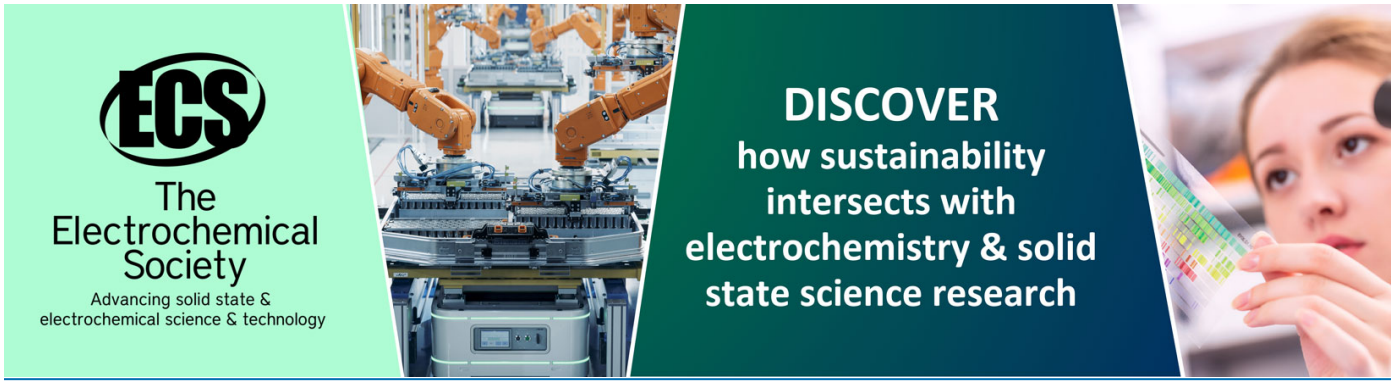
Viaduct Over The Lorupe Ravine



VIADUCT OVER THE LORUPE RAVINE

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Abstract. On the 20th July 2018, it was the 50th anniversary of the day when the Lorupe viaduct was opened. Its idea, design and construction were a significant turning point in bridge construction in the whole Soviet Union. In the comparatively small Republic of Latvia it was a unique project that required a lot of boldness and skills of road workers. Therefore, construction of this bridge is memorable, especially since several bridges were built using this technology later in the former Soviet Union. Latvian road workers with their courage, creative and meticulous work implemented a European scale project in difficult, constrained circumstances.

Keywords: Viaduct, ravine, longitudinal sliding, flexible piers, courage.

Introduction

More than fifty years ago, on the 20th July 1968, viaduct over the Lorupe ravine was opened. It is one of the greatest structures of Latvian bridge builders. In many aspects structure of the viaduct and its construction technology has been mentioned internationally. It has also started a new stage in the bridge construction in the former superpower Soviet Union.

The Lorupe ravine is 30 m deep and 200 m wide with very steep banks. A road was crossing the ravine already in the time of Russian Tsar in the middle of the 19th century. When automobilization developed, driving on this road was connected with numerous road traffic accidents, especially in winter.

Design work on the new road began in the early 1960s.

The overpass, 200 m long, was designed as two continuous girders of reinforced concrete with box cross-section. It was a novelty to slide this structure from one side onto bridge piers. It required additional bearings on which to slide the enormous concrete mass. A solution was found – plates of a super slippery material, fluoroplastic. However, this required a structure never seen before – structure of flexible piers that would react flexibly to vibrations during assembly and use. In that time, the structure assembled with this method was the first engineering work of this kind in the former Soviet Union and the second one in the world (Venezuela had the first).

Flexible piers, stressing, assembly, scenic research, methods of ecological approach and the construction process itself involving many road construction companies was a great teacher to the bridge builders of that time.

The viaduct was reconstructed in 2000.

