Rehabilitation strategies for steel and movable bridges in Rotterdam

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Summary

Recently a new Dutch Design Code Series (NEN8700) has been issued, prescribing minimum reliability requirements for existing building structures according to Dutch law. First practical experiences with this codes have shown that especially for prewar and historic bridges it is nearly impossible to fulfil these minimum requirements in conjunction with Eurocode bridge design loading requirements, without executing elaborate strengthening programmes. However preliminary studies have indicated that a significant difference in traffic count and axle loading exists between urban traffic and highway traffic. This paper reflects project experiences of the last decades rehabilitation and replacement programmes of older urban movable steel bridges. The movable bascule Leuvebrug is the first Rotterdam bridge recalculated by the new NEN8700 code, as a result bridge replacement, earlier based on codes for new bridges, was no longer considered necessary.

Keywords: bridge rehabilitation, traffic loading, structural reliability, movable bridge, existing bridges.

1. Introduction

For the design of new bridges in the Netherlands only highway traffic has been calibrated with Eurocode design traffic loading. As a minor reduction of the design axle loading would result in a dramatic decrease in renovation costs, an urban traffic measurement programme has recently been initiated by the Rotterdam Municipality. Purpose of the programme is to obtain more accurate and object specific traffic loading data in order to minimise unnecessary bridge strengthening.

2. Structural reliability levels for existing bridges [1,2]

The level of safety of a building structure is defined as the risk of failure during the reference lifetime of the structure. Instead of describing the risk of failure, the Eurocode generally defines this risk in terms of the reliability index: β. In the past all Dutch bridges have been designed according to a minimum reliability level of $\beta n \geq 3{,}6$ for static capacity verification, according to the highest Dutch safety class 3 and taken independent of the consequence of failure. This resulted in partial safety factors of $\gamma F = 1{,}5$ for all load effects. After the introduction of the Eurocodes, bridges in the Netherlands may be classified by one of the consequence classes CC1b, CC2 or CC3 according to classification rules presented in EN1990. For new bridges values for βn are given in EN1990-Annex B. (CC1b: $\beta n = 3{,}3$, CC2: $\beta n = 3{,}8$, CC3: $\beta n= 4{,}3$). Bridges have to be checked at CC3 level if they are located in or passing motorways, railways or major shipping routes. Thus for urban bridges classified at CC2 the reliability level remained approximately unchanged in comparison to prior Dutch national codes. Eurocode partial load factors γ are given as G =1,35 for permanent loads and T=1,35 for traffic loads for new urban CC2 classified bridges. These figures may be reduced according to NEN8700 to G = 1,2 and T = 1,1 for application at rejection level verification.

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For existing structures the characteristic design loads are to be taken similar to new bridges but under circumstances lower reliability levels may be acceptable. One of the issues is that reference time and trend for existing bridges are reduced to 15 years only. The trend effect incorporates the increase of the (traffic)loading effect during the technical life. Research by the institution of TNO in the Netherlands resulted in two sets of lower boundary values for (i) rejection: reliability levels describing legal lower boundary of approval of the actual use and application and (ii) renovation: referring to structural change and/or enlargement based situations. These denominated reduced values are valid for single structure and "incident" based application, and therefore may possibly be a little unconservative when larger numbers of structures are considered. By Dutch law structures below the rejection level of reliability are to be closed for public use immediately. NEN8700 presents the minimum values for rejection as: $\beta a \geq \beta n - 1{,}5$, and for renovation as: $\beta v \geq \beta n - 0{,}5$.

Most existing urban bridges in Rotterdam have been designed to carry vehicles with a traffic capacity of Class 450 (3*150 kN axle vehicle) or Class 600 (3*200 kN axles) in combination with 4 kN/m2 distributed load, all to be multiplied by an impact factor. Generally most C600 designed bridges have a statically sufficient capacity to fulfil the requirements of characteristic LM1 traffic loads at rejection level. Major reason is the applied low static stress levels especially for directly wheel loaded parts of bridges, due to the fact that fatigue resistance is governing. About 50% of the Rotterdam urban steel bridges have been designed according to traffic load class C450. These bridges will not stand the reliability requirements based on unadapted LM1 traffic loads. Up till now no static or fatigue capacity problems due to lack of structural capacity have been reported for thousands of urban steel bridges in the Netherlands, other than due to design or execution failures. As serious questions can be raised on the accuracy of the LM1 traffic model for urban application an initial study has been executed. Both national as well as international data show considerable difference in mean axle values for different types of roads. Furthermore the Dutch Authority for Road traffic (RDW) issues special dispensations for axle loads up to 12 Ton for highways and 10 Tons for other roads. The next step taken is that Rotterdam currently implements a Weigh in Motion (WiM) system on several carefully chosen bridge locations. If this measurements show to be successful other bridge owners will participate in the programme. Purpose of these measurements is to execute a general probabilistic analysis of heavy urban traffic.

3. Discussion, Conclusions and Acknowledgements

For the Rotterdam urban area, over 50 movable and numerous fixed bridges are maintained by the Municipality. In the past a renewal programme was applied for the exchange sequence of bridge superstructures that no longer fulfilled the functional/durable requirements and or structural reliability demands. Since last decade a risk based maintenance approach has been adopted. For existing bridges lower reliability index levels are facilitated by the new NEN8700 code for existing structures. In addition the Municipality started a measurement programme for the determination of traffic weight for urban bridges. Significant reduction of Eurocode characteristic design traffic loads for new bridges are expected. As a result bridges that were previously listed for replacement can now be assigned with significant life time extension and or in other situations with significantly reduced renovation scope. In all cases a significant reduction of financial needs is achieved. Even in situations of bridge widening this approach has proven to be effective in reducing renovation scope. The new maintenance system turned out to be successful in obtaining improved LCC scores and in reducing traffic hindrance.

4. References

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