COST ACTION TU1406

QUALITY SPECIFICATIONS FOR ROADWAY BRIDGES, STANDARDIZATION AT A EUROPEAN LEVEL

Appendix A5

Bridge Case study

Arch bridge Nerstce Czech Republic

Prepared by:

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CONTENTS

1. GENERAL DATA ON THE BRIDGE

The inspected bridge is a five-span concrete arch structure built in 1953. The bridge carries road across the river Skalice between Čimelice and Osečany villages. General views of the bridge are presented below.

Fig. 1 Side view of the bridge (left side)

Fig. 2 Side view of the bridge (right side)

Fig. 3 A view along the road in the Prague direction

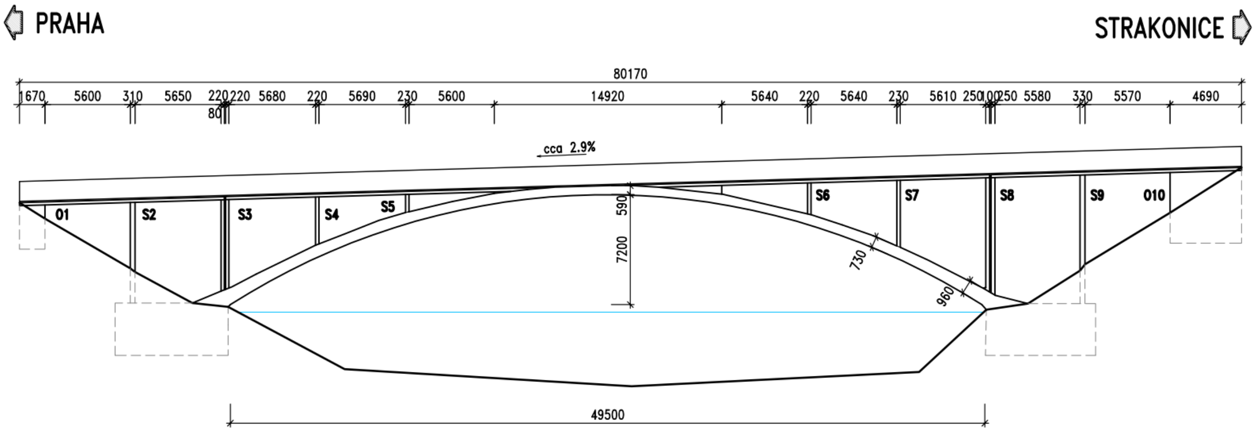

Fig. 4 Elevation of the bridge

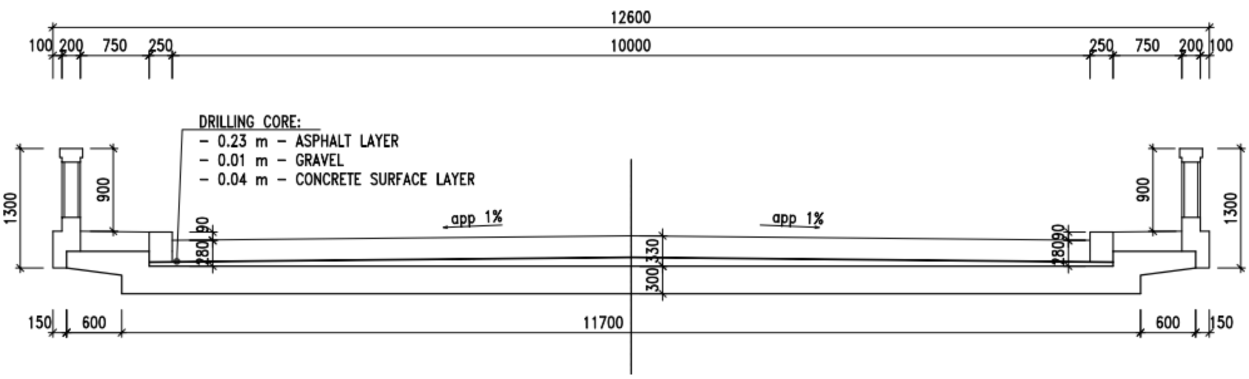

Fig. 5 General cross section of the bridge

1.1. TRAFFIC INFORMATION

The last information about the traffic are from the last counting in 2010.
Number of cars / 24h : 9679
Number of heavy cars / 24h : 1953