1. Road history

Sigulda is a town in Latvia that attracts a lot of tourists. Latvians and travellers from other countries go there to enjoy the beautiful surroundings and views of the Gauja river valley. Not far from the Gauja is the Lorupe, a small tributary on the left bank of the Gauja river. It is 11 km long and begins in the Ummuri lake. The Lorupe has a considerable drop – 89 metres, i.e., 8.1m per km. Due to this fact, the river has formed a deep ravine with steep banks (Jemeļjanovs, 2018). Today, the Lorupe viaduct crosses this ravine, but once only a winding road in the bottom of the ravine was there for the travelers. The road that led from the Lorupe to Sigulda has a long history. It was used since the 12th century (Jemeļjanovs, 2018). However, the first images of bridges were discovered only from the end of the 18th century, when Johann Christoph Brotze, a remarkable researcher of local history, painted them in his pictures.

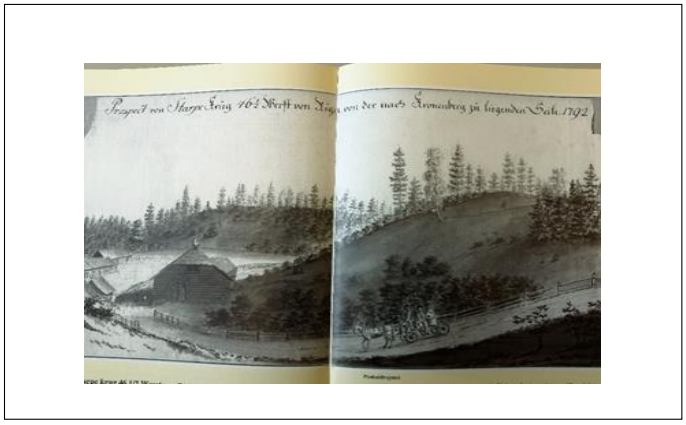


Figure 1. View of Starpas tavern and road from the Lorupe to Sigulda. Picture by J. Ch. Brotze. 1792 (Broce,2002).

In 1856, the Russian Empire constructed a highway Riga – Pskov in place of the old road. The highway was an important mail path. For crossing the Lorupe, a culvert from chiselled granite blocks was built [2]. Nowadays, this culvert and the old road section have been restored and may be seen.

The old road that crossed the Lorupe was winding. It was built by bypassing the old watermill of Kronnenberga Manor that was located 50 m above it.

There is an old legend that says that the miller had a beautiful daughter. A man fell in love with her, and he was designing the road. He wanted to spare the mill, so he deliberately made the road with so many bends. (Jemeljanovs, 2018), (Vecvagars,1998)

In the 20th century road transport was developing. Driving on the winding road, especially in winter, was difficult and there were many road traffic accidents.

Figure 2. Road in the Lorupe ravine. 1960. (Latvian Road Museum, n.d.)

This picture shows how the road went through the Lorupe ravine in the beginning of 1960-ties.

Figure 3. A traffic accident in the area of the Lorupe culvert in the beginning of 1960-ties. (Vecvagars, 1999)

2. The project of crossing the Lorupe ravine

In the beginning of the 20th century, the crossing of the Lorupe ravine has been preoccupying minds of several generations of Latvian engineers, according to information from Kārlis Gailis, professor of the University of Latvia, and documents of the former Department of Soil Roads and Highways (Vecvagars & Binde, 1998). To improve traffic in this road section, alignment research works had already begun in 1942, during the time of German occupation when one German construction company was financing it (Vecvagars, 1999). Due to political circumstances, the work did not continue.

The research works restarted for the second time in 1959, when specialists from Bridge Department of the institute "Ceļuprojekts" (Road Design) undertook the preparation for reconstruction of the Lorupe ravine crossing. By examining the new alignment, the specialists concluded that the best solution for straightening is the axis for ravine crossing outlined already in 1942 (Vecvagars & Binde, 1998).

In 1960, design works started and they had several stages. The first and most important question – how should a road profile in the Lorupe ravine be created? There were two technical options: to build a road over the ravine as a high embankment or to cross the ravine with an artificial structure – viaduct. In this matter, aesthetical architectural factors and technically economic factors were equally important. Therefore the architect Velta Reinfelde worked alongside road engineers in all the stages of research and design. The architect achieved synthesis of structural solutions and aesthetical architectural ideas. After a dendrological research of the area, the project provided for preservation of valuable and significant trees in the landscape, as well as, reconstruction of the current typical terrain (Vecvagars, 1999).

