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Composite Bridges in View of Existing Standards and Eurocode

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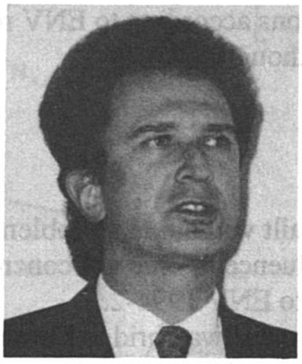

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Summary

For the design of composite bridges some comparative calculations between Austrian standards and Eurocodes have been made. Simple span and continuous span railway bridges, a simple span truss railway bridge and a cable-stayed road bridge have been examined. The results and the major interesting aspects for the practical use of ENV 1994-2 are presented in this paper.

1. Introduction

Austrian standards for the design of composite railway bridges are not compatible with load specifications and steel structure specifications. There are no standards for composite railway bridges available. However, several bridges have successfully been built with the knowledge and common sense of engineers in the last few years.
In Austria prestressing without tendons is mainly used, e.g. erection methods like lowering the concrete slab at supporting points.

2. Standards

The main Austrian standards for the design of composite bridges compared with Eurocodes are indicated below.

	Eurocode	**ÖNORM** (Austrian standard)
General design	ENV 1994-2 (draft) 07-96	ÖN B4500
Steel Structure	ENV 1993-2-2 (draft) 04-96	ÖN B4600 ÖN B4300
Concrete slab	ENV 1992-2 10-95	ÖN B4200 ÖN B4700
Fatigue in steel construction	ENV 1993 2-2 (draft) 04-96	ÖN B4600-3 ÖN B4300-5
Fatigue in concrete slab	ENV 1993-2-2 (draft) 04-96	not available
Composite road bridges	ENV 1994-2 (draft) 07-96	ÖN B4502
Composite railway bridges	ENV 1994-2 (draft) 07-96	not available

3. Loads

For a critical examination of standards for bridges the design regulations as well as the load specification have to be compared.
The different way of calculation of load actions according to ENV regulations does not bring about a significant influence on the design, though.

4. Simple span bridges

Simple span composite bridges have been built without any problems in the last twenty years. As a simplification for small bridges the influence of creep of concrete may be taken into account by use of modular ratios according to ENV 1994-2.
The comparative calculation for a simple span railway bridge has shown that there are only minor differences between ÖNORM and Eurocode.

5. Continuous span bridges

There are various methods to minimise cracks in the concrete. Prestressing by tendons has been the main method in Germany for many years. In Austria prestressing methods by lowering the composite girder are used.

5.1 Calculation without tension stiffening effect

This method is used in ÖNORM and DIN and can also be applied according to ENV 1994-2.

5.2 Calculation with tension stiffening effect

In tension members in composite beams the stiffness and the conrete tensile strength can be taken into consideration. A comparative calculation for a continuous span railway bridge with variably high beams shows that there are great differences depending on whether tension stiffening effects have been taken into consideration or not.

