Abstract

Heavily overconsolidated clays like London Clay present an interesting challenge for constitutive models. Their stress history, fissures and orientated structure differentiate them from the normal to lightly overconsolidated materials so aptly described by conventional critical state models. Recent large scale geotechnical projects within the London Clay stratum such as the Terminal 5 Heathrow Airport expansion and the twin tunnels at Saint James's Park prompted intensive research to fully characterise this soil type. These studies have highlighted several unique features of heavily overconsolidated clay that should be considered by comprehensive soil models, for example: stiffness anisotropy, strength anisotropy, destructuration and stress history effects.

In this thesis, two soil models with a history of application in London Clay have been selected for further improvement. The first model, BRICK (e.g. Simpson [1992]), has been employed successfully on a wide variety of geotechnical projects by Arup Geotechnics for more than two decades, including the British Library excavation and redevelopment of the King's Cross/St Pancras rail station. BRICK is a nonconventional model comprised of multiple kinematic yield surfaces in strain space. The second model, M3SKH (e.g. Grammatikopoulou [2004]), is a variant of the popular 3SKH model by Stallebrass [1990]. It is a critical state model in stress space comprised of a bounding surface and two kinematically-translating yield surfaces. Both models have found some success with heavily overconsolidated clay because of their ability to account for recent stress history effects and highly nonlinear, inelastic pre-failure behaviour.

The general behaviour of the BRICK and M3SKH models is examined in this research. Both models are sufficiently able to capture the undrained deformation of London Clay; however, they struggle to capture the deformation behaviour during drained conditions and the development of pore pressures during undrained conditions. To account for this observation, both models have been enhanced to consider stiffness anisotropy. Anisotropy is included in BRICK through an evolving transformation of the strain space coordinate system. Anisotropy is included in M3SKH in three ways: 1) elastic anisotropy, 2) rotated yield surfaces, and 3) nonassociativity in the meridian plane.

The improved performance of the new models is demonstrated through material point simulations of a variety of conventional and nonconventional laboratory tests. The importance of anisotropy for boundary value problems is then demonstrated through 2D and 3D finite element analyses of real case histories, including construction of a three-pinned arch and embankment in Western London, excavation of the Heathrow Trial tunnel and construction of a deep excavation at King's Place with a single layer prop system.