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Strength Assessment of Reinforced Concrete Voided Bridge Slabs

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Abstract

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The maximum vehicle weight legally permitted on the roads in the UK and other countries has had a tendency to increase over time due to economic pressures. This increase presents a challenge to bridge engineers who must assess existing structures to ensure that they possess sufficient reserves of strength to carry the increased loads. In the case of many voided slab bridges, the original design was based on the beam-strip method of analysis, which ignores the transverse strength of the structure. If the same analysis method were to be used for assessing the capacity of these bridges under the increased traffic loads, many would be deemed inadequate. As a result there is significant economic benefit to be derived from using less conservative methods of analysis that consider the contribution of the transverse strength to the overall capacity of the voided bridge slab

Voided slabs are a common form of bridge construction, comprising approximately 10% of the Highways Agency bridge stock. However, despite their widespread use, relatively little is known about their ultimate strength. This thesis shows that much of the current guidance for the analysis of voided slabs is potentially unsafe in certain circumstances, despite being over-conservative in many cases.

Methods for analysing the ultimate strength of voided slabs are examined, and especially the transverse strength, about which very little is currently known.

A test programme was carried out on a series of voided beams representing one-third scale transverse strips of voided slabs. Together with similar tests carried out by other researchers, this provided sufficient data to develop new methods for assessing the transverse strength of voided slabs.

The majority of the voided beams failed as a result of shear. Based on the results of these tests, a method is proposed for assessing the transverse shear resistance of voided slabs. The method derives the shear resistance from that of a solid slab, reduced by a factor determined from the ratio of void diameter to effective depth of the slab. This method gives an average ratio of actual/predicted failure load of 1.03 for the nine beams that failed in shear.

The geometry of voided slabs is such that transverse shear forces set up local bending moments, or Vierendeel moments, within the webs and flanges of the slab, which can cause local failures at these locations. A method is presented to assess the resistance

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of voided slabs to these Vierendeel moments. In situations where the reinforcement was suitably positioned to resist the Vierendeel moments this method, in conjunction with that for assessing the shear capacity, produces good predictions of strength, with an average ratio of actual/predicted failure load of 1.36. However, many voided slabs appear to have been designed with no thought to Vierendeel bending, and as a result contain reinforcement that is poorly positioned to resist these forces. These structures gain much of their resistance from the tensile strength of the concrete. In such situations the proposed method provides poorer predictions of the capacity of the beams, but importantly these predictions are always conservative, hence safe.

Two tests to failure were also conducted on a quarter-scale voided slab. From the results of these tests it is determined that the yield-line method is not suitable for the analysis of voided slabs. This is because the transverse flexural capacity of a voided slab is a function of the transverse shear force, due to the Vierendeel bending moments that occur within the flanges. As the yield-line method does not consider shear, it is not possible to allow for this effect in the analysis.

Punching shear tests were also carried out on the voided slab. Along with the results of two tests on voided slabs previously carried out by the author, guidance is presented for assessing the resistance to punching of loads through the full depth of the slab. Using this guidance, ratios of actual/predicted failure load of between 1.06 and 1.55 were obtained for the six tests considered.