INTEGRAL BRIDGES - LENGTH LIMITATION, TRANSITION SLABS, EXAMPLES

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Summary: *Integral abutment bridges are becoming popular in Europe, mainly due to long term reduced maintenance costs. The lack of bearings and expansion joints means that the consumables are eliminated ensuring a longer life span of the structure and minimizing the need of human intervention.*
Most integral bridges usually have small or middle lengths, but in the last years longer bridges are being built. Special attention should be given to the soil-abutment interaction, as the bridge lengthens and shortens during the day and during the year, due to temperature differences and loading. Therefore the soil structure should accommodate the cyclic movements of the abutment and avoid settlements and cracks. Transition slabs are also key elements and targeted design can improve the behavior of the bridge.
In the past years several integral bridges were built in Romania. The paper presents examples with bridges from the Romanian Motorway system, addressing the specific needs and adopted solutions in regard to their lengths.

Keywords: *Integral abutment, jointless bridge, transition slab*

1. INTRODUCTION

The traffic volume today is high and deterioration of consumables used in the bridge construction is expected at close intervals. Integral bridges offer the solution to the problems posed by the use of bearings and cover equipment for expansion joints, especially when thinking long term, by eliminating all joints. It is easy to see why many countries seek to implement integral bridges on their transport infrastructure, as they offer easy, cost effective maintenance and at the same time are robust structures.

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In the United States of America (USA) integral and semi-integral bridges were introduced decades ago and at present there are more than 13000 such structures [1]. Europe has gained experience in the last years, the United Kingdom now uses frequently integral bridges for lengths up to 60 m and counties such as Germany, Switzerland and Austria are now publishing design manuals [2]. Poland is also a good example, having already built many integral bridges since the year 2000 [3].

Romania is currently constructing its Motorway system and engineers have the opportunity to build new and modern structures. In December 2013 the Orăștie-Sibiu lot 1 was finished and all bridges are integral (26 structures), with one exception which is a semi-integral bridge [4]. At present a Motorway section under construction, Sebeș-Turda lot 2, has 18 integral and 3 semi-integral bridges.

Integral bridges (Figure 1) are jointless and therefore do not have bearings and expansion joints. In addition to the fact that this is an initial cost saving, the usual maintenance or replacement of these consumable equipment becomes obsolete and corrosion resulting from leaking joints is eliminated. Because integral bridges are frame structures, the decreased moments in the field area allow a more economical deck conformation. The substructure is connected to the superstructure and the structure acts as a whole. The substructure should accommodate the expansion of the superstructure occurring due to loading or temperature changes.

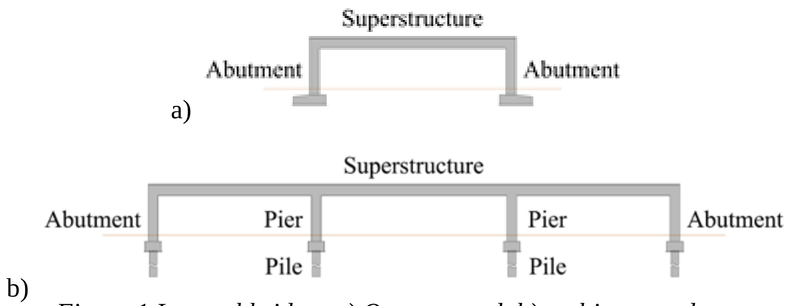

Figure 1 Integral bridge: a) One spanned, b) multi spanned

Fully frame structures are used mainly for small to middle lengths. For long bridges with bigger expansion expectations semi-integral structures (Figure 2) can be used. The definition of such structures differs depending on the country, in the USA and in some European countries semi-integral structures have at the abutments either expansion joints or bearings. In Germany a bridge is considered semi-integral if it is not integral and if in at least 2 axes the piers are monolithically connected to the superstructure, while the abutments and the remaining piers have bearings [5]. In Romania there is currently no official definition for semi-integral bridges, and this paper uses the German one.

