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Behaviour of tie confined reinforced concrete columns subjected to standard fire exposure

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Abstract

The fire resistance of Reinforced Concrete (RC) Columns, defined as the duration for which the columns can withstand fire exposure without losing structural integrity, is influenced by confining parameters such as cross ties, tie anchorage, and tie spacing. This paper evaluates the influence of various confining parameters, including tie reinforcement diameter and diamond tie configuration. Additionally, the study determines the optimized configuration of cross ties and tie spacing for assessing the fire resistance of RC Columns. These parameters are examined under two spalling scenarios: normal and explosive. Nine full-scale RC columns, cast at two concrete grades, are experimentally tested to determine fire resistance. It is found that fire resistance increases by 49% when tie confinement is improved in normal-strength concrete columns and by 149% when tie confinement is improved in high-strength concrete columns. Numerical simulation is conducted to determine the level of confinement indicated by the moment-curvature behavior of columns. 3D solid element models are sequentially analyzed to assess the fire performance of column sections, and parametric analysis is performed.

Keywords

concrete, column, confinement, fire resistance, spalling

Introduction

Fires continue to devastate urban infrastructure globally, with the United States alone incurring estimated annual costs of approximately $2 billion for firefighting efforts (Short, 2017). High-profile incidents such as the Grenfell Tower fire (2017) and the Wilton Paes fire in Sao Paulo (2018) underscore the vulnerability of multistory reinforced concrete (RC) buildings to severe fire damage. Ensuring public safety depends on the ability of building structures to withstand fire-induced failure while maintaining structural integrity for a specified duration. In RC structures, failure often initiates with thermally induced spalling—sometimes explosively—leading to a loss of confinement in RC columns, a critical factor contributing to overall structural failure during fires (Du et al., 2020; Kalifa et al., 2000; Li et al., 2021; Phan, 2008; Serga, 2015; Shah and Sharma, 2017).

Spalling can be classified into two types: *normal spalling*, where gradual and controlled loss of concrete fragments occurs due to thermal exposure, and *explosive spalling*, a sudden and violent release caused by rapid vaporization of internal moisture (Zhang et al., 2020). Explosive spalling, in particular, can rapidly compromise the load-carrying capacity of RC columns, heightening the risk of progressive collapse during fire events.

Despite the recognized significance of fire resistance in RC columns, existing literature remains fragmented in addressing effective improvement strategies. Research has shown that concrete cover thickness is a dominant parameter influencing thermal protection for reinforcement during fire (Han et al., 2006; Kodur et al., 2004). Reinforcement detailing, including tie configurations and anchorage methods, has also been identified as critical in maintaining column integrity under elevated temperatures (Buch and Sharma, 2019b, 2019a). Furthermore, cross-sectional dimensions and slenderness ratios influence temperature gradients and deformation profiles during fire exposure (Almeshal et al., 2022; Buch and Sharma, 2023). Material properties, particularly the degradation of compressive strength and modulus of elasticity of concrete and

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