Engineering Failure Analysis
Volume 1, Issue 3, October 1994, Pages 243-253

The tay bridge disasterâ€”Faulty materials or faulty design?

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https://doi.org/10.1016/1350-6307(94)90022-1

Abstract

The first railway bridge over the Firth of Tay in Scotland entered service in May 1878. With a total length of 2 miles it was the longest iron bridge in the world. Over most of the crossing the single-track line ran above lattice-work spans made from wrought iron. However, over the central section of the bridge, the track ran inside the lattice-work spans. This central section (called the â€œHigh Girdersâ€) consisted of thirteen spans (eleven of 245 feet and two of 227 feet). In order to allow shipping to pass beneath the bridge there was a clearance of 90 feet between the High Girders and the high-water mark. The High Girders were supported on latticework columns 77 feet high which were bolted to sandstone foundations. Each column consisted of a set of six vertical cast-iron pipes which were braced together by bars of wrought iron. On 28 December 1879 the High Girders were blown into the Tay while a train was passing through them, drowning 75 people.

An analysis of the collapse leads to the conclusion that the combined wind loading on

the train and the High Girders was sufficient to make the latticework columns fail in shear. The probable wind speed at the instant of collapse was estimated by finding the wind pressure which would have been needed to bring the lightest vehicle in the train (a wooden four-wheeled carriage) to the point of overturning. By following the methods set out in BS 5400 (the British Standard code for bridge design) it was possible to show that the lateral wind force acting at the top of a single column was approximately 60 tons. The shear strength of the column was then found by postulating a plastic collapse mechanism. This involved the gross yielding of the diagonal ties and the development of plastic hinges at the ends of the cast-iron pipes. The model gave a collapse load of â‰ˆ163 tons.

Experiments performed for the original Court of Inquiry found that the cast-iron housings which held the ends of the bracing bars failed at â‰ˆ24 tons. In theory, the housings should have been capable of taking â‰ˆ200 tons. Evidence given to the enquiry indicated that the quality of the castings was often poor, and housings were sometimes in a cracked condition when they left the foundry. By comparison, a tie would have yielded at â‰ˆ52 tons. Accordingly, the column could not shakedown plastically and behaved as an elastic-brittle structure instead. This gives a collapse load which is nearer to 50 tons, and explains why the columns failed. The suprising conclusion is that, if the ties had been made significantly weaker (with a yield load of less than 24 tons), the structure would have shaken down before the cast-iron lugs could have snapped and the bridge might have survived.

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