LCP 방법에 의한 초고강도 섬유보강 I형보의 수치해석

Numerical Simulation of UHPFRC I-beam by the Linear Complementarity Problem

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ABSTRACT

This paper presents a numerical simulation of quasi-brittle fracture in UHPFRC I-beam. A linear complementarity problem (LCP) is used to formulate the path-dependent hardening-softening behavior in non-holonomic rate form, and the PATH solver is employed to solve the LCP.

요약

이 논문은 초고강도 I 형보의 quasi-brittle 파괴역학적 수치해석을 수행하였다. Non-holonomic rate 형태로 변형경로에 의존하는 경화-연화거동 관계 방정식을 구성하기 위해 linear Complementarity 방법을 사용하였으며, PATH solver 를 사용하여 LCP 방법의 해를 구하였다.

1. Introduction

As ultra high performance fiber reinforced concrete(UHPFRC) exhibits tensile hardening after cracking, the simulation of quasi-brittle fracture in UHPFRC is different from other concrete. Based on the investigation of Tin-Loi and Attard[1], the simulation of fracture in concrete has been extended to model UHPFRC I-beam by including a tensile hardening.

2. Constitutive law

Fracture is simulated through a hardening-softening constitutive law in tension(in Fig.1) and a softening constitutive law in shear(in Fig.2). For UHPFRC, Young's Modulus is 42GPa, compressive strength150Mpa, yielding tensile strength f_t 8MPa, ultimate tensile strength f_t' 12Mpa, friction angle ϕ and dilatancy angle ψ 37°, hardening opening crack-width λ_{tc}^{h} 0.8mm, ultimate opening crack-width λ_{tc} 1.7mm, and shear opening crack-width λ_{sc} 1mm. If the interface generalized force vector reaches the inelastic failure surface shown in Fig.3, the structure generalized force vector Q must satisfy Eq.1 that is a typical LCP in non-holonomic rate form. *H* is the

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structure hardening/softening matrix, N the structure normality matrix, and λ irreversible deformation vector.

$$0 \geq \dot{\varphi} = N^T \dot{Q} - H\dot{\lambda} \perp \dot{\lambda} \geq 0 \quad (1)$$

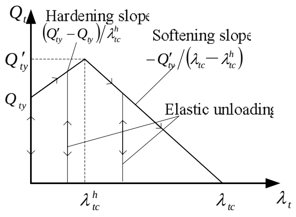

Fig.1Constitutive law for tensile mode

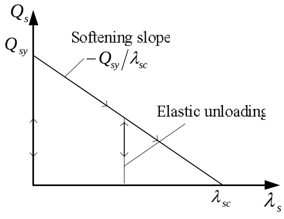

Fig.2 Constitutive law for shear mode

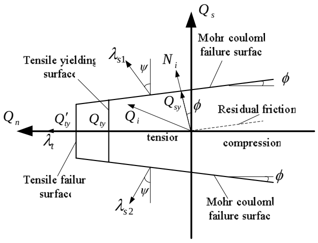

Fig.3 Interface inelastic failure surface

3. Example

This is a three-point bending beam with a span of 7.6m. Fig.4 shows the simplified cross section and the meshing of UHPFRC I-beam. It can be see from the results of simulation(in Fig.5 and Fig.6) that the proposed model is fit for the simulation of quasi-brittle fracture in UHPFRC I-beam.

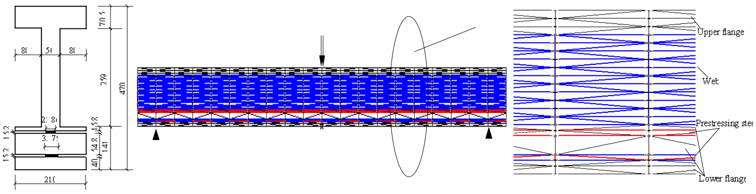

Fig.4 The simplified cross section and the meshing of UHPFRC I-beam

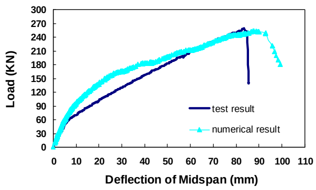

Fig.5The load-deflection curve

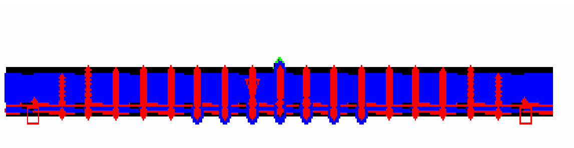

Fig.6 Ultimate state cracking

4. Conclusions

It can be concluded from the numerical simulation:

1) The tensile hardening after cracking must be considered when defining this model
2) LCP is an effective approach to simulation of quasi-brittle fracture in UHPFRC.

Reference

1. Attard M., Tin-Loi F. Numerical simulation of quasi-brittle fracture in concrete. Engineering Fracture Mechanics, 2005; (72):387-411.