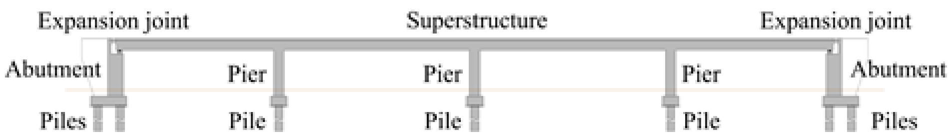

Figure 2 Semi-integral bridge

2. LENGTH LIMITATION

Most integral bridges usually have small or middle lengths. Europe already has a vast experience building integral bridges with lengths up to 50…60 m using concrete, pre-stressed or steel-concrete composite superstructures. In the last years progress has been made and longer integral bridges with lengths up to 100 m were constructed.
The transition slab is designed to improve the balance of the vertical and horizontal relative displacements at the structure ends. Expansion joints placed between the abutment and transition slab may be used to avoid cracks. Soil stabilization measures can be taken to prevent settlements. The piers contribute also to the general behavior of the bridge. The pier design should consider both the external loads and be stiff and the temperature respectively shrinkage and be flexible to enable expansion and contraction. In chapter 4 examples of bridges with different lengths are presented.
There is no imposed length limitation for integral bridges, but the longer the bridge, the bigger the longitudinal deformations. Innovative abutment-soil transition systems can be used, but from a certain length settlements and cracks in the road structure are hard to avoid.
Semi-integral bridges can be used when bigger longitudinal deformations are expected. Bearings and/ or expansion joints placed at the abutments can accommodate larger deformations.
A viaduct over railway and national road from the Orăștie-Sibiu lot 1 motorway section in Romania is a semi-integral structure with a total length of 240 m (Figure 3). All piers are monolithically connected to the superstructure and bearings and expansion joints are placed only at the abutments. Compared to a classic deck solution with bearings at each substructure elevation, replacements of cover equipment and bearings over time were reduced significantly, considering that the structure has a total of 8 bearing axes.

Figure 3 Semi-integral bridge on Orăștie-Sibiu lot 1

3. END OF THE BRIDGE. TRANSITION SLABS.

Bridges lengthen and shorten during the day and during the year, due to temperature differences and loading. The length variations of integral bridges are similar to the conventional bridges despite constraints [5]. Through cyclic movements of the integral abutments progressive consolidation of the backfill is triggered and settlements and

cracks may occur. The soil structure should accommodate the cyclic movements of the abutment, but for longer bridges transition slabs (approach slabs) are recommended.
The displacement length of the abutment wall determines the type of backfill and transition slab. Countries like Germany [5] and Switzerland [6] offer design indications for transition slabs. The German norm proposes different types of designs in accordance with the length of the bridge, the expansion, the deck type and the traffic category (Table 1). Small bridges are not required to have transition slabs.

Table 1 Simplified representation of the area of application for transition slabs [5]

Type of transition slab	Expansion [mm]	Bridge length for symmetrical structures [m]		
		Presstresed concrete	Reinforced concrete	Steel-concrete composite
Type I	≤ 25	≤ 50	≤ 60	≤ 65
Type II	≤ 37,5	≤ 50	≤ 60	≤ 50
Type III	≤ 65	≤ 95	≤ 115	≤ 130

The type I (Figure 4) transition slab is connected to the abutment by an articulation using crossed reinforcement. In type II (Figure 5) an asphaltic plug joint is placed between the abutment frame corner and the transition slab, while the transition slab is still articulately connected to the abutment. Type III (Figure 6) uses a joint cover equipment embedded in concrete between the abutment frame corner and the transition slab. In this case the transition slab is separated from the abutment using a gliding material between the two concrete surfaces.

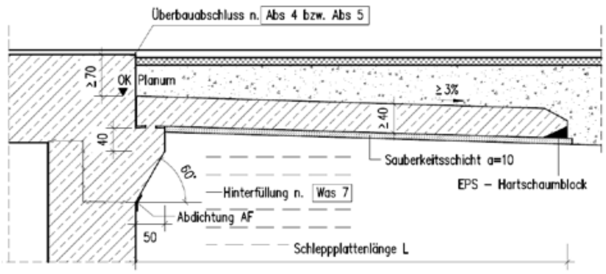

Figure 4 Transition plate Type I from the German drawing code [5]

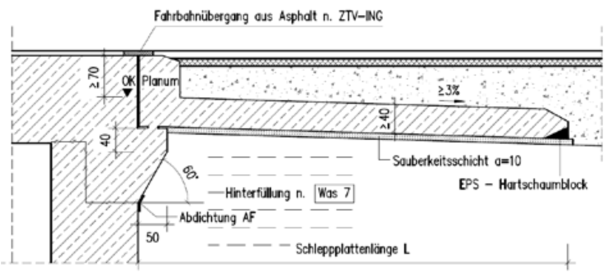

Figure 5 Transition plate Type II from the German drawing code [5]

