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EFFECT OF CHLORIDE ION DIFFUSION ON REINFORCED CONCRETE STRUCTURES

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ABSTRACT

Steel bars in reinforced concrete constructions are susceptible to corrosion in areas high in chloride. A thorough grasp of the variables affecting chloride ion diffusion in concrete is necessary to solve this problem. An overview of the variables affecting concrete corrosion from chloride attack is given in this article. In summary, the implementation of anti-corrosion methods, electrochemical treatments, and corrosion inhibitors decreases corrosion of reinforced concrete and increases the structure's longevity.

INTRODUCTION

The exceptional performance of concrete buildings has led to their widespread use in civil engineering projects, such as bridges, industry structures, and house construction. There are frequently many pores and fissures on the outside and inside of this substance that are too small to be seen with the human eye. However, if the amount of chloride ions (Cl^-) in the concrete is too high during mixing, they will react with the calcium ions (Ca^{2+}) to generate calcium chloride ($CaCl_2$), a very weak powder. Localized loosening of the concrete may result from this process, greatly diminishing its strength and longevity. Furthermore, concrete structures sustain damage more quickly due to the electrochemical corrosion that is catalyzed by chloride ions. Steel corrosion is caused by chloride ions from two different sources: (i) Chlorides that come from outside sources like de-icing salts or marine environments and (ii) chlorides that are blended into the concrete. There are three types of chloride ions in concrete free, chemically bonded, and physically adsorbed. Steel corrosion is mostly caused by free chloride. Corrosion weakens the bond between steel and concrete decreases the steel's effective cross-sectional area, and causes the volume of corrosion products at the concrete/steel interface to increase two to four times. This leads to the protective layer cracking and spalling which ultimately causes structural failure (Alexander, 2019; Qu, 2021; Ma, 2025).

Factors Influencing Chloride Ion Penetration In Concrete:

Water To Binder Ratio:

The resistance to chloride ion penetration and pore structure can be successfully enhanced by lowering the W/B ratio. Concrete's pore structure can be densified by hydrating cementitious materials, which will decrease pore size and chloride ion diffusion. Generally speaking, a low W/B ratio can significantly improve the concrete's pore structure, increasing its ability to bind chloride ions and preventing their diffusion. Furthermore, when compared to regular Portland cement, the diffusion of chloride ions in concrete can be reduced by employing high pozzolan substitutes, such as silica fume or fine blast furnace slag. Therefore concrete's resistance to chloride ion penetration can be further increased by combining a low W/B ratio with the use of high pozzolan replacements (Xu, 2024; Zhang, 2022).

Additives

Pozzolana and non-pozzolana materials like metakaolin, silica fume, slag, and fly ash can be added to concrete to increase its resistance against chloride ion penetration. The amount o active component and specific surface area determine how well additives block chloride penetration. When active additives combine with hydrated products, like pozzolanic materials when reacts with portlandite to generate CSH, which can absorb chloride ions and densify the pore structure, they can further improve the pore structure. In comparison to regular concrete, binary or ternary combinations of pozzolanic materials in concrete exhibit superior resistance to chloride ion penetration and efficiently lower the corrosion rate (Angst, 2009; Zhang, 2022).

Cracks

Although they are a common problem, concrete cracks are regrettable because they increase the material's pores, which allows moisture and corrosive substances to enter. Numerous studies have examined and verified the connection between concrete's crack width and chloride ion diffusion. When the fracture width is less than the critical crack width, it has no effect on the diffusion of chloride ions in concrete. However, the diffusion rate of chloride ions increases when the crack width exceeds the critical crack width. This critical crack width may change according to the ambient temperature (Travnicek, 2024).

Environmental Temperature

Care, reports that heat-treating cement pastes at 45°C, 80°C, and 105°C increased the cement slurry's overall porosity and caused its pores to grow. This is because high temperatures have the potential to generate a roughening effect, which makes cement and concrete more porous and creates more diffuse channels for the transport of chloride ions. Temperature has a major influence on the chloride ions ability to bond in the concrete matrix. However, CSH breaks down and physically releases the combined chloride as the temperature rises. In addition, the higher temperature speeds up the pace of hydration, which improves the chloride's chemical combination in the hydrated paste (Xu, 2024; Song, 2010).

Relative Humidity

It has been demonstrated that the relative humidity-usually the humidity inside the concrete has a major effect on the diffusion effect of chloride ions in concrete because it acts as a carrier in the porous nature of the material. At relative humidity levels below 70%, the diffusion of chloride is comparatively less impacted. Nevertheless, at greater humidities, the relative humidity has a major effect on the diffusion of chloride (Xu, 2024; Song, 2010).

Dry And Wet Cycles

Under the alternating cycles of wetting and drying, the concrete flows between saturation and unsaturation. When there is moisture present, the concrete's internal humidity quickly rises to saturation and chloride ions penetrate into the concrete with the water. Within the impact depth, the chloride ions crystallise when the relative humidity steadily drops due to the internal water evaporating in a dry environment. Under the influence of capillary suction, surface chloride ions are subsequently carried and deposited inward. This accelerates the corrosion process and the migration of chloride ions since the concrete structure is exposed to cycles of wetting and drying for a long time (Xu, 2024; Song, 2010).

CONCLUSION

The elements affecting the degradation of reinforced concrete under chloride attack are listed in this article. Although the addition of additives reduces the development of early age strength, it increases the concrete's resistance to chloride penetration. While curing conditions have less of an impact on chloride diffusion coefficients as concrete strength increases, they may still have a considerable impact on low strength concrete. While laboratory diffusion and accelerated migration experiments are dependable for identifying variables influencing chloride penetration in concrete, it is challenging to establish relationships between findings from various techniques. In conclusion, the longevity of the structure is ensured by the application of a variety of anti-corrosion techniques, including surface coatings, corrosion inhibitors, and electrochemical treatments.

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