23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

SHEAR FORCES OF THE APPROACH SLABS OF THE ROAD BRIDGES

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Abstract: *The transition zone of the road bridges is located right behind the abutment. Function of this structure is to ease the vehicle transition from the bridge on the rigid support to the embankment with much smaller subsoil stiffness. Very important element of the transition zone structure is the approach slab. It is the reinforced concrete slab, which by its longitudinal span overcomes the uneven settlement of the bridge abutment and the embankment. This paper is focused on the shear forces caused by traffic loads represented by uniform distributed load (UDL) and tandem systems (TS) according to European standards. The results from the model with spring area support are also compared with conservative model.*

Keywords: Approach slab, Transition zone, Shear forces, Springs with gap.

1. Introduction

The approach slab is designed to compensate the different settlement of the bridge abutment and a road embankment. In Fig. 1 the typical cross section of the transition zone can be seen.

Driving comfort can be interrupted by the so called "bump" on both ends of the bridge. These disorders caused by the exceeded size of the different settlements should be eliminated by the approach slabs. When the settlement difference is increasing, the structural scheme of the slab is also changing and shear forces and bending moments are higher.

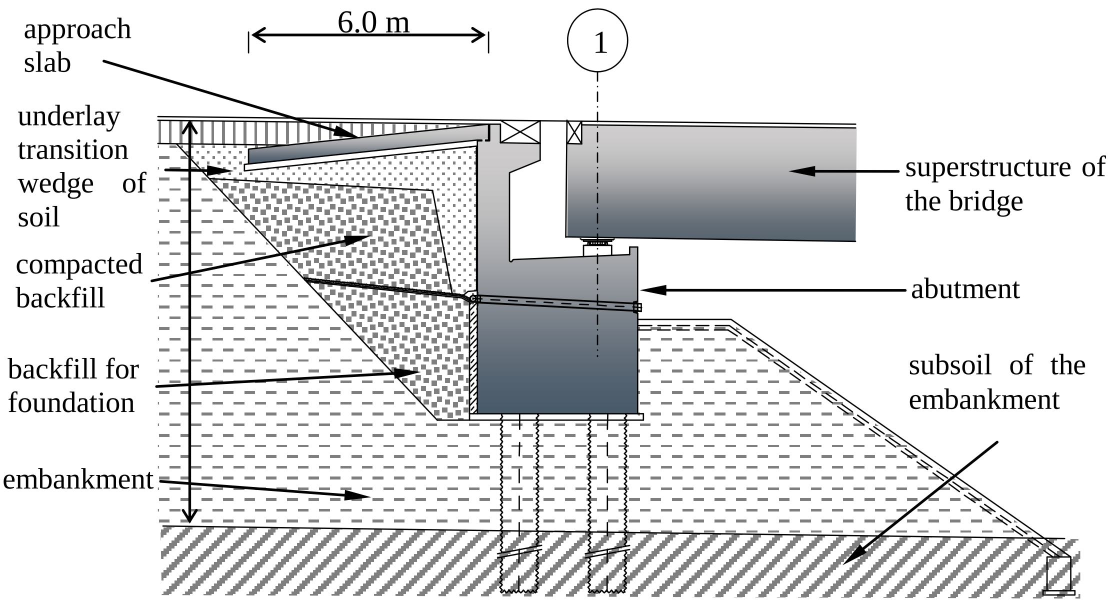

Fig. 1: Typical cross-section of the transition zone.

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2. Structural Model of the Approach Slab

Simplified structural model can be represented by the slab with hinged line support in the place of the connection to the abutment and another line support at the free end of the approach slab. Description of the structural scheme of the approach slab is difficult, because it is changing during its life span. Right after the completion of the bridge and transition zone construction the scheme can be described with hinged line support representing the joint with the abutment and the bottom area is supported by subsoil (which can be modelled as springs with constant stiffness). After the bridge opens to traffic the slab and its subsoil have to resist the cyclic action caused by trespassing vehicles. The uneven settlement is increasing, what can cause the gap creation under the slab. There are also another reasons such as consolidation of the subsoil, or accidental situation (e.g. washout of the fine particles). Possible structural schemes are shown as sections in Fig. 2. Fig. 2a is scheme with constant area stiffness, Fig. 2b with linear changing stiffness, Fig. 2c simplified, Figs. 2d and 2e based on support reaction forces.

