Gas Sealing Behavior of Gasketed Segmental Joints in Shield Tunnels: An Experimental and Computational Study

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Abstract: When shield tunnels pass through gas-bearing strata, leakage may happen through the gasketed segmental joints, which puts threats on the safety during construction and operation process. Previous studies on sealing performance of the gasketed joints have focused on the waterproof behavior. However, differences in physical characteristics between liquid and gas, lead to different permeation properties. This paper presents a combined experimental and computational study to investigate the gas sealing behavior of the gasketed joints used for a shield tunnel project, i.e., Sutong GIL Utility Tunnel, which passes through soft soil strata rich in high-pressure biogas under Yangtze River. As double-gasket seals was used in the tunnel, 2 gasket profiles were tested using a gas sealing testing apparatus developed in-house, which correspond to the inner gaskets and the outer gaskets respectively. The tests were aimed to measure the air leakage rates through the gasketed joints under various combinations of joint openings and offsets under different pressures. Since both “slight leakage” and “rapid leakage” happened in the tests, where the leakage rates differ drastically in magnitude, this paper takes “critical pressure”, which corresponds to the leakage rate of 0.1 $L \cdot min^{-1}$ per meter joint length, as the index of the capability to resist sealing failure under extreme conditions, takes leakage rate (under same pressures) as the index of gas sealing performance during long-term "slight leakage", and evaluates the influences of joint deformation on the joints' gas sealing behavior from both aspects. Finite element models of the inner gasket-groove structure were created and set with different joint openings and offsets, loaded with different pressures. Gasket deformation and contact stress under different conditions were studied. Comparison between numerical results and test phenomena was conducted to investigate the sealing failure process. Based on the existing gas sealing model of rough surfaces, computational method of leakage rate was developed and validated, which can be used at the stage of long-term "slight leakage". Based on the study, gas sealing performance of the gasketed joints was analyzed and suggestions of improvement were given.

Keywords: Shield tunnel; gasketed segmental joints; gas sealing behavior; experiment; finite element analysis; theoretical computational method