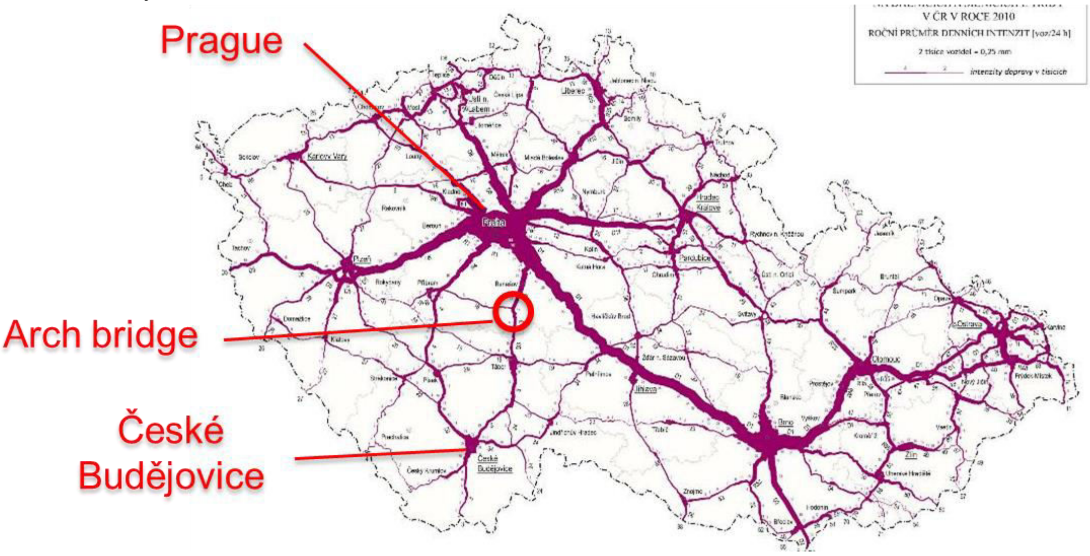

Fig. 6 Location of the bridge on the map of traffic intensity

1.2. FOUNDATION

Foundations are inaccessible, and there are no existing drawing, showing them. According to type of structure and according to the sketches from BMS we expect they are pad foundations on the rock.

1.3. SUBSTRUCTURE

Substructure is formed by the abutments from the concrete and the massive foundation blocks of the arch. It seems, that they are connected in the ground, however no evidence was found to prove that.

1.4. SUPERSTRUCTURE

The superstructure is divided to the three dilatation parts. The side parts are formed by the concrete frames with two spans. The concrete deck it connected rigidly to the abutment and supported on two slab piers. The bridge deck is in the central part supported by the concrete arch of rectangular shape and by slap piers. The deck is a continuous frame of three spans on each side of the arch, and it is fixed to the top of the arch by the hinged connection.

1.5. ACCESSORIES

There is asphalt pavement on the bridge of enormous thickness, up to 200 mm!!. The walkway is also asphalted and surrounded by the stone side blocks. The railing is made from concrete.
The drainage is made several times on the bridge and the water is drained by vertical tubes to the ground.

1.6. LOAD CAPACITY

The load capacity of the bridge is considered as:

- Normal capacity of the unlimited number of vehicles: V_n = 26.7 t
- The capacity of the one single vehicle on the bridge: V_r = 66 t
- Exceptional capacity for the heavy special transport: V_e =175 t

Critical members are considered vertical walls for Vn and bridge deck for Vr.