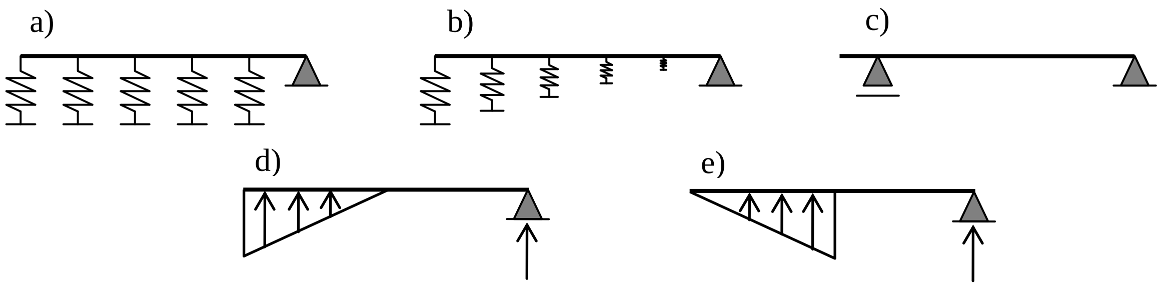

Fig. 2: Alternative structural schemes and models of the approach slab (right end – connection with abutment, left end – free end of approach slab).

3. Numerical Model of the Approach Slab

Fig. 3 represents the numerical model in FEM software SOFiSTiK. The approach slab is modelled by 2D elements with defined concrete and reinforcement properties. The main bottom reinforcement along the span of the slab is Φ16 with 125 mm spacing. The other layers of the reinforcement are Φ10 with 200 mm spacing. The length of the slab is 6.0 m, width 11.75 m and thickness 0.3 m. Thickness and the bars of the main reinforcement were chosen according to previous study (Laco, Borzovič 2016) performed on conservative scheme.

By current Slovak technical specifications for the design of the transition zones (OTN 73 6244, 1981) the gaps of the springs were chosen. Allowable change of the slope of the approach slab is 0.4 % for the highways and motorways with the speed limit above 80 km/h. For the other roads it is 0.8 %.

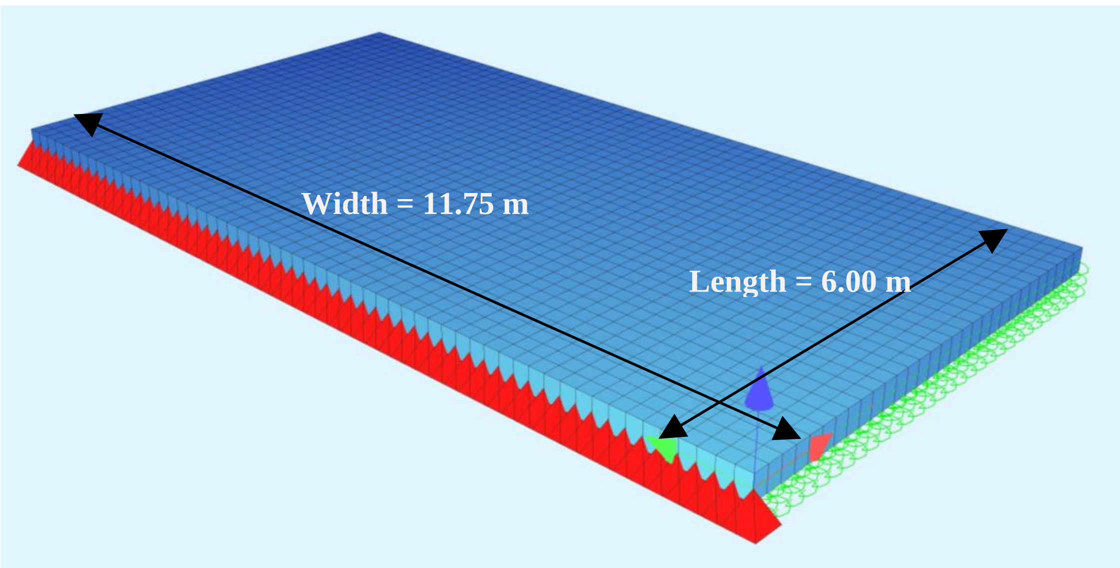

Fig. 3: Numerical model of the approach slab.

Properties of the springs were set for well graded gravel with modulus of subgrade reaction of 22 MN/m^3. Transverse spring stiffness value is multiplication of the factor 0.4 and axial stiffness. Values of the gaps of the springs have linear function from maximum in the line hinged support to 0 at the free end of the slab. Two cases were analysed, with maximum gap 24 mm for 0.4 % change of the slope and 48 mm for 0.8 % change.