Figure 4. Viaduct sketch of the architect Velta Reinfelde, 1959 (Latvian Road Museum, n.d.)

For a 30 m high road embankment, almost 200,000 m³of gravel would have to be brought in the ravine. The width of the embankment in its foot would reach 150 m. In addition, 140 m long culvert would have to be built for the river to pass. Extraction of soil in such proportions from the closest quarries would damage the beautiful surroundings that were included in the natural preserve foundation of the republic (currently the territory of the Gauja National Park). The huge mass of embankment would divide the ravine in two parts (Vecvagars & Binde, 1998), (Vecvagars, 1999).

However, a scaffold bridge of light construction with narrow, light piers would allow the ravine to preserve its unity and beauty.

The technical solution of the new engineering structure had to maximally preserve spatial unity of the beautiful ravine, and technology of construction works had to meet the requirements of environmental protection.

Considering these issues, the authors selected the artificial structure – a reinforced concrete viaduct– as the key solution. Construction costs were approximately the same for both options (Vecvagars & Binde, 1998), (Vecvagars, 1999).

Inspiring from crossings of ravines of mountain rivers in other countries, as seen in West Germany magazines, Ziedonis Vecvagars, Head of Bridge Department of the institute "Ceļuprojekts" at that time, considered that filling up the Lorupe ravine was unacceptable from the aesthetical point of view. However, to refer to foreign experience in the advocacy process for the viaduct solution was not appropriate and even dangerous on a personal level. It could mean losing a job or even personal freedom (Vecvagars, 1999).

After long discussions with functionaries of the Soviet Union, the scales tipped in the favour of the viaduct. The next issue was the selection of viaduct structure. Solution was made more complicated by the campaign "Combatting of excesses" initiated by Nikita Khrushchev. A. Afanasjevs, Deputy Minister of Road Transport and Highways of the Latvian SSR at that time, supported this campaign enthusiastically. He considered the Lorupe viaduct to be an example of excess. According to his views, ravine should be crossed with a bridge that complies with the standards of bridge construction of the USSR – several interrupted beams on 2 m thick, firm piers (Vecvagars & Binde, 1998).

To avoid this, Latvian engineers had to select an unconventional structure – a continuous girder – and to build it themselves basing on individual design (Vecvagars, 1966).

In technical magazines of that time, there were descriptions of bridge construction in Venezuela. In 1962, stressed continuous girder was built over the Caroni river. This girder, approximately 10,000 t heavy, was put on piers with a unique method in construction of reinforced concrete bridges – longitudinal sliding (VSL International LTD, 1977). If not for this prototype, bridge designers in Latvia or USSR would not have come to an idea to use sliding in the installation of reinforced concrete girder. This example determined the selection of technology for span construction and installation of the viaduct (Vecvagars, 1999).

Long, creative search for the best versions of viaduct had begun. After careful calculations and comparisons, the designers concluded that the most appropriate structure is a continuous, prefabricated, stressed girder that stretches as a concrete band from one ravine bank to another. However, stressed continuous girder was a very rare phenomenon in the practise of bridge construction, even rarer in prefabricated reinforced concrete structures.

Until that time, bridge piers were associated with something massive, mighty and indestructible. The piers of the Lorupe viaduct are not washed by a rapid stream, they do not have to take on the impacts of broken ice; therefore, they are very light and flexible. Already narrow bodies of the piers get even more narrower at the bottom to be able to bend freely in the connection point with support. In all the length of the viaduct, there is only one rigid point – anchor support in the Sigulda bank. Its big mass is hidden in an alcove carved out in a sandstone rock (Vecvagars, 1999).

It was decided to create continuous girder with five spans according to the following scheme: 33 + 3 x 43.25 + 33 m on 24 m high piers (Vecvagars & Binde, 1998).

3. Construction stages of the viaduct

Construction of the Lorupe viaduct took place from April 1965 until July 1968. Considering originality of the bridge structure and construction technology, speed of construction was indeed very fast. From today's perspective, construction costs seem small – 400,000 roubles (Kalnins, 1965), (Vecvagars, 1999)

The construction works may be divided into the following sets of works::

1. Construction of accesses was done in two stages: in 1965, alignment preparation, main earth works and partial construction of road foundation were done; from April until July 1968, construction of road foundation was completed, asphalt concrete laid and finishing works carried out.

