Analysis of the stress field and effective shear modulus of porous structures containing periodic holes with surface effects in anti-plane shear

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Abstract

As a special category of multiple holes, periodic holes are of particular interest since they often exist in porous media. To address periodic holes, one usually needs to impose periodic boundary conditions on the edge of corresponding representative unit cell (RUC). Despite this, complex variable methods are still applicable in the mechanical analysis of periodic holes. And to authors' knowledge, no effective procedure (based on complex variable methods or other analytic methods) so far has been established in the literature to solve the problem of periodic non-circular holes especially for imperfect boundary conditions on the edge of the holes. In our work, a complex variable-based scheme is presented to calculate the anti-plane shear properties of a porous structure containing periodic holes under uniform (anti-plane shear) loadings. Our scheme is featured by practically arbitrary shapes of the holes and the surface effects (resulting from surface elasticity) incorporated on each hole's boundary. Numerical examples are given to verify the feasibility of our scheme and to study the influence of the hole shape and surface effects on the stress concentration around the holes and the effective (longitudinal) shear moduli of the structure. It is shown that the stress concentration around periodic holes can be treated approximately as that around a single hole (for the same hole size and surface shear modulus) when the hole volume fraction is less than 7%. It is also found that for (reasonably) given surface shear modulus, hole volume fraction and hole size, the structure containing periodic circular holes can achieve larger effective shear moduli but lower sensitivity of effective shear moduli to the surface effects as compared with those containing periodic regular polygonal holes.

Keywords: Porous material; Arbitrarily-shaped hole; Periodic holes; Surface effect; Effective modulus