Lessons Learned from Long-term Testing of Steel in Reinforced Concrete

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ABSTRACT

When epoxy coated reinforcement (ECR) was introduced into widespread use in the 1980s, there was tremendous excitement that this type of reinforcement would solve many of the corrosion issues associated with salt-contaminated reinforced concrete. However, when certain coating and exposure issues became evident in particularly aggressive environments shortly after introduction, it became clear that modifications of the ECR, as well as the search for alternative reinforcement materials would still need to continue. This led to additional research on ECR, other coated reinforcement, galvanized reinforcement, stainless-clad and solid stainless reinforcement, as well as other inherently corrosion resistant materials.

Some of the existing, newer and emerging reinforcement materials will be described in this paper, as well as some of the available and proposed testing procedures. In addition, some laboratory and field performance of selected materials will be discussed. Some of these results are based on more than ten years of exposure and testing.

KEY WORDS: Corrosion; steel; concrete; epoxy coated reinforcement; alternative reinforcement

INTRODUCTION

Corrosion of steel in concrete is an extensive problem worldwide; it can lead to the reduced service life of structures to the point where they may be structurally unsound. In fact, the subject of deficiency in certain structures has become a serious issue that has attracted the attention of the media (CBS, 60 Minutes, November 23, 2014). Some of the ways in which the problem can be minimized include increasing the concrete cover; decreasing the permeability of concrete using fly ash, other by products, and/or admixtures; using more sophisticated monitoring with embedded or other types of sensors; using inhibitors, using cathodic protection; removing the reinforcement altogether; using non-metallic reinforcement such as fiber reinforced rebar; and using coated and/or more corrosion resistant reinforcement (Darwin et al., 2007). This paper will focus on the use of alternative reinforcement materials, such as coated and/or more corrosion resistant reinforcement.

When ECR was developed as an alternative to black steel, there was great excitement in the concrete community. This followed extensive research that focused on more than 20 alternatives (Clifton et al., 1975). There was some concern about the potential for and consequences of defects in the coated bars, but this was considered a negligible factor.

ECR has been used as an alternative to black or carbon steel since the late 1970s and much of the enthusiasm seemed to continue during the early years. However, once ECR was in widespread use, several premature failures were observed in Florida (Weyers 1985, Weyers & Cady 1987, Sagues & Powers 1990). One of the issues that became a factor was the level of damage associated with ECR and the effect this damage might have on the long-term behavior of structures made with ECR.

Of the many projects that were initiated to examine this issue, one took place at the University of Texas at Austin (Kahhaleh et al., 1994). The subject of alternative reinforcement will be examined from the prospective of selected early research, projects that have been carried out over the years, and where we are now. This examination will highlight some of the work that has been done at the University of Texas at Austin.

SELECTED INVESTIGATIONS

ECR, Kahhaleh et al., UT Austin, 1994

The corrosion performance of ECR in aggressive environments was investigated using a series of experimental studies that included using holiday detection for assessing damage to the coating; hot water testing and knife testing to determine coating adhesion; assessment of materials and procedures for repairing coating damage; evaluation of mechanical damage caused during placement with metal head and rubber head vibrators; and accelerated corrosion testing of concrete (macrocell and beam) specimens for more than four years.

One important specimen type that was used in this investigation was the concrete macrocell, with approximate concrete dimensions of 11 x 6 x 4.5 inches (280 x 150 x 115 mm). This has now become an ASTM standard, ASTM G109. The concrete macrocell specimens consist of two layers of reinforcement; one bar centrally located and about 0.75