Decreasing the hot spot stresses of welded tubular bridge nodes by diaphragm stiffening

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Summary

Tubular arch bridges comprise many welded tubular nodes, which are the most critical parts, since they reduce the fatigue strength of the bridge. Due to geometric discontinuity and the welding process, various stress concentrations are introduced at the nodes, making this type of bridge prone to fatigue damage caused by the varying traffic loads. High peak values of stresses, so-called hot spot stresses, are reached near the weld toe of the nodes. The objective of the present research is to increase the fatigue strength of these nodes or to reduce the hot spot stresses. A possible solution is to provide diaphragms inside the main tube. These diaphragms will reinforce the main tube thus reducing the in-plane deformation of this tube. Calculations show that the diaphragms have a positive influence on the hot spot stresses near the weld toe. The fatigue resistance of the whole bridge increases considerably due to this reduction of the weld stresses.

Keywords: Tubular arch bridges; welded tubular nodes; fatigue damage; diaphragm stiffening; hot spot stress; FE-models; strain measurements.

1. Introduction

Circular hollow sections are being used in various modern bridges. The use of tubes offers structural advantages because of their equal bending stiffness, strength and resistance to buckling in all directions. High torsional stiffness and a high strength-to-weight ratio are additional advantages of circular hollow sections. The welded nodes can be assembled thanks to modern cutting, preparation and fabrication processes making these bridges more feasible and competitive. Although these bridges are highly appreciated because of their aesthetic value, they are considered to be costly, mainly due to the use of welded nodes. The fatigue strength of these structures is an important aspect because high stresses, so called hot spot stresses, are reached near the weld toe of the nodes. Due to geometric discontinuity and the welding process, various stress concentrations are introduced at the nodes, making this type of bridge prone to fatigue damage due to the varying traffic loads. In tubular bridges, the braces, connected to the main tube also introduce local bending of the arch tube, according to the ratio of the tube diameters. Consequently these welded nodes are the weakest parts and determine the global strength of the structure. If the hot spot stresses can be decreased, then the fatigue strength of the arch bridge will increase. The thickness of the tubes must be increased to decrease the in-plane deformation of the main tube, reducing the hot spot stresses in the weld. These stresses must be kept sufficiently low to increase the fatigue resistance of the welded nodes. This means that the main tube is larger than necessary and is not used up to his actual capacity. The larger main tube increases the weight and the cost of the bridge, making this type of bridge not interesting. The fatigue strength of a thicker tube is also lower than a thinner tube of the same geometry, subjected to the same magnitude of stresses [1]. A local reinforcement of the main tube at the welded nodes without damaging the aesthetics of the structure will be researched to improve the design of a tubular arch bridge.

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