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Effects of fire on precast members: A case study

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Abstract

A cotton thread plant located in Kahramanmaras, Turkey was burned down in 2003. During the fire, the plant was used as a storage space for cotton fibers and waste. The plant was constructed by precast concrete structural members in 1997 and its construction area was 8142 m^2. Riverbed aggregate and Portland cement was used in the production of concrete. Compressive strength of concrete was 25 MPa. All precast structural members had 1.5 cm concrete cover. Roof covers made by aluminum panels. In the plant, there were no interior walls and all the exterior walls were made by hollow clay bricks and plastered. There was no protection against fire in all precast concrete structural members. The construction was heavily damaged and collapsed. The estimated loss of goods was around $6,000,000.

Keywords: Fire; Concrete; Precast members

1. Introduction

In this study, a cotton thread plant in Kahramanmaras, Turkey, which was burned in 2003, was investigated. The plant was constructed by precast concrete structural members in 1997 and its construction area was 8142 m^2. General view of the plant after the fire was shown in Fig. 1.

Fire has different effects on different materials. In steel structures, the fire causes the steel members to expand and soften. Therefore, the steel members deform excessively and finally led the structure to collapse. On the 9/11 bombing, the twin towers were collapsed due to excessive expansion and softening under high temperature [1]. However, in reinforced concrete structures, concrete provides fire protection for the reinforcing steel bars up to certain level of temperature. The structure and members do not suffer from any damage under low level of temperature [2].

The concrete is a fire-resistance material. However, certain changes were observed in the characteristics of calcium silicate hydrate, C–S–H, aggregate and reinforcing steel bars. Also, partial evaporation was determined in C–S–H at the temperature of 500 °C or higher [3]. Evaporation of capillary water and water in gel pores leads to increase in pore volume in the concrete when the temperature exceeds 500 °C. Moreover,

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Fig. 1. General view of plant after fire: (a) collapsed structural members and (b) deformed column and beam.

calcium hydroxide $Ca(OH)_2$ and calcium silicate hydrate, C–S–H in cement paste decompose when the temperature exceeds 500 °C and they completely collapse at the temperature of 900 °C [4]. Aggregates show different behavior depending on their structures. Quartz, which is component of sand, gravel and volcanic rocks, expands gradually until the temperature of 573 °C. However, at the temperatures above 573 °C, about 0.85% sudden increase in volume occurs by the transformation of α-quartz to β-quartz. Limestone also expands until the temperature of 900 °C and decomposes at temperatures higher than 900 °C, which causes the release of CO_2 [5]. Changes in the compressive strength of concrete depending on temperature were determined as shown in Table 1 [6]. Also, changes in the color of concrete depending on temperature were shown in Fig. 2.

Reinforcing steel bars show a continuous drop in the yield and ultimate strength starting at 200 °C and 300 °C, respectively. Between 400 °C and 600 °C, there is a significant decrease in the yield and ultimate strength [9]. Due to fire resistance characteristics of the concrete, there is a big difference in temperature in the exterior and interior of the concrete. This difference in temperature leads to hot outer layer spalls from cool interior and consequently expose the reinforcing steel bars to high temperature. Moreover, due to difference in thermal expansion coefficients of concrete and steel, reinforcing steel bars also leads to an increase in cracks in the concrete.