# Study on Toughness of Strain Hardening Cementitious Composites (SHCC)

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Abstract: Lower tensile strength and worse toughness of cementitious composites are the dominant reason of incidental cracks and deterioration of durability for reinforced concrete (RC) structures. The experimental results indicate that high elastic modules Polyvinyl Alcohol (PVA) Fiber can enhance the ductility of the cementitious composites and present strain hardening and multiple cracks. Consequently durability of RC structure can be improved. Force-deflection curves of PVA-SHCC with different mix proportions and loading velocity were achieved by four-point bending tests. Fracture energy was calculated by CONSOFT software as well. The results show that silica fume increases the compressive strength, while the maximum flexural load capacity, deflection and fracture energy decrease. High performance of methyl cellulose improves the brittleness of PVA-SHCC. When the loading velocity is reduced, numbers of multiple cracks manifold and strain hardening behavior manifest markedly. The maximum sand diameter of SHCC is larger than that of Engineered Cementitious Composites (ECC). Although the ultimate tensile strain is lower than that of the latter, its suitable for application. Study on toughness of SHCC is one applied method, which can optimize SHCC durability oriented.

Key words: ECC; fracture energy; PVA Fiber; strain hardening cementitious composites (SHCC); toughness
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The brittleness of cementitious composites cause cracks easily in RC structures. Consequently stiffness of members is reduced and corrosion contaminant will have an access to the structure. The RC structures are deteriorated and service time is shortened simultaneously. Applying fiber to reduce the brittleness of inorganic-bonded composites has existed for thousands years. High modulus PVA fiber has the advantage such as innocuous, hydrophilic, alkali-resistant, acid-proof, daylight age resistant etc. Performance, mechanisms and applications of ECC have been investigated[1-2]. Only the strength is far from comprehensive evaluation of SHCC in terms of durability, and also it is necessary to find a convenient method and clear assessment standard to optimize SHCC design. Based on the Force-Deflection curve acquired by 4-point bending test in this contribution, fracture energy was obtained and used to evaluate the performance of SHCC.

## 1 Experiments

Size of the specimen is $40\times40\times160$ mm and the clip gauge was fixed on both sides of it. Test data are real-time collected by the computer. P. O. 52.5 cement, REC15 PVA fiber, Methyl cellulose (MC) and super-plasticizer were used. Volume fraction of fiber is 2%.

Tab. 1 Mix Proportions of SHCC kg/m³

| | C | W | S | FA | SF | SP | MC |
|---|---|---|---|---|---|---|---|
| F0P* | 637 | 456 | 510 | 773 | -- | 3.4% | -- |
| F1P* | 637 | 456 | 510 | 773 | -- | 4.0% | 0.5% |
| FS1* | 637 | 494 | 510 | 773 | -- | 3.5% | -- |
| FS2* | 637 | 494 | 510 | 773 | 35 | 3.5% | -- |
| FS3* | 637 | 494 | 510 | 773 | 35 | 4.0% | 0.2% |

## 2 Results and Discussions

The results indicate that applying MC made the fracture energy of SHCC decrease notably and the maximum load reduced accordingly. When loading speed dropped from 0.20 to 0.05 mm/min, SHCC presents better performance of strain hardening along with increase of the numbers of multiple cracks and the corresponding deflection of the maximum load increases markedly. Silica fume made compressive strength increase and brittleness becomes distinct, while fracture energy, peak value of load and corresponding deflection decreased simultaneously. The results calculated by CONSOFT in Fig. 1 show that strain hardening parame-

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ters and fracture energy will be good evaluation index for optimized the SHCC materials durability oriented.

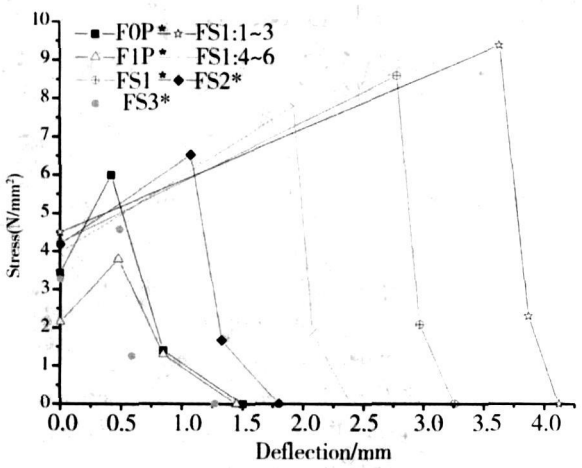


Fig. 1 Simplified curve by strain hardening parameters of SHCC SHCC

## 3 Conclusion

PVA-SHCC can improve the brittleness and durability of cementitious composites. The ductility of SHCC meets the requirements of engineering. Also, Studies on fracture energy and strain hardening parameters indicates the quantity index by optimizing the SHCC.

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# 应变硬化水泥基复合材料 -SHCC韧性性能试验研究

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摘 要：水泥基材料抗拉强度低、韧性差是其易开裂的主要原因之一。高模量 PVA纤维可增强基材韧性，使其呈现准应变硬化和多缝开裂特征，改善结构耐久性。通过四点弯曲试验得出了不同加载速率和配比 SHCC的力－变形曲线并用 CONSOFT软件计算断裂能。结果表明，硅灰使材料抗压强度有所提高，但最大抗弯承载力和变形下降，断裂能降低。甲基纤维素使 SHCC脆性增大。加载速率降低，材料表现出更好的应变硬化性能，微裂缝条数增多。 SHCC砂子最大粒径高于 ECC，虽达不到后者的最大拉应变，但可降低成本并满足工程需要。韧性性能研究给出了基于耐久性能优化设计和评定 SHCC的实用方法。

关键词：ECC；断裂能；聚乙烯醇纤维 （PVA）；应变硬化水泥基复合材料 （SHCC）；韧性

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