Regularity and finite element approximation for two-dimensional elliptic equations with line Dirac sources

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We study the elliptic equation with a line Dirac delta function as the source term subject to the Dirichlet boundary condition in a two-dimensional domain. Such a line Dirac measure causes different types of solution singularities in the neighborhood of the line fracture. We establish new regularity results for the solution in a class of weighted Sobolev spaces and propose finite element algorithms that approximate the singular solution at the optimal convergence rate. Numerical tests are presented to justify the theoretical findings.