Analysis of the cyclic behaviour of steel fibre reinforced concrete – Summary

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Steel fibre reinforced concrete (SFRC) is known for its enhanced post-cracking tensile strength, reduced crack width and improved ductility in comparison to regular concrete, because the fibres bridge cracks and dissipate energy. However, its applications in the construction sector are limited because only few design codes are established concerning SFRC since its introduction in civil engineering in the 1960s. To widen the potentials of SFRC, more research is necessary. Previous researchers have demonstrated that the improved post-cracking behaviour also enhances the cyclic behaviour of SFRC, which became the key topic of this study. A method is presented to obtain the cyclic constitutive laws of SFRC through sectional analysis, using a limited amount of input parameters. Hence, the main question of this thesis is: "How does steel fibre reinforced concrete behave under cyclic loading?".

Tensile tests and flexural tests are both monotonically and cyclically performed on concrete with different fibre types and fibre volumes in order to quantify the properties of four SFRC compositions. The test setups are equipped with acoustic emission sensors to monitor the crack development inside the specimens. With this non-destructive technique, more knowledge about the amount of damage, damage process and location of cracks is obtained, before cracks are even visible at the surface of the concrete.

The results of the monotonic bending tests are first used to establish a monotonic model and predict the uniaxial stress-crack width curves or constitutive laws of SFRC. Although the constitutive laws can be derived directly from tensile tests, this inversed method is cost and time efficient since the execution of tensile tests is challenging. The monotonic model is based on sectional analysis, which divides the cracked section into several layers for which a uniform stress is assumed. Imposing a force and momentum equilibrium at different stages of the bending test then results in deformation and stress profiles throughout the test. The constitutive law that fulfils the beam's equilibriums with the smallest error, is chosen as the optimal solution of the monotonic model. These modelled constitutive laws are compared with the experimental tensile tests and show good agreements.

The constitutive laws are further used to find the cyclic behaviour of SFRC. Because of the repeated loading, the tensile stresses depend on the constitutive law and the damage introduced into the specimen during the previous load steps, which reduces the stresses. This damage is determined by the crack width and their relation appears to be independent of the fibre type and volume. Therefore, the cyclic behaviour can be deduced from only performing monotonic bending tests to find the constitutive law, and the equation that determines the damage based on the crack width. The model shows promising results, validated by experimental cyclic bending tests. Finally, an extension has been made from cyclic to fatigue loading, which shows good agreements with S-N or Wöhler curves found in literature, indicating the real potential of the model.

Although previous researchers have already found suitable methods to model cyclic constitutive laws, they do not apply sectional analysis. With this technique, a better understanding of the cracked section can be reached because a detailed evolution of the deformation and stress profile is obtained. Additionally, the (cyclic) constitutive behaviour can be derived from the less complicated monotonic flexural tests and there is no need for direct tensile tests.