Application of Abaqus secondary development in finite element analysis of rebar behavior in reinforced concrete member

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Abstract

A new type of subroutine VUMAT (tj_fiber) is developed to simulate the mechanical behavior of rebar in reinforced concrete members under cyclic loading. The constitutive model used for tj_fiber was with reference to the adjustment of the Clough hysteresis model, involving the strength deterioration of reinforcement due to effective hysteretic energy dissipation under cyclic loading, together with loss of load capacity caused by interface bond-slip, buckling, and fracture of rebar. Finite element analysis was performed based on Abaqus\Explicit module for typical reinforced concrete column and shear wall, respectively, to demonstrate the application of tj_fiber. The numerical results show that using finite element analysis with tj_fiber accurately simulates the local and global behavior of reinforced concrete compression-flexure members subjected to cyclic lateral load.

Keywords: Abaqus secondary development; reinforced concrete members; rebar hysteresis model; cyclic loading test; finite element analysis.

1 Introduction

For reinforced concrete structures subjected to moderate to large earthquakes, beams, columns, and shear walls generally exhibit substantial nonlinear behavior. It is challenging to acquire sufficient data considering the cost and test technology limitations of experimental methods to conduct seismic studies for reinforced concrete members. Consequently, finite element analysis of reinforced concrete members using three-dimensional solid elements can efficiently compensate for the inadequacies of experimental studies. The mechanical properties of the members are investigated under a variety of scenarios utilizing a small proportion of reference tests and a significant number of numerical simulations.

It is essential to accurately estimate the cyclic stress-strain behavior of the reinforcing steel in the critical region of the member when utilizing a finite element analysis to determine the response of reinforced concrete members under earthquake-induced loads. Yousser and Ghobarah[1] argued that the degradation of the member's strength could be effectively simulated by incorporating the whole degradation of the member's strength in the reinforcement hysteresis stress-train relationship.

Numerous studies have been conducted to calibrate models of steel rebar materials, the majority of which are suitable to implicit finite element methods. Nevertheless, once the concrete is cracked in tension or enters a significantly nonlinear stage, the drastic stiffness shift renders Newton approach extremely hard to obtain an implicit solution to the nonlinear equations. Meanwhile, the developed constitutive model of steel bars suitable for explicit finite element analysis disregards factors such as buckling, strength degradation, and rapture of rebar, making it difficult for the finite element model to accurately reflect the mechanical behavior