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Pore effect on macroscopic physical properties II: three-dimensional composite elasticity and its application to a porou

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A porous system has distinct macroscopic proprieties that are very different from those of a non-porous matrix. In the present study, a three-dimensional buffer-layer finite element method (FEM) model was developed to investigate the porosity effect on macroscopic elasticity without introducing assumptions or approximations. This is the natural extension of a previous two-dimensional study by Yoneda and Sohag [2011]. Using the three-dimensional buffer-layer FEM model, the porosity effect was systematically analyzed by changing the degree of porosity, aspect ratio of the ellipsoidal pore, and elasticity of the matrix. Consequently, various useful relations were found through three-dimensional analysis of porosity effects. Derivatives of normalized elastic stiffness constants over porosity are integers, if the Poisson ratio of a matrix is zero. These derivatives are nearly constant below 5% porosity, suggesting that the interaction between neighboring pores is insignificant if the representative size of the pore is less than one-third of the mean distance between neighboring pores. The relations we obtained in this work were applied to correct ultrasonic velocities measured on a porous sintered specimen of Cmcm-CaIrO3, which is a well-known analog of the post-perovskite phase of MgSiO3. The resulting rigidity of Cmcm-CaIrO3 after correction for the porosity effect was significantly higher than values predicted by theoretical calculations, and the Poisson ratio of 0.284 is consistent with ratios predicted by theoretical calculations made for the post-perovskite phase of MgSiO3. Considering the similarity of the Poisson ratios, Cmcm-CaIrO3 may be a good analog for the post-perovskite phase of MgSiO3 at around 120 GPa.

Keywords: composit elasticity, finite element method, CaIrO3, post perovskite