Behaviour of concrete elements subjected to cyclic bending

Description
This thesis is dedicated to the investigation of the behaviour of concrete beams subjected to cyclic loading. In addition to standard data acquisition tools such as DIC and CATMAN, a new measuring system is used in this project. Optical fibers from LUNA FIBER OPTICS are glued onto the longitudinal reinforcement bars to measure a complete strain profile along the entire length of the sample. The focus of the analysis was twofold. First, the feasibility of the fiber optics is investigated and secondly, the difference between shear and flexion cracks is examined as well.

Experimental campaign
To gather enough data, three beam samples are produced. The main characteristics are listed below. For each sample, the front side is filmed with DIC cameras allowing the direct analysis of crack openings. At the same time, CATMAN is used to gather information on the vertical displacement using five different LVDT’s which are placed alongside the sample length. Finally, optical fibers are glued directly onto the surface of the rebars to measure the longitudinal strain. By measuring the top as well as the bottom side of the bars, it is possible to create localised strain profiles at every point of the sample.

Results
The three samples are tested at three different load levels (Level 1: 24 kN, Level 2: 50 kN, Level 3: 80 kN) to investigate the behaviour during each of the critical phases - crack development phase, crack opening phase as well as creation of the Critical Shear Crack (CSC). All of the samples failed in shear. However samples 1 and 2 failed during the static loading which was performed after at least 50 cycles had been completed successfully. The failure load was 92 and 94 kN respectively. The last sample failed during the 22nd cycle at a load of 78 kN.

Analysis
For further analysis of the data, it is critical to know the exact location of the cracks. As the cracks were traced both on the front as well as the back surface of the sample (see figure 2), their intersection with the rebar is known for both sides. However, the cracks can cross the sample at an oblique angle and the crack position on the surface does not correspond with the crack position at the rebar. Figure 3 shows the process used to determine the exact crack location - Comparing the crack pattern (Figure 3, top) with the DIC images (Figure 3, centre) as well as the fiber strain of the top and bottom of the rebar (Figure 3, bottom).

Strain development
For selected cracks, detail analysis of the crack development as well as the strain development are performed. In the case of the sample tested at 80 kN, figure 5 shows clearly the difference between the critical shear crack (on the left) and one where the strain remains constant during the cycles (on the right).

Vertical profiles
By combining the measurements from all three data acquisition tools, specific flexion cracks are selected for which the data is the most suitable and vertical profiles are created (see figure 6) showing the development of strain (green), stresses (red and yellow) as the well as crack opening (blue) during one chosen unloading cycle. The results obtained show good agreement with existing models.