Evaluation of the bridge Champangshiel by using static assessment methods

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Abstract

The evaluation of existing buildings regarding their bearing capacity and serviceability is very important today. Especially for bridges, which become increasingly older, the assessment of the remaining useful life and the detection of possible damages become more and more relevant. The investigation of the current state of a structure is normally based on visual inspections and continuous monitoring, which are costly and time consuming.

Therefore, the University of Luxembourg carries out a project to investigate an efficient application of different assessment methods taking into account praxis relevant test conditions. One part of this project is the practicability use of non-destructive testing methods to investigate bridge structures. These results are compared to the evaluation of a structure by in situ loading tests.

Within this paper the results of in situ loading tests of a two span box girder bridge in Luxembourg, which was destined to demolition after the performed tests due to urban transformation, are analysed in order to describe the approach. Different damage scenarios, realized by cutting of a defined number of tendons, were elaborated and, for each damage scenario, static load tests performed. The results of these loading tests will be presented by analysing the load-deformation behaviour.

1 Introduction

Today, more and more buildings come to the end of their calculated utilisation period. But normally the local authority has not enough money to replace these old constructions precautionary with new ones. So bridge inspections and the assessment of the current state of the structure become more and more important today. In the past the current status of a bridge was determinate by periodic visual inspections, by a continuous monitoring and if necessary by an object-related damage analysis together with a static calculation. However this kind of investigation and especially the detailed inspection are time consuming and cost intensive. For that reason, the University of Luxembourg investigates an efficient non-destructive way of bridge inspection by using static, dynamic and non-destructive testing methods.

As a part of this project, the University of Luxembourg investigates efficient use of in-situ load tests to evaluate the condition of a construction. Normally in-situ tests are used to determine the maximum load bearing capacity of a construction. In this project, in-situ load tests are used to detect a damage of a structure. To reach this goal the University got the possibility to damage a structure and investigate its structural behaviour with increasing damage. The here analysed bridge, which is called Champangshiel, was destined to demolition after the performed tests due to urban transformation [1].

1.1 Bridge description

The investigated bridge is a prestressed concrete box girder bridge, which was built from 1965 to 1966 (Fig. 1). It is a straight longitudinal bridge with a total length of 103 m, which is separated in two different spans. The large span is 65 m and the short one 37 m long between the axis of the bearings. For the static calculation a total length of 102 m is used (Fig. 2). Primarily the superstructure was made of prestessed concrete including 32 parabolic, 24 upper straight lined and 20 lower straight lined tendons. Additional to these tendons, 56 external prestressed steel cables were added inside the box girder in the large field in 1987 (Fig. 3).

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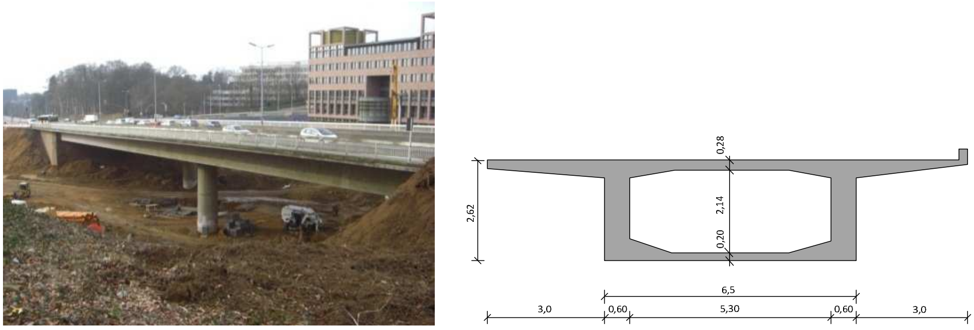

Fig. 1 Side view of the bridge (left) and cross section (right)

