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Fatigue of flange thickness transitions in welded girders with web cutout (FATTGirder) | AiF No.: 21739N

Summary of the research project AiF No.: 21739N

Flange thickness transitions are an essential and frequently used design detail for structures in order to effectively adapt the cross-sections of crane runway or bridge girders to changing bending moment curves. In the case of long-span girders, flange thickness transitions are often implemented in conjunction with a joint weld and an additional web opening in the area of the flange butt welds. Although the combination of flange thickness transition with web cutout is an efficient and popular design detail in engineering practice, its fatigue strength is neither covered in Eurocode 3 nor are there any findings on fatigue behavior in the literature.

Since, in the area of flange thickness transitions with web cutouts, the stress and strain states do not solely result from the global load-bearing behavior, but the change in stiffness ratios within the girder cross-section causes additional local stress and strain states, the load-bearing and fatigue behavior cannot be accurately captured using classical girder theory. As part of the present research project, the operational fatigue strength of thickness transitions with thick plates and flange thickness transitions with web cutouts was analyzed using experimental investigations and combined analytical-numerical simulations.

To determine the load-bearing and fatigue behavior, both notch detail tests on thickness transitions in plates and large-scale fatigue strength tests on girders with flange thickness transitions and web cutouts were carried out. The component tests enabled the identification of the geometry- and stress-dependent key failure points of the structural detail, i.e. web plate at the web cutout, flange plate at the web cutout and transverse butt weld in the flange plates. Furthermore, a fundamental assessment of the load-bearing and fatigue behavior was carried out, taking into account all implicit influencing factors, in particular the weld geometry and the structural and fracture mechanical material properties, and the results were used to validate the phenomenological two-phase model for predicting the service life. Using the two-phase model, it was possible to distinguish between the phases of crack initiation and crack propagation and thus to evaluate the fatigue behavior in more detail. The recording and validation of the crack initiation and crack propagation phase was experimentally possible due to the com-

prehensive measurement concept consisting of strain gauges, digital image correlation and strain measurement using fiber optic sensors.

The crack initiation lifetime could be reliably predicted using the notch strain concept and showed a high sensitivity. The investigations showed that the local notch effect due to the weld geometry and the component effect were the decisive influencing parameters for the lifetime prediction. The results of the crack propagation phase were significantly influenced by material fracture parameters of the Paris equation. The methodical implementation using the extended finite element method, X-FEM, for the numerical calculation of crack propagation for unknown crack paths taking into account the stiffness ratios showed a good agreement with the experimentally determined crack areas. A variation of the above-mentioned influencing factors in the two-phase model can reproduce the scatter of the large-scale fatigue tests.

The two-phase model can help realistically predict the fatigue behavior of flange thickness transitions with web cutouts, taking into account the influence of the weld seam geometry and the cross-sectional geometry, and the scientific basis for this design detail, which is frequently used in engineering practice, can be provided.

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