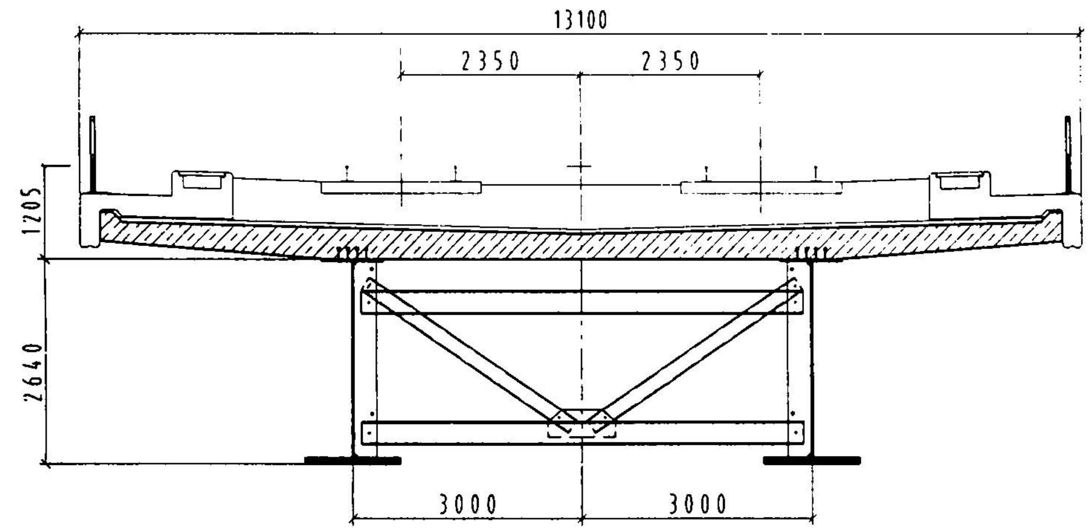

Fig. 1 Cross section of railway bridge near Melk/Austria

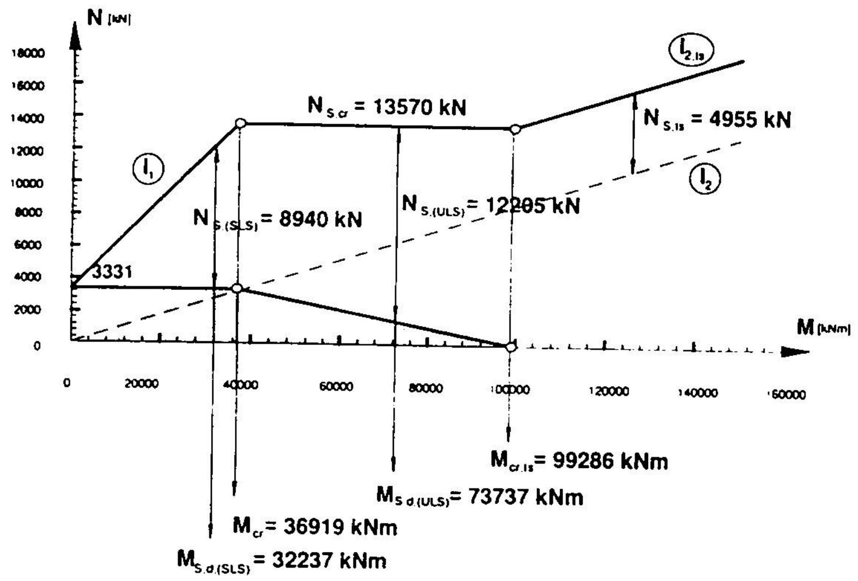

Fig. 2 N_s-M Diagram of the hogging bending moment at the internal support

Region (a) gives the behaviour of the uncracked section, region (b) the behaviour in the stage of initial crack formation and region (c) the behaviour in the stage of stabilised crack formation. Comparative calculations have shown that the consideration of the tension stiffening effect according to ENV 1994-2 will result in an economization of steel quantities by about 10 % in contrast to ÖNORM.

6. Trusses with concrete slabs

There are no regulations in ÖNORM for calculating composite truss bridges. ENV 1994-2 allows an economical calculation according to Annex L. Detailed examples are given in [9].

