Railway corridors construction using rigid geogrids reinforcement in the Czech Republic

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Keywords: Geogrids, Reinforcement, Railway

ABSTRACT: This article deals with usage of biaxial geogrids within the upgrading of the existing railway network in the Czech Republic. The use of geogrids was accepted as an alternative to the original designed solution after considering climatic and economic conditions. Today this technology has become commonly used on the Czech railways (CD) lower construction. Geogrid reinforcement for the improvement of all layer characteristics has now been included as one of the standard solutions in the CD Ruling for railway lower construction. Referred to as Ruling S 4.

1 INTRODUCTION

An important point in the Czech history was the “velvet” revolution of 1989, which started the integration of this country into European structures.

Integration required infrastructure improvement, including the upgrading of the existing railway network. This is divided into separate corridors I, II, III. and IV. Corridor I is now in the final stage of reconstruction and works on corridor II are now being intensified.

One of the main requirements is upgrading the network to tolerate speeds of 160 km/h. To be able to satisfy this requirement, it is necessary to carry out complex reconstruction of railway lower construction (sub-soil, sub-grade and sub-base) and upper railway construction (ballast, sleepers and rails).

This paper describes reconstruction of railway lower construction and it deals with problems related to the reconstruction

2 PLANNED CORRIDORS IN THE CZECH REPUBLIC

The following section provides a description of each corridor considering its route, length, design speed and construction time.

Railway sections in the Czech Republic are divided according to their importance into 4 corridors:

Corridor I: (Germany) -Decin – Praha – Ceska Trebova – Brno – Breclav – (Austria);
corridor length is approximately 430 km;
design speed 120 – 160 km/h;
construction time: from 1996 to 2003

Corridor II: (Austria) - Breclav – Prerov – Ostrava – Petrovice – (Poland);
corridor length is approximately 240 km;
design speed 140 – 160 km/h;
construction time: from 1998 to 2005

Corridor III: (Germany) – Ceské Kubice (Cheb) – Plzeň – Praha – Ceska Trebova – Olomouc – Prerov – Ostrava – Petrovice - (Poland);
corridor length is approximately 540 km;
design speed 100 – 160 km/h;
construction time: from 2003 to 2010

Corridor IV: (Germany) -Decin – Praha – Ceské Budejovice – Horni Dvoriste – (Austria);
corridor length is approximately 200 km;
design speed 120 – 160 km/h;

Findings in this article are drawn from Corridor I and II construction.

3 CONSTRUCTION PREPARATION

The construction is quite extensive and demanding, so a detailed engineering – geological investigation had to be carried out. Design documentation was prepared from the investigation results, which had to fulfil all the requirements of the Czech railways (CD) network Ruling.

In the CR the most important Ruling for lower construction is the S4 CD Ruling - “Lower railway construction” (Ruling S4) containing recommendation for design. According to this rule, bearing capacity improvement can be achieved by different methods, for example by stabilisation, increased thickness of granular material or geosynthetics reinforcement.

3.1 *Engineering – geological situation*

The detailed engineering – geological investigation in many track sections had shown that the sub-grade strength was not sufficient and it would be necessary to take action to obtain the required bearing capacity.

According to the results of the investigation, separate corridors were divided into sections according to subsoil characteristics; i. e. zones classified according to sub-grade bearing capacity were defined. Rigid geogrid reinforcement was subsequently adopted within areas classified as soft soils. These soils had plate bearing test performing values E DEF lower than 30 MPa. According to the Czech Code 72 1002 “Soil Classification for Highway Constructions [2] these are prevailingly soils classified as F5, F6, F7 and F8, of pasty to solid consistency. This norm classifies soils in the following way:

volume weight:	γ = 20 – 21 kNm-3
undrained shear parameters:	c_u = 20 kPa az 60 kPa; φ_u = 0°
modulus of deformation:	E_{def} = 1 az 6MPa
Poisson´s constant:	ν = 0,40 or 0,42

Besides these soil types blowing sands were also found at these sections (at section Bzenec – Rohatec) or loose sand (at the railway station Hrusky).

With regard to the design of lower railway construction layers, the most important parameter is the modulus of deformation Edef2, which is determined by static loading test.

