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Dynamic Analysis of Underground Tunnels Subjected to Internal Blast Loading

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Abstract

In the recent decades, explosion incidents caused by terrorist activities have become a growing threat to the human civilization and civil infrastructure. Underground tunnels used for roadway and railway, utility lines and water pipe lines are an indivisible part of the modern civil infrastructure. Blast loading inside tunnel may cause numerous lives and severe damage of properties. Internal explosion in tunnel may lead to multiple reflections of the blast induced shock wave and the result in channeling of the shock wave. The underground tunnels are seldom designed adequately for sustaining the blast loading. Hence, in order to safeguard the tunnels from blast loading, it is necessary to understand the response of these structures when subjected to blast. Experimental determination of the response of underground tunnels under blast loading often becomes difficult due to socio-political issues. Hence, advanced numerical analysis of tunnels subjected to blast loading is of utmost importance.

The present study deals with three dimensional nonlinear finite element analyses of an underground tunnel in soil subjected to internal blast loading. The coupled Eulerian-Lagrangian (CEL) analysis tool in finite element software Abaqus/Explicit has been used for the analysis purpose. Soil and concrete tunnel linings have been modeled using three dimensional eight node reduced integration Lagrangian elements (C3D8R). Three Explosive charges of 5, 10 and 50 kg have been used. The explosive TNT has been modeled using the three dimensional eight node reduced integration Eulerian elements (EC3D8R). The reinforcement embedded in tunnel lining has been modeled using the beam elements (B31). The stress-strain response of soil, concrete and reinforcement has been simulated using strain rate dependent Drucker-Prager plasticity, Concrete Damaged plasticity and Johnson-Cook plasticity models, respectively. The TNT explosive has been simulated using the JWL equation-of-sate. The stress-strain, deformation and damage behavior of the tunnel lining and the surrounding soil have been studied. Propagation of shock wave through tunnel and soil has been investigated. It has been observed that tunnel lining faces severe damage under blast loading. High deformation of soil has also been observed.