Numerical Analysis of Ultra High Performance Fiber Reinforced Concrete I-beam

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ABSTRACT

이 논문은 초고강도 섬유보강 I형 보의 거동을 Diana를 사용하여 3차원 유한요소해석을 수행하였다. 보통 또는 고강도 콘크리트의 구성방정식과 달리 초고강도 섬유보강 콘크리트의 재료적 특성 즉, 인장 변형률 강화를 고려한 탄-소성 파괴 역학적 모델을 제안하여 해석에 반영하였다. 인장영역에서는 인장 변형률 강화를 고려한 다차원 고정 균열 규준을 사용하였고, 압축영역에서는 associated flow rule을 고려한 Drucker-Prager Criterion을 채택하였다. UHPFRC(Ultra-High Performance Fiber Reinforced Concrete) I형 보의 하중변형관계, 최초 균열, 최초 대각 균열, 극한상태 등의 결과를 실험결과와 비교하여 해석법의 유용성을 입증하였다.

1. Introduction

Ultra high performance fiber reinforced concrete(UHPFRC) possesses very low permeability, extremely high compressive strength and tensile strain hardening forit has higher quantity of fiber reinforcement(usually 2% in volume of metallic fibers), and a more dense fine matrix. Normally the compressive strength of UHPFRC is in the range between 150 and 220 MPa, and the tensile strength of UHPFRC is in the range of 7 to 15 MPa. Although it is called concrete, UHPFRC which is well adapted for the improvement of strength and durability of structural elements should not follow the path of normal and high strength concrete application. Among these kinds of applications several traffic bridges can be listed: the first road bridge "Shepherds Bridge"in Australia with 15 meters long by 21 meters wide, Vehicle Bridge in U.S.A with 33m simple span, Sherbrooke footbridge in Canada, Seonyu footbridge in Korea, the Kuyshu expressway bridge and the Sakata Mirai footbridge erected in Japan[1] and so on.

Since it is very important to predict material strength, deformation performance and failure process in the design of structures, it is necessary to perform nonlinear finite element analysis for UHPFRC. Hence a numerical study of UHPFRC I-beam is performed in this paper.

2. Finite element model

2.1 Finite element meshing

There are two models which have the same cross section and the dimension in the analysis. Fig.1 shows the cross section and the dimension. Due to symmetry, Fig.2 only shows the half I-beam elevation.

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The black small triangle locates the location of support point. The two models are represented by FP-W5 and NP-W5, respectively. The initial prestressing force is 60ton in model FP-W5, and there is no prestressing force in model NP-W5. Only the finite element meshing of model FP-W5 is shown in Fig.3(a,b) for the two models have the same meshing.

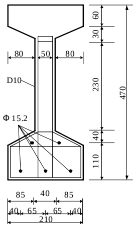


Fig.1. cross section and dimension

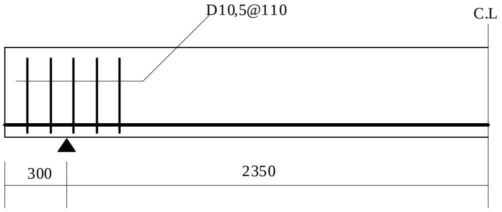
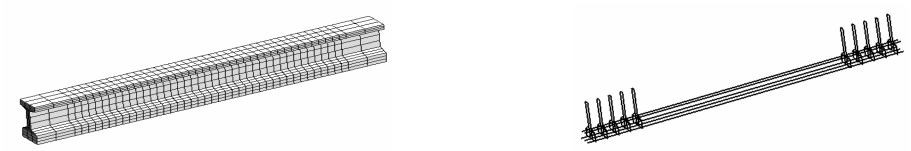


Fig.2. model elevation



(a) I-beam finite element meshing

(b) Reinforced bar finite element meshing

Fig.3. Finite element meshing of model FP-W5

2.2 Material model

2.2.1 Constitutive model of UHPFRC

The proposed constitutive model is an elastic-plastic fracture model which considers the tensile strain hardening and softening after crack. A multi-directional fixed crack model is used for the description of crack in the tensile region and Drucker-Prager yield criterion is employed to describe the failure of UHPFRC in the compressive region. For defining the constitutive model, some material parameters which are shown in Table1 are required.

