Strength of Corroded Bridge Wires and Repair Methods

Shun-ichi NAKAMURA
Professor, Tokai University
Kanagawa, JAPAN
snakamu@keyaki.cc.u-tokai.ac.jp

Shun-ichi Nakamura, born 1950, received his BEng and MEng from Kyoto University, and PhD from Imperial College of Science and Technology, UK.

Keita SUZUMURA
DEng, Manager
Nippon Steel Engineering
Kanagawa, JAPAN
suzumura.keita@eng.nsc.co.jp

Keita Suzumura, born 1965, received his BSc and MSc from Hokkaido University, and DEng. from Tokai University, Japan.

Summary

Corroded galvanized steel wires on different corrosion levels were produced at laboratories, and their mechanical properties and remaining strength were investigated. Actual tensile strength of corroded wires did not decrease with corrosion levels, whereas elongation decreased sharply after the zinc layer was partly depleted and the steel started to corrode.

Accumulated amount of diffusive hydrogen of corroded wires was less than 0.2 ppm, which was well below the critical concentration of 0.7 ppm to cause brittleness. On the other hand, fatigue strength significantly decreased after steel corrosion below the galvanized layer progressed. Fatigue strength further lowered when the steel wire was cyclically stressed under wet environments. It was estimated that the wires were fractured by the mixed effects of corrosion, cyclic stresses and hydrogen.

Various repair methods were applied to the corroded wires: zinc rich paint, epoxy resin paint, zinc powder paste, filling with oil and dehumidification method. Then, effectiveness of these repair methods was evaluated by the corrosion simulation tests. Mass loss of test wires with these repair methods were measured for 15 months and effectiveness of the repair methods is compared. It is shown that the dehumidification and epoxy resin paint ant filling methods are most effective.

Keywords: bridge wires; corrosion; galvanized steel wires; hydrogen embrittlement; corrosion fatigue; repair; zinc rich paste; epoxy resin paint; dehumidification.

1. Mechanical properties of corroded bridge wires

Suspension bridge cables are under severe corrosion environments; wires are wet at high temperature. To simulate this environment, galvanized steel wires are wrapped with wet gauze and kept in an enclosed box at a temperature of 40 ^{o}C. Water and oxygen are needed to corrode steel, and the wet gauze supplies both. It was proved by the past study that this simulation test with wet gauze produced the steel wires corroded in an actual corrosion environment of suspension bridge cables. The wire specimen is 5 mm in diameter, its tensile strength is 1570 MPa and the attached zinc mass is 350 g/m^2, which is equivalent to 50 μm in thickness. The specimens were taken out from the enclosed box after 90 days, 250 days and 360 days, producing the corroded wires on different corrosion levels.

Tension tests were performed with the corroded specimens. The actual tensile strength of the specimens, the breaking force divided by the reduced cross sectional area due to corrosion, does not decrease with the corrosion level. On the other hand, elongation of the galvanized steel wire specimens decreases sharply after the corrosion level-1 (the reduced mass of about 100 g/m^2) and that of the bare steel decreases linearly with the reduced mass due to corrosion. Elongation does not change when only the galvanized layer is corroded but it decreases when the steel starts to corrode.

The absorbed hydrogen emits from the steel wire when it is heated. There are two peaks in a typical hydrogen evolution curve. The first peak is at around 100-150 ^{o}C and the second peak is at around 250-300 ^{o}C. The first peak associates with diffusive hydrogen and the second peak associates with

https://doi.org/10.2749/222137908796292281

non-diffusive hydrogen which is trapped into the lattice structure strongly and cannot move. It is known that only diffusive hydrogen affects the brittleness and hydrogen embrittlemnt does not occur when the accumulated amount of absorbed diffusive hydrogen is less than 0.7 ppm. The measured accumulated amount of diffusive hydrogen is about 0.15 ppm which is well below 0.7 ppm, indicating that hydrogen embrittlement is unlikely to occur.

Fatigue tests were conducted for the new wires and corroded wires at corrosion levels-1, 2 and 3. There is not much difference between the fatigue strength of the new and corrosion level-1 specimens. However, the fatigue strength of the level-2 specimens is lower than that of the new and corrosion level-1 wires, and that of the level-3 specimens is further lower than that of the level-2 specimen. It is therefore clear that the fatigue strength does not change when only the galvanized layer is corroded, but it significantly decreases after the steel corrosion below the galvanized layer progresses. It is found that from the tests under wet environments that the fatigue strength under wet environments is lower than that under dry environments.

2. Comparison of repair methods for corroded bridge wires

It is an important subject how to repair corroded wires. Seven cases were compared in evaluating effectiveness of different repair methods of corroded wires: (1) taking no measure, (2) coating only the surface wires with epoxy resin paint with a thickness of 80μm, (3) coating only the surface wires with zinc rich paint with a thickness of 50μm, (4) coating and filling the surface and inside wires with oil containing inhibitor with a thickness of 1.0mm, (5) coating and filling the surface and inside wires entire wires with epoxy resin paint, (6) coating the surface layer with thick paste containing zinc powders with a thickness of 1.0mm, and (7) dehumidifying the inside of a cable.

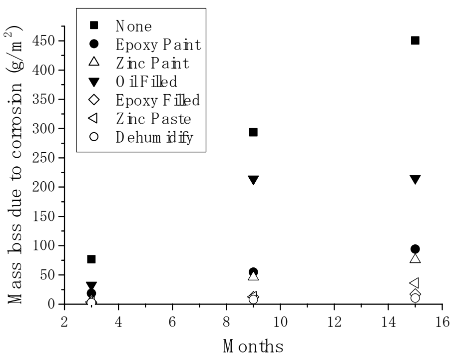

Fig. 1: Mass loss of surface wires

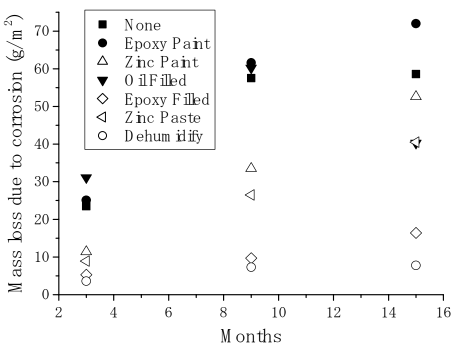

Fig. 2: Mass loss of inside wires

A test cable consisted of 19 parallel galvanized wires. It was wrapped with wet gauze, except case (7), and kept in a chamber at a temperature of 40^{o}C for 15 months. The appearance and corrosion conditions of the surface and inside wires, the mass loss of these specimens were checked in 3 months, 9 months and 15 months.

Fig.1 shows the mass loss due to corrosion of the surface wires with different repair methods. Fig.2 shows the mass loss due to corrosion of the inside wires. The mass loss of the surface wires in case (1) for 15 months is 450 g/m^2 and that of the inside wires is 60 g/m^2, which is much lower than the surface wires. From Fig.2 the mass loss of the repaired wires is much lower than that of non-repaired wires. Among the repair methods the dehumidification method (case 7) was the most effective followed by epoxy resin paint and filling of surface and inside wires (case 5), zinc powder paste (case 6), and zinc rich and epoxy resin paint of surface wires (case 2 and case 3). The oil filling (case 4) was not very effective compared with other repair methods.