JOINT TRANSPORTATION RESEARCH PROGRAM

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Post-Fire Assessment of Prestressed Concrete Bridges in Indiana

Introduction

This project focused on evaluating the effects of fire-induced damage on concrete bridge elements, including prestressed concrete bridge girders. A series of controlled heating experiments, pool fire tests, material tests, and structural loading tests were conducted. The results were used to establish the effects of heating due to standard ISO-834 and hydrocarbon fires on (1) temperature profiles through the concrete depth, (2) concrete material degradation due to decomposition of calcium hydroxide (CH), (3) concrete spalling and cracking through the depth, and (4) flexural and shear strength of prestressed concrete girders. The findings were used to develop guidelines for post-fire assessment of prestressed concrete bridges.

Findings

Two concrete bridges from the I-469 bridge over Feighner Road were heated for different time durations (40–80 minutes) following the ISO-834 standard fire curve. Six prismatic specimens were designed and built to simulate the bottom flanges of prestressed bridge girders with different section layouts (two-strand and six-strand). Four (of the six) prismatic specimens were heated in the laboratory following the ISO-834 standard fire curve for different durations (30, 40, and 80 minutes) and heating conditions (two-sided and four-sided). Two (of the six) prismatic specimens built in the laboratory, and two AASHTO Type I girders, decommissioned from the bridge carrying I-469 over Feighner Road, were subjected to hydrocarbon pool fire tests conducted in the field for a duration of 48 minutes using approximately 135 gallons of kerosene.

The temperature profiles through the depths of all the specimens were measured during heating and natural cooling. After cooling, concrete samples were cored from the specimens for material analysis. Different types of material tests such as scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and differential scanning calorimetry (DSC) were conducted to evaluate the extent of calcium hydroxide decomposition and the extent of concrete microstructure cracking through the depth of the concrete. For the AASHTO Type I prestressed girders, structural loading tests were conducted on control beams (without fire damage) and beams with extensive fire damage. After structural testing, material tests were also conducted on concrete cores taken from the girders.

The results from the experimental investigations indicate that the duration of heating determines the temperature profile through the thickness of concrete. If the fire lasts for a longer duration, the temperature through the depth of the concrete increases. The portion of concrete subjected to temperatures higher than 752°F (400°C) loses significant amounts of calcium hydroxide (CH), which decomposes by losing water and converting to calcium oxide (lime). The decomposition of CH increases porosity of the affected area. The portion of the concrete affected by CH decomposition also developed significant cracking, which further reduces the strength and increases permeability. It is highly recommended that the portion of concrete exposed to temperatures higher than 752°F (400°C) be considered fully damaged, and therefore repaired or replaced with new material.

When concrete components are heated following the ISO-834 standard fire curve, 0.25 in. of concrete from the exposed surface is compromised after approximately

40 minutes due to loss of CH and extensive cracking. After about 80 minutes of ISO-834 standard fire heating, 0.75 in. of concrete from the exposed surface is compromised by the loss of CH and extensive cracking. After about 50 minutes of an intense hydrocarbon fire, 0.75–1.0 in. of concrete from the exposed surface is compromised by the loss of CH and extensive cracking.

Prestressed concrete girders exposed to about 50 minutes of intense hydrocarbon fire undergo superficial concrete material damage with loss of CH and extensive cracking and spalling extending to the depth of 0.75–1.0 in. from the exposed surface. The reduction in the initial stiffness of the specimens may be notable due to concrete material damage, cracking, and spalling. In spite of the superficial concrete material damage, cracking, and spalling, these prestressed concrete girders do not undergo significant reduction in flexural strength or shear strength. Additionally, there does not seem to be significant influence on the bond between strands and concrete, and the prestressing force (or losses) in steel strands.

Implementation

Based on these conclusions, guidelines for post-fire assessment of prestressed concrete bridges are included in this report along with a step-by-step checklist. Bridge inspectors can infer the extent of damage to prestressed concrete bridge girders in the event of a fire and develop a post-fire assessment plan cognizant of the findings. In most cases, no more than 1.0 in. of the concrete from the exposed surface undergoes material damage/deterioration due to loss of CH, cracking, and spalling. The impact on the strength of prestressed concrete girders is relatively minor based on experimental results. Their initial stiffness, however, will likely be reduced. Recommendations for future work including research on long-term durability of fire damaged girders, and development of long-term repair methods are also included in the report.

Recommended Citation for Report

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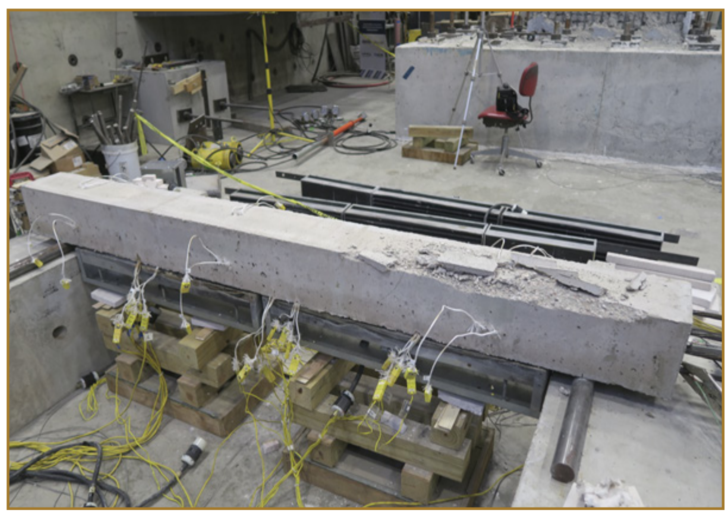
Deck specimen after heating.



Prismatic specimen after heating.