Investigation of the Concrete Lining after the Mont Blanc Tunnel Fire

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Summary

After the Mont Blanc tunnel fire, investigations for assessing the damage to the concrete lining were performed with the objective of determining the need for repairs. It was an opportunity to test new methods. Two innovative methods were tested: colour measurements inside the lining, and the Modal Analysis of Seismic Waves (MASW) method, normally used for soil investigation. These two methods are presented in this paper. Some results from other more classical methods are given, showing results in good accordance. From the identification of burnt concrete to the measurement of concrete thickness, the MASW method is under development for other applications in the world of tunnels like impervious membrane position.

Keywords: Mont Blanc tunnel fire; colour measurements inside lining; MASW (Modal Analysis of Seismic Waves) method; shear wave velocity (Vs); understanding concrete behaviour by innovative approach; heated concrete; tomography; experimental slab.

Introduction

The Mont Blanc Tunnel Fire

The Mont Blanc tunnel is a work of international statute linking Italy to France. It was opened for use in 1965, and its overall length is about 11,6 km, including 7,64 km on French territory and 3,96 km on Italian territory. The tunnel consists of a bidirectional tube with two lanes, one in each direction. The tunnel has a roadway width of 7,0 m with two sidewalks, each 0,75 m wide. The height of the tunnel, above the roadway, is about 6,5 m.

On March 24, 1999 at 11:51 hrs a fire was detected in the Mont Blanc tunnel, which started from a truck stationed near garage 21 (6550 m from the French entry point). The fire lasted for 53 hours and was equivalent to burning 200 tons of hydrocarbons. A very high temperature developed, due to which 39 people died and 34 vehicles were burnt, including 23 trucks. The trucks coming from France stopped behind the first burning truck at garage 21, and trucks coming from Italy stopped at garage 22, at a distance of 300 m from garage 21.

The damages to the concrete vault (not reinforced) were limited, and rescue teams were delayed only by heat. The length of tunnel most exposed to the fire that lay between garages 19 (5950 m) and 23 (7150 m from the French entry point) was approximately 1200 m. Compared to other fires (Channel Tunnel, Great Belt Tunnel, Tauern Tunnel) where major spallings occurred, the concrete in the Mont Blanc tunnel remained in place. Some falling concrete did occur in the tunnel but it came from old repaired zones. The extent of damage to the concrete vault was an important issue to be examined after the fire. References [1 and 2] present the different methods used for the investigation of the vault.

This paper presents two innovative methods used for testing the integrity of the vault. In the first method, the authors have used the change of colour of the concrete when heated. For the second method, the Modal Analysis of Seismic Waves (MASW) used in soil investigation was adapted to concrete.

Peer-reviewed by international experts and accepted for publication by SEI Editorial Board

Paper received: August 29, 2006
Paper accepted: February 7, 2007

Behaviour of Heated Concrete

When concrete is heated, the following changes occur in its crystal structure:

- 80–100°C: free water becomes steam
- 180–300°C: first dehydratation of C-S-H (silicate hydrates)
- 450–550°C: decomposition of Portlandite $Ca(OH)_2$
- 600–700°C: second transformation of C-S-H (silicate hydrates)
- 800°C: decomposition of all C-S-H (silicate hydrates)

For aggregates, at 573°C α–quartz becomes β–quartz and between 700 and 900°C calcereous aggregates become lime.

This evolution produces changes in the colour perception, as white light reflected from different crystal surfaces is modified in the spectrum of the light. Crystal transformations in concrete are not reversible, so the colour of a concrete surface is related to the highest temperature attained by concrete. The measurement of colour is carried out with a chromameter giving three coordinates. The accuracy of the measurement is very high, much better than by visual perception. Several types of coordinates exist for colour measurement, but the authors used here the L, a, b coordinates.

Colour Measurements on the Vault

The first attempt of the measurement was on the vault for mapping it. Chromaticity coordinate measurements were made on more than 1000 points of the vault. As the measurements were made between four and seven months after the fire, and as the concrete was dirty (soot and dust), the vault had to be cleaned before five measurements were made with a chromameter. The white light from the chromameter illuminating the sample formed a circle of 50 mm diameter, on which the measurements were done. Five measurements were taken by moving the chromameter but keeping the same proportion between the