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Effect of fiber volume fraction on crack propagation rate of ultra-high toughness cementitious composites

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ABSTRACT

An investigation on the fatigue crack propagation law and the effect of fiber volume fraction on crack propagation rate of ultra-high toughness cementitious composites is carried out in this paper. Three fiber fractions, 1.5%, 2.0% and 2.5% are adopted. The research result shows that multiple random cracks are generated for the fracture specimens of this material under fatigue load, while the crack number depends on fatigue stress level and fiber fraction. With the increase of fiber volume fraction, the crack growth threshold is improved, while the crack propagation rate is decelerated. Meanwhile, the crack propagation rate is obviously affected by the fatigue loads.

1. Introduction

Ultra-high toughness cementitious composites (UHTCC), with the characteristics of multiple cracking and pseudo strain hardening under uniaxial tension, is a kind of fiber reinforced cementitious material [1]. Polyvinyl alcohol (PVA) fiber is usually used to produce UHTCC. As a ductile material, UHTCC exhibits ductile fracture [2]. The fracture energy of this material has been researched before [3–5]. The results show that the total composite fracture energy is composed of an off-crack-plane matrix-cracking component and an on-crack-plane fiber-bridging component. Recently, a double *J*-integral model, used to calculate the fracture toughness of this material, is introduced by the authors [6]. Then, on the basis of this fracture model, A fatigue crack propagation law similar to Paris law of this material is built, with the two parameters as *J* integral and crack covering area [7]. Furthermore, investigations on the fatigue damage property and the fatigue process of UHTCC-concrete composite beam have been carried out on basis of these researches on fracture property [8,9].

This paper presents a fracture fatigue research on UHTCC with different fiber volume fraction, for the purpose to study the effect of fiber fraction on the fatigue crack propagation rate with the crack propagation law.

2. Experiment study

2.1. Experiment preparation

Three-point flexural test were adopted. UHTCC specimens were cast with cementitious binders, fine sand, water, super plasticizer and PVA fiber. The superplasticizer was polycarboxylate type. The proportion of the matrix is: cementitious

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Nomenclature

A crack covering area
A_1, A_2 initiate and final crack covering areas of stage II
C Paris constant
J_{max}, J_{min} maximum and minimum values of J-integral in a fatigue cycle
m exponent of the fatigue crack propagation equation of UHTCC
N number of load cycles
N_F full fatigue life
ΔN_{II} fatigue life of stage II
P applied load
P_a amplitude of fatigue loads
P_m mean value of fatigue loads
P_{max} maximum value of fatigue loads
P_{min} minimum value of fatigue loads
S_{max} maximum fatigue stress level
ΔA increment of crack covering area in fatigue stage II
ΔJ amplitude of J-integral value
ΔJth critical J-integral amplitude of crack propagation threshold

Abbreviations
CMOD crack mouth opening displacement
CTOD crack tip opening displacement
PVA polyvinyl alcohol
UHTCC ultra-high toughness cementitious composites

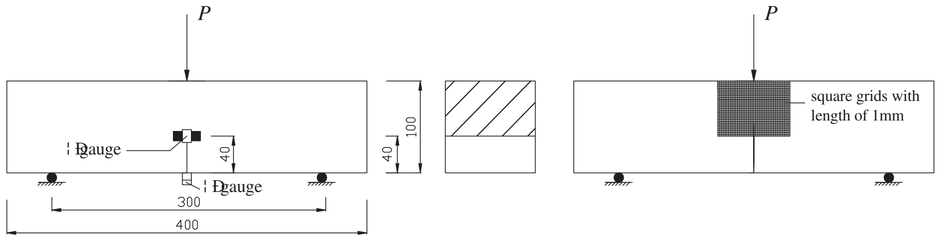

Fig. 1. Test setup and measuring method/mm.

Table 1
Fatigue loads and corresponding stress levels.

Fiber fraction V_f (%)	Ultimate static load P_u (kN)	Specimen No.	Mean load, P_m (kN)	Amplitude, P_a (kN)	Maximum load, P_{max} (kN)	Minimum load, P_{min} (kN)	Maximum stress level, S_{max}
1.5	7.51	F1.5-1	4	2.5	6.5	1.5	0.865
		F1.5-2	3.5	2.5	6	1	0.799
		F1.5-3	3.25	2.25	5.5	1	0.732
		F1.5-4	3.5	2	5.5	1.5	0.732
		F1.5-5	3	2.5	5	1	0.666
2.0	8.42	F2.0-1	4.5	3	7.5	1.5	0.890
		F2.0-2	4	3	7	1	0.831
		F2.0-3	4	2.5	6.5	1.5	0.771
		F2.0-4	3.5	2.5	6	1	0.712
		F2.0-5	3.75	2.25	6	1.5	0.712
		F2.0-6	3.5	2	5.5	1.5	0.653
2.5	10.60	F2.5-1	5	4	9	1	0.849
		F2.5-2	5	3.5	8.5	1.5	0.802
		F2.5-3	5	3	8	2	0.755
		F2.5-4	4.5	3	7.5	1.5	0.707
		F2.5-5	4	3	7	1	0.660