The load for the analysis was represented by TS and UDL with two alternatives of the notional lane system distribution. The first, with the most loaded lane at the edge of the slab. The second, placing the heaviest traffic load in the middle. Each of the alternatives has 20 load cases for different position of the TS along the slab.

4. Analysis of the Shear Forces of the Approach Slab

The main goal of the analysis was to verify whether the values of the shear forces on the conservative structural scheme has unfavourable results as the slab supported by springs with gap.

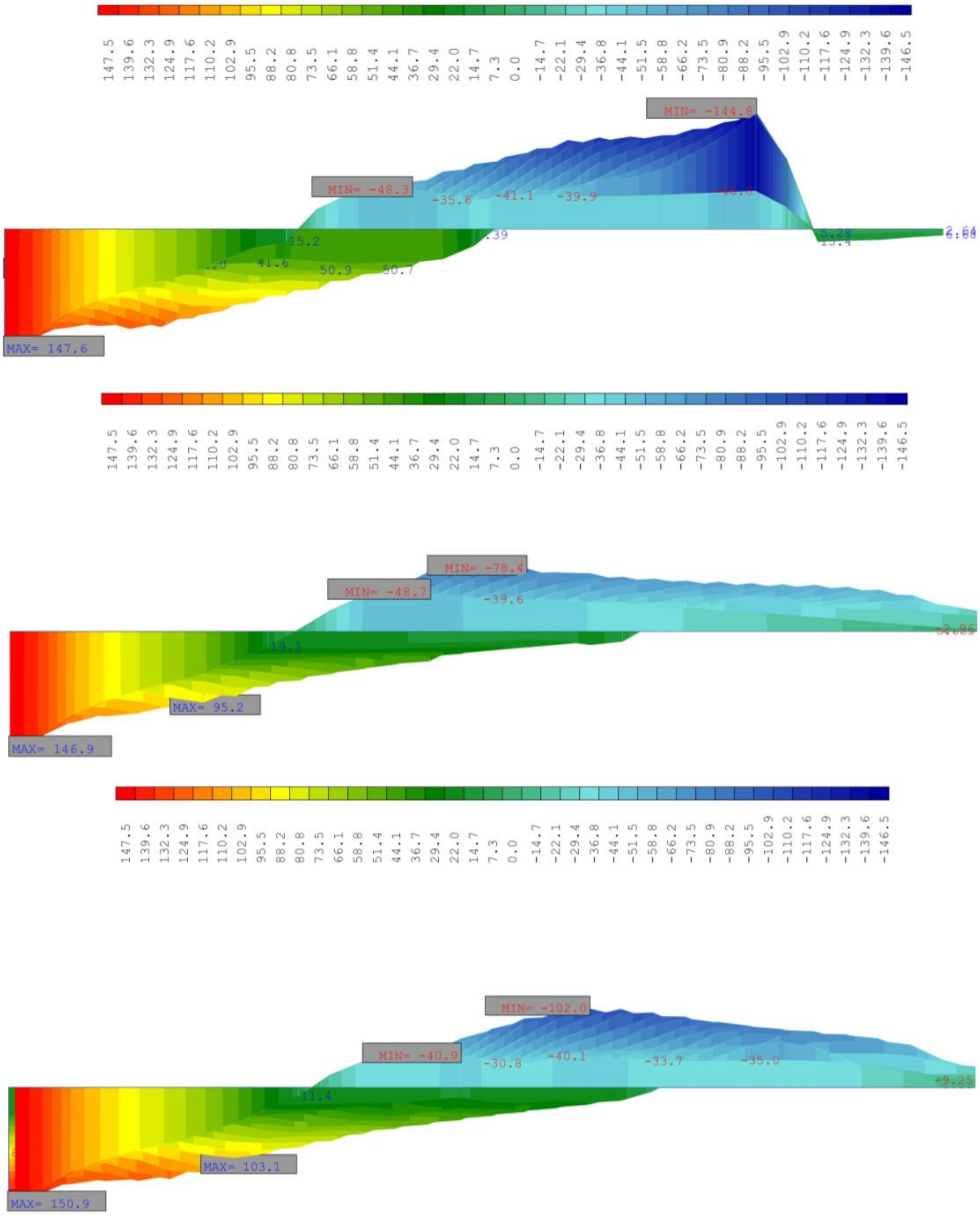

Fig. 4: Envelope of the shear forces v-x [kN/m] in the axis of wheel of the TS (from above: 1 - on simplified scheme, 2 – 0.4 % change of slope, 3 - 0.8 % change of slope).

