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NUMERICAL MODELLING OF COOLDOWN CONDITIONS IN AN ALL-CONCRETE LNG TANK

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ABSTRACT

The all-concrete LNG tank (ACLNG) is an alternative technology to the conventional 9% Ni LNG tank. Arup has been at the forefront of this technology since late 1990's. The LNG is stored in the tank at -165 degC therefore, the thermal-structural interactions between the product and the surrounding concrete tank is essential especially during the cooldown process, filling and accidental spill case scenario where the LNG in its liquid state spills into the outer tank.

This paper concentrates on the thermal aspects associated with the transient effects of cooldown and the coupling of thermal effects with the structural problem. The thermal stress is combined with the structural stress response given by the structural loads such as vertical and horizontal pre-stress and self weight to provide the final stress maps in the inner tank as well as outer tank. The material model employed throughout this work is of particular importance. The transient nature of these analyses requires that thermal conductivity, specific heat and density be employed. These parameters were taken as temperature dependent in the range of -165^0 C to 20^0 C as per CEIB No 145/1982 [11].

Since cracking in concrete is the principal parameter controlling the overall tank design, a complex material model based on damaged plasticity was used. The material model is based on a post-failure stress-strain relationship where the cracking displacement vs tensile stress and cracking displacement vs tensile damage are discretised using non-linear procedure offered by a commercial finite element software. The tensile stress at cracking for the damaged plasticity model was taken as $0.5\sqrt{f'_c}$ = 3.16 MPa (based on split cylinder). In compression the behavior of the concrete used the typical compression hardening curve as shown in BS 8110.

Non-linear transient heat transfer analyses were carried out for a variety of cooldown condition, lock-out conditions as well as spill condition. The thermal maps were subsequently used as an input for the stress problem. The cooldown case scenario was simulated for a period of 15 days. A 30 deg Celsius temperature gradient was considered as a limiting parameter across the inner tank wall in order to avoid the onset of tensile stress associated with cracking. The design criteria for the ACLNG tank is governed by the requirements stated in a variety of codes such as ACI 376, ACI 350,

BS 7777 and BS 8110. These requirements usually refer to a certain section size across the wall being subject to compressive stress as well as limiting tensile stress under normal and abnormal loadcase combinations. A discussion of these criteria and stress limits is provided in this paper.

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