3.2 *Rules and requirements of the Czech republic railway network*

According to CD S4 [1], geosynthetic reinforcing materials are usually used in lower railway construction when we want to get the required bearing capacity on railway sub-base (in accordance with Table 1), or if we want to reduce construction layer thickness compared with an unreinforced layer. More detailed description is below:

- if $E_{or} > 0{,}6E_{0,min}$, then required bearing capacity E_{pl} could be achieved by reinforcement or
- if $E_{or} > E_{0,min}$, then reduction of lower railway construction layer thickness could be achieved, where:

E_{or} = reduced measured sub-grade modulus of deformation
$E_{0,min}$ = required minimal value for sub-grade modulus of deformation (Table 1)
E_{pl} = required sub-base modulus of deformation (Table1)

Table.1: Minimal required values of sub-grade E_o and sub-base E_{pl} modulus of deformation [1]

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Track type	Minimal required modulus of deformation values	
	$E_{0,min}$ [MPa]	E_{pl} [MPa]
New work:		
- for speed > 160 km.h^{-1}	60	100
- for speed up to 160 km.h^{-1}	40	80
Existing tracks:		
a) main track and station rails on tracks		
- national for speed 120 to 160 km.h^{-1}	30	50
- national corridor for speed < 120 km.h^{-1}	20	50
- other national for speed < 120 km.h^{-1}	20	40
- regional	15	30

4 PROBLEMS WITH CORRIDOR CONSTRUCTION

Following completion of the design documentation, work on corridor construction could start. According to the the S4 Ruling inadequate track sections with respect to subsoil strength were to be improved by stabilisation, reinforcing geotextiles, construction layers from loose materials insertion .

During construction works many problems occurred, which decelerated the works, or designed precautions was found as non-productive with regard to geotecnical conditions. The arisen problems must had been sorted out very fast, because construction time for each corridor section was fixed.

A simple solution proved to be the use of geogrids. The concept of using geogrids was not well known in the Czech Republic in the past and only few designers knew how to use and design with these materials. Many technical discussions with designers and with railway representatives resulted in development of a design procedure for bearing capacity improvement by use of rigid biaxial geogrids. The new technology was then put to use to solve problems emerging at the construction site (long-term showers, very soft sub-soils, lack of granular material and the need for rapid construction operations etc.).

An important factor that led to increased use of the rigid geogrid technique was the finding that at some section where alternative sub-grade stabilisation of insufficient thickness had been carried out, the rails failures were found with time, caused by stabilised layer cracking and its pushing back in the weak sub-grade. For sub-base layers reinforced with geosynthetics this effect was significantly reduced. The construction is more elastic, more able to transfer differential settlements than rigid stabilisation.

5 RIGID GEOGRIDS USAGE AT CORRIDORS

5.1 *The design method for reinforced construction layers*

The design of reinforced construction layers initially followed the design diagrams determined by Beckman [3]. This method was subsequently dropped because the Beckman's methodology is based upon determination of modulus of deformation Ev2 (German method), whereas the Czech Railways use the parameter Edef,2. The differences between these two moduli are described below.

5.2 *Measurement and Rating peculiarity of static load test using the Czech Railways methodology*

It is necessary to point out the different determination of this parameter according to the Czech code Ruling and methodology used in most other countries. To bring an example it was used methodology comparing of the CD and Deutsche Bahn. Some basic data of both methodologies are stated in the Table 2 and diagrammatized in the picture 1 and 2.

Table 2. Modulus of deformation determination comparing

	DB	CD
diagram of circular plate: D [m]	0,30	0,30
Maximum load: p [MPa]	0,50	0,20
Calculation of modulus: $E_{v,2}$ resp. $E_{def,2}$	$E_{v,2} = 1{,}5 \cdot \Delta \delta_{é} \cdot r$	$E_{def,2} = 1{,}5 \cdot p \cdot r / y$