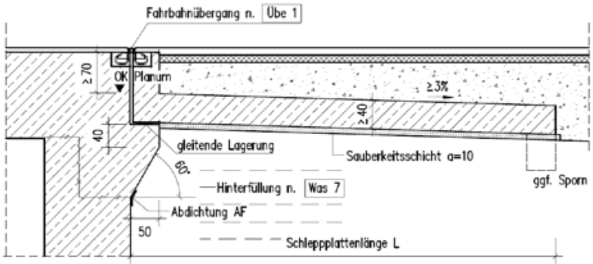

Figure 6 Transition plate Type III from the German drawing code [5]

In the Swiss norm [6] for short integral bridges with small abutments no transition slabs are provided. Short bridges with higher abutments will use the type I4 transition slab and longer straight bridges will use type I3 (Figure 7). The types I3 and I4 have a flexible conformation. Structures with pronounced curvature will use a stiff connection for the transition slab.

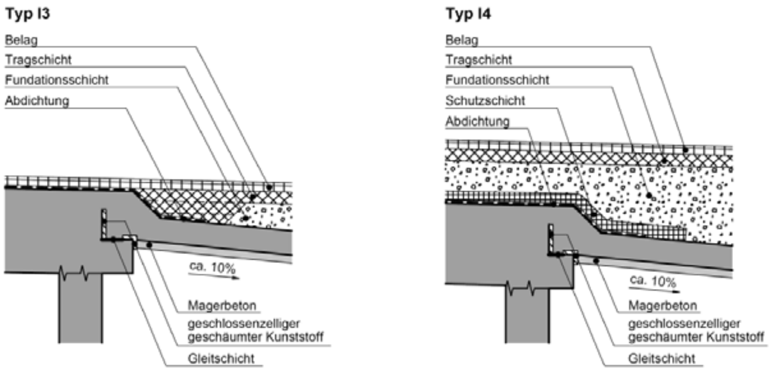

Figure 7 Transition plate from the Swiss construction details (left – Type I3, right – Type I4) [6]

4. INTEGRAL BRIDGES IN ROMANIA

The following examples are from the Romanian Motorway and are located on the sections Orăștie-Sibiu lot 1and Sebeș-Turda lot 2. They present general details about integral motorway underpasses, overpasses and bridges. A total of 44 integral bridges were built on these motorway sections. Except for the underpasses all the structures were initially planned as classical deck bridges with bearings and expansion joints, but in the end didn't comply with the financial forecast and the tight schedule. They were redesigned as either integral or semi-integral.

Motorway underpasses were designed as box bridges (Figure 8) and have the following characteristics:

- They are simple concrete frame structures.
- They have one or two spans with lengths up to 12 m.
- They may have prefabricated precast slabs or small height girders for the deck.

- Direct foundation.
- No transition slabs were used.
- Road structure above.

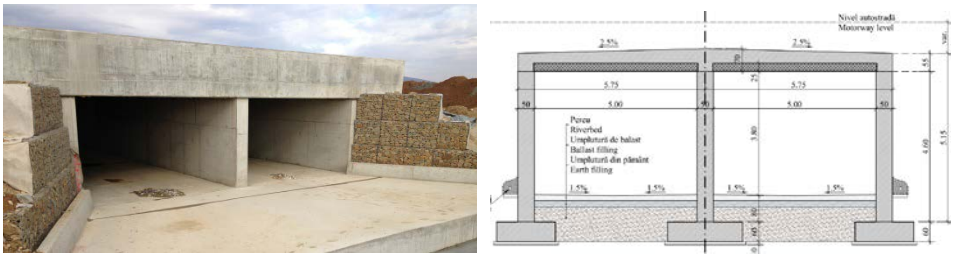

Figure 8 Motorway underpass, box bridge with 2 spans

While in Romania it is usual to design underpasses as frame structures, the integral solution for longer bridges has only recently been introduced.
Motorway overpasses (Figure 9) were designed as one spanned bridges, with no middle support between the motorway lanes. The length of the span was chosen after accommodating the requirements of the Beneficiary. In case of the Motorway Orăștie-Sibiu lot 1 the span is ~36 m and in case of the Sebeș-Turda lot 2 the span is ~40 m.
The deck is made of either prefabricated prestressed girders or composite girders. Prefabricated slabs with small height of 8 - 10 cm were placed between the girders and act as formwork for the in situ concrete slab.
Indirect foundations with bored reinforced concrete piles with a diameter of 1,20 m were used. The piles were arranged in one row in longitudinal direction, to permit an elastic behavior of the frame structure. For the section Orăștie-Sibiu lot 1 (Figure 10, left) foundation slabs were used at the top of the piles. For the newer project Sebeș-Turda lot 2 (Figure 10, right) no foundation slabs were used, placing the abutment wall directly on the pile heads. Leaving out a construction phase, reinforcement and time were spared.
The abutments are 1,50 m wide and have a simple wall shape made of in situ concrete. After placing the prefabricated girders and slabs, the frame corner was concreted along with a portion of the slab and the back walls. The back walls shall not interfere with the relative displacements of the abutment and have only the height of the frame corner. Lastly the remaining slab area was poured. All concrete elements from previous phases are provided with connection reinforcement to ensure a unitary structure. Transition slabs are connected to the frame corner with an articulation and positioned at a distance from the road level.

