Transportation Consortium of South-Central States (Tran-SET)

Monotonic and cyclic behavior of high strength reinforcing steel (HSRS) after high temperature exposure

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Evaluating HSRS after high temperature exposure

Conventional reinforced concrete transportation structures in North America often use Grade 60 reinforcing steel with a yield stress of 60 ksi. The introduction of high strength reinforcing steel (HSRS) with higher yield strength in the reinforced concrete industry has led to many economic and workability advantages such as construction time saving, reduced labor cost and steel consumption which in turn alleviates congestion of reinforcement, savings in transportation and deliveries that finally results in lower carbon emission. Despite these benefits, many states, including those in Region 6, have not widely adopted the use of higher strength reinforcing steels in practice due to lack of knowledge and comfort level with implementing new technologies and techniques, and the serviceability and durability concerns. In addition, bridge surveys among 18 states have shown that fire has caused more bridge collapses than earthquakes. In general, there are three common types of ASTM steel bars that are produced with yield stresses above 60 ksi: ASTM A615, ASTM A706 and ASTM A1035. Given the lower ductility of HSRS rebars compared to conventional reinforcement along with the lack of knowledge on different types of HSRS and their behavior when exposed to elevated temperatures, studying the behavior of HSRS after high temperature exposure is deemed to be necessary. In this study, four different tests will be conducted on three different ASTM reinforcement (A615, A706, and A1035): monotonic and cyclic tensile tests (high strain low cycle), pullout and endbeam bond tests. Each test shall be performed at both ambient and elevated temperatures. After the test, each specimen will be analyzed using Energy dispersive X-Ray (EDX) and scanning electron microscopy (SEM) to investigate the possible change in material composition and failure analysis of fracture surfaces, respectively. The results will be reported and compared with the previous studies on conventional and HSRS reinforcements.

Problem Statement

High-strength reinforcing steel (HSRS) are typically considered to have a yield stress greater than 60 ksi. There are three common types of regular ASTM steel bars that are produced with yield stresses above 60 ksi: ASTM A615-20, ASTM A706-16 and ASTM A1035-20. Bars conforming to ASTM A1035-20 are furnished to three different chemical composition, designated as CL, CM and CS. The chemical composition of these different types, presents that these alloys mainly vary in carbon and chromium content. Despite the difference in chemical composition, most of the literature is conducted on the CS alloy type due to its higher corrosion resistance and there is no major publication on the CL and CM alloy type to the best of our knowledge. There is clearly a gap in this field that needs to be addressed. Bridges surveys among 18 states have shown that fire has caused more bridge collapses than earthquakes. In addition, reinforcements can present brittleness (blue brittleness) at elevated temperatures, as well as lose about 20% of their design strength that in turn can result in structural collapse. The issue becomes more critical for HSRS reinforcement that already exhibit lower ductility than regular reinforcement. Given that bridges are subjected to cyclic loads along with the lack of knowledge on different types of HSRS and their behavior when exposed to elevated temperatures, studying the behavior of HSRS after high temperature exposure is deemed to be necessary.

Objectives

Within the proposed research, experimental research will be conducted on three common types of ASTM HSRS rebars, i.e. ASTM A615, ASTM A706 and ASTM A1035 (CL, CM and CS) to: 1. Enhance the knowledge and understand the behavior of different types of commercially available HSRS under monotonic and cyclic uniaxial tensile tests at both ambient and elevated temperatures; 2. Enhance the knowledge on the bond behavior of HSRS rebars under monotonic and cyclic loading at both ambient and after elevated temperatures; 3. Evaluate the applicability of current literature and code specifications to HSRS rebars and their bond to concrete after elevated temperature exposure and provide necessary recommendations.

Intended Implementation of Research

The research results will be presented in national conferences, such as upcoming TRB and TranSET and in online webinars to engineers at DOTs, municipalities, and local governments. Results will also be submitted to recognized peer-reviewed journals such as but not limited to ACI structural journal, ACI materials journal, ASCE journal of Structural Engineering, Engineering Structures, etc. In addition, progress and final technical reports shall be submitted to TranSET.

Anticipated Impacts/Benefits of Implementation

There are many reinforced concrete structures, including bridges and buildings in Region 6 that can exploit the benefits of using HSRS such as savings in construction time, labor costs, and congestion of reinforcement among others. However, states nationwide have been using this type of reinforcement with reservation due to the lack of knowledge about different types of HSRS under different loading conditions. More specifically their bond to concrete after behavior after high temperature exposure caused by fire and other extreme events may have exacerbated the reluctance for implementation. This research will help bridge the gap of knowledge in this area and to help authorities with decision making processes so they can take advantage of the inherent benefits of using HSRS in transportation projects.

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.