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Structural performance of a post-tensioned concrete floor during horizontally travelling fires

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ABSTRACT

This paper highlights the structural performance of a bonded post-tensioned concrete floor subject to fires that travel horizontally between zones within the floorplate. The floorplate was previously analysed by the authors based on experimental and numerical investigations on one-way spanning bonded post-tensioned concrete slab strips. In the previous studies, a nonlinear finite element model was developed for the floor that considered the mechanical and thermal material nonlinearities of the floor's components, interfaces between the components, different natural fire severities, different applied static load during the fire and different restraint conditions. The previous studies highlighted the importance of investigating the whole-building behaviour and provided a useful insight into the temperature distribution throughout the floor slab, failure modes, comparisons with current design rules and time–displacement behaviour of the floor under fire conditions. This paper extends the previous studies and uses the validated finite element model to investigate different horizontal travelling fire scenarios between zones and different inter-zone time delays to represent fire travelling time. The time–temperature distribution throughout the floor slab was predicted at different locations in the floor subject to travelling fires. Furthermore, the time–deflection and time–axial displacement relationships were predicted at different locations in the floor. The current study has shown that horizontally travelling fire scenarios and the inter-zone time delay affect the time–deflection behaviour considerably. The change in heating/cooling scenarios between zones has resulted in a cyclic deflection pattern, which has previously not been considered when designing post-tensioned concrete floors against fire. Based on the analysis of the results presented, it is shown that the worst case in terms of maximum vertical defection or maximum residual deflection, at a given point in the floorplate, could occur either under the assumption of a uniform fire or a travelling fire. It is therefore recommended that designers should consider the integrity of floorplates using various travelling fires.

1. Introduction

Whole-building behaviour of post-tensioned concrete floor slab systems exposed to a uniform fire has been the subject of previous investigations by the authors [1,2]. The presented investigation on whole-building behaviour was based on the results of fire tests available in the literature on this form of construction [3–6] and the results of twelve extensively instrumented fire tests on unbonded and bonded post-tensioned concrete slabs, conducted at the University of Manchester [7–9]. In addition, observations from real fires in actual buildings, with unbonded post-tensioned concrete slabs [10–13], were taken into account. Based on this research work, design recommendations have been proposed for post-tensioned concrete slabs exposed to fire [9].

The previous research on post-tensioned floorplates, leading to design recommendations, has been based on the assumption that the fire will simultaneously affect the whole floorplate. In reality a fire will grow from its ignition source and, depending on the internal floor layout, travel throughout the floorplate until it is either extinguished or successfully contained by fire-rated compartment walls. A previous investigation by Bailey et al. [14] on bare two-dimensional steel-framed buildings highlighted the structural performance of steel-framed buildings under progressive fire spread. The study [14] showed that a travelling fire produced greater vertical beam displacements within a floor compared to the case where the floor was simultaneously heated. Although Bailey et al. [14] showed that a travelling fire produced the worst case, in terms of structural response, the study was limited in that it only considered simple

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