ANISOTROPIC CONCRETE EXPANSION DUE TO ALKALI-SILICA REACTION

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Throughout the world, nuclear power plants are preparing for license renewal to extend their lifespan. The long-term operation of nuclear power plants requires an assessment of structural integrity against internal and external hazards. The structural resiliency of concrete structures is affected by degradations in concrete structures caused by prolonged exposure to environmental and operation stressors (e.g., moisture, temperature, irradiation). Among the varied concrete aging modes, Alkali-Silica Reaction (ASR) is a slow-evolving chemical reaction between the reactive silica in the aggregate and the alkali generally contained in the cement that produces an expansive gel in the presence of high moisture (~>70% relative humidity). The gel expansion-induced pressure causes the formation of cracking and leads to significant degradation in mechanical properties of the concrete. Seabrook Nuclear Power Plant is the first plant in the U.S. where ASR-induced concrete degradation has been observed. Continued safe operation requires to assess the aging concrete condition and the structural significance of ASR against extreme external hazards such as seismic loads and wind-induced impact loads. Thus, it is critical to predict expansion and damage caused by ASR. This study proposes a new model to simulate the time-dependent ASR-induced expansion in concrete for different states of stress during the life of a structure.

Past research shows that the total volumetric ASR-induced strain in concrete is barely affected by mechanical stresses confinement. It also shows strong evidence of a volumetric ASR-induced expansion transfer and that the expansion is largest in the direction of least resistance whereas it is reduced in the loading direction. In this study, a new approach is presented for time-dependent simulation of ASR-induced expansion in concrete considering the constant volumetric strain and the expansion transfer assumptions. The ASR-affected concrete expansion is investigated by including the ASR-induced degradation and coupling the chemical and physical mechanisms. The main contributions of the proposed approach are (1) that it provides a practical approach implantable in commercial finite element codes used by the industry and, (2) that it combines the degradation due to ASR with its effect on the mechanical and creep strains. The proposed model considers the anisotropy of the expansion, and the creep and shrinkage effects. Total strains of ASR-affected concrete are calculated and results are compared with different models as well as the experimental studies for different states of stress. The progression of strains in the ASR-affected concrete structures and their loss of strength over multiple decades are determined. The proposed approach shows good agreement with the findings from the past experimental study and represents the anisotropic expansion accurately.