2.Construction of viaduct piers – foundation was built in 1965, bodies of piers and headers – in 1966.

3.Span blocks were manufactured from January until June, 1967.

4.Assembling of span structure and sliding it on the piers – from June until November, 1967.

5.Rearrangement of stressed cable bundles for operation and canal injection was performed in two stages: September and October, 1967, for the first girder, and March and April, 1968, for the second one.

6.Pouring of concrete over stressed cable bundles and joining of both girders was carried out in April and May, 1968.

7.Construction of carriageway and sidewalks was performed in June and July, 1968.

8.Scaffolding and subsidiary buildings were demolished and the whole territory tidied out from May until July, 1968. (Vecvagars & Binde, 1998).

4. Challenges during the bridge construction

Due to the poverty and underdeveloped technical capacity of the USSR, there were many challenges to address.The 200 m long girder of the prefabricated, continuous span structure weights more than 1000 t. Installation of such structure could not be solved with the usual methods in these specific circumstances. Therefore, attention of designers was attracted to the sliding method. However, this issue was very complicated, almost unsolvable, when this method for assembling classical steel bridges is applied to reinforced concrete. During the installation, the girder during sliding reaches a condition that according to calculations is opposite to the one it will be later in during the time of operation. For a steel girder, such condition change is not dangerous, since they both resist tension and compression equally well. Steel girders may also be reinforced in a constructively simple way during installation. Reinforced concrete resists well only the compression, it takes on tensile stresses poorly. It is also very hard to reinforce the reinforced concrete girder during installation, since the cables that take on tension are hidden deep in the concrete mass (VSL Internationas Ltd, 1977).

Modification of sliding equipment was also a complicated matter. Steel spans are being slid on rollers. Spans are relatively light and rolling friction between rollers and sliding tracks formed in the steel is insignificant. Analogue method is not suitable for reinforced concrete spans. They are very heavy and concrete would crumble coming into contact with the circular surface of rollers (Vecvagars & Binde, 1998), (Vecvagars, 1999).

Notwithstanding, it was decided to install the spans of the Lorupe viaduct with sliding, even without temporary piers. The play of forces in the span, depending on the condition during installation, was regulated with special, movable stressed cable bundles. Therefore, it was possible to create artificially as big compressive stress as necessary in the respective installation moment on any side of the span (Vecvagars, 1999)

Issue of sliding equipment was also solved. Help came from the latest achievements in chemistry. Girders were not pushed but slid on plates of special polymer material – polytetrafluoroethylene. Friction between fluoroplastic and concrete surfaces was only few per cent. Therefore, the whole girder that weighted thousand tons could be easily slid with the help of several winches with the pulling capacity of few tons. In addition, there was an option to use a special material – concrete cylinders coated with neoprene cord – instead of fluoroplastic plates (Vecvagars & Binde, 1998).

5. Construction of the viaduct

Since a completely new technology for structures and construction works was used for the construction of the Lorupe viaduct, many and different auxiliary devices and special materials were necessary. Most of the auxiliary devices were non-standard. Therefore, companies in the industry manufactured them. Only the special equipment – hydraulic jacks and pumping stations – were brought in from other republics (Vecvagars & Binde, 1998).

Height of every bridge pier had to match the ravine terrain. The concrete was poured in a way that there would be no interruptions, so that all the mass from the foundation to the top would be poured without any possible gaps in between. It was not easy. Cranes for delivering the concrete upwards could not be used. The workers themselves have constructed an elevator-like concrete vat that could be lifted between the scaffolding. With its help, the concrete, that was prepared on site, was lifted in uninterrupted flow up to very top (30 m high) (Vecvagars & Binde, 1998).

