Determining the fire resistance of the Maastunnel with a mobile oven

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Summary

The Maastunnel in Rotterdam (The Netherlands) is the world's oldest immersed concrete tunnel. Today's increasing fire safety regulations require that both new and existing tunnels should reach high requirements on structural concrete integrity when exposed to extreme fire conditions.

A new mobile furnace has been used to execute in-situ tests with the ISO fire curve as well as the EC tunnel fire (RWS fire curve) on the existing Maastunnel in Rotterdam, The Netherlands.

This paper shows the use of the new furnace and the results of the EC tunnel fire and interpretations of the tests. Special attention is given to the effectiveness of the ancient structural fire protection with Chamotte tiles as a heat resistant layer. It will be shown that the mobile furnace gives important information about the concrete spalling behaviour in existing tunnels, which is crucial to prove for owners, engineers, authorities and advisors.

Keywords: Fire resistance; Mobile furnace; RWS fire curve; EC fire curve; Immersed tunnel; The Maastunnel; Tunnel safety; Chamotte;

1. Fire resistance

The Maastunnel is the longest immersed road tunnel in Europe and the world's first immersed tunnel with a rectangular cross-section, constructed in reinforced concrete with a steel lining at the outside. Today, 70 years later, the Maastunnel still is one of the main traffic links in Rotterdam.

The tunnel is composed of river sections and two land sections. The land sections have ventilation tubes situated above the traffic deck, separated by a false ceiling (figure 2). In the river section, the ventilation tubes are situated below the traffic deck. It is distinctive that the concrete is covered by so called chamotte tiles. Chamotte is a kind of baked clay and is an ancient fire protective material. The functionality of chamotte in the Maastunnel is not exactly known, but it is plausible to say that these tiles were intended to act as fire protection.

New regulations prescribe that both new and existing road tunnels should reach high requirements in 2014 on fire safety. The Maastunnel should reach the requirements for existing tunnels as prescribed in the Dutch building code. The land sections must withstand a tunnel fire for at least 30 minutes, and the river section for at least 60 minutes.

The question is how to prove that the requirements from the building code are fulfilled. The fire resistance is determined according to NEN-EN1991-1-2. It gives detailing rules on which the fire resistance can be calculated. The Dutch national annex of the Eurocode also prescribes the EC (Eurocode) tunnel fire curve, formally known as the RWS fire curve, figure 1.

There is an essential assumption: the concrete should not spall, in order to use the calculation procedures. Spalling behaviour of concrete is highly unpredictable. The commonly performed laboratory spalling tests for existing structures are questionable at best. Therefore, the idea was formed to determine the fire resistance on site with a new innovative method using a mobile furnace. Thus a greater accuracy of the actual behaviour of the tunnel could be established.

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A mobile furnace, which is able to reproduce the EC tunnel fire was not available. However, this furnace was already being developed and the Maastunnel is the first structure where it was applied. The furnace is capable of exposing a surface of 1.00 x 1.00 m^2 to a full 120 minutes EC fire curve

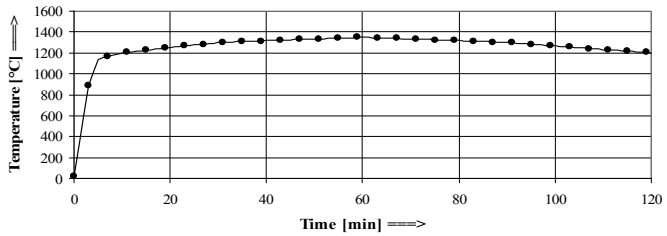

Fig. 1: EC tunnel Fire curve. Temperature as function of time

The tests were executed (1) to determine the contribution of the false ceiling to the fire resistance of the outer tunnel lining, (2) to determine the sensitivity of the concrete to spalling, (3) to determine the insulation properties of the chamotte tiles and (4) to find if and when the tiles will come off. These four questions needed to be answered in order to be able to determine the fire resistance according to NEN-EN1991-1-2 and to verify predictions, made in a desk study prior to the tests. During the 120 minutes long test with the EC fire curve observations were made at 30, 60, 90 and 120 minutes with a special camera in the furnace and temperature sensors, previously drilled from the unexposed side of the ceiling.

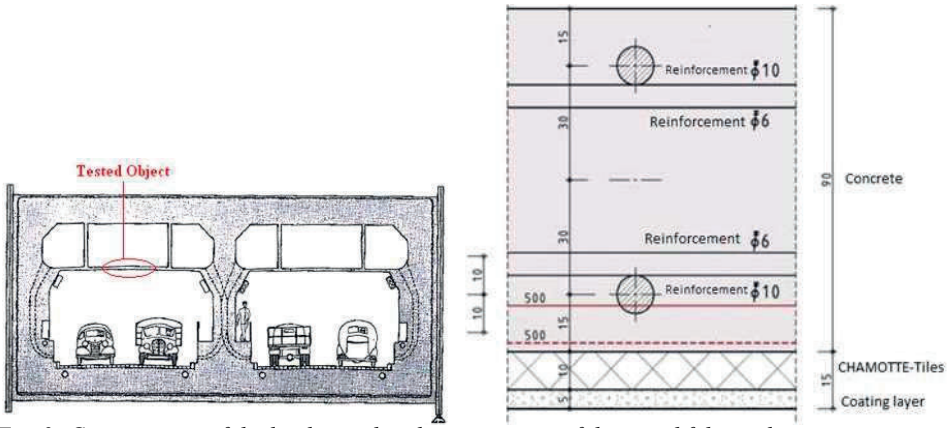

Fig. 2: Cross-section of the land tunnel and cross-section of the tested false ceiling

The false ceiling of the land tunnel proved to be able to resist 60 minutes of the EC fire curve. When proof has been provided that spalling will not occur to the ceiling of the river section as it does in the land sections, then the tunnel as a whole meets the requirements of the Dutch building code. This will require an additional test because it is questionable if the outcome of the test is suitable for the river section. The amount of moisture in the roof of the river section might differ, making it perhaps more sensitive to spalling. Moreover, the main structure of the river section heavily prevents thermal expansion an deformation.

The in-situ fire test has proven to be highly valuable to analyse the fire resistance and serves as a basis for:

- further research on different locations in the tunnel
- analysis of options to assure usability after a fire and the types traffic allowed in the tunnel
- determination of fire resistance for all existing (concrete) tunnels as the mobile furnace will form a crucial tool to be able to jeep, maintain and exploit the concrete tunnels.