On Saint-Venant's Problem for an Inhomogeneous, Anisotropic Cylinder—Part I: Methodology for Saint-Venant Solutions

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Author(s):
S. B. Dong, Mem. ASME
Civil and Environmental Engineering Department, University of California, Los Angeles, CA 90095-1593

J. B. Kosmatka, Mem ASME
Department of Applied Mechanics and Engineering Science, University of California, San Diego, CA 92093-0085

H. C. Lin
Civil and Environmental Engineering Department, University of California, Los Angeles, CA 90095-1593

In this paper, the first in a series of three, a procedure based on semi-analytical finite elements is presented for constructing Saint-Venant solutions for extension, bending, torsion, and flexure of a prismatic cylinder with inhomogeneous, anisotropic cross-sectional properties. Extension-bending-torsion involve stress fields independent of the axial coordinate and their displacements may be decomposed into two distinct parts which are called the primal field and the cross-sectional warpages herein. The primal field embodies the essence of the kinematic hypotheses of elementary bar and beam theories and that for unrestrained torsion. The cross-sectional warpages are independent of the axial coordinate and they are determined by testing the variationally derived finite element displacement equations of equilibrium with the primal field. For flexure, a restricted three-dimensional stress field is in effect where the stress can vary at most linearly along the axis. Integrating the displacement field based for extension-bending-torsion gives that for the flexure problem. The cross-sectional warpages for flexure are determined by testing the displacement equations of equilibrium with this displacement field. In the next paper, the cross-sectional properties such as the weighted-average centroid, center of twist and shear center are defined based on the Saint-Venant solutions established in the present paper and numerical examples are given. In the third paper, end effects or the quantification of Saint-Venant's principle for the inhomogeneous, anisotropic cylinder is considered.

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