Inflatables for Protection of Tunnels: An Overview of Ten Years of Progress

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Abstract

The safety of underground civil infrastructure continues to be a high priority for transportation and transit security agencies. Rail transit tunnels running under bodies of water are susceptible to disruptions due to flooding originated by extraordinary climatic events or other events resulting from human activities. In the past decades, several incidents demonstrated the need to mitigate vulnerabilities or, at least, minimize the consequences of catastrophic events. Although it is impossible to prevent all situations that can lead to flooding, damage can be substantially minimized by reducing the area affected by the incident. In the case of rail tunnels, a possible approach is to compartmentalize the tunnel system by creating temporary barriers that can contain the propagation of flooding until a more permanent solution can be implemented. One way to create a temporary barrier is by the deployment of a set of large-scale inflatable structures, also known as inflatable plugs. In such an application, the inflatable structure is prepared for placement, either permanently or temporally, and maintained ready for deployment, inflation, and pressurization when needed. Once deployed, the internal plug pressure exerts a normal force against the tunnel wall surface, and the friction between the plug and tunnel surfaces oppose the axial movement of the plug. The sealing effectiveness depends on the ability of the inflatable structure to self-deploy and fit, without human intervention, to the intricacies of the perimeter of the conduit being sealed. Primary design constraints include having the inflatable structure stowed away from the dynamic envelope of the vehicles and being able to withhold the inflation and flooding pressures.

This work presents a compilation of the lessons learned and main results that demonstrate the viability of implementing large-scale inflatable plugs for the containment of flooding in rail tunnels systems. More than 400 coupon and specimen tests, over 200 reduced-scale tests, and 100 full-scale tests were conducted over a 10-year research and development program to demonstrate the efficacy of the design and performance of different prototypes. The culmination of the research and development work was 12 full-scale flooding demonstrations in which the inflatable plug was shown able to be deployed remotely and withstand a fully pressurized simulated flooding event.

References

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