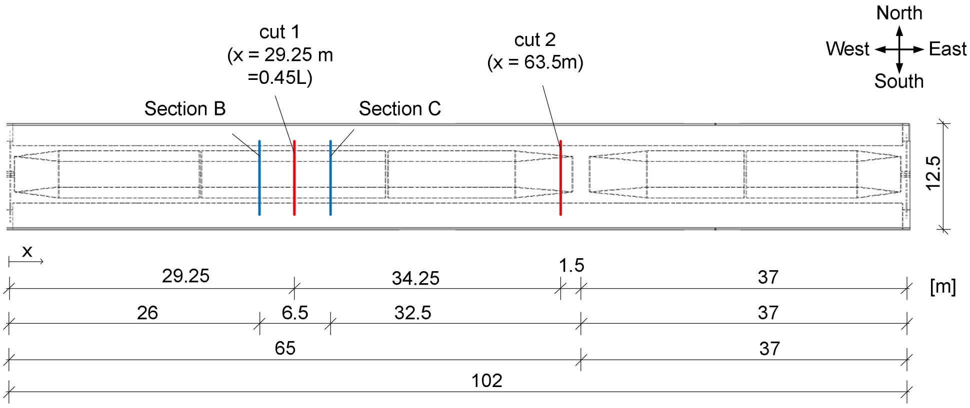

Fig. 2 Longitudinal section of the bridge

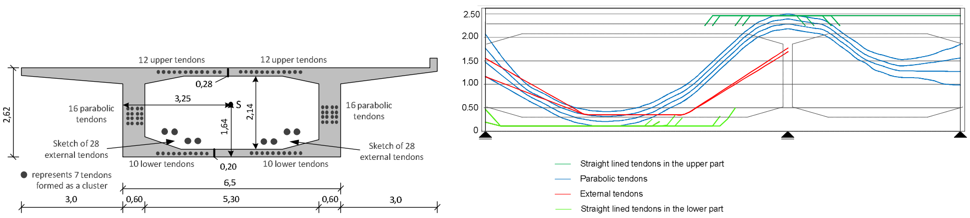

Fig. 3 Cross section of the box girder with the description of the tendons (left) and longitudinal schematic view of the prestressed tendons (right)

2 Executed tests

To evaluate the possibility of damage detection by using an in-situ load test, the superstructure is gradually damaged. The artificial damage is produced by cutting a defined part of the prestressed tendons. This should simulate a local loss of pretension and a local sectional weakening. During the whole test period, four different damage scenarios are realized to observe the reaction of the bridge to an increasing damage (Table 1). These damages are created at different positions of the superstructure to investigate, if this influences the detectability of damage. For each damage scenario an in-situ load test is accomplished. For a constant load in each damage scenario, the superstructure is loaded by 38 steel beams, which means 245 t. The centre of this experimental load is positioned in x = 0.45•L (Figure 4), which corresponds to the section where the first damage is created. The experimental load is removed before the next damage is created.

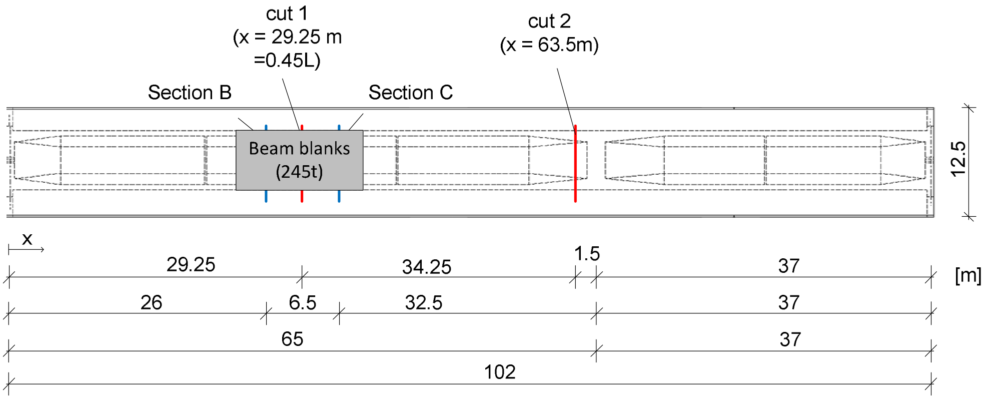

Fig. 4 Position of the steel beams

Before the first damage could be created, the initial state of the superstructure was measured. Therefore, a first in-situ load test is done in the undamaged state (damage scenario #0).