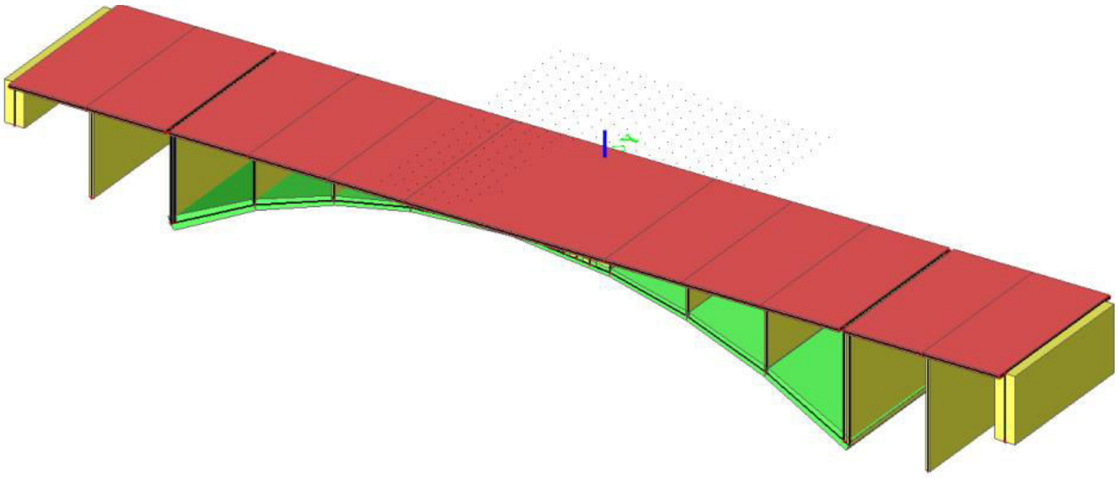

Fig. 7 The view on the numerical model for the load capacity calculation.

1.7. RATING OF THE BRIDGE

According to the Czech rating system, the status is V (bad) for the superstructure and substructure as well, on the scale between I (excellent) and VII (emergency),
The availability is of the grade 3 (available with limitations) on the scale between 1 (available) and 5 (Unavailable)

2. TECHNICAL CONDITION

2.1. COLLECTION OF DEFECTS

The types of defects discovered on the analyzed bridge are:

1. Fractures of spandrel walls
2. Damage waterproofing of the arch and spandrel walls
3. Concrete deterioration, the reinforcement corrosion. Mainly below the expansion joints on the piers and arch.
4. Cracks in the slab piers
5. Defects of pavement, enormous thickness of pavement
6. Waterproofing defects,
7. Inefficiency of drainage
8. Deterioration of the concrete railing

All the defects on the main members are presented on the sketches below.

