Degradation of concrete elements under thermal and mechanical loads and its repair

D. Harinadha Reddy

B.M.S. School of Architecture, Bangalore India.

Ananth Ramaswamy

Indian Institute of Science, Bangalore India.

Contact: ananth@iisc.ac.in

Abstract

Details of an experimental program comprising of concrete cylinders exposed to different combinations of uniaxial loading, temperature and exposure time, to assess change in its stiffness and strength properties is discussed. Further, an attempt to repair companion thermo-mechanically damaged cylinders using carbon fiber reinforced polymer (CFRP) for mechanical strengthening and geopolymer for thermal insulation before exposing them to combinations of mechanical load and temperature is also presented to assess the efficacy of this system. A Hygro-thermo-chemo mechanical model that has been discussed in the literature is used to obtain strains both in the primary concrete and in the insulated repaired system. Concrete is treated as a deformable, multiphase porous material and so is the geo-polymer repair material. FRP is treated as an elastic brittle material.

Keywords: Concrete; CFRP; Geo-polymer; Thermal damage; Repair; Hygro-Chemo-Mechanical Model.

1 Introduction

Concrete undergoes many physical, chemical and mechanical changes when exposed to high temperature. The water inside the pores of concrete evaporates and results in a build-up of pore pressure under high temperature conditions. This pore pressure is just high enough to cause an explosive spalling in weakly permeable concretes. The differential expansion between the aggregate and cement paste develops higher interfacial stresses and leads to cracking in the interfacial transition zone (ITZ) at high temperature conditions. The high temperature in cement paste removes the chemically bound water and weakens the cement mortar. This phenomena leads to loss in mechanical properties of concrete and causes thermal spalling. Influence of the magnitude of temperature on the mechanical properties of high volume fly ash (HVF) concrete and self-compacting concrete (SCC) under stressed and un-stressed test conditions is limited. However many studies [1, 2] report on mechanical properties of HVF Concrete and SCC at ambient conditions. A fresh concrete has higher moisture content than the older concretes. The moisture inside the concrete will contribute to build up of pore pressure when exposed to high temperature as the water evaporates and is not able to migrate due to the development of a moisture clog. The evaporation of water due to high temperature can result in the vapour migrating either to the high temperature or to the low temperature zone. Movement to the low temperature zone results in condensation and a clog for further moisture migration. This phenomenon is referred to as the moisture clog theory [3].

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