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Residual response of reinforced concrete columns exposed to design fires

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Abstract

This paper presents results from residual capacity tests on fire damaged reinforced concrete (RC) columns. Two RC columns, were first subject to structural loading and fire exposure, as experienced in a typical building, and then loaded to failure upon cool down to ambient conditions. The response of the column including temperatures, deformations, and spalling in the columns was monitored during heating, and cooling phases of fire exposure. Upon complete cool down, the fire damaged columns were incrementally loaded until failure to evaluate their residual capacity. Results from these fire tests indicate that RC columns retain significant residual capacity after exposure to typical fires experienced in buildings.

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Keywords: Reinforced concrete columns; Fire exposure; Residual capacity

1. Introduction

Reinforced concrete (RC) structural members exhibit high fire resistance due to relatively low thermal conductivity, high thermal capacity, and slower degradation of mechanical properties of concrete with temperature. Statistical data clearly suggest that although fires do occur in buildings, complete collapse of structural members due to fire is a rare event [1]. This is primarily due to the active fire protection systems present in buildings together with

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improved fire-fighting strategies adopted in recent years. In such cases, RC structural members retain much of their structural capacity after a fire incident.

However, visual inspection following fire exposure does not provide extent of residual capacity retained in structural members. Unlike fire induced spalling, which shows visible sign of damage on loss of cross section, structural deterioration due to degradation of mechanical properties at elevated temperatures and any redistribution of stresses within the member is not too apparent [2]. Thus, it is imperative to ascertain the residual capacity of members through rational engineering methods in order to ensure that the desired residual capacity is present in structural members even after fire. Such an assessment would be indispensable for undertaking subsequent repair and retrofitting strategies as well.

At present, residual response of fire damaged RC columns is still not well established. There is limited experimental data on post-fire response of RC columns. Further, in previously reported studies, response of the columns during cooling phase, as well as post-fire residual deformations were not monitored [3–5]. To overcome these limitations, two RC columns were tested for residual axial capacity, after exposing the columns to fire scenarios representative of a typical building compartment. Thermo-structural behavior of the columns, both during heating phase of fire exposure, and cooldown due to decay in fire temperature, was traced through advanced instrumentation and visual observations. Subsequently, after complete cool down, the fire damaged RC columns were loaded incrementally to failure to evaluate their residual axial capacity. This paper presents detailed results from these experiments both during fire exposure, as well as during residual capacity tests on concrete columns.

2. Experimental study

The experimental program consisted of fire exposure tests, followed by residual capacity tests on two reinforced concrete columns. The tested columns have the same geometry, reinforcement details, and similar concrete mix design. The following sections detail the features of the experimental program.

2.1. Design and fabrication of test specimens

Two RC columns, designated as C-1 and C-2, were tested for residual capacity after exposure to design fire scenarios under realistic load levels. Both columns were designed as per ACI 318 specifications [6] and had same cross sectional detailing. The columns were reinforced with four Ø 19 mm rebars and Ø 10 mm stirrups at a spacing of 200 mm center to center, and steel in these rebars is of 420 MPa yield strength. Cover to middle of main reinforcement was 50 mm. Column C-1 was fabricated 8 years ago, while column C2 was fabricated in 2017. The test day compressive strength of concrete was measured to be 50 MPa for column C1, and 62 MPa for column C2. The elevation, cross sectional dimensions, and instrumentation configuration for the fabricated columns are shown Fig. 1.

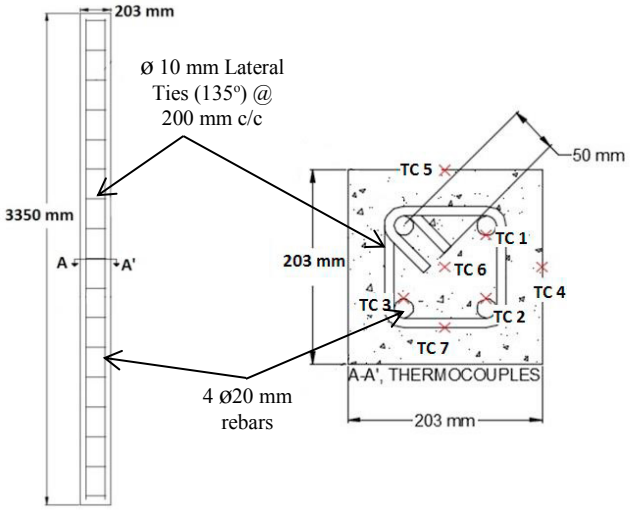

Fig. 1. Dimensions, reinforcement details, and instrumentation configuration of RC columns.