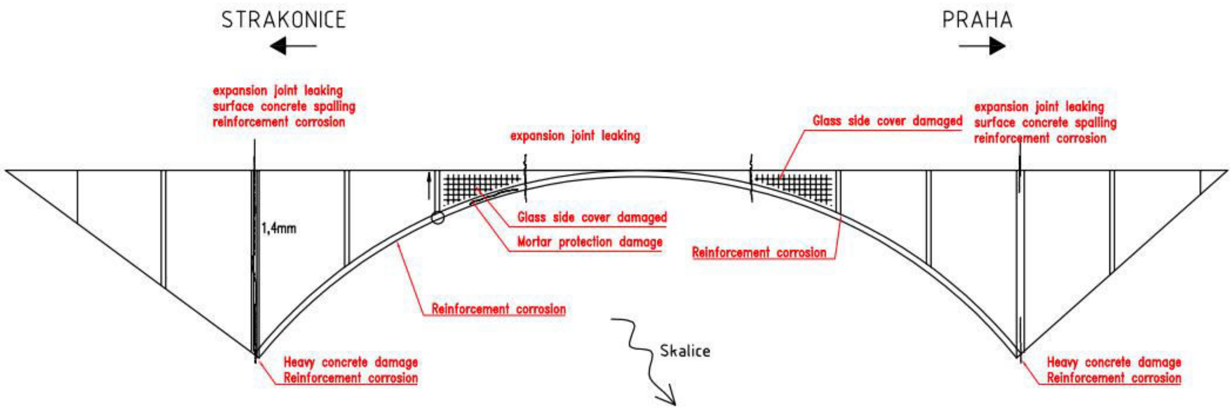

Fig. 8 Schematic left view on the bridge with the defects

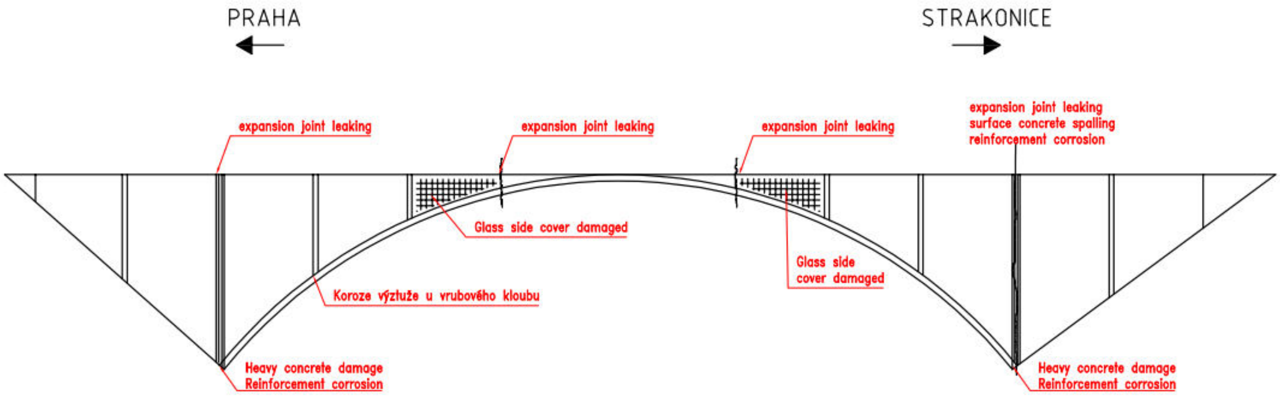

Fig. 9 Schematic right view on the bridge with the defects

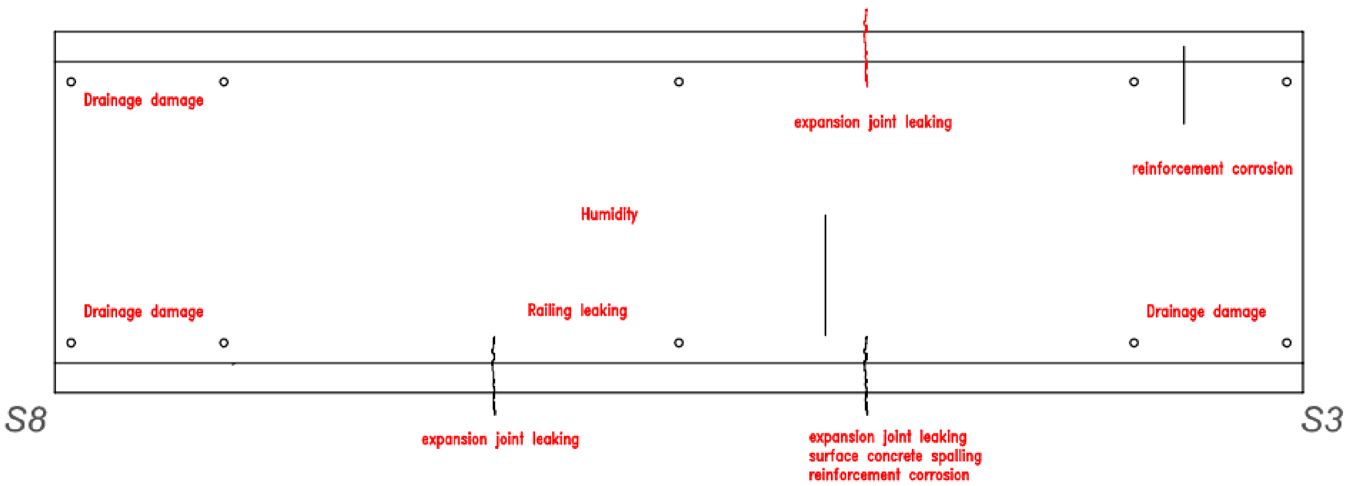

Fig. 10 The lower surface of the arch with the defects

2.2. DEFECTS OF THE MAIN STRUCTURAL ELEMENTS

2.2.1. FOUNDATION DEFECTS

Fig. 11 Deterioration of the foundation at the abutment – the status 6 years old, repaired

2.2.2. DAMAGE OF THE SUPERSTRUCTURE

Fig. 12 The view on the piers S8-S9-O10. The corrosion of the reinforcement and concrete damage.

