NAD for traffic load bridges

NAD for Traffic Load on Bridges

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Summary

The first draft of a Danish National Application Document for ENV 1991-3:"Eurocode 1 - Basis of design and actions on structures - part 3 : Traffic load on bridges" was issued in September 1995 for the road and footbridge part. The ENV 1991-3 with the NAD will when published replace the existing Danish requirements. Some modifications of the loading models have been introduced in the NAD and the load safety factors have been adjusted in order to be consistent with the material safety factors defined in the Danish codes. The Eurocode safety level is kept unchanged. The set of models of special vehicles is considered in relation to the classification of existing bridges. Simple calculations have been made to clarify the consequences of introducing the Eurocodes for the design of bridges in Denmark. Only insignificant changes in cost and safety are involved.

1. Introduction

A National Application Document for ENV 1991-3 :"Eurocode 1 - Basis of design and actions on structures - part 3 : Traffic load on bridges" is in preparation by the Road Directorate in Denmark for the road and footbridge part. The first draft was issued in September 1995 and the final version is expected to be completed in the autumn of 1996.

It is the intention that the final NAD shall cover railway as well as road and footbridge loadings. Railway bridges are not included in this paper because the responsibility for preparation of the NAD is divided between the Road Directorate and the Danish Railways, each authority covering its own field. Before publication, the contributions from the Danish Railways and the Road Directorate will be adjusted in order to avoid inconsistencies in the final document.

In this paper the implementation of the Eurocode with the corresponding NAD is discussed. Some of the main subjects to be decided on in the NAD are discussed and the adjustments described.

2. Objective

The objective of the NAD is to adjust the ENV 1991-3 to the design of small and medium size bridges in Denmark. The aim is to limit the additions and changes to ENV 1991-3 as far as possible, as this will make the full transition to a uniform Eurocode system easier.

3. Implementation

It is the policy of the Road Directorate in Denmark to implement the Eurocodes for design and execution of structures and other works related to roads as soon as possible after publication. The argument is that bridges and roads are influenced by developments in other European countries, especially the neighbouring countries Sweden and Germany. Since the traffic crosses the borders more or less freely it is obvious that the loadings and the safety requirements should be equalized. Furthermore, it is preferable to spend time and money in adjusting the Eurocodes to Danish requirements rather than preparing new Danish documents.

It is the intention to implement the ENV 1991-3 together with the Danish NAD as soon as these documents are ready for use. This shall of course be seen in relation to other codes in use at the time of issue. For example, it would be advantageous if the Eurocodes for Design of Concrete and Steel Bridges were to be implemented simultaneously with the Eurocode for Loadings on Bridges.

A Road Regulation is a collection of requirements and/or instructions for the design of a specific bridge/road item, prepared and issued by the Danish Road Directorate. In the future Road Regulation for design of bridges it will be stated which codes are to be used and, if necessary, supplementary instructions will be given. In this way we hope to be able to make the use of ENV 1991-3 together with ENV 1991-2 : "Eurocode 2 part 2 : Design of Concrete Bridges" obligatory in 1996. The Road Regulation will thereafter be updated in accordance with the development of the relevant Eurocodes.

4. Safety

As stated above it has been the intention to limit the NAD adjustments of the Eurocode as far as possible. Due to this as well as consequence evaluations it was therefore decided to maintain the Eurocode safety level in the Danish application. In order to do so, the partial safety factors and the reduction factors as well as the different loading combinations are in principle kept unchanged.

It is crucial that the system of partial safety factors in ENV 1991-3 be compatible with the other Eurocodes and NADs to be used in the design of bridges. In the preparation of Danish NADs for ENV 1992-1 and ENV 1993-1 it was decided to convert the values of the material partial safety factors into the present Danish values. This is expected also to be done for Part 2 concerning bridge structures. In order to keep the safety level unchanged an adjustment factor is introduced. By multiplying this factor on the load partial safety factors as specified in the Eurocode safety system, these safety factors will be more or less consistent with the material safety factors defined in the Danish system and transferred to the Danish NADs.

