NONLINEAR ANALYSIS OF TUNNEL-SECTION SUBJECTED TO EXPLOSION LOADING

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The increasing amount of vehicles for transportation of explosive and combustible cargo, represents particular danger in connection with tunnels. To limit the damage in case of accidental events, the loadcarrying capacity must sustain possible impulsive loadings. This was the subject for a case study within the field of structural analysis, which has been performed at TNO Building and Construction Research. The study was carried out under contract with the Ministry of Transport, Public works and Water Management, Civil Engineering Division, in the Netherlands.

A typical tunnel-section in reinforced concrete, approximately 30 m wide and 8 m high, containing two compartments, was under consideration. The applied loadings consisted of an idealized impulse, which could be due to an internal gas explosion in one of the compartments, as well as external insitu loadings and deadweight.

To get a first approximation of the physics involved, the structure was modeled with beam elements. The analysis showed that the interface between structural members, such as the connection between wall and roof, were vulnerable areas, being heavily subjected to shear forces. Hence, to improve the shear description, 8-node plane stress quadrilaterals were applied. In both cases, the nonlinear behavior of concrete was accounted for by a smearedcrack approach with non-orthogonal angles between consecutive cracks. The constitutive behavior of cracked concrete was taken according to a tension stiffening approach. The reinforcement bars were modeled as elastic/perfectly plastic.
Under the assumption that the impulse load would cause a shear failure between structural members, and that the duration of the applied impulse was long compared to the low-frequency vibrations of the structure, also static analyses were performed. In order to determine the load-carrying capacity, and the associated failure mode, the areas of interest were modeled with a high Resolution membrane mesh. For the remaining parts of the structure, beam elements were applied. In the interface, the membranes and beam elements were connected by linear constraints.

The results of the analysis showed that reinforced concrete members are capable of absorbing a significant amount of energy without loosing structural integrity, especially high rate loading conditions.