Fig. 13 The corrosion of the reinforcement, concrete deterioration.

Fig. 14 The corrosion of the reinforcement, concrete deterioration – pier S6 on the arch

Fig. 15 The significant reinforcement corrosion of the pier slab, at the arch ends.

2.2.3. WATERPROOFING DAMAGE

Fig. 16 The waterproofing leakage at the old inspection holes

2.2.4. REINFORCEMENT CORROSION

Fig. 17 The significant reinforcement corrosion of the pier slab, at the arch ends.

2.2.5. DEFECTS OF PAVEMENT

Fig. 18 Cracks and shoving of the pavement at the expansion joint

Fig. 19 The thickness of the asphalt layers shown on the drainage level

2.2.6. INEFFICIENCY OF DRAINAGE

Fig. 20 The damaged drainage at the abutment

Fig. 21 The damaged drainage at the S8 pier

3. POTENTIAL FAILURE MODE OF THE BRIDGE

In accordance with current condition of the bridge following failures are considered:

- Vertical walls under the expansion joint failure – global bridge failure due to loss of stability under live load due to concrete degradation and reinforcement corrosion under leaking expansion joint.
- Main arch failure – global bridge failure due to concrete degradation and reinforcement corrosion under expansion joint location due to expansion joint leakage.
- Top slab failure in arch-slab joint – failure of top slab in the weakest slab position due to leakage and concrete degradation and reinforcement corrosion.
- Loss of abutment stability – stability loss of undermined abutment 01 due to bad water management of pavement surface water (drainage system outlet).

4. MATERIAL TESTING

4.1. COMPRESIVE TEST RESULTS

Fig. 22 The samples for the concrete strength testing

Fig. 23 Specimen no. NK1 during loading test

The received results of the tests are given below.

Specimen	Height [mm]	Weight [kg]	Unit weight [kg.m^{-3}]	Force [kN]	Compressive strength [MPa]
NK1	97.0	0.955	**2290**	158.0	**33.8**
01_1	122.5	1.231	**2338**	142.0	**31.7**
01_2	116.0	1.210	**2427**	167.0	**36.9**
02_1	111.5	1.138	**2374**	135.0	**29.8**
S1	154.5	1.511	**2275**	138.0	**32.1**
S2	127.0	1.292	**2367**	141.0	**31.8**

The concrete can be considered as a **C30/37**.

4.2. ALKALI – SILICA REACTION

The Rhodamin method was used to identify the existence of the silica gel. As shown on the figure, only cement changed color to pink, not the aggregate. It means, that ASR is not a problem here.

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Fig. 24 Specimens after Rhodamin application

4.3. CARBONATION

The next test was focused on the carbonation of the concrete. The results are shown in the table.

Sample No.	Carbonation depth [mm]
NK1	0
01_1	0
01_2	0
02_1	0
S1	2/8
S2	0/0

4.4. CHLORIDES

The chlorides amount was measured by potentiometric method. The results are given bellow.

Sample	Amount (mg/l liquid)	Amount (mg/g sample)	Max. amount of Cl- compared to the cement amount (%)
NK1	1,4	0,034	0,003
S1	2,1	0,054	0,005
S2	2,6	0,059	0,006
01_1	1,4	0,049	0,005
01_2	6,8	0,170	0,017
02_1	14,7	0,589	0,059

4.5. FREEZING RESISTANCE

All samples were exposed to the 75 freezing cycles. The results show, that the concrete can resist to the freezing. The only sample that failed is shown below.

Fig. 25 Specimen no. 01_2 – after the freezing test

5. KEY PERFORMANCE INDICATORS

Key performance indicators are provided in accordance with best practice knowledge of the research team and experiences with bridge inspection in Czech Republic. The indicators are evaluated and failure modes of the bridge are estimated.
Furthermore, two life time cycle approaches are shown to evaluate the life time costs, reliability, availability and safety of considered arch bridge in following 100 years.

