This paper presents a finite volume implementation of a porous, nonlinear soil model capable of simulating pore pressure accumulation under cyclic loading. The mathematical formulations are based on modified Biot's coupled theory by substituting the original elastic constitutive model with an advanced elastoplastic model suitable for describing monotonic as well as cyclic loading conditions. The finite volume method is applied to discretize these formulations. The resulting set of coupled nonlinear algebraic equations are then solved by a 'segregated' solution procedure. An efficient return mapping algorithm is used to calculate the stress and strain relation in each control volume level. Test cases show very good performance of the model.