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FINITE ELEMENT MODELING OF UNDERGROUND GLASS-REINFORCED COMPOSITE PIPE UNDER DIFFERENT LOADING SCENARIOS

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Summary: Two regional finite element (FE) models of an underground glass-fiber reinforced composite pipe have been developed at the National University of Singapore (NUS). The model replicates an arbitrary site whereby fuel is being transported through the 400 mm diameter line, and comprises of multiple components such as the valve pit, 45 degrees and 90 degrees pipe bends, and a service road consisting of the surface course and subbase course layers that cuts across the buried pipeline at the ground surface.

The regional models are developed to investigate several loading scenarios that may be experienced by the composite pipe throughout its lifetime. Properties of the soil strata are provided by soil investigation (SI) reports while the anisotropic properties of the glass-fiber composite pipe are obtained from both in-house testing of coupons machined from the actual composite pipes and from the pipe manufacturer.

In this paper, five cases are presented to study the buried pipe response, in terms of the induced hoop and axial stresses and the resulting pipe displacement, due to pit settlement and an applied 38 tonnes truck load on the service road. The effect of internal pressurization of the pipe and the comparison of response between the glass composite pipe and a traditional stainless steel pipe is also investigated. In-house mechanical characterization (pipe axial and hoop directions) conducted on coupons obtained from machining of the actual 400 mm diameter composite pipe are performed at 3 different rates and at 3 different temperatures. FE models of the test pieces are then assigned with the obtained mechanical and damage properties to validate the models before extending them for use in the regional model.

The regional models span across 60 m (length) by 11 m (width) by 12 m (depth) and consist of a total of 1.095M elements. The composite pipe is buried 3.5 m under the ground surface. The bell and spigot pipe joints connecting the individual 12 m pipe sections have also been modelled to allow the study of relative slippage of the slot-fitting joints for the various loading scenarios. Other parameters such as the resulting soil stresses, ground settlement and pipe vertical displacement are also investigated. Locations of potential leakage and burst are also identified by comparing stresses with the thresholds of pipe hoop and axial failure strength provided by the manufacturer.

The simulation results provided insights to the response of buried composite pipes and in particular the pipe-soil interaction that occurs for mutual transfer of loads between the soil and the pipe. In depth analysis of the damage and failure of the buried glass-reinforced composite pipe in the real application for fuel transportation has been investigated. Subsequent pipe-level tests are also scheduled where loads will be applied to actual pipes, instead of test coupons, to analyse different failure patterns in the composite structure. The failure analysis will employ X-ray or Computed Tomography (CT) to determine post-test failure modes in these composite pipes.