First Referenced approach consider a lack of any repairs of bridge except of very basic ones on the pavement. The bridge defects are developed till bridge failure and whole bridge is replaced with new structure.

Second Preventative approach consider set of repairs during life time cycle to prevent further defect development and overall damage to the structure.

The life time costs consider every year maintenance costs, pavement replacement costs every 20 years, bridge repair every 40 years and other costs described in following sections depending on considered approach.

5.1. CURRENT STATE EVALUATION

In accordance with current state of the described structure following KPIs are considered:

Structure	Component	Material	Design and construction	Failure mode	Vurnerable zone	Symptoms
Arch concrete bridge	Wall under E.J.	Reinforced concrete	1955	Global failure	E.J. connection	E.J. leakage, reinforcement corrosion
	Arch	Reinforced concrete	1955	Global failure	Arch under E.J.	E.J. leakage, reinforcement corrosion
	Top slab	Reinforced concrete	1955	Local slab failure	Slab in hinge position	Hinge leakage and reinforcement corrosion
	Abutment 01	Subsoil	1955	Loss of stability	Abutment foundation	Undermined abutment
	Parapets	Reinforced concrete	1955	Parapet collapse	Bottom section of parapet	Reinforcement corrosion
	Pavement	Asphalt concrete	1995	Skid resistance	Top surface	Crack & sweating & deformation

KPI	Performance indicator		Estimated failure time
Reliability (Structure safety)	2	2	**20 years**
	2		**35 years**
	2		**35 years**
	2		**40 years**
Safety	2	2	**10 years**
	2		**5 years**

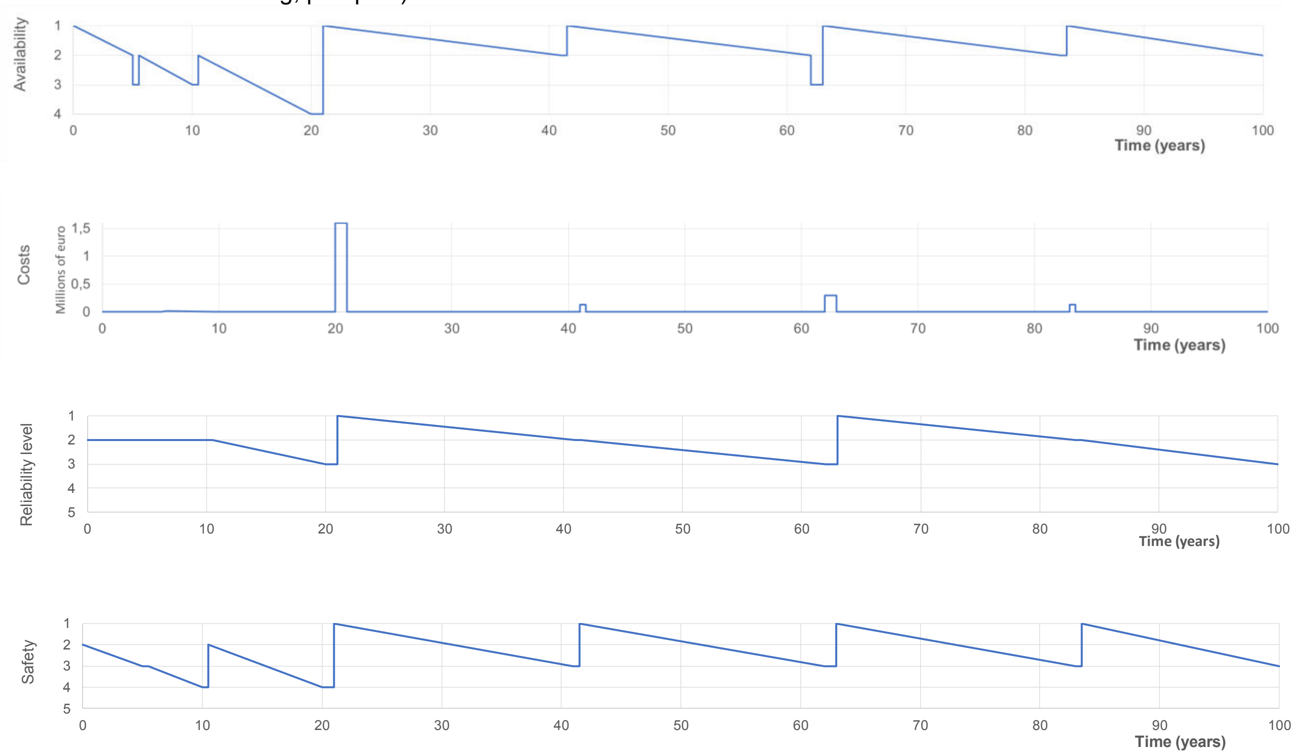
The estimated failure time is assumed according to research team experience with concrete structures in Czech Republic and estimated progress of the defects. It is however safe assumption under severe conditions.