The first damage (damages scenario #1) is created by cutting 20 straight lined tendons in the lower part of the superstructure. The position of this damage is in the large field at x = 0.45•L (cut 1 in Figure 2). As second damage scenario, eight straight lined tendons in the upper part of the superstructure are cut (damage scenario #2). The tendons are cut 1.5 m away from the pylon axis (cut 2 in Figure 2). The third damage state (damage scenario #3) is created by cutting the external tendons. The tendons are cut by a flame cutter from the upper side of the superstructure through a hole in the top plate of the box girder (at the position of cut 2). Finally, a fourth damage scenario (damage scenario #4) is created by cutting the last 16 straight lined tendons in the upper part of the bridge and 8 parabolic tendons. This damage is also produced from the upper side in the section of cut 2. In the following evaluation damage scenario #4 is not considered because the displacement transducers are removed after the third damage scenario (damage scenario 3). All damage scenarios are summarized in table 1.

Table 1 Description of the damage scenarios

Damage scenario	Damage
#0	Undamaged state
#1	Cutting all 20 straight lined tendons in the lower part of the bridge (bottom plate of the box girder) at 0.45•L
#2	Additional cutting of 8 straight lined tendons in the upper part of the bridge (top plate of the box girder) over the pylon
#3	Additional cutting of the external tendons
#4	Additional cutting of 16 straight lined tendons in the upper part of the bridge (top plate of the box girder) and also 8 parabolic tendons

3 In-situ load test

3.1 Load cases

For each damage scenario, the loading and unloading of the superstructure define already two different load cases. Furthermore, respectively a load case is related to the time-dependent behaviour of the bridge after each cutting, loading and unloading. Table 2 describes these five different load cases for each damage state.

Table 2 Description of the load cases

Load case	Damage scenario	Description
#0	#0	Initial measurement
	#0-L	Measurement after the bridge was loaded
	#0-L-Cr	Measurement 19 h after the bridge was loaded
	#0-U	Measurement after the bridge was unloaded
	#0-U-Cr	Measurement 30 minutes after the bridge was unloaded
#1	#1	Measurement after the first cut
	#1-Cr	Measurement 44 h after the first cut
	#1-L	Measurement after the bridge was loaded
	#1-L-Cr	Measurement 19 h after the bridge was loaded
	#1-U	Measurement after the bridge was unloaded
	#1-U-Cr	Measurement 94 h after4 the bridge was unloaded
#2	#2	Measurement after the second cut
	#2-Cr	Measurement 19 h after the second cut
	#2-L	Measurement after the bridge was loaded
	#2-L-Cr	Measurement 18 h after the bridge was loaded
	#2-U	Measurement after the bridge was unloaded
	#2-U-Cr	Measurement 27 h after the bridge was unloaded
#3	#3	Measurement after the third cut
	#3-Cr	Measurement 19 h after the third cut
	#3-L	Measurement after the bridge was loaded
	#3-L-Cr	Measurement 20 h after the bridge was loaded
	#3-U	Measurement after the bridge was unloaded
	#3-U-Cr	Measurement 20 h after the bridge was unloaded
#4	#4	Measurement after the fourth cut

L = loaded state
U = unloaded state
Cr = consideration of the time-dependent behaviour

3.2 Additional cracks in the superstructure

Additional to and as a function of the artificial damage, cracks in the superstructure can be observed during the tests. The first cracks appear in load case #1, during the cutting of the tendons, and are limited to the bottom plate (Figure 5). The first bending crack can be observed after the structure is loaded in this damage state (load case #1-L). In this load case a crack can be seen in both sidewalls of the box girder (Figure 5).

In damage scenario #2 no crack can be visually detected. The next cracks appear in damage scenario #3, during cutting the external tendons. More cracks in the bottom plate and especially in the sidewalls can be seen (Figure 5). The first cracks in the top plate appear in damage scenario #4.

