STATIC PUSHOVER ANALYSIS OF CFRP-RETROFITTED RC COLUMNS WITH SUSTAINED LOADING

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Introduction

Bonding carbon fiber reinforced polymer (CFRP) laminates to concrete columns can give rise to significant enhancements in their capacities, ductility and energy dissipation. The mechanical of CFRP-confined concrete has already been extensively explored and many stress-strain models have been proposed [1-4]. However, those explorations were centered on the columns without the consideration of sustained loading. The influence of such loading on the behavior of CFRP-retrofitted concrete columns is not well identified yet. And such influence is possibly considerable in some circumstances [5]. Due to some experimental difficulties arise from two-stage loading procedures, the availability of corresponding test data are limited [6-7]. The limit data have led to different or even contrary conclusions. Combination of physical test data and virtual numerical analysis has bee regarded as a good solution to some complex engineering issues. The purpose of this paper is to study the static lateral responses of CFRP-retrofitted concrete columns with sustained loading, by using the commercial finite element (FE) analysis software ABAQUS.

FE modeling

In the FE model, the damaged plasticity model of concrete included in ABAQUS is adopted to describe the property of concrete. This model consists of damage failure mechanisms, i.e. cracking in tension and crushing in compression [8]. The uniaxial stress-strain relations adopted for compressive and tension concrete are proposed by Guo and Zhang [9] and Jiang [10]. The damage index proposed by Zhang et al [11] is applied to determine the status of concrete. For reinforcing bars, the linear hardening model is selected, in which the hardening modulus of elasticity is taken as 1 percent of initial elasticity modulus. The CFRP laminate used in the analysis is unidirectional laminate. Only tensile resistance in its longitudinal direction is taken into account. The resistances for other directions are ignored. The compressive resistance of the four-node linear membrane element M3D4 with zero bending stiffness used to model CFRP laminate is eliminated in the analysis. As for concrete, the eight-node linear reduced integration element C3D8R in ABAQUS is selected for modeling concrete. This element has two advantages over other elements based on full integration in two aspects, i.e. computationally efficient and stable. The reinforcing bars in columns are modeled by the two-node linear truss element T3D2. Perfect bond between concrete and CFRP laminates is always assumed throughout the analytical process. In the FE model (in Fig.1), all the DOFs of the nodes close to base are constrained.

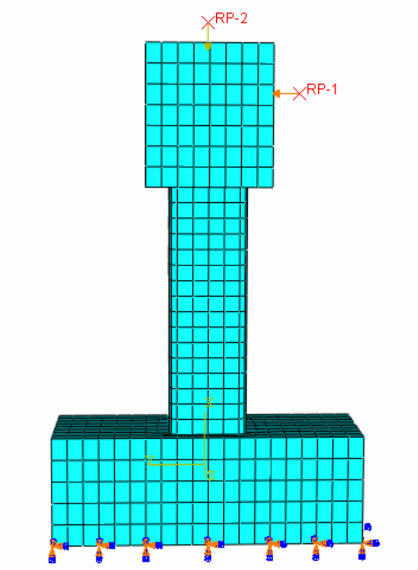

Fig.1 FE model

In the analysis, a constant axial load, i.e. sustained loading, N_0, is applied before wrapping CFRP laminate and static pushover process. The so-called preloading stress level index, n_0, introduced in Ref.[5] that defined as the ratio of N_0 to the ultimate axial capacity of the column is also used to characterize the sustained loading. Force control and displacement control schemes are adopted for the sustained loading and lateral displacement, respectively. The strategy of birth and death is applied to model the preloading in the membrane element M3D4 for CFRP laminate. With this strategy, the mesh of reinforcing bars, concrete and CFRP laminate can be set completely prior to pushover analysis. There is no need for remeshing any more in the analysis. the only thing that we do is to remove and add the strengthening elements. Therefore, the second pushover analysis is substantially eased.

Validation

The test data from Ref.[12] is used to validate the model developed as above in the ABAQUS. As indicated in Fig.2, results of the static pushover analytical (P-Δ) curves from the test and prediction fit very well with each other.

Parametric study

The effects of some influencing factors, e.g. preloading stress level index, longitudinal reinforcement ratio, volumetric reinforcement ratio, concrete strength, CFRP reinforcement ratio, etc, on the lateral responses of CFRP-retrofitted columns are studied. The results indicated that longitudinal reinforcement ratio and yield strength affect the maximum lateral force of P-Δ curves only. Volumetric lateral reinforcement ratio only has a significant effect on the slope of descent segment in P-Δ curves, i.e. the ductility of columns. CFRP reinforcement ratio put an effect on the ductility of columns in the similar way to volumetric lateral reinforcement ratio. Concrete can affect the ductility of retrofitted concrete columns as well their lateral resistances.

Most important observation in this study is that preloading stress level index, n_0, has put significant effect on both lateral resistance and ductility. As indicated in Fig.3, as the index, n_0, increases, the maximum lateral resistance firstly increases and then decreases quickly. As the case considered, the transition point is about n_0=0.45. The greater preloading stress level index is, the worse the ductility is. With extremely high preloading stress level, strengthening is not practical.

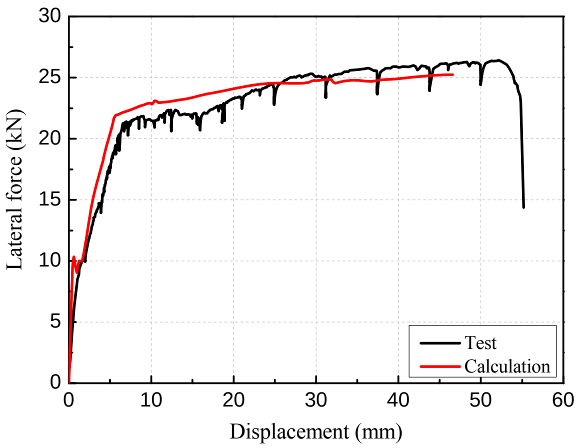

Fig.2 Comparison of results from test and prediction

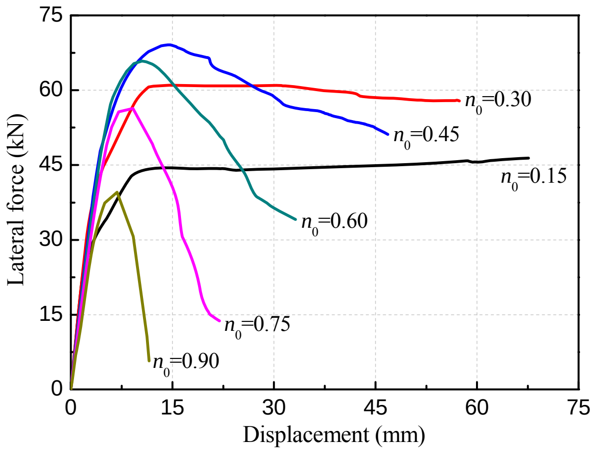

Fig.3 Predicted lateral responses with different preloading stress level indexes

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