5.2. REFERENCED APPROACH

Lack of any major repairs of superstructure and accessories except of basic pavement repairs leads to the defects development up to the bridge failure. In accordance with previous section the existing structure defects, development and estimated failure times are assumed as follows:

- pavement failure in five years due to crack development, sweating and deformation in five years (as noted the pavement layer shall be repaired).
- Here17500 Euro pavement repair is assumed, the repair will temporarily decrease the availability.
- Concrete parapets collapse in 10 years (decrease of availability & safety)

- Here, and installation of concrete barrier of price 7500 Euro is expected, this will partly increase the availability, but not fully as the width is decreased, and increase safety.
- Doubled wall under expansion joint failure in 20 years (bridge failure and replacement with new structure).
- The drop of the availability, bridge will be closed. The cost of the repair is 1600000 Euro.
- Preventative approach on the new bridge (pavement replacement every 20 years and bridge repair every 40 years).
- The repair will be done by halves of the bridge, so temporarily the availability is decreased. The cost of the pavement repair is 130 00 0 Euro, cost of the complex repair (pavement, crash barrier, railing, parapets) is 300 000 Euro.



5.3. PREVENTATIVE APPROACH

First the bridge repair shall be designed and done in 10 years. The whole bridge structure and accessories repair is considered. The life time cycle is considered as follows:

