Estimation of Flexural Post Cracking Behavior of SFRC Beams using X-ray Photograms

Waseda University, JSCE Student Member, ○Sopokhem Lim
Waseda University, JSCE Student Member, Takehiro Okamoto
Waseda University, JSCE Member, Mitsuyoshi Akiyama

1. INTRODUCTION

Steel fiber reinforced concrete (SFRC) is a material that is characterized by an enhanced post-cracking residual tensile strength due to crack-bridging stresses of fiber reinforcement. Many parameters affect fiber dispersion and orientation inside individual structures, and causes different post-cracking behaviors, even if structures include the same amount of steel fibers (di Prisco, 2013). As a result, prediction models of post-cracking behavior of SFRC beams without considering variation of fiber dispersion and orientation often could overestimate or underestimate their responses (DE Montaignac et al., 2012). The main objective of this study is to establish a reliable method for predicting the post-cracking behavior of SFRC beams by using X-ray images. The parameters relating to post-cracking strength are derived from the representative number of fibers, using fiber distributing properties at the critical location measured on several X-ray images of individual specimen.

2. FLOWCHART FOR ESTIMATING THE POST-CRACKING BEHAVIOR OF SFRC BEAMS

Figure 1 shows a flowchart for estimating the post-cracking behavior of SFRC beams based on X-ray image. Different distribution properties of each fiber (orientation α, embedded length Le, and location Lo) at an assumed crack plane straight from the top of a notch are measured on several X-ray images of each beam. The total number of fibers was then converted to representative number of fibers, RNF, by assigning assumed scores to individual fibers considering the pull-out strength performance that was provided by the distribution properties of each fiber. From the experimental *P*-CMOD curves, two designed strength parameters f_{R1} and f_{R3} that correspond to the loads F_1 and F_3 are determined according to *fib* model code 2010. The relationship between design strength parameters and RNF is established by a linear regression. From this relationship, f_{R1} and f_{R3} can be derived using the distribution properties of fibers measured on the X-ray images of the beam as an input. In this study, a bilinear stress-crack width σ-*w* under uniaxial tension that is used to characterize the SFRC can be identified using f_{R1}, f_{R3}, and the tensile strength f_t that are obtained from the compressive strength test. Finally, a cross-section analysis based on non-linear hinge model in Olesen (2001) is used to predict the *P*-δ responses. The validity of predicted *P*-δ responses is demonstrated by comparing with the experimental results.

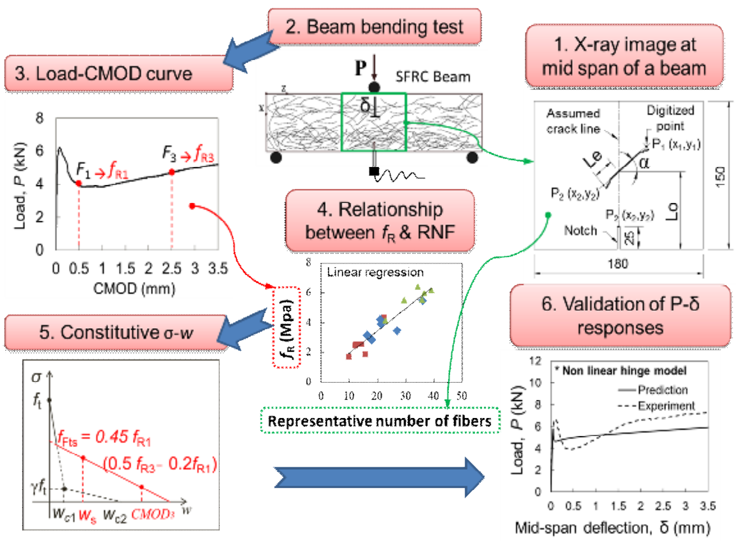

Fig. 1 Flowchart for estimating the post-cracking behavior of SFRC beams

3. EXPERIMENTAL PROGRAM

To achieve the above purpose, three series of specimens are fabricated. Each series contain 6 notched beams and 6 cylinders (200 mm × 100 mm). Beam series F025, F0375, and F05 contain different fiber contents of 20 kg/m^3, 30 kg/m^3, and 40 kg/m^3, respectively (see Table.1). The steel fiber used in this experiment has a length of 60 mm and diameter of 0.9 mm. Before the beam bending test, the X-ray radiography is used to visualize and capture the steel fiber dispersion in the middle part of beams. The details of beam bending test configuration are shown in Fig.2.

Table.1 Details of specimens

Specimen notation	#	Dimension	Fiber content	Fiber shape
		mm	Kg/m^3	
F025	6	550 × 150 ×75	20	
F0375	6	550 × 150 ×75	30	
F05	6	550 × 150 ×75	40	

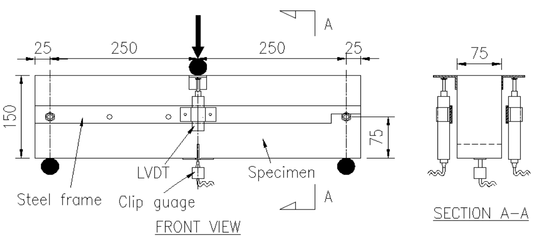

Fig. 2 Details of beam bending test setup

Keywords: SFRC, X-ray, Post-cracking behavior, Steel fiber distribution
Contact address: Bldg. 51-16-09, Oukubo 3-4-1, Shinjuku-ku, Tokyo 169-8555, Japan, Tel: +81-3-5286-2694

4. EXPERIMENTAL RESULTS AND DISCUSSSION

Figure 3 shows that the beams in series F025 has a large scatter of residual loads in the post-peak region with coefficients of variant (COV) varied from approximately 40% to 55% despite of having the same fiber content (20 kg/m^3). This depends on the variability of non-uniform distribution of steel fibers shown in Fig. 4. For instance, Fig. 4 (e) shows that the specimen 5F025 has the largest number of fibers at the notch location, and thus it exhibits highest performance of residual loads comparing to the others (see Fig. 3). On the other hands, Figs. 4 (c) and 4 (d) indicate that both of the specimens 3F025 and 4F025 have the lowest number of fibers at the notch location. As a result, their residual load performances are lowest comparing to other specimens as shown in Fig. 3. The fiber distribution at a critical section has a significant effect on the post-cracking residual loads of SFRC beams.

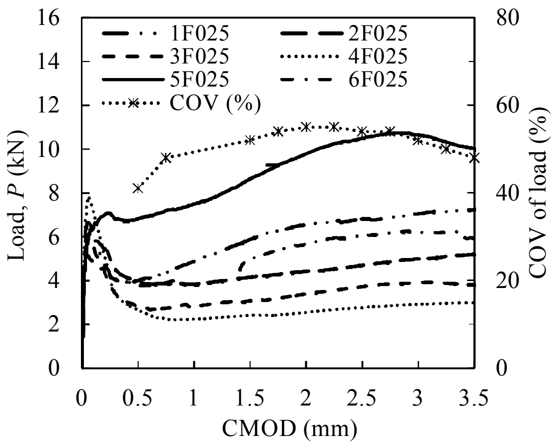

Fig. 3 P-CMOD curves of beam series F025

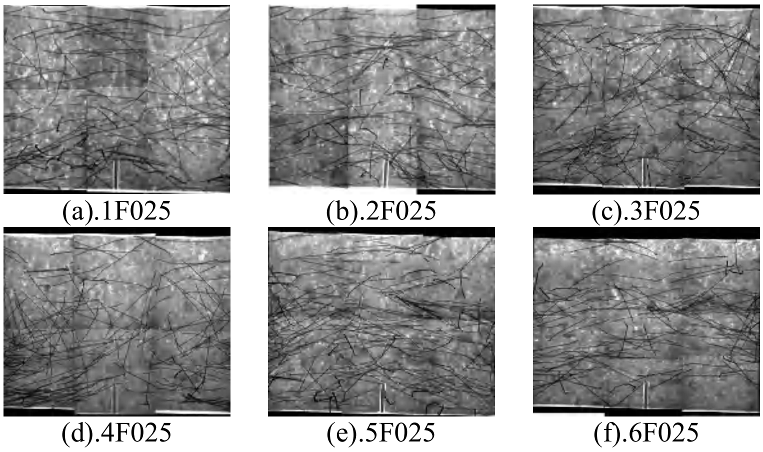

Fig. 4 (a) to (f) X-ray images of beam series F025

5. VALIDATION OF PROPOSED METHOD

The validation of proposed method is demonstrated by comparing the computational P-δ responses with the experimental ones (see Fig. 5). The estimated results are in good agreement with the experimental ones for specimens with different fiber contents as shown in Figs. 5 (a), (b), and (c); however, there are a few discrepancies, often overestimation such as the specimen 4F025 as shown in Fig. 5 (d). This points out that the estimation method still need to be improved.

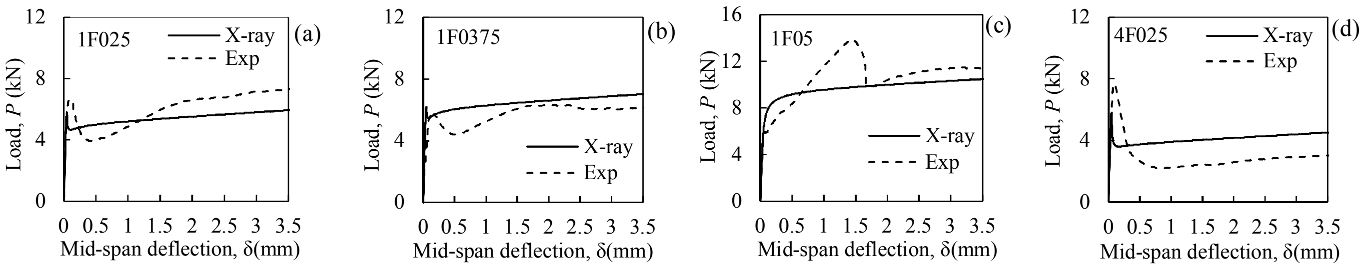

Fig. 5. Predicted versus experimental P-δ responses

6. CONCLUSIONS

A procedure for predicting post-cracking behavior of SFRC beams by using X-ray images has been established, and its validation is also verified. From the experimental results, a large variation of post-cracking behaviors of SFRC beams was found to be significantly affected by a large variability of fiber distribution at the critical planes. In the predicted method, the variability of fiber dispersion in each specimen was taken into account by using RNF that is obtained from the fiber distribution properties measured on X-ray images. Although the predicted results were in good agreement with experimental ones, there are a few overestimated cases. The proposed method still needs to be improved.

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