Table1. Material parameters

UHPFRC Young's modulus (GPa)	40	Uniaxial ultimate tensile strength f_t' (MPa)	12
Poisson's ratio	0.2	Compressive strength (MPa)	150
Uniaxial elastic tensile strength f_t (MPa)	8	The initial internal frictional angle	37°

2.2.2 The prestressing steel constitutive law and yield criterion

The perfect elastic-plastic model under von Mises yield condition is employed to describe the stress-strain relationship of the prestressing steel. The yield stress is 1000MPa, Steel Young's modulus 200GPa.

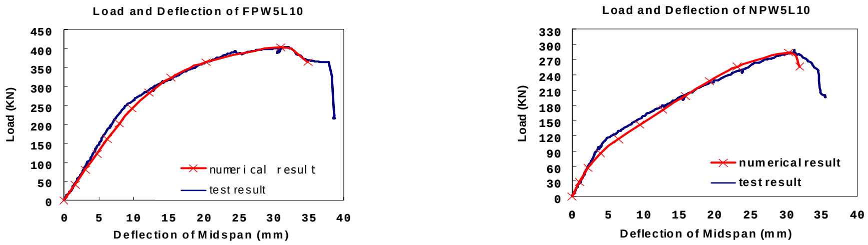
2.3 Boundary condition and load application

The location of support is defined according to the black small triangle location in Fig.2. The concentrated load is applied on the midspan, and the load magnitude is designed based on the test load. The prestressing force is acted on the prestressing steel in the form of initial stress.

3. Analysis results and comparison with test results

3.1 Load-deflection relationship

The load-deflection relationship at the loading point is shown in Fig.4, where the solid line represents the test results, and the line with cross represents the finite element analysis results. In each case, the load-deflection curve consists of a relatively steep initial segment representing the state before cracking, a less steep segment caused by reduced cracked stiffness and a descending segment when beam loses the load carrying capacity. The numerical results agrees with the test result very well.



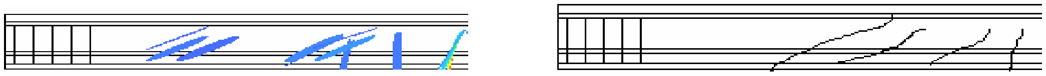
(a) (b)

Fig.4 load-deflection relationship

3.2 The simulation of cracking and crushing

The extent of cracking and crushing is simulated under the first crack load, the first diagonal crack load and the ultimate state load. Only the simulative results of model FP-W5 isdiscussed and compared with the test results. Due to symmetry, the half-span cracking and crushing process of model FP-W5 shown in Fig.5, in which the left figures are numerical results and the right figures are the test results. Compared the numerical results with the test results, it can be seen that, under the same load level, the finite element models simulate the cracking and crushing of test very well,. Hence a conclusion can be made from the above comparison that the finite elementmodels fit to simulate the failure process of UHPFRC I-beam.

(a): First crack



(b) First diagonal crack

(c) Ultimate state

Fig.5. Cracking and crushing of model FP-W5

4. Conclusions

By investigation, the following conclusions can be made:

1. The numerical results are in good agreement with the test results. The proposed elastic-plastic fracture constitutive model which considers the crack strain hardening in tension fits to simulate finite element analysis for UHPFRC

2. Prestressing steel which enhances the carrying capacity and deformation capacity of UHPFRC has great influence on the property of model.

3. Fromthe analysis results of the first crack, the first diagonal crack and the ultimate state, it can be seen that the finite element model is reliable to simulate the crack and failure.

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