Bond anchorage of prestressing steels and shear load capacity of precast pretensioned segments made of self-consolidating concrete

The application of self-consolidating concrete (SCC) for precast pretensioned segments means an advancement in concrete constructions regarding economical, engineering and aesthetic aspects. Due to its higher powder content and its viscosity, the microstructure and the mechanical behaviour of SCC differ from conventional concrete. Thus, it had to be clarified whether the regulations for bond strength and shear design can be adopted from conventional concrete. Besides theoretical investigations, 144 pullout tests and 5 tests on the transfer of prestressing forces were carried out. Furthermore, beams were subjected to bending in order to investigate the bond anchorage and beams under shear load were tested as well. Three SCC types (powder-type with fly ash, powder-type with limestone, combined type containing fly ash and a viscosity-modifying admixture) and two prestressing steels (strands, ribbed bars) were investigated.

The present investigations revealed, that the bond of SCC generally corresponds to the bond in conventional concrete, whereas the bond strength of SCC depended on the mix design. Here, the bond strength of the mixture using limestone was better than the one containing fly ash. Depending on the mix design, the existing code regulations regarding the transfer length can be adopted for SCC although they were derived for normal and high strength concrete.

For the beams subjected to bending the required minimum dimensions (concrete cover, strand clearance) were obtained from the own tests on the transfer length of prestressing forces. However, this did not prevent uncontrolled splitting cracks from occuring within the transmission zone due to the prestressing forces in any case. Sufficient lateral reinforcement prohibited the cracks from propagating toward the surface and improved the bond strength considerably. The additional bending induced forces in the prestressing steel caused an abrupt anchorage failure with spalling of the surrounding concrete for ribbed steel. Using strands, their increased slip led to failure.

Due to the higher tensile strength of SCC compared to conventional concrete, the shear cracking and the transfer of the tensile forces to the stirrups occur more sudden. The cracks mostly inclined straightforward. Despite gaping cracks after crack initiation, the shear load was able to be increased until a secondary failure of the compressive flange took place. The shear load transfer to the bearings can be described by a strut and tie model and an additional component. The latter consists of the contribution of the compressive zone and is enforced by an arch action, whereas a higher level of lateral reinforcement reduces the additional component. According to the present investigations, the existing shear design concept of the German Building Code DIN 1045-1 yields conservative results for beams made of SCC providing little lateral reinforcement. This behaviour corresponds to conventional concrete. For pretensioned beams made of SCC with a high level of lateral reinforcement, the code provisions may be on the unsafe side.