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Failure of a Tied-Arch Bridge Submitted to a Severe Localized Fire

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Summary

In 1985 a tied-arch bridge near Liège was submitted to a severe localized fire due to the explosion of a gas pipe and collapsed after a short period. Numerical simulations have been performed using the SAFIR computer code developed at the University of Liège. The bridge has been analysed at ordinary temperature and under increasing temperatures. The fire resistance duration as well as the failure mode deduced from numerical simulations are in agreement with the observations made on site when the collapse occurred.

Keywords: accidental situation, bridge, fire resistance, numerical modelling.

On August 14th 1985, a gas pipe running under the Vivegnis Bridge located near Liège exploded for a reason still presently unknown. The accident took place at the foot of one of the bridge abutments. A severe localized fire occurred leading to the collapse of the bridge after a short period.

In order to understand what happened to the bridge on that day, numerical simulations have been performed using the SAFIR computer code developed at the University of Liège, and the modelling of the whole structure has been studied carefully.

The Vivegnis Bridge located near Liège is a tied-arch structure with a span of 136 meters, crossing the Albert Canal. The bridge deck comprises two main steel I-girders acting a ties. Steel cross girders supporting a composite concrete slab interconnect the two main girders. Arches are steel box girders linked together by means of bracings.

The main girders, cross girders, concrete slab, arches and bracings are modelled through 3D-beam finite elements. These elements deal with large displacements, material non-linearity and progressive spread of plasticity on the cross-section as well as along the elements. The suspenders are modelled by truss finite elements.

In a first step, the bridge is analysed at ordinary temperature considering different traffic load cases. This static cold analysis aims at validating the numerical model by comparing the results obtained with measurements collected on site at the time of loading tests. The main problem is the modelling of the concrete slab, which was cracked due to shrinkage restraint effects. After analysis and comparison with test results the most suitable model was adopted.

In a second step the bridge is analysed under increasing temperatures. One of the difficulties is the modelling of the fire environment. The fire source is localized at the foot of one of the abutments and it may be assumed that in this zone, the evolution of the air temperature according to time is described on the basis of the hydrocarbon curve of Eurocode 1, part 1-2.

In order to assess the decrease of temperature along the bridge from the fire source, the following procedure has been adopted. Visual observations have been made on bridge elements still existing on the bank of the canal in view of determining the steel elements not affected by the heat and their distance from the fire source. From there the fire has been modelled through six different fire zones with decreasing intensities. Beyond the sixth zone the bridge is assumed not to be heated anymore

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Fig. 1.

The results obtained by
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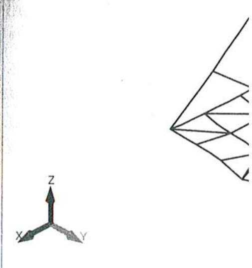

Fig. 1 Displace

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The hot analysis is performed by means of the dynamic version of the SAFIR computer code, which allows the analysis of the structure in a post-critical phase. In the static previous version of the code simulations could not go on as soon as a local failure occurred, whereas with the dynamic version of SAFIR, it is possible to bring the calculations to the global failure of the structure.

The thermal analysis performed with SAFIR allows the calculation of the temperature evolution in the different structural elements subjected to the predefined fire conditions.

The dynamic structural analysis under elevated temperatures is then performed. It reveals that a local failure first takes place after about 4 minutes, corresponding to the buckling of the bracing located near the fire source. At this time, the stability of the whole structure is still ensured and the global analysis may carry on. The structural failure of the whole bridge arises after 8 minutes and 57 seconds: the main girder in the hottest zone collapses and the arch portion located in the same zone becomes unstable. The displacements of the structure just before failure are illustrated in Fig. 1.

The results obtained by SAFIR with the assumptions adopted here are quite satisfactory, as the failure mechanism corresponds to the one that could be seen on site. They are also in agreement with the observations of witnesses regarding the fire resistance duration of the bridges until its collapse in the canal.

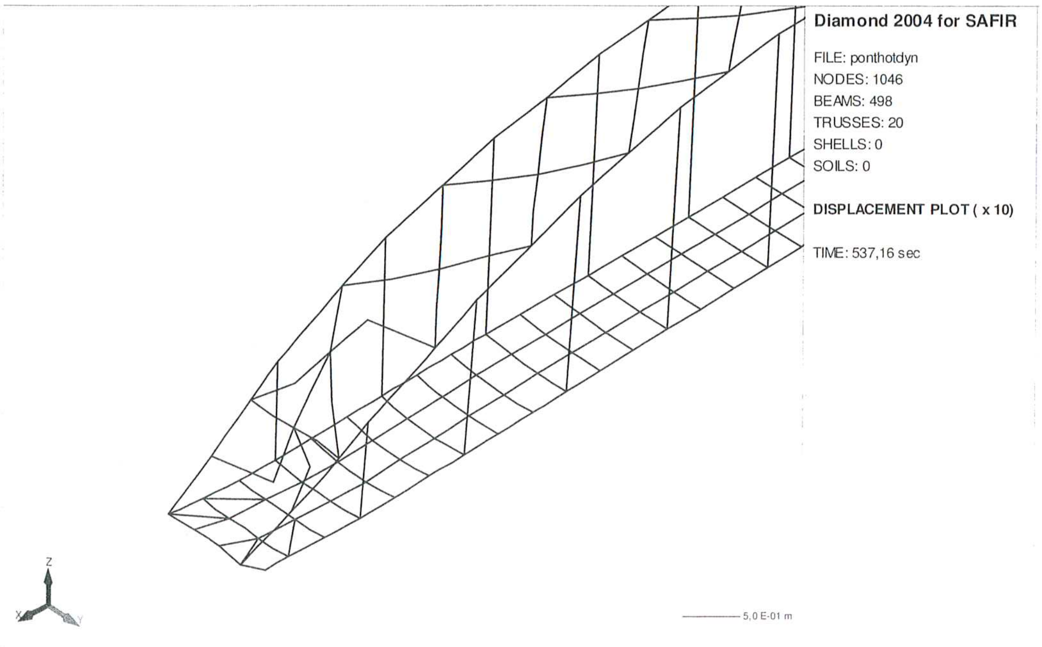

Fig. 1 Displacements of the structure just before failure (zoom on the fire source zone)