Structural Analysis of the Fire Response of a Cut and Cover Tunnel

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Abstract

This paper analyses the fire response of a 500 m long cut-and-cover tunnel with a rectangular cross section. The tunnel is submitted to the combustion of a truck carrying dangerous goods inside. The analysis uses a performance approach with three basic components: a model of the fire event using Computational Fluid Dynamics, a heat transfer analysis to obtain the temperatures within the structure of the worst tunnel cross section and a simplified model to obtain the tunnel structural response via the isotherm 500° method. Results show that the tunnel top slab is the critical element and that it would collapse 30 minutes after the beginning of the fire. Therefore, the tunnel would require special protective measures. The analysis also shows the advantages of a performance based approach vis-à-vis a prescriptive approach.

Keywords: Fire Engineering, Computational Fluid Dynamics, Thermo-structural Analysis, Cut and Cover Tunnel, Rectangular Cross Section Tunnel, Reinforced Concrete.

1 Introduction

Tunnel fires have specific features (e.g. oven effect, poor visibility and increased toxic gas concentrations) that make them have consequences much more severe than open air fires. In addition, from the point of view of structural analysis, the sharp rise of the ceiling gas temperature, often in excess of 1000°C within a few minutes, induces abrupt reductions of the structural capacity of the tunnel structural elements.

Therefore, tunnel fires deserve special attention as also proved by previous incidents.

This paper shows a methodology based on a performance approach in order to evaluate the structural response of a cut and cover tunnel through a fire model analysis using Computational

Fluid Dynamics, a heat transfer analysis evaluated by Finite Element method and a structural analysis applying the isotherm 500°C method.

2 Fire Model

Creating an adequate fire model is an iterative process based on the analysis of all the factors and conditions that can influence the fire behaviour. The aim is to optimize the difference between reliability and computational cost. On this basis, it is vital to evaluate each of these factors and analyse how the model outputs are modified in each case.

2.1 Fire Scenarios

In order to model the fire scenario and obtain the temperature field within the tunnel domain, the FDS software (Fire Dynamics Simulation) has been used. FDS is a Computational Fluid Dynamic software orientated to fire dynamics. The analysis is developed within a computational domain created by rectangular cells generating a rectilinear Cartesian grid. FDS provides numerical solution for the low-speed thermal flow Navier-Stokes

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