A newspaper of that time “Latvijas Auto un Ceļu Darbinieks” (Latvian Road Worker) published the following: “Several scaffoldings of bridge piers rise as mighty skyscrapers over serrated spruce treetops. When one is looking from their tops and imagining how is it going to look like when the road is ready, the impression is magnificent” (Latvijas Auto un Ceļu Darbinieks, 1968).

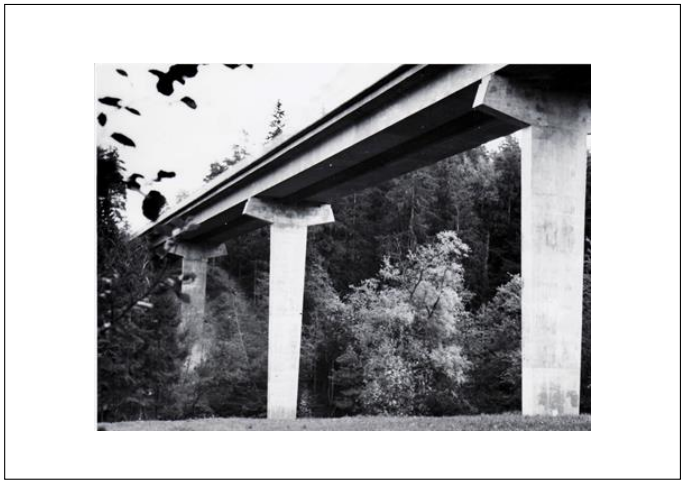


Figure 5. A view of the Lorupe viaduct piers,1967 (Latvian Road Museum, n.d.)

Construction of the Lorupe viaduct is characterized by very high work culture and quality. Organization of works ensured that environmental damages to the Lorupe ravine were minimal. Only few trees and bushes that were included in the design and encumbered pier construction works were cut down. Preparation of blocks and assembly of girders were performed on access roads. The construction site did not take more space than a right-of-way. Making span blocks on construction site justified itself completely. Their quality was considerably better than that of mass production of reinforced concrete shop. This success was achieved by the conscientious and creative attitude of workers (Vecvagars & Binde, 1998).

The newspaper "Latvijas Auto un Ceļu Darbinieks" described the process of sliding the girder sections on piers:

"So the sliding of span girders on the bridge has already begun. Currently the speed is 6 m per hour or 1 m in 10 minutes.

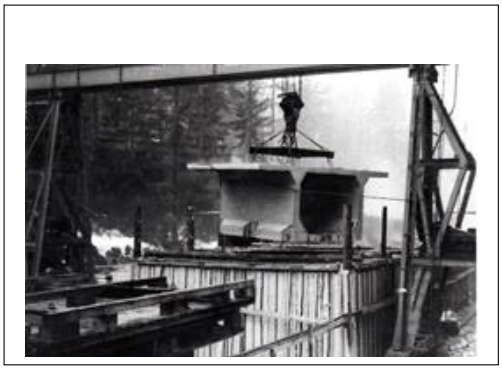
Only when looking closely, it may be seen that the first twenty sections of span girders that weigh more than 3 t are indeed slowly moving in the direction of ravine. The first ones, right after the pushing mechanism, are lined right next to each other on support structure on a special rail track without any support.

Farther ones, already stressed and concreted in one section, are moving over abutment. In the front, the long iron launching girder has already passed the "fifth" pier. For a moment, the engine stops. Men transfer the next section on the tracks with a crane, and the peculiar "train" continues its slow movement.

At the top of the closest pier, workers are regulating sliding of the launching girder and span section over the pole with different mechanisms. Chromium-plated metal plate and a plastic plate is being placed between them so that the brake friction would not come into effect. The pier itself is carefully linked with iron cables. The workers are laughing: in the past, bridges were built; now they are crossing over themselves (Kaugurs, 1967).

Figure 6. Sliding of span girder section (Latvian Road museum, n.d.)

The workers implemented many small improvements during the sliding of span girders, as well. The biggest and the most modern project of the Latvian road workers at that time was created with intense, interesting and creative work.



Figures 7. and 8. Cross section of a span girder and pouring of concrete on stressed cable bundles (Latvian Road Museum, n.d.)

