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Investigation for plastic damage constitutive models of the concrete material

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Abstract

In this paper, some simple stress-strain relationships of the concrete material recommended in relevant Codes are appropriately simplified, then the damage factors of the simplified plastic damage constitutive model is determined based on Sidiroff's energy equivalence principle. Mechanical characteristics of the concrete material under the simple tension or compression are analyzed by Finite element method. Through the comparison of numerical analysis results and Code constitutive relations, the damage factors of the simplified plastic damage constitutive model is verified. The unreinforced concrete beam static tests by Petersson is simulation analyzed by the nonlinear finite element method and plastic damage constitutive model. The effect of the unit size and the different linear softening constitutive relation on the analysis results are considered. The results show that there is no obvious size effect on the plastic damage analysis results based on fracture cracking criterion, the results of the bilinear softening constitutive analysis have good accuracy, and the form of softening constitutive relation has a great influence on the result.

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Keywords: finite element method;concrete;plastic damage;nonlinear analysis;

1. Introduction

The stress-strain relationship of concrete under multiaxial stress plays an important role in the finite element analysis of the nonlinear response of concrete structures. There are a lot of constitutive model of concrete based on

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the experimental and theoretical study, such as linear elastic model, nonlinear elastic model, plastic theory model, viscous - plastic theory, internal theory, fracture theory , damage theory and so on.

However, due to the complex nature of concrete materials, there is no common constitutive model of concrete. Plastic Damage Constitutive Model it is assumed that the damage of concrete material is mainly caused by tensile cracking and compression crushing. Some studies have been made on the damage factors and related parameters in the plastic constitutive model of concrete, Yao Guohuang etc. [1] studied the parameters in the plastic damage model and applied it to the static analysis of steel-concrete composite structures. Lei Tuo etc. [2] through the analysis of reinforced concrete simply supported beam, discussed the dilation angle, viscosity parameter, tensile stiffening and other constitutive parameters on the analysis results. Cao Ming [3] proposed a plastic damage factors calculation method, and analysed the reinforced concrete simply supported beam. Zhang Jin etc. [4] carried out the relevant damage parameters for the concrete uniaxial constitutive relation given by the relevant norm. Qin Hao etc. [5] studied the method of taking the concrete damage factors in ABAQUS program.

In this paper, the calculation method of plastic damage parameters in ABAQUS program is further studied, and the modified constitutive model of concrete plastic damage is proposed and verified. The nonlinear static plastic damage analysis of the plain concrete beam is carried out, and the results are compared with the experimental results.

2. Plastic damage model

The plastic damage constitutive model in ABAQUS program is suitable for concrete and rock [6,7] quasi-brittle materials, which can simulate the tensile cracking and compressive crushing of concrete materials, considering the isotropic elastic damage and plastic behavior of materials.

In general, the strain rate $\dot{\boldsymbol{\varepsilon}}$ can be decomposed into elastic strain rate $\dot{\boldsymbol{\varepsilon}}^{el}$ and plastic strain rate $\dot{\boldsymbol{\varepsilon}}^{pl}$:

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^{el} + \dot{\boldsymbol{\varepsilon}}^{pl} \qquad \text{* MERGEFORMAT (1)}$$

And the elastic damage constitutive relationship is:

$$\boldsymbol{\sigma} = (1-d)\mathbf{D}_0^{el} : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}^{pl}) = \mathbf{D}^{el} : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}^{pl}) \qquad \text{* MERGEFORMAT (2)}$$

where $\mathbf{D}_0^{el}$ and $\mathbf{D}^{el}$ are the initial (undamaged) elastic stiffness of the concrete and the degraded elastic stiffness ,and d is the damage factor, the scalar stiffness degradation variable, which can take values in the range of zero (undamaged material) to one (fully damaged material).

The damage factors d_c and d_t represent the stiffness degradation rate of the concrete caused by the damage of the concrete during compression and tension,under the condition of uniaxial stress,from the formula (2) ,get the tensile and compressive damage constitutive relationship, as shown in Fig. 1.

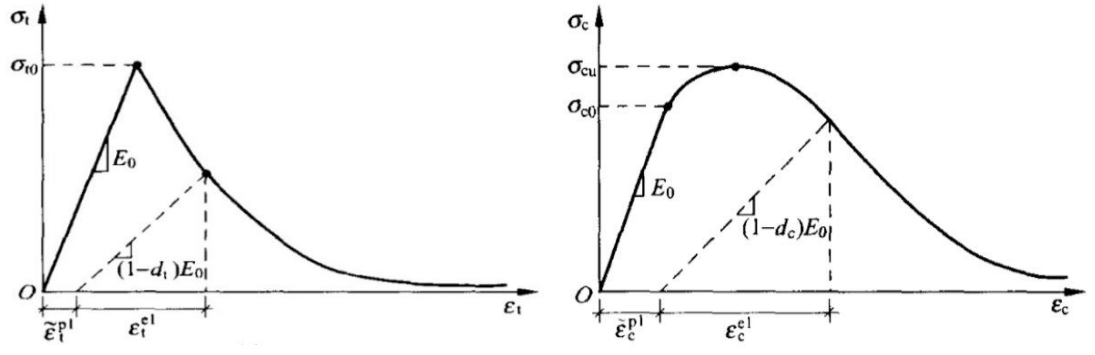

Fig. 1. Uniaxial damage constitutive curve of concrete:(a) uniaxial tension; (b) uniaxial compression.

The yield function F which consider the yield strength of tension and compression is [6,7]: