論 文 の 内 容 の 要 旨

論文題目　Mechanics of High Performance Fiber Reinforced Cementitious Composite (HPFRCC) under Principal Stress Rotation
（主応力軸回転下における複数微細ひび割れ型繊維補強セメント複合材料（HPFRCC）の力学特性）

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In the past two decades, considerable work has been made relating to the development of high performance fiber-reinforced cement-based composite (HPFRCC), a cement based material that is more ductile than concrete. One of the breakthroughs is Engineered Cementitious Composite (ECC). One major difference of ECC compared to conventional concrete is on its ductile tensile behavior and its self-generated multiple cracking characteristic in tension. Unlike concrete, current ECC typically excludes the use of coarse aggregate.

To utilize HPFRCC, or specifically ECC, in broader applications likewise concrete, the presents study first focuses on investigating the mechanics of ECC after cracking. Particular attention is paid on post-cracking stress-strain mechanisms under general loading conditions, including average stress-strain parallel and normal to cracking as well as interface shear transfer. The former behaviors have been extensively investigated, while the later has been overlooked thus far. For this reason, this study aims at revealing average interface stress-strain transfer of ECC. Although the material shows a remarkable tensile performance, it is of concern here that it may be prone in shear owing to the absence of aggregate interlocking. In an effort to gain insights on this concern, an experimental program was conducted and a new testing technique was implemented.

The experimental investigation shows that when pre-cracked ECC is subjected to principal stress rotation, its crack interface does not provide a sufficient interface shear transfer, thus resulting in a somewhat orthogonal cracking pattern. More importantly, degradation in flexural strength was evident once the applied shear at crack interface is substantial. A weakening effect to the tensile stress-strain carrying mechanism due to closely-spaced transverse cracking was also observed. In short, it is important to properly identify the orientation of the pre-exiting crack in ECC.

To provide a rational basis on the experimental result, finite element analyses were conducted. The analytical framework is based on smeared fixed crack modeling which has been proven to be an efficient means of predicting nonlinear mechanics of reinforced concrete under general and

non-proportional loading conditions. For the purpose of the analyses, stress-strain relation of cracked ECC was implemented based on current cracked concrete models, previous experimental results of ECC, and parametric analyses. The models were then used to predict the behavior of pre-cracked ECC plates tested earlier in this study. Good agreement was obtained in terms of macroscopic response and plate deformation. The analysis results reveal that the behavior of cracked ECC differs substantially from un-cracked ECC, although crack in ECC is relatively small and bridged by fibers. This is very consistent with the aforementioned experimental finding.

Furthermore, the proposed “un-reinforced” ECC models were further extended to predict the behavior of reinforced ECC (R/ECC) panels subjected to uniform shear stress. A good correlation was observed. Nevertheless, for the accurate prediction of peak strength and deformation of the panels, accurate information of tensile strength and ductility of the ECC is essential. Due to limited data available, this information still cannot be obtained. Meanwhile, once the tensile strength and tensile ductility were properly set, the analysis indicates a unique shear model of ECC. This verification is very important to conceive that cracked ECC can be reasonably modeled based on fixed crack approach, with a separated material models (compression, tension, and shear models).

To further verify the applicability of the computational framework, the proposed models were later used to predict the response shear-critical R/ECC beams subjected to cyclic loading conditions. A good correlation was again observed, provided that tensile stress-strain obtained from material tests has to be decreased to account shrinkage effects and several other influencing factors. This is very reasonable as the cross-sectional of the test beams is relatively small. Parametric analyses were further carried out to provide a link between structural performance and material property. The developed computational framework can be a viable tool to further explore potential use of ECC.

Apart from this work, further experimental investigation was carried out as an endeavor to improve interface shear transfer of ECC. Different amount and size of aggregates were introduced into a given ECC mixture. The results reveal that it is possible to enhance interface shear transfer, while still maintaining high tensile ductility. Stable macroscopic performance and secondary cracking were evident due to good collaboration between the aggregates and the fibers in transmitting tensile and shear stresses across cracking. Apart from improving of shear interface, it was found that adding coarse aggregate may also result in higher probability of cracking, if the composite is preloaded.

Finally, a preliminary study on average stress-strain transfer on an ultra high performance fiber reinforced concrete (UHPFRC) was carried out. The same testing method was also employed. The test results showed a comparatively higher interface shear transfer. Yet, degradation in strength was also observed. Further investigation showed that rather than due to interface shear transfer, this occurs due to the non-uniformity fiber orientation. It is thus necessary to pay attention on the distribution and the actual fiber orientation.