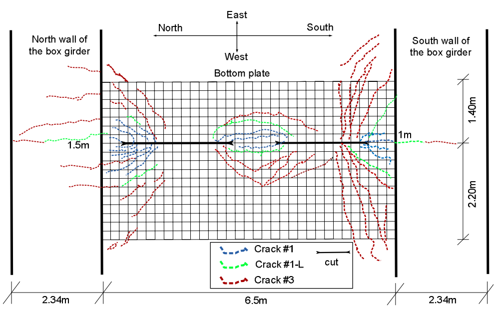

Fig 5 sketch of the cracks after damage scenario #1, #1-L and #3 at 0.45L [1]

3.3 Vertical deflection

To evaluate the structural behaviour, the vertical deflections of the superstructure are measured by two displacement transducers (S_{axisB} and S_{axisC}) in two sections (section B and section C) during the whole test period. Section B is the position of the maximum bending moment at x = 0.40•L. Section C is the middle of the large field (x = 0.50•L). Additionally, the vertical deflection is measured at six sections (section A to F) by a digital levelling (Figure 6). This kind of measurement is executed for several times (one measurement for each load case).

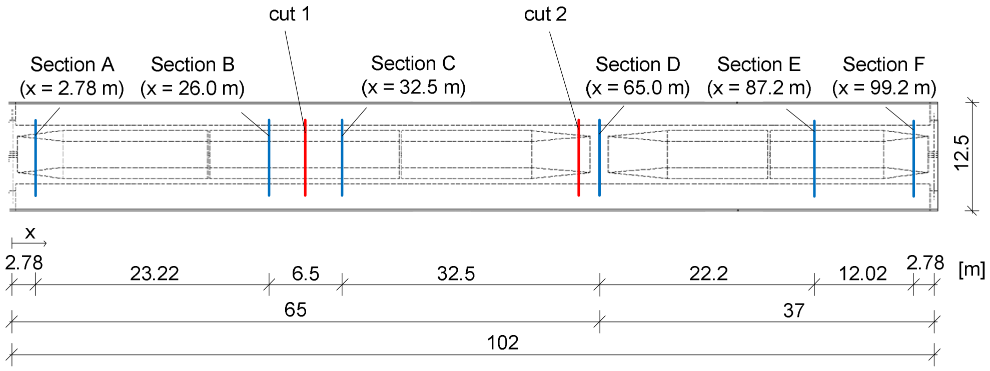

Fig. 6 Position of the measurement sections

Figure 7 illustrates the vertical deflection measured by the displacement transducers for the whole test period including the temperature variations. The two upper lines present the deflection in section B (S_{axisB}) and section C (S_{axisC}). The four lower lines present the variation of the air temperature and the variation of the temperature of the construction measured in section C. The construction temperature is measured in the top plate, the bottom plate and both sidewalls of the box girder.

