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THE SAW-TOOTH CONNECTOR: AN EFFECTIVE JOINT-ELEMENT FOR SLENDER CONCRETE DECKS

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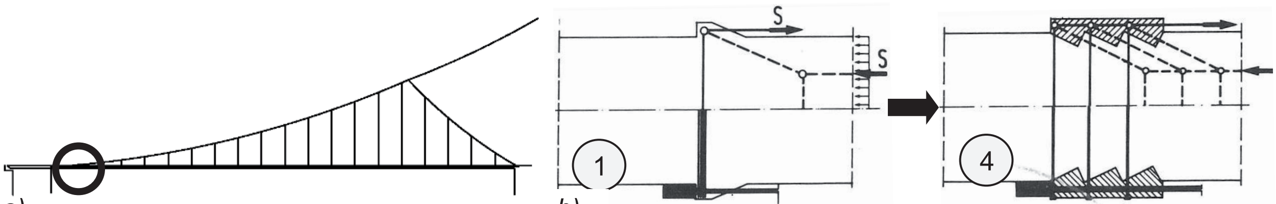
The saw-tooth connector is a devise for very high load transfer between steel and concrete that has its origin in footbridges. This paper relives the emergence and the current research on a connection detail that embodies a promising alternative especially for hybrid and composite footbridges. In the late 1980's and early 1990's the question was raised on how to realize self-anchored suspension footbridges. In that case, the main cables might need to be supported on the slender concrete deck of such a footbridge. A study based on strut-and-tie models led to an embedded steel plate with a toothed surface that pointed inside the concrete, the saw-tooth connector. First footbridges were built in the Stuttgart area. A primary attempt to design the connector was the plasticity theory, which claimed an evenly distributed flow of forces along the connector. A second and much more fitting approach was the elasticity theory, that indicated an uneven flow of forces. In relation to the strut-and-tie model, the connector then needed to support compression struts under verifying angles. A specific geometry was suggested for the toothed outline of the steel connector based on the elasticity theory. A first experimental study improved and verified the geometry. Four types of slender concrete slabs with integrated connectors are determined to experimentally investigate the load-bearing behavior. The specimens represent basic build-in situations that are likely to occur on footbridges. The measurements and results endorse the elasticity theory.

Keywords: composite structures; concrete; steel; shear connector; joint elements; slender slabs; testing

1. The development of the saw-tooth connector from the first idea to the current research

What led to the composite element called the saw-tooth connector? Costs, carbon dioxide balances and improvement of design are getting higher priorities as public awareness increases constantly. As a logical consequence, mixed material structures become more and more the focus of attention. The purpose of such composite structures is the efficient use of material. In order to properly address the specifics of each material, it is necessary to find an effective technology to combine these various materials. It is well known that the low traffic loads of footbridges allow designers to use materials to their greater extent. In this particular case, self-anchored suspension footbridges with concrete decks started a process of thinking which eventually resulted into the saw-tooth connector.

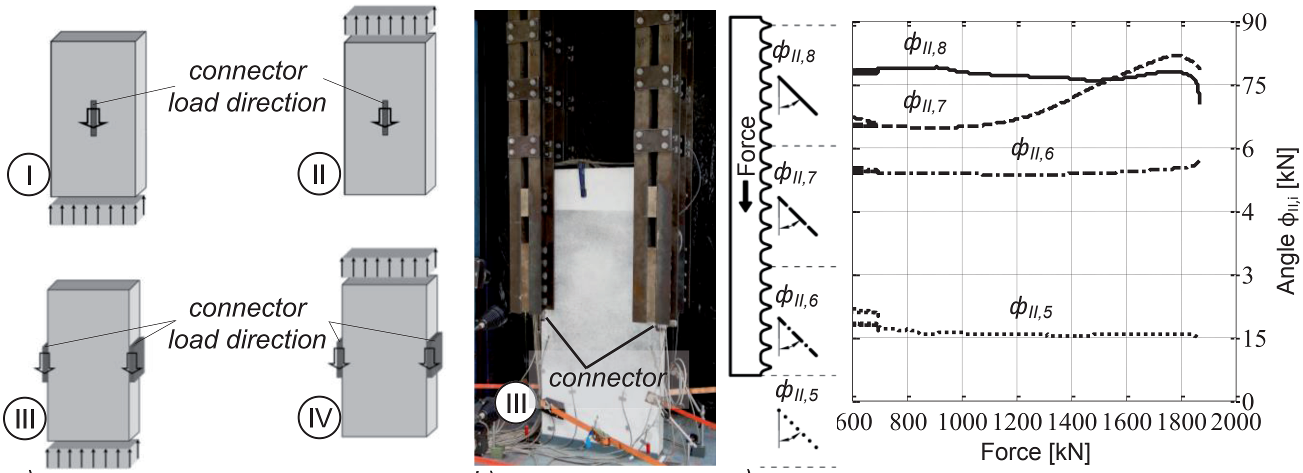
To build a self-anchored suspension bridge is a great challenge due to various reasons. To anchor main cables on a very slender concrete deck, as only a footbridge would allow, creates a keen situation. Therefore, a new interface was to be found between the steel cable and the concrete deck (Fig. 1a). The well-established sheer struts did not qualify for a concentrate load-transfer within such a limited concrete area. Fig. 1b ① shows the starting point of a determining train of thought. An obvious solution is the usage of a bracket to hold the cable. However, the rather small bracket does not provide enough room for anchoring length of the transversal reinforcement. An embedded steel plate provides support for the cable and the transversal reinforcement. Fig. 1b ④ displays a solution for an effective steel plate after a few sub-steps of shaping and comparing strut-and-tie models. Beveled surfaces along the steel plate encourage the nature of the flow of forces and favor a simple strut-and-tie model. Reducing the beveled parts to a more usable size will end up in the characteristically toothed surface.



a) b)

Fig. 1 a) Suspension bridge with the anchorage of the main steel cable on the deck b) ①→④train of thought behind the saw-tooth connector [1]

At first, the plasticity theory disrobed the bearing behavior, that supposed the compression struts to align under the constant angle Φ along the connectors flank. Later the elasticity theory was suggested, which takes account of the stiffness of the connector and the concrete slab as well as the main stress state of the concrete slab. An evaluation of a preliminary linear-elastic finite element model reveals a more realistic distribution of the compression struts in differing angles along the connectors flank. A geometry was found to support the verifying angles without reducing the compressive strength of the struts [2]. Tests confirmed the specific geometry [3]. Four basic testing arrangements of slender slabs with embedded saw-tooth connectors represent possible build-in situation on footbridges Fig. 2a. One, the connector can be located in the middle or on the edge of a slender deck. Second, the main longitudinal force inside the deck can be tension or compression. Test III (Fig. 2b) represents the initial situation in Fig. 1. The measurements on the specimens confirm the elasticity theory with verifying struts (Fig. 2c). The comparison of the tests shows that the loading of the slab has a strong impact on the load capacity. The authors are working on the fundamentals to establish the saw-tooth connector as a countable alternative for the future of footbridge design. The current research investigates the fatigue behavior of the saw-tooth connector, which is expected to be promising.



a) b) c)

Fig. 2 a) Four different types of specimens b) compression test with the connector on the edge of the slab c) angles of struts (Strain Gauges)

2. References

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