In Fig. 4 envelopes of the shear forces along the slab are presented. The cut is placed in the axis of most loaded wheel of TS. Three cuts are from alternative, where the most loaded lane is in the middle of the slab. Similar results are also in the second alternative.

The main difference of the gap model and simplified one are the concentration of the shear forces near the free end. The gap model has more realistic distribution of the forces near the free end. Minimum values for the model with 0.4 % change of slope are all below values of the simplified model. In model with 0.8 % change of slope the values of the shear forces are much closer to simplified, especially near the middle of the slab. The peak is distributed because of area spring support at the free end. The gap model is also showing the behaviour of the supporting springs. In Fig. 5 can be seen, that with TS located in the middle of the slab, spring forces below the slab are creating similar pattern as structural scheme in Fig. 2e.

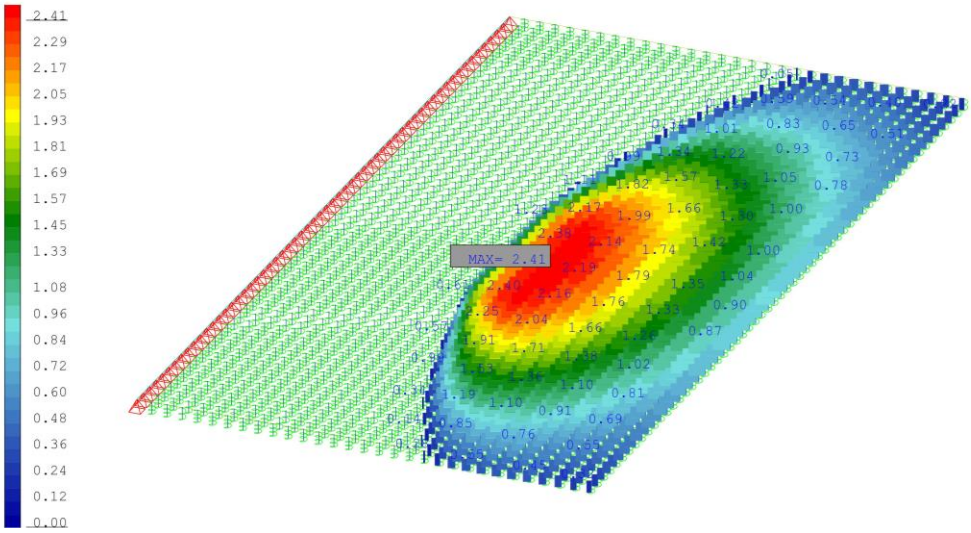

Fig. 5: Supporting forces of the activated springs [kN].

5. Conclusion

Using the simplified scheme for the shear reinforcement design is time-effective and apart from the concentration of the shear forces at the free end of the slab not so exaggerated. For the approach slabs used on roads with speed limit of 80 km/h values for conservative and gap model are very similar.

Chosen conservative scheme with linear support with the distance Length/6 from the free end chosen in previous work (Laco et al, 2016) seems to be suitable also for the shear reinforcement design. Although for the parametrical study and calculations for the possible change of the current Slovak technical specification for the transition zone design (OTN 73 6244, 1981) the gap model will be used.

Extensive parametrical study, where various lengths, subsoils and widths will be used, will serve as the background for the preparing tool for the structural engineers. The tool will help designers to choose suitable structural scheme, but also for quick design graphs, schemes and tables for geometry, bending and sheer reinforcement design will be available.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the contract No APVV-15-0658 and by the University Science Park (USP) of the Slovak University of Technology in Bratislava (ITMS: 26240220084).

Authors gratefully acknowledge technical support provided by companies YIT Reding and Geoexperts.

References

Laco, K. and Borzovič, V. (2016) Design of Approach Slab of Road bridges, in: Solid State Phenomena : selected, peer reviewed papers from the 22nd International Conference Concrete Days 2015, Litomyšl, Czech Republic. Vol. 249, (2016), ISSN 1012-0394, pp. 215-220.

OTN 73 6244 (1981) Transition zones of the roadway and highway bridges. Praha, (in Slovak).