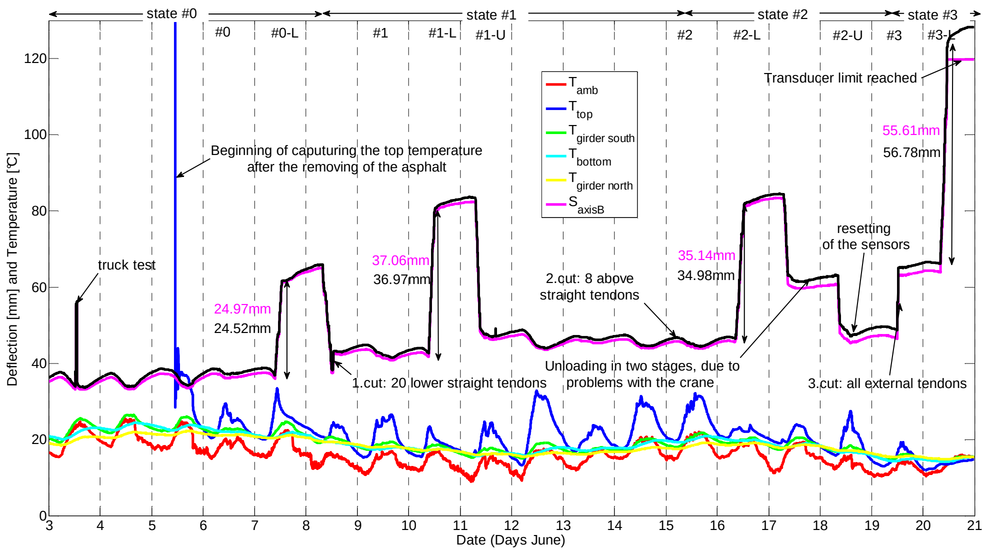

Fig. 7 Vertical deflection measured by a displacement transducer in section B (S_{axisB}) and C (S_{axisC}) and temperature changes during the test period

Figure 7 presents that every loading in each damage scenario lead to an increase of the vertical deflection. In the undamaged state, the loading leads to an increase of 24.97 mm in section B. In damage scenario #1 the vertical deflection increases of 37.06 mm as result of the loading. So, after the first damage and after the first observed cracks, the vertical deflection resulting from the loading is

12.09 mm higher than the deflection in the undamaged state. The vertical deflection in damage scenario #2 (when no crack could be detected) increases of 35.14 mm due to loading, which is less than in damage scenario #1. In damage scenario #3, the loading leads to an increase of the vertical deflection of 55.61 mm. In this scenario more cracks in the bottom plate and in the sidewalls can be observed.

A view to the vertical deflection measured by digital levelling in section A to F shows the same than the displacement transducer. Figure 8 illustrates the vertical deflection curve of the superstructure measured by digital levelling for the loaded structure.

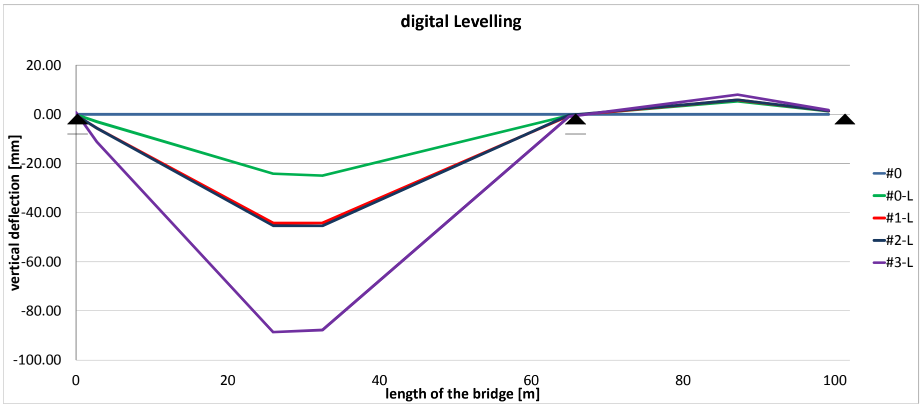

Fig. 8 schematic vertical deflection curve for the loaded superstructure measured by digital levelling

It can be seen that there is nearly no difference between the deflection curve of load case #1-L and #2-L.

The analysis of the vertical deflection in the unloaded state shows a clearly increase due to damage scenario #1 and #3 (Figure 7). In contrast to this, the artificial damage scenario #2 does not lead to an increase of the vertical deflection. Figure 7 also presents that the vertical deflection, which results from temperature changing, is larger than the vertical deflection of such a small damage like damage scenario #2.

4 Conclusion

It has been shown, that high damages like damage scenario #1 or #3, which leads to cracks in the superstructure, could be detected by measuring the vertical deflection. The loading of the superstructure amplify this effect. However, a small damage like damage scenario #2 could not be detected. Here the influence of the temperature changing could be higher, so that it is important to know its influence prior to all test result evaluations. This means, that the knowledge about the behaviour of the structure for different temperatures is necessary.

References

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