MODELLING THE SPALLING BEHAVIOUR OF CONCRETE IN FIRE

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Spalling of concrete is a common phenomenon in reinforced concrete structures subjected to fire. As there are both macroscopic and microscopic factors involved, studying the behaviour of concrete spalling in fire is complicated. Permeability, pore pressures, moisture content, heating rate, and concrete type have been identified as contributing factors that influence concrete spalling in fire. Various experimental studies have been conducted to identify the behaviour of concrete spalling in fire. However, there is no exact method to determine spalling depth without conducting fire tests. Reduced cross-section and exposed reinforcement in a structural member due to spalling would significantly affect the overall stability of the structure.

This research study presents a macroscopic finite element model to predict the spalling behaviour of concrete in a fire. The behaviour of concrete at elevated temperatures was modelled using the Concrete Damaged Plasticity (CDP) model, and temperature-induced transient creep strain in concrete is explicitly accounted for in the analysis, which is more representative of fire-exposed concrete structures. The finite element analysis program, ABAQUS, was used to model the reinforced concrete walls subjected to load and exposed to hydrocarbon fire. A nonlinear finite element analysis model for the rectangular concrete specimens was analysed using a sequential approach composed of a pure heat transfer analysis followed by a pure mechanical analysis. Thermal and mechanical responses of the model were validated using results obtained through fire tests conducted at the University of Melbourne. The developed finite element model was used to assess the effect of reinforcement concentration and clear cover on concrete spalling in a fire.

Based on the results from the developed finite element model, it is evident that reinforced concrete with large cover thickness has a higher tendency to spall out in fire and also, cover to reinforcement has a major impact on the spalling of concrete. In addition, previous researchers have also experimentally identified that when the clear cover to reinforcement exceeds 40 mm, the spalling depth seems to have a greater tendency to become serious. It happens because the mass of concrete without support is significant. Other than that, it can be concluded that the concentration of reinforcement also has a minor impact on the spalling of concrete. Based on the above results, it is evident that densely reinforced concrete walls have a higher tendency to spall out in fire when the reinforcement spacing is less than 100 mm. It happens because of high thermal expansion and higher heat transfer rate through the structure. Further enhancements that can be used to improve the accuracy and reliability of the model are discussed.

Keywords: Concrete damaged plasticity; Finite element modelling; Fire resistance; Spalling

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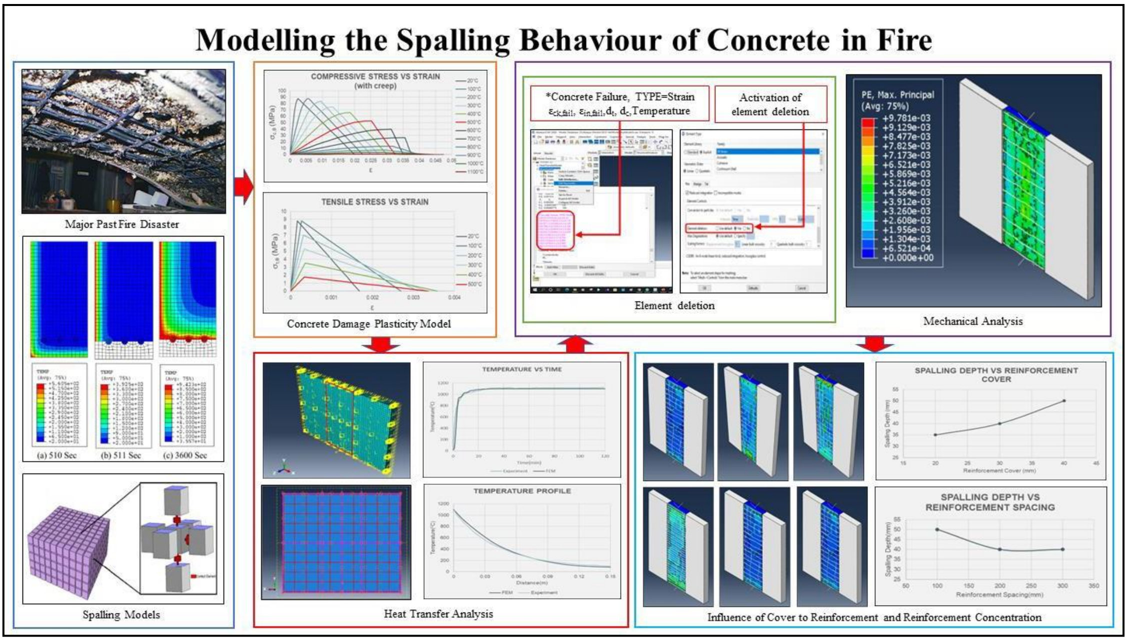
Modelling the Spalling Behaviour of Concrete in Fire
Major Past Fire Disaster
(a) 510 Sec
(b) 511 Sec
(c) 3600 Sec
Spalling Models
COMPRESSIVE STRESS VS STRAIN
(with creep)
TENSILE STRESS VS STRAIN
Concrete Damage Plasticity Model
*Concrete Failure, TYPE=Strain
Activation of element deletion
Element deletion
PE, Max. Principal
(Avg: 75%)
Mechanical Analysis
TEMPERATURE VS TIME
TEMPERATURE PROFILE
Heat Transfer Analysis
SPALLING DEPTH VS REINFORCEMENT COVER
SPALLING DEPTH VS REINFORCEMENT SPACING
Influence of Cover to Reinforcement and Reinforcement Concentration