Probabilistic design of composite girders - Transferability of brittle and ductile Daniels systems to the composite joint

When designing a composite beam, the failure of the highest loaded dowel is currently taken into account as the failure criterion of the composite means. The failure of the girder is therefore triggered by the failure of only one dowel. Possible force redistribution is not considered. Thus, hidden safeties are present in the current design and lead to a more conservative design than it would be necessary from a probabilistic point of view.
A system in which force redistributions is included is the so-called Daniels-system. This probabilistic model, originally developed for determining the load-bearing capacity of thread bundles, can be applied to other areas, i.e. for steel cables. The more individual wires are used for a cable, the more accurately the maximum load or the probability of failure can be predicted. The safety of a Daniels-system also increases with the number of individual wires.

In this master's thesis, various theoretical models for the load-bearing capacity and safety of systems consisting of several components were considered. Results are verified by numerical analysis. Subsequently these models and various modifications were applied to the composite joint.
First an ideal-brittle force-slip behaviour, i.e. a brittle failure of the composite dowels, was assumed. This was applied to single and multiple dowel systems assuming different models, such as the series system or the Daniels-system. In addition to a uniformly distributed load, the concept of hypercubes considers a possible uneven load distribution with different failure sequences.
Second a ductile material behaviour of the composite dowels was assumed. Ideal systems with and without correlation of resistances were considered. The analysis of the plastic moment capacity of a composite beam in the form of a limit state equation led to an ideal-plastic system. With an increasing number of dowels, an increasing safety factor could be observed for all systems.

Instead of an increasing global safety factor and a constant partial safety factor, the partial safety factor can be decreased while the global safety factor is held constant. A new partial safety factor was determined as a function of the number of composite dowels for systems with ductile material behaviour. This factor was below 1.0 for all the usual safety indices required by the Eurocode, even for a small number of dowels.
Brittle and plastic systems incorporate an ideal redistribution of the load. This does not correspond to the actual redistribution in the bonded joint and the safety is overestimated in these models. However, if no load redistribution is applied, the safety index remains constant. Compared to the current design, a load redistribution results in an increase of the safety index.
The current partial safety factor $\gamma = 1.25$ therefore could be reduced.

The actual redistribution is considered in the hypercube model. Due to limited computing capacities, the calculations using this concept can only be applied up to a number of composite dowels of $n = 5$, maximum $n = 6$. The hypercube model probably describes the actual course of the safety index best. In order to implement the calculations on composite beams despite the limitation to n=6, grouping the composite means of a beam could be considered as a further step.
The concept further offers potential for transfer to other disciplines of civil engineering. For example, it could be applied to laminated glass or glulam. For laminated glass with up to six panes, the failure of individual panes and its influence on the load-bearing capacity and safety could be considered from a probabilistic point of view. Analogously, this could be done for glulam with up to six lamellas.