The value of the adjustment factor is obtained as the ratio between the material partial safety factors given in the Eurocode and the corresponding values given in the Danish code. Since the these ratios vary from material to material, an average value has been selected. This will result in some variation in safety between the different materials. This variation is assessed to be insignificant. It should be noted that the use of this adjustment factor is strictly valid only for linear limit states.

A framework with all load combinations to be considered has been set up in order to facilitate the engineers' work and to avoid errors and misunderstandings. An example of such a framework is given in Figure 4.1.

EC Safety System

<u>Ultimate Limit State (ULS):</u>

Load Combinations for In-service situations: $\sum \gamma_{Gj} G_{kj} + \gamma_P P_k + \gamma_{Q1} Q_{k1} + \sum \gamma_{Qi} \Psi_{0i} Q_{ki}$

Load Combination	a	b	c	d	e	f	g	h	i	j	k
Permanent Loads											
Dead Load	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35
Superimposed Dead Load	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35
Earth Pressure	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35	1.00/1.35
Prestressing	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Settlements of supports	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Variable Loads											
Traffic Load											
gr1: LM1: TS	1.35	0.75x1.35=1.01			1.01		(1.01)	1.01	1.01	1.01	1.01
UDL	1.35	0.40x1.35=0.54			0.54		(0.54)	0.54	0.54	0.54	0.54
Footway/Cycle tracks	1.35										
gr2: Braking and Acceleration Forces, Centrifugal Forces	0.40x1.35=0.54	1.35									
gr3: Footway/Cycle tracks			1.35								
gr4: LM4: Crowd Loading				1.35							
Footway/cycle tracks				1.35							
gr5: LM3: Special vehicles					1.35						
gr6: LM2: Single Axle Load						1.35					
Wind Load: F_{wk}	0.35x1.90=0.67	0.67	0.67	0.67	0.67		1.90	0.67		0.67	0.7x1.9=1.33
(F^*_w)	(1.0x1.9=1.90)	(1.90)	(1.90)	(1.90)	(1.90)			(1.90)		(1.90)	(1.90)
Temperature Effects								1.50			
Horizontal Mass Load									1.50		
Ice Load										1.50	
Wave and Current Loads							0.7x1.5=1.05				1.50

Figure 4.1

In order to be able to compare the Eurocode load combinations, safety factors and reduction factors inclusive, with the Danish load combinations, a second adjustment factor is introduced. This adjustment factor has arisen from the difference in the return periods on which the characteristic load values are based. ENV 1991-3 has based its definition of the road traffic loads on 1000-year return periods (90% fractile, reference period 100 years), whereas the Danish code uses a 50-year return period (98% fractile, reference period 1 year). An adjustment factor has been estimated from calculations based on assumptions concerning the traffic load distribution.

5. Loading models

The present Danish load models are in principle very similar to those given in ENV 1991-3.

The main loading system in the Danish model consists of two three-axled vehicles, one with a total load of 780 kN and the other with a total load of 390 kN. The heavy vehicle is defined in order to take heavy vehicles moving with the normal traffic into consideration. The uniformly distributed load in lane 1 is somewhat larger in ENV 1991-3 than in the Danish rules but the positioning is the same. The difference between the Danish rules and the Eurocode is significant only for small bridges and for local effects.

The Danish rules include a single load of 260 KN for local effects, similar to that of ENV 1991-3 load model 2.

A set of models of special vehicles forms the basis of the classification of existing bridges in Denmark. This classification system is a very important tool for the administration of heavy vehicles moving with the normal traffic (see below). The present Danish classification system is described in a Road Regulation, separate from the bridge design Road Regulation.

In order to evaluate and adjust the load models given in ENV 1991-3, bridge classes were defined similar to the bridge classes in the Danish regulations. Three classes are defined in the NAD :

Bridge class 1 : Road bridges for public roads with normal traffic and for privately-owned common roads with equivalent traffic.

Bridge class 2 : Road bridges for privately-owned common roads and public roads with light traffic only.

Bridge class 3 : Footbridges with only pedestrian and cycle traffic.

