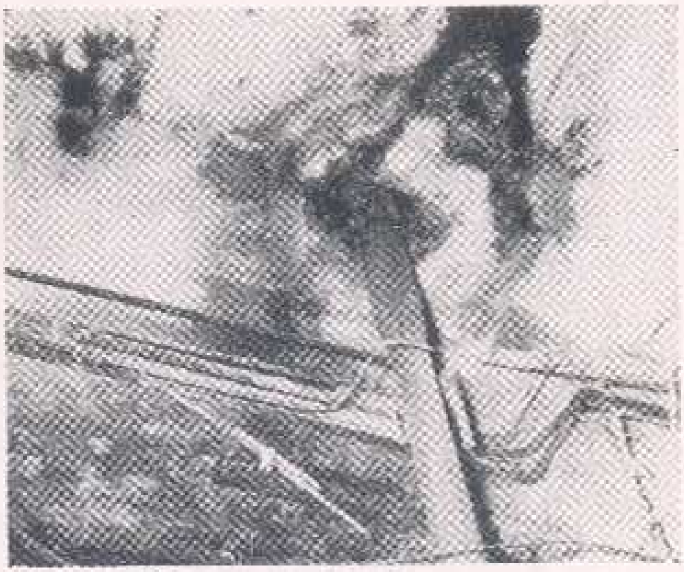

Fig. 2 Efflorescence stains

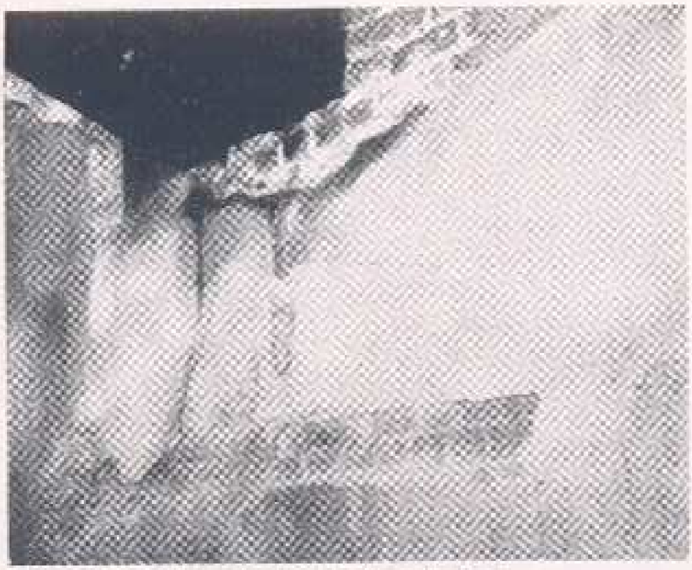

Fig. 3 Failure of external rendering

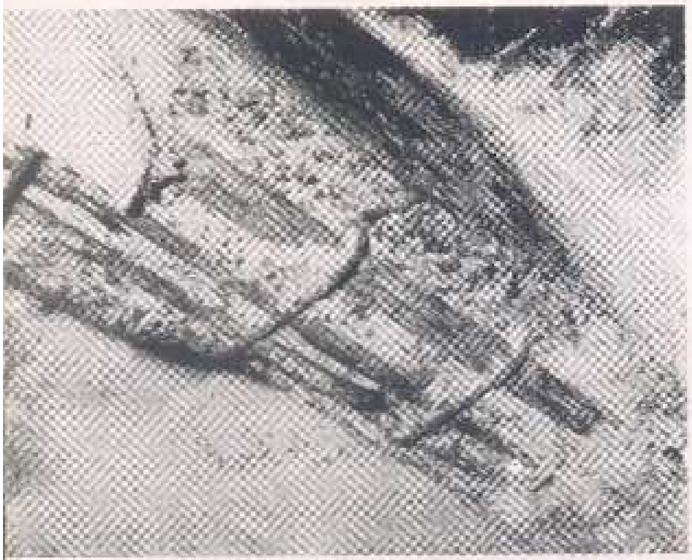

Fig. 4 Spalling of concrete cover over steel reinforcement

Fig. 5 Disintegrated pieces of concrete

ted by aggressive agents/environment, though to different extents. The deterioration could be broadly divided into three degrees. The least severe one was characterized by appearance of spots on finishes, discolouration, failure of external renderings and finishes, decorative and/or protective finishes. The more severe one meant cracking, progressive reduction in strength and stability of structural units like bricks and reinforced concrete beams, columns, roof and floor slabs. The most severe one was typified by cracking and spalling of concrete cover over steel reinforcement (Fig. 4), reduction in reinforcement section, rusting of reinforcement, and disintegration of concrete (Fig. 5), by dissolution of cementing matrix.

Diagnosis — The deterioration in the concrete stıucture was a combined effect, over 3-4 years, of :

a) the process reactants, mainly, nitric acid both in solution and vapour forms;

b) the reaction product, that is, ammonium nitrate solution;

c) the calcium ammonium nitrate dust (CAN); and

d) the CAN solution formed by the absorption of water by CAN dust.

Of these, ammonium nitrate present in CAN dust was the cause of major and more extensive damage.

The mode of attack was essentially interaction of the acid or the acidic solutions with the hydration products of cement, and formation, in their place, of new products of lower and negligible strength property. Another possible mode was expansive stresses from the corrosion products of steel reinforcements which could have led to spalling and failure of concrete.

Protection — The protective measures suggested included overdimensioning, application of protective coatings and paints from a wide range, and use of acid-resisting ceramic and plastic tiles and acid-resisting bricks as lining or floor finishes. Among the preventive measures, emphasis was placed on control of CAN dust emission, such as through improvement in dust collection and effective venting off of the dust. Also, precautions were indicated to stop leakages of reactants and reaction products to the extent practicable. Repair techniques were suggested for portions with deteriorated concrete; the techniques were such as not to require shutting down of the plant.

CRI METHODOLOGY

CRI's investigations in the case have led to a comprehensive methodology for such studies. It comprises essentially, examination of the affected concrete with the help of advanced techniques, such as differential thermal analysis (DTA), X-ray diffraction and infrared spectroscopy for identification of the products of chemical reaction, followed by laboratory tests simulating plant conditions. Based on the integrated picture obtained herefrom, the probable mode of chemical attack and the mechanism of failure of concrete are elaborated. Then, suitable preventive and protective measures as also details of repair, renewal and/or replacement for already deteriorated portions are formulated with due reference to their economics. Preventive measures include use of special cements with known resistance to chemical attack, control or modification of the building environment, sealing of leakages, and periodical checks on the deterioration of the building components. Protective measures may comprise from application of chemical resisting protective coatings, lining with ceramic and plastic tiles or bricks etc, to over dimensioning of the structural members. Repair and restoration techniques are the same as applied for damaged concrete in general, with the difference that a chemically resistant cement is employed for the concrete or mortar and the new surface is protected against fresh attack.

CRI is equipped to offer detailed guidance on particular problems of deterioration of concrete structures by chemical action and safeguarding these from further attack as also suggesting protective and other measures for adoption which will enhance the life of concrete structures expected to withstand chemical attack.

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