Before opening of the viaduct, it was tested with loading. The test was performed by the workers of the Riga Polytechnic Institute. The total weight in the test reached 109 – 120 % of the normative load – 2 columns of loaded heavy vehicles. The test results showed that the actual span deflection was ten times smaller than the permissible standard. Concrete of the viaduct has good elastic properties (Vecvagars, 1999).

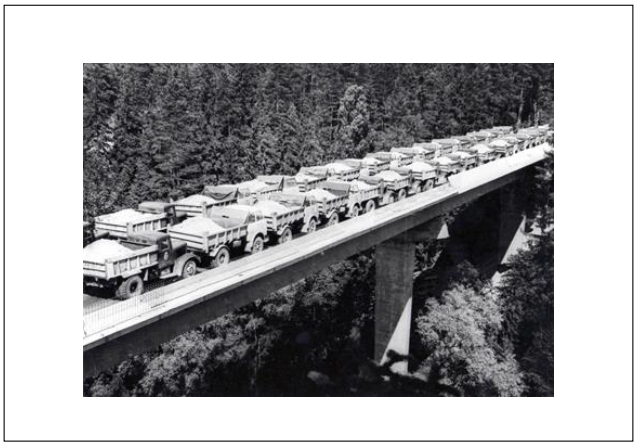


Figure 9. Static loading of the Lorupe viaduct, 1968 (Latvian road Museum, n.d.)

On the 20th July, 1968, the new viaduct over the Lorupe ravine was opened.

6. Importance of construction of the Lorupe viaduct in the Soviet Union

The most qualified and objectively minded engineers and representatives of scientific organizations in the USSR were following the process of design and construction of the Lorupe viaduct with great interest. At the same time, there were specialist circles that did not like that an experimental structure of this magnitude is in the hands of representatives of a small national republic and not in theirs. The construction site was often visited by representatives of large bridge construction companies and design organizations subjected to the Ministry of Construction of Transport Structures of the USSR. However, when the German technical magazine "Die Strasse" started to publish materials about the viaduct construction, the Ministry of Construction of Transport Structures of the USSR called a special meeting where colleagues in Riga were criticized about "implementing the foreign experience". There were also other attempts to stop the expansion of the method of longitudinal sliding of bridge spans. However, its victory march through the whole territory of the USSR was unstoppable. Construction without any handles or cranes is organically connected with constructive nature of a continuous girder. Until the collapse of the USSR, 14 reinforced concrete bridges were built according to this technology, one of them in Latvia (Vecvagars, 1999).

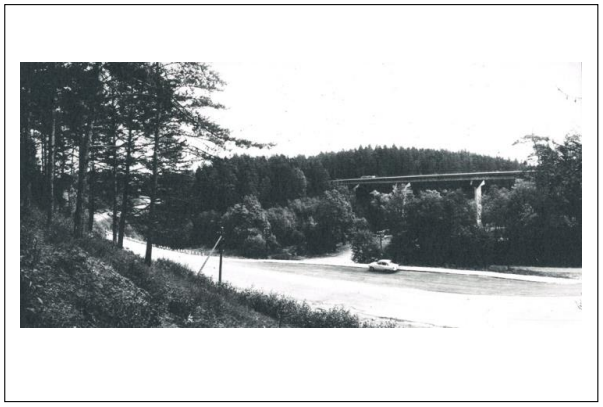


Figure 10. The Lorupe viaduct, 1970-ties (Latvian Road Museum, n.d.)

Conclusions

It has been 50 years since the construction of the Lorupe viaduct. Generations have changed, and young bridge builders have little knowledge of challenges and hardships that workers of 1960-ties had to overcome during the viaduct construction. Nowadays bridge assembling with longitudinal sliding is a common practise. However, the principle of the project implemented for the first time in the Lorupe ravine has stayed the same. The purpose of this paper is not only to describe the idea and construction stages of this bridge, but to tell a wider society about the courage, initiative, creative and meticulous work of the Latvian road workers that allowed to implement a European scale project in difficult, constrained circumstances.

Author contributions

Laura Reble and Mārtiņš Dambergs translated the work in English.

Disclosure Statement

I do not have any competing financial, professional, or personal interests from other parties.

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