Considering the main loading system (load model 1), the first approach in the NAD is to apply the following α-values :

Bridge class 1 : $\alpha_{Qi} = 1.0$ and $\alpha_{ql} = 1.0$

Bridge class 2 : $\alpha_{Qi} = 0.8$ and $\alpha_{ql} = 3.0/9.0$

For bridge class 1 it is under consideration to set $\alpha_{ql} = 6.0/9.0$ and in addition to require design for special vehicle class 900/150 (load model 3). This is believed to be more in agreement with future traffic intensities in Denmark and with the Danish tradition of designing for a heavy special vehicle moving freely around in the traffic.

For the single axle load (load model 2) located in the most adverse position on the carriageway, $\beta_Q = 0.8$.

The set of special vehicles (load model 3) has not been evaluated in detail so far, because it is of little relevance for the present design of bridges. In the long term it may become relevant for heavy vehicles (see below).

Amendments to centrifugal forces are under consideration and a lateral force such as side-impact will probably be included in the NAD.

When looking upon fatigue load models generally, the traffic intensity given in ENV 1991-3 Table 4.5 has to be decreased considerably for the design of Danish bridges. As a first approach, values from the Great Belt Bridge Basis of Design, and the values given in the present Road Regulations are applied, but further investigations may be carried out in the near future.

The fatigue load models 2 and 3 are considered not applicable, and the number of lorries to be investigated in load model 4 is reduced from five to two, as can be seen in Figure 5.1. The Table shown has to replace Table 4.7 in ENV 1991-3.

Only the first lorry (axle loads 70 and 130 kN) and the third lorry (axle loads 70, 150, 90, 90 and 90 kN) should be considered.

The percentage of the two standard lorries in the traffic flow should be taken as :

Lorry (axle loads)	Long Distance	Medium Distance	Local traffic
	Lorry Percentage	Lorry Percentage	Lorry Percentage
70 and 130 kN	20	50	80
70, 150, 90, 90 and 90 kN	80	50	20

Figure 5.1

6. Classification of existing bridges

A bridge classification system is in use for handling heavy transports in Denmark.

The Basis of Design for Bridges has changed significantly through the years, from no design basis at all to the detailed rules we have today. The existing bridges in Denmark therefore have different capacities for the passage of heavy vehicles. In order to administer applications for permission to pass with vehicles that exceed the limits given in the traffic regulations it is necessary to have a consistent and unambiguous classification system covering both bridges and vehicles.

Because of international road traffic this is an important European matter; we would therefore like to have a European classification system. Whether it is possible to convert the series of standard vehicles into the series of ENV 1991-3 load model 3, and thus to take the first step towards a common European system, is to be investigated.

7. Evaluation of consequences

A preliminar comparison between bridge design according to Eurocodes and bridge design according to the present Danish rules was made in spring/summer of 1994. NAD amendments were not taken into consideration.

The consequences were determined from the static loadings only. Dynamic loading and fatigue were not taken into consideration. Normally dynamic loading and fatigue have no effects on reinforced concrete bridges, but they have considerable effects on steel bridges.

The following conclusions were derived from the investigation:

- There is no significant difference in the safety level obtained by design according to Eurocode and Danish requirements/codes.
- The above applies to both dead load-dominated cases and live load-dominated cases.
- There is no significant change in the quantity of construction material.
- There is no change in the relative competitiveness of concrete and steel bridges.

When comparing design of prestressed bridges according to Eurocodes and Danish codes the conclusions derived above still apply.

Since the adjustments of ENV 1991-3 in the Danish NAD do not have any influence on the safety level, the consequences when considering the NAD are more or less the same as those for the Eurocode itself.

More detailed calculations and comparisions have to be made before it is possible to clarify the full consequences of designing Danish bridges according to Eurocodes. Since most of the Danish small to medium-size bridges are of reinforced concrete, interest is primarily focused on this bridge type, but it is of course important also to clarify the consequences for steel bridges. It will be of great interest to see whether the bridge class (heavy vehicles) according to the Danish classification system changes with the change from Danish design regulations to Eurocodes.

The detailed investigations will be carried out after the entire set of Eurocodes for the design of bridges, including the corresponding NADs, has been issued.