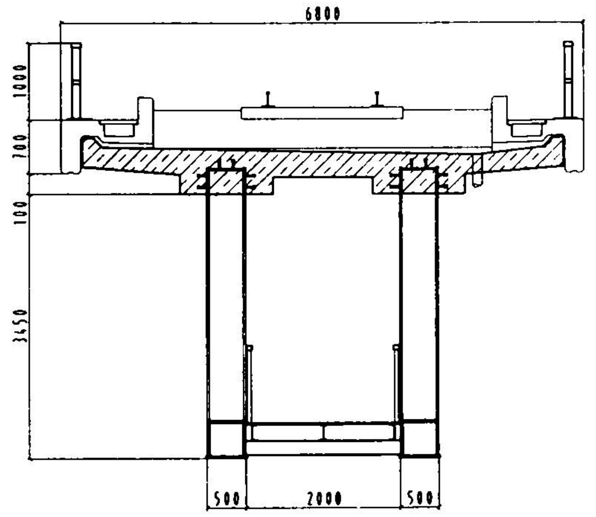

Fig. 3 Cross section of railway bridge Siemensstraße/Austria

7. Tension members in bowstring arch- and cable-stayed bridges

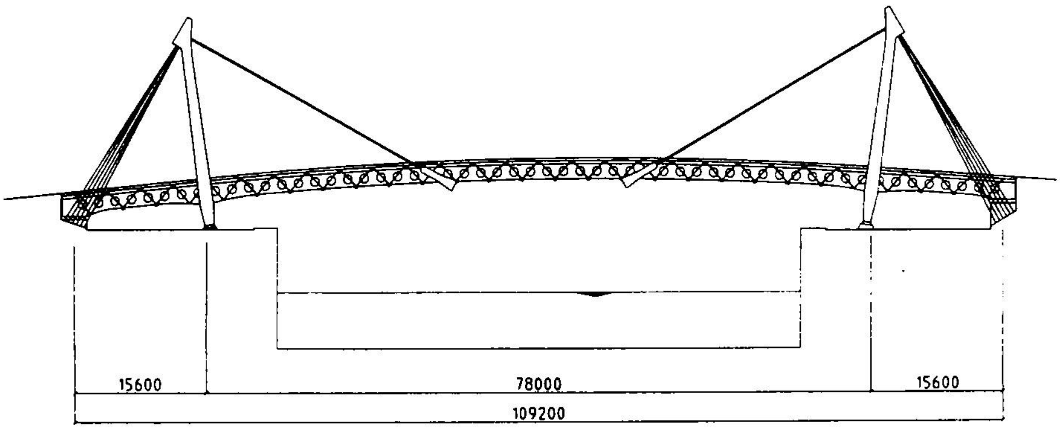

Fig. 4 View of the cable-stayed road bridge Freudenau/Austria

In ÖNORM there are no regulations if the complete or larger parts of the conrete slab are under tension. The application of ENV-1994-2 to tension members in concrete slabs offers the possibility to calculate composite bowstring arch- and cable-stayed bridges.

8. Serviceability limit states

In ENV 1994-2 serviceability limit states cover limitation of stress, crack and decompression control, deformation and vibration.

8.1 Classification for design criteria

According to ENV 1994-2 a bridge or parts of the bridge have to be classified into design categories. The category has to be indicated in the project specification.

	Combination of actions for the verification of:	
Category	Decompression	Crack width
A	infrequent	--
B	frequent	infrequent
C	quasi permanent	frequent
D	--	frequent
E	--	quasi permanent

Existing road- and railway bridges which were built according to Austrian standards comply with category C of ENV 1994-2.
Categories A and B can only be fulfilled with prestressing by tendons.

8.2 Control of cracking

In ÖNORM regulations of crack control and minimum reinforcement are given for road bridges only. In ENV 1994-2 clear regulations are given for both road- and railway bridges. These regulations are stricter than those of ÖNORM B4502. Due to the advantages of considering the tension stiffening effect it is justified to increase the reinforcement quantity, however.

8.3 Deformations

According to ENV 1994-2, as a simplification the effective sections for calculation of deformations may be taken from sagging moment area of the global analysis over the whole length of the bridge. The tension stiffening effect may be included in the calculation of the deformations.

9. Ultimate limit states

Composite bridges are supposed to be proportioned in such a way that the basic design requirements for the ultimate limit states are satisfied. As a simplification the influence of creep of concrete may be taken into account by use of modular ratios. According to ENV 1994-2, in sections where the concrete slab is assumed to be cracked, the primary (isostatic) effects due to shrinkage may be neglected in the calculation of secondary (hyperstatic) effects.

10. Ultimate limit states for shear connections and fasteners

Comparisons indicate that welded stud shear connectors calculated according to ENV 1994-2 can carry 45% more shear load than those calculated according to ÖNORM. The influence of fatigue of shear connectors on railway- and road bridges have to be taken into account.

11. Fatigue in the steel structure

In contrast to ÖNORM B 4600-3 the regulation of ENV 1993-2 requires more steel consumption. In the past, fatigue in the steel structure of composite bridges has not been decisive for dimensioning. Comparative calculations for continuous span bridges result in an increase in the amount of steel by 10%, if designed according to ENV.

12. Fatigue in the concrete slab

In the past no fatigue regulations for the concrete slab have been applied. The fatigue strength of reinforcing steel and prestressing steel should be taken into account according to ENV 1992-2. A comparative calculation reveals less than 5% influence on the quantity of reinforcement.

13. Comparative calculations

As stated above, the main dimensions can change about +/- 10% by calculation according to ENV 1994-2.
Due to serviceability limit states, category C of classification for design criteria has been applied for all comparative calculations. Categories A or B would increase the cost of composite bridges considerably.

14. Advantages and changes of the Eurocodes

Advantages by using ENV 1994-2:
- Economising the amount of steel due to consideration of tension stiffening effect
- Regulation for truss-, bowstring arch- and cable-stayed composite bridges
- Reduction of umbers of shear bolts
- Regulation for different kinds of shear connectors
- Regulations for composite slabs with profiled steel sheeting and composite slabs
- Regulations for decks with precast concrete slabs

Changes by using ENV 1994-2:
- Increase of steel quantity due to fatigue in steel structure
- Increase of reinforcement due to fatigue in concrete slab
- Static analysis becomes more extensive and expensive
- Prestressing tendons are necessary if categories A or B of classification for design criteria are required

15. Conclusion

The ENVs are a compromise of technological usage in different countries and the latest state of research at universities.This endeavour has taken a lot of experts´ time and money. Therefore they should not be applied only for theoretical calculations. All responsible authorities should make the use of the ENVs compulsary for new projects as soon as possible.

Composite bridges are a very economical solution for bridges.
Simple and clear standards are the precondition for a new generation of bridges.

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