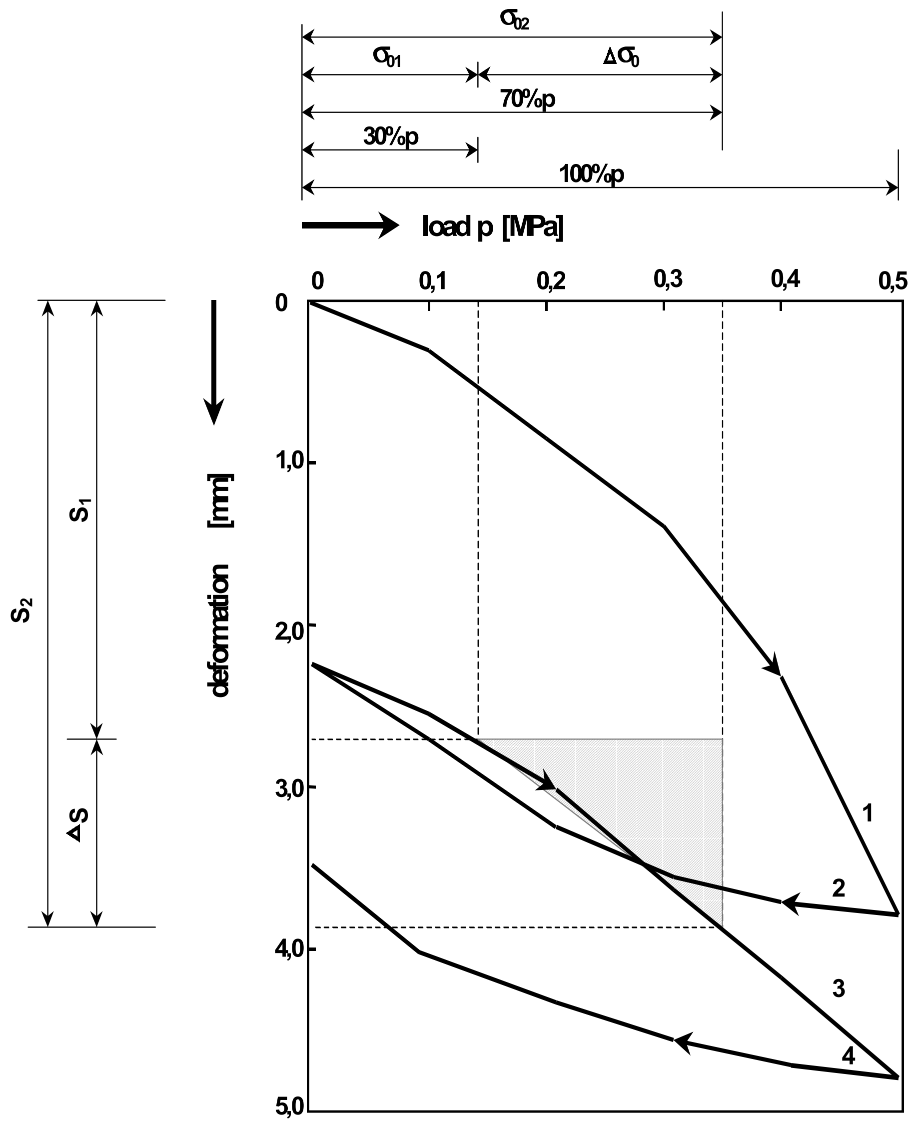

Figure1 Modulus of deformation determination according to the CD methodology [1]

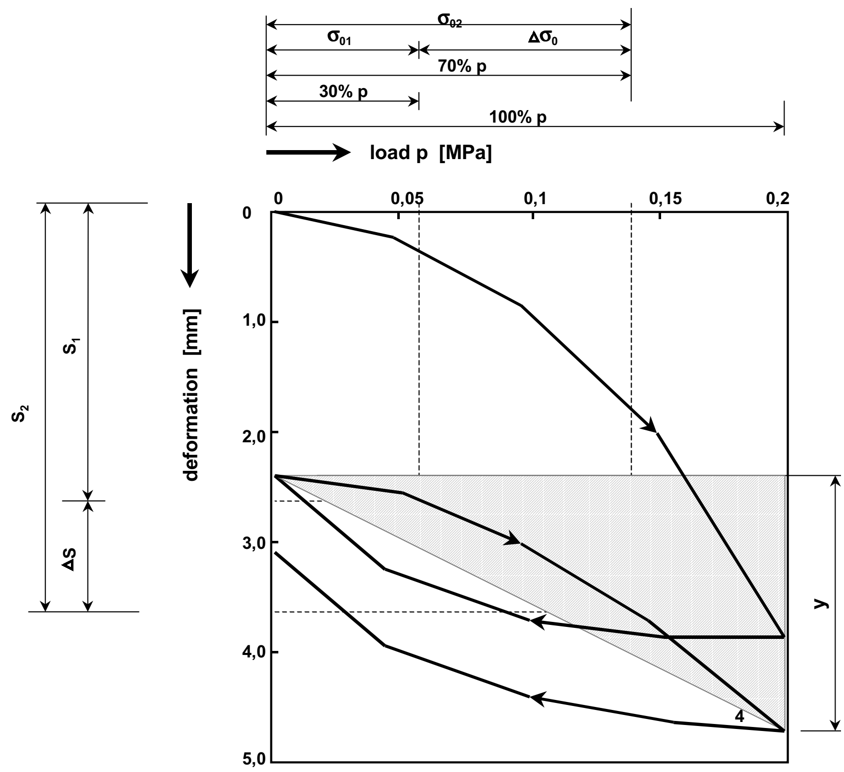

Figure 2 Modulus of deformation determination according to the DB methodology [4]

The question arose of how to sort out this contradiction (difference). Firstly there was an effort to find a relationship between the moduli Ev, 2 and Edef,2. However, this aproach was found to be impracticable, because there was insuffcent data available. From the available data there emerged quite a significant variation, which could not provide a safe and economical design. Prof. Tyc from CVUT Prague carried out an investigation, which confirmed this[4].