- pavement failure in five years due to crack development, sweating and deformation in five years (shall be repaired).
- Concrete parapets partial collapse in 5 years (whole bridge and accessories repair is considered in the same time).
- The drop of the availability, bridge will be partly closed, but one lane will remain in the service. The cost of the repair is 1200000 Euro.
- In following years the preventative approach on the repaired bridge is assumed (pavement replacement every 20 years and bridge repair every 40 years).
- The repair will be done by halves of the bridge, so temporarily the availability is decreased. The cost of the pavement repair is 130 000 Euro, cost of the complex repair (pavement, crash barrier, railing, parapets) is 300 000 Euro.
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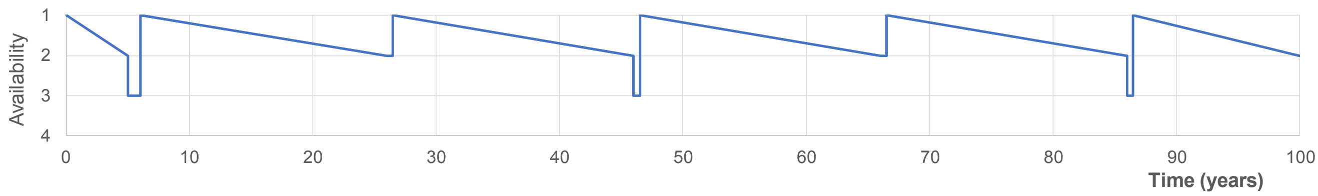
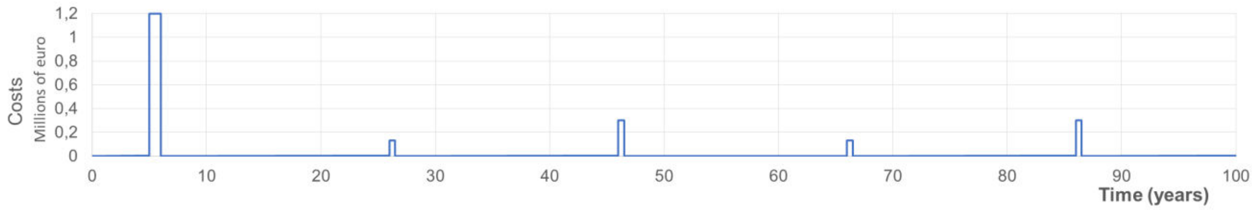
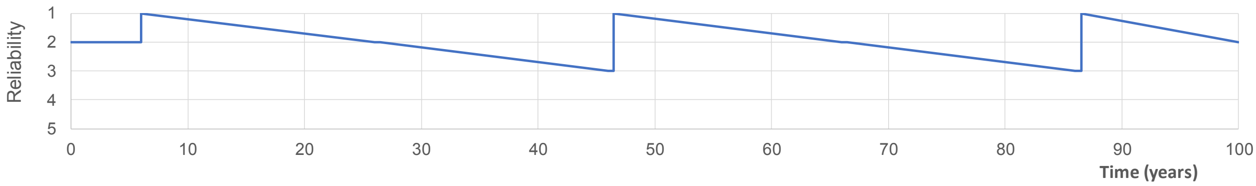
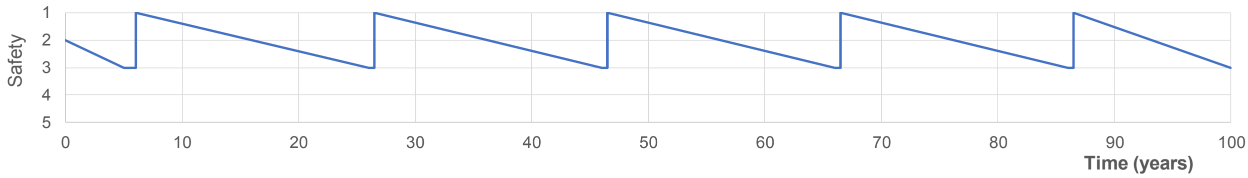


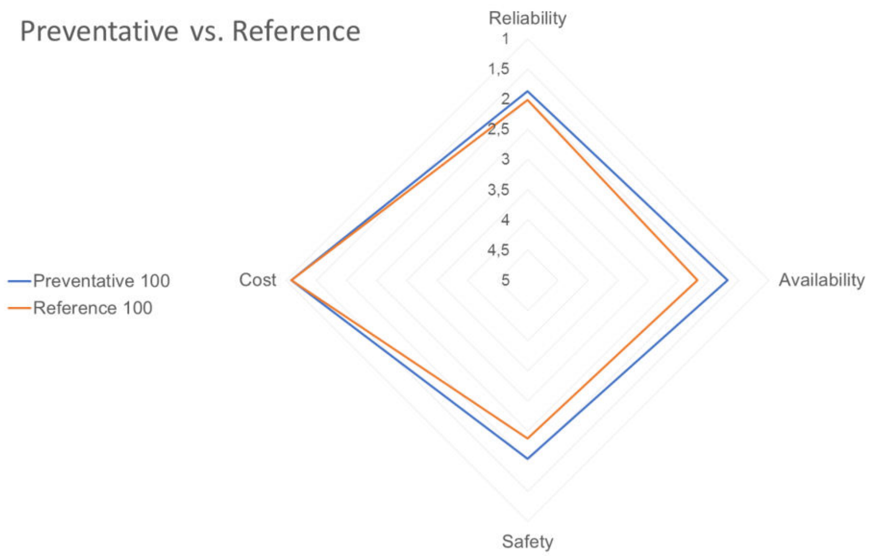






5.4. COMPARISON OF THE APPROACHES

A comparison of the two considered approaches is shown in following “spider” diagram:



According to the carried out analysis the preventative approach is more appropriate for the arch bridge - the indicators shows more favorable results for all aspects – safety, reliability, availability. Only the costs are almost comparable - the reason is the normalization of the costs based on the interest rate 2%.

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