cific qualities of the microstructure that may influence crack growth or fracture stress.

Implications to Grouted Post-Tensioned Tendons

Structures incorporating post-tensioned tendons are expected to have a service life of many decades, but often need rehabilitation within several years of service due to corrosion. Corrosion, in many cases, has occurred in regions of grout deficiencies in the form of voids formed by bleed water accumulation and subsequent reabsorption or evaporation through incomplete anchorage sealing. Other possible causes of corrosion include intrusion of external chloride and water through anchorages or defects in the HDPE and possible adverse galvanic coupling between anchorage components and the strand. In some cases, corrosion of the steel may be accompanied by hydrogen absorption and subsequent embrittlement resulting in brittle failure.[15]

In establishing the susceptibility of a system to HE, the sources of hydrogen, its absorption and transport rates, and the influence on mechanical performance need to be identified. According to the reported failures, voided tendon ducts seem to play a primary role in the failure modes. While hydrogen is not usually present in the environment within post-tensioned ducts, hydrogen uptake by prestressing steels in voided regions has been reported. Fernandez et al.[15] measured the amount of hydrogen uptake by stressed steels in voided ducts reflecting the construction period following placement of the strands and prior to grout placement, which in some cases can be a couple of weeks. Strands contained within closed voided ducts with water showed a much higher hydrogen content than strands contained within closed dry ducts.

Additionally, Hartt et al.[16] showed that within galvanized steel ducts, as used in the Wando River Bridge at the site of failure, hydrogen is cathodically produced at the strand surface due to galvanic coupling to the galvanized duct immediately following grouting. The authors suggested that enough hydrogen is produced during this time to potentially cause embrittlement. However, the amount of hydrogen that was absorbed into the steel during the period immediately following grouting was not measured. Immediately following placement of the grout, the grout is wet and has a high conductivity, which promotes galvanic actions between the galvanized duct and the steel strands. As the grout cured, the coupling diminished. Based on this information, the question arises of what may occur if aggressive water infiltrates the galvanized steel tendon duct, potentially resulting in a highly conductive grout.

If conditions are present that promote hydrogen production, even if the absorbed hydrogen does not lead to substantial material embrittlement, it may have an influence on the corrosion resistance of the material. Absorbed hydrogen has been shown to influence the stability of the passive film and result in increased corrosion rates.[17] On passive metals, the H atoms diffuse through the passive film, reduce the O^{2-} ions to OH^- ions, and OH^- ions to water (H_2O) molecules. These products may exchange with the Cl^- ions, if present, and destabilize the passive film. Also, the presence of hydrogen may cause a reduction in the stability of the passive film and may result in a decrease in its thickness. In nonpassivating conditions, adsorbed hydrogen can also increase the corrosion rate of steels. The potential impact of hydrogen on corrosion rate of these steels may be influenced by several factors including decohesion of metallic bonding, increasing mobility of dislocations, hydrogen-induced phase transformation, and formation of vacancies in the metallic lattice.[18]

Summary

The primary mechanisms of HE of cold-drawn pearlitic steels include HEDE and HELP. A micromechanical model may be used to identify which mechanism controls at given levels of strain, but for a given failure due to HE both mechanisms may occur.

While relationships have been developed to describe the change in mechanical properties due to hydrogen absorption and diffusion of steels in general, few have been proposed specifically for cold-drawn pearlitic steels. An emprical model based on the results of the CERT test suggests a logarithmic relationship between diffusible hydrogen concentration and the local fracture-initiation strain.

Prior evidence shows the possibility of galvanic coupling between steel and galavanized structural components could promote hydrogen production. Therefore, high conductivity grout, either a result of improper mixing or water intrusion, may promote HE. In the case that voids are present in the grout leaving the steel strand unprotected, hydrogen absorption could occur through corrosion processes or previously absorbed hydrogen could enhance corrosion activity. Further work is required to quantify the potential influence of HE combined with corrosion on the mechanical properties of cold-drawn pearlitic steels.

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