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Improved numerical approach for evaluating the behavior of reinforced concrete members with flexural strengthening using strain hardening cementitious composite

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A B S T R A C T

Strain hardening cementitious composite (SHCC) is an attractive construction material used for reinforced concrete (RC) strengthening, and a simplified method has been previously proposed for evaluating the behavior of SHCC flexural strengthening RC member (Zhang, Engineering Fracture Mechanics 2014; 121–122: 11–27), whereas the load carrying capacity of strengthened RC member is over-estimated using the simplified method. In this study, a numerical approach improved from the aforementioned method is presented for accurately evaluating the behavior of SHCC flexural strengthening RC member, considering the influence of the tensile strain capacity of SHCC, presence of localized concrete cracks and varying SHCC layer thickness, in which a zero-span tensile model with fictitious material is adopted to obtain the average tensile behavior of SHCC layer for strengthening RC member with crack. The effectiveness of the improved numerical approach is confirmed thorough the comparison between experimental and numerical investigations.

1. Introduction

Strain hardening cementitious composite (SHCC) has obvious advantages for strengthening reinforced concrete (RC) member [1], since it is an attractive construction material with excellent material property, such as large tensile strain capacity with pseudo strain hardening behavior as well as permeability and compatible thermal expansion [2,3]. However, the multi-cracking behavior of SHCC for RC strengthening is obviously reduced from those of SHCC in uniaxial tensile test, and the corresponding tensile strain capacity is thus decreased [4,5], which is affected by various complex factors such as the presence of crack within RC and the varying SHCC layer thickness [6], whereas the influence of which has not sufficiently understood until now, and the effective analytical approach is thus greatly needed.

In previous study, a simplified method has been previously proposed for evaluating the behavior of SHCC flexural strengthening RC member in [7], whereas the load carrying capacity of strengthened RC member is over-estimated using the simplified method. In order to accurately evaluate the behavior of SHCC flexural strengthening RC member, a numerical approach improved from the aforementioned method is presented in this study, considering the influence of the tensile strain capacity of SHCC, presence of localized concrete cracks and varying SHCC layer thickness, in which a zero-span tensile

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Nomenclature

ε	strain
σ	stress
εA	strain at point A
σA	stress at point A
εB	strain at point B
σB	stress at point B
εC	strain at point C
σC	stress at point C
$\varepsilon_{A'}$	strain at point A′
$\sigma_{A'}$	stress at point A′
$\varepsilon_{B'}$	strain at point B′
$\sigma_{B'}$	stress at point B′
$\varepsilon_{C'}$	strain at point C′
$\sigma_{C'}$	stress at point C′
L_{elm}	element size
L_{eq}	equivalent element length
L_s	crack spacing
l_m	measured length in uniaxial tensile test
G_f	Fracture energy in uniaxial tension
G_{fc}	compressive fracture energy
τ_{max}	bond strength corresponding to bond stress at 0.2 mm slip
τ	bond stress
s	slip
D	diameter of rebar
d	thickness of SHCC layer in zero-span tensile model with fictitious material
L_{loc}	strain distributed area length in zero-span tensile behavior

model with fictitious material is adopted to obtain the average tensile behavior of SHCC layer for strengthening RC member with crack. Moreover, the effectiveness of the improved numerical approach is confirmed thorough the comparison between experimental and numerical investigations.

2. Experimental behavior of RC member with flexural strengthening using SHCC

2.1. Uniaxial tensile behavior of SHCC

Fig. 1 demonstrates the uniaxial tensile stress-strain curves and ultimate crack pattern of dumbbell-shaped SHCC specimens with 100 mm measured length, the mix proportions of which is listed in Table 1. All the specimens exhibit significant strain hardening behavior until ultimate tensile strength (B1 or B2 in Fig. 1), since multiple fine cracks occur and propagate after the initial tensile strength with an initial crack (A in Fig. 1). The specimens are finally failed due to localization of some multiple fine cracks. Moreover, the compressive strength and Young's modulus of SHCC are 72 MPa and 25 GPa respectively, and those values of concrete are 27 MPa and 23.5 GPa. The Young's modulus and yield strength of longitudinal reinforcement are 200 GPa and 345 MPa respectively, and those values of stirrup are 200 GPa and 295 MPa.

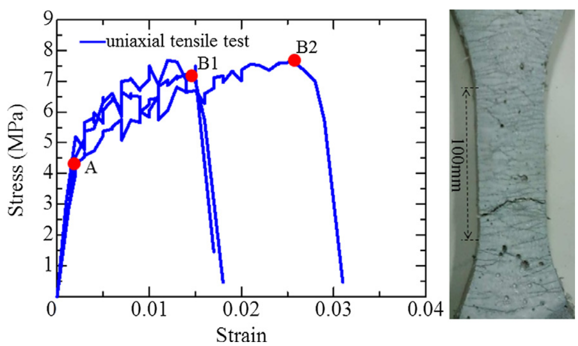

Fig. 1. Result obtained from uniaxial tensile test.