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The experimental behavior of FRP-strengthened RC beams subjected to design fire exposure

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ABSTRACT

The results from fire resistance experiments on five rectangular reinforced concrete (RC) beams are presented in this paper. Four of these RC beams were tested after being strengthened with carbon fiber reinforced polymer (CFRP), while the remaining one was tested as a control RC beam specimen. The beams were tested by exposing them to fire and service load, computed based on the nominal capacity of an unstrengthened/strengthened beam in accordance with ACI 318/ACI 440.2R provisions. The test variables included type of fire exposure, anchorage zone, insulation type, and restraint conditions. The data from the fire tests is used to evaluate the thermal and structural response, as well as failure patterns in FRP-strengthened RC beams. The test results indicate that the anchorage configuration plays a critical role in limiting the deflections of the strengthened beam after debonding of the FRP occurs at $T_g \pm 10$ °C, where T_g is the glass transition temperature. Also, FRP-strengthened RC beams supplemented with 25 mm thick spray-applied insulation can survive failure under ASTM E119 standard fire or a design fire. Further, the fire-induced axial restraint force significantly increases the fire resistance of FRP-strengthened/unstrengthened RC beams, provided that the location of restraining force is below the geometric centroid of the beam and that the beam's deflection is sufficiently small along the entire span.

1. Introduction

In recent years, fiber reinforced polymers (FRPs) have found wide use in civil infrastructure applications, and they are often used for the strengthening and retrofitting of RC beams, due to their high strength, durability, and ease of application. Currently, most applications of FRPs are in bridges and other infrastructure where fire safety is not a critical issue. However, when used in buildings, FRP-strengthened RC beams have to satisfy fire resistance requirements specified in building codes and standards.

In the last decade, a few fire tests have been conducted on FRP-strengthened RC beams to generate fire endurance ratings. Most of these tests were under standard fire exposure aimed at obtaining fire resistance ratings, rather than studying the response of FRP-strengthened members under fire conditions. Thus, there is a lack of understanding of the response of FRP-strengthened RC beams under realistic fire, loading, and failure limit states. This lack of fire test data and fire design methods is posing a major obstacle for wider use of FRP in buildings and parking structures [1].

To overcome the current knowledge gaps, a research project is currently underway at Michigan State University (MSU) to quantify the influence of various parameters on the fire performance of FRP-strengthened RC beams. This paper presents the results from fire tests on five beams exposed to standard and design fire (non-standard fire) conditions. The effectiveness of new insulation systems, anchorage patterns, axial restraint effects, and design fire exposure on fire resistance of FRP-strengthened RC beams is specifically evaluated.

2. Research significance

The main impediment for the use of FRP in buildings is due to lack of information on its behavior under elevated temperatures. Most studies reported in the literature have focused on evaluating the fire resistance of FRP-strengthened RC members under standard fire conditions, and this led to developing proprietary fire resistance ratings. Currently, specifications in codes and standards (including ACI 440-R2) are based on standard fire conditions, and they often assume FRP to be completely ineffective in the event of fire. The research presented herein aims to quantify performance of FRP-strengthened RC beams under realistic fire scenarios. The data from the fire tests is utilized to study the influence of critical parameters such as the effects of the anchorage zone, non-standard fire exposure, and fire-induced axial restraint force on fire response of FRP-strengthened RC beams. The results presented in this paper offer an insight into the fire response of FRP-strengthened RC beams under non-standard fire exposure and also provide valuable data for validating numerical models. The validated models can be

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