To solve the problem, a basic scientific approach was followed – to experiment. Test sections within the construction corridors were established, where the effect of geosynthetics reinforcement was measured. Besides these measurements, static load tests were also carried out. These compared the bearing capacity of the sub-grade and reinforced construction layers. These measurements provided step by step data, which was subsequently evaluated and is going to become the basis of a methodology for design of rigid geogrid reinforced sub-base layers in the Czech Republic.

A range of Tensar biaxial geogrids were used as the reinforcement (SS20, SS30, SS40, SSLA20 and SSLA30) together with granular material – crushed or recycled crushed stone with various particle size (0-32 mm, 0-63 mm and 0-125 mm). The thickness of construction layers varied between 300 and 500 mm. The measurements proved that the use of geogrid reinforcement is effective in areas, where the sub-grade modulus of deformation is lower than 30 MPa.

Particular sections with biaxial geogrids are sumarised in Table 3.

Regarding the whole corridor length I and II (670 km) ,125 km incorrporated reinforcing geogrids, 9 % of the existing track (rails) length. A total area of cca 500 000 m2.

Table 3. Geogrids usage at track sections in Cxeck Republic.

		locality	geogrid typ	length [m]
CORRIDOR I	railway stations	Ceský Brod	SS20	25
		Blansko	SS20, SS30, SS40	5 000
		Rajec	SS40	4 750
		Skalice nad Svitavou	SS40	7 500
		Podivin	SS20	250
		Rajhrad	SSLA30	150
		Modrice	SSLA30	200
	sections between sta-tions	Skalice nad Svitavou - Letovice	SS20	23 750
		Letovice - Svitavy	SS20	31 250
		Svitavy – odb. Opatov	SS20, SS30	15 625
		Breclav - Podivin	SS20, SS30, SS40	3 125
CORRIDOR II	railway stations	Hrusky	SSLA30	10 000
		Hodonin	SSLA30	6 000
		Staré Mesto	SS30	300
		Hustenovice	SS30	9 450
	sections between stations	Hrusky – Moravska Nova Ves	SS30, SS40	500
		Moravska Nova Ves - Luzice	SS30	1 000
		Hodonin - Rohatec	SS30, SS40	1 250
		Rohatec - Bzenec	SS40	3 000
		Napajedla – Otrokovice	SS30	750
		Prerov - Hranice	SS30	350

6 ELABORATION OF A NEW CD RULING S 4 FOR REINFORCING GEOSYNTHETICS USAGE

The geosynthetics reinforcement is a new technology in Czeck Republic, so there were some doubts at the beginning in CD. Positive experience has helped to overcome these doubts. Geogrid reinforcement has now become one of the standard methods for CD constructions and has been included into the S4 Ruling [1], which had contained only reinforcing geotextiles till that time.

The new CD Ruling S4 narrowly defines the conditions for establishment of construction layers. First of all the required bearing capacity on railway sub-base is defined with regard to track type, rail type and running speed. Also the minimum values for modulus of deformation on ground sub-grade are defined. The use of geogrid is allowed for improvement of lower construction bearing capacity.

According to [1] reinforcing geotextiles, geogrids. composite geotextiles and geocells can be used as geosynthetics reinforcement in the lower railway construction. Each geosynthetics reinforcement has according to its character, specific properties, which contribute to the improvement of railway construction layers bearing capacity.

According to [1] reinforcing geogrids and geotextiles must have these properties:

- tensile strength (transverse and longitudinal) min. 30 kN/m
- tensile strength at 3% elongation (transverse and longitudinal) min. 10 kN/m
- ductility (transverse and longitudinal) max. 20%

7 CONCLUSIONS

Geogrids became first of all a replacement for stabilisation (calcic, cement). The main reasons for this replacement were above all high rainfall, during which it was not possible to carry out stabilisation. Another reason was very low subsoil bearing capacity (E def,2 < 8 MPa) in certain sections. At these sections, stabilisation solutions was also designed, but during the project it proved to be impossible to gain access for the specialist installation equipment over the week subsoil.Geogrids provided not only reinforcing effect but also easy access onto the construction site.

Experience from the completed sections has helped to draw the following conclusions. Designs incorporating geogrid in the construction layers satisfy all the conditions required from newly established construction layers and they can be constructed during the whole year, except during extraordinary rainfalls and frosts bellow - 5 °C.

This technology has become commonly used in CD constructions these days and the CD S4 ruling refers to geogrids on an equal basis as the other traditional methods used for bearing capacity improvement.

8 REFERENCE

[1] Ruling CD S4 “Zeleznicni spodek” (updated 1997)
[2] Czech Code CSN 72 1002
[3] Beckmann, Projekt 752 Tensar Geogitter im Straβenbau
[4] German Code DIN 18 134 Plattendruckversuch, 1993
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