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Development of Inflatable Structures for Tunnel Protection

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ABSTRACT

Tunnel safety has been of rising concern for transportation and government agencies in several developed countries. Fires, toxic fumes and gasses, and flooding threats have occurred in major transportation systems of highly populated cities around the world, and these situations triggered the need of research on protection systems such as inflatable structures. However, tunnel protection using an inflatable structure brings new challenges, due to the large scale of the problem and the complex geometry to which the inflatable has to conform. Researchers at West Virginia University jointly with industrial collaborators and transportation agencies are developing the Resilient Tunnel Plug concept (RTP). This concept involves an inflatable structure that is currently being designed using a gradual approach to the final solution. Experimental techniques at different scales as well as numerical techniques, such as Finite Element Analysis (FEA), are being used to simulate different scenarios of an inflatable system built with state-of-the-art materials and representing the geometric complexities of tunnel sections. The RTP concept consists of deploying one or more inflatable structures inside a tunnel, within a specific strategic location, to seal the tunnel section in case of a threatening event.

Using an inflatable structure to seal a tunnel provides favorable advantages compared to other sealing systems such as the compact space required by the packed inflatable and its low weight makes the RTP system easy to adapt to any tunnel without requiring major modifications of the tunnel geometry. In addition, the simple and fast installation of the RTP can avoid costly, and often nearly prohibitive, traffic interruptions of a system and associated problems for transportation authorities and users. These advantages and expected relatively low cost (compared to other sealing systems) make possible to install the RTP at multiple locations, increasing the number of protected areas.

The first phase of the RTP project consisted in the development of a prototype that was successfully deployed inside an operational subway tunnel. This prototype was developed for low inflation pressures and the design has proved the validity of the concept, as it is capable of sealing a real transportation tunnel in an inflation time lower than the time required to contain most of the considered threats. This prototype also proved the advantages of the RTP system as its installation was performed without affecting the tunnel geometry. The project is currently in its second phase of development. Tests were conducted at quarter-scale and full scale facilities constructed especially for the project at WVU. A second full-scale prototype is under development at this phase. The final RTP system has to be able to sustain large inflation pressures that can be found in some specific scenarios and will require using advanced materials capable of conforming complex geometries in order to reduce the stresses in the inflatable structure.

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