Figure 9 Motorway overpass, Composite integral bridge L = 39 m

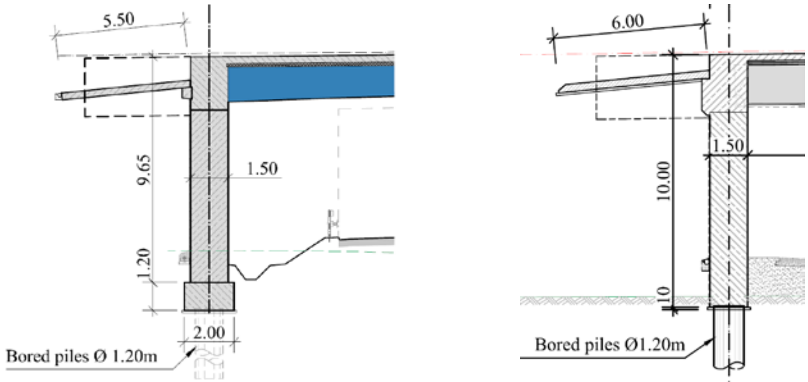

Figure 10 Abutments. Left – Orăștie-Sibiu lot 1. Right – Sebeș-Turda lot 2

Motorway bridges are made of 2 parallel structures, one for each driving direction, with common abutments. One spanned bridges were designed similarly to the motorway overpasses (Figure 10).

Figure 11 One spanned motorway bridge, deck with prefabricated prestressed girders

Multi spanned bridges with lengths up to ~ 100 m were also designed as integral bridges. The piers are made of slender columns resting on a common foundation plate. On top they have a cap beam for supporting the prefabricated girders during the construction phase. The pier heads are concreted to create the frame structure (Figure 11).

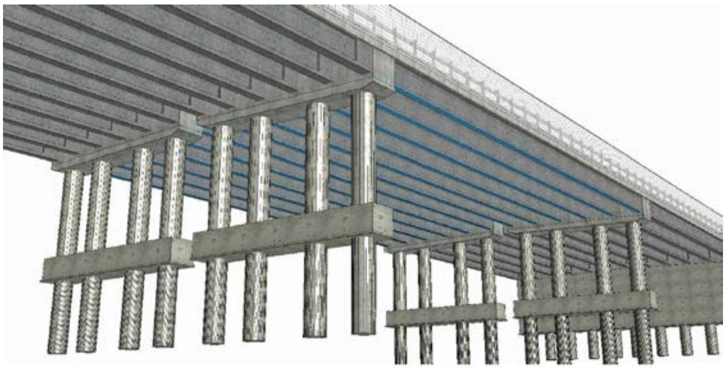

Figure 12 3D model of three spanned integral bridge with pier view, L = 103 m

When the length of the integral bridge was bigger than 70 m the transition slab was separated from the abutment using elastomeric supports or steel plates and asphaltic plug joints were placed at the abutment ends (Figure 12).

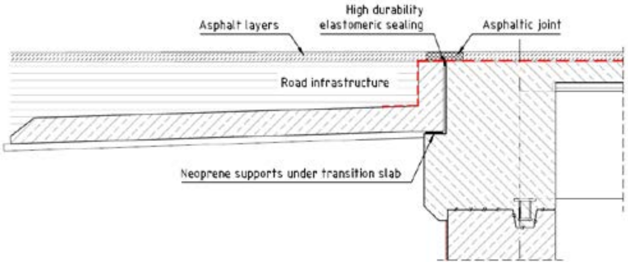

Figure 13 Transition slab for bridges with lengths bigger than 70 m

5. CONCLUSION

Integral bridges offer improvements in maintenance and construction costs compared to traditional bridges. Slender, elegant and yet robust structures can be designed by giving up on bearings and expansion joints. Semi-integral structures are an alternative option when fully integral structures cannot be used, maintaining some of the advantages by reducing the number of joints. In many European countries design codes for such structures have not yet been released, but knowledge in the field is available and building integral or semi-integral bridges is possible. The experience with such structures in Romania was positive and new developments are expected.

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