COST ACTION TU1406

QUALITY SPECIFICATIONS FOR ROADWAY BRIDGES,

STANDARDIZATION AT A EUROPEAN LEVEL

TU1406 WG4 Final report Appendix A13

Bridge Case study

C-58, PK 25+490 Spain

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Date: December 22, 2018 Rev.1.0

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1. GENERAL DATA ON THE BRIDGE

1.1. GENERAL DESCRIPTION

The bridge is located on the Viladecavalls stretch of the C58 road. It passes over train tracks with three girders of 15.93, 19.05 and 11.50m in length and a variable width of 10.60m.

The bridge consists of an old and new part. The structure was initially 11.6m wide but, due to the extension of the road, the width was extended by creating a section parallel to the previous one with a variable width between 4 and 7m. All the damages detected were in the old part of the bridge.

The analysis in this document concerns the old part of the bridge, where the damage was identified.

Fig. 1 The general view the bridge

Fig. 2 The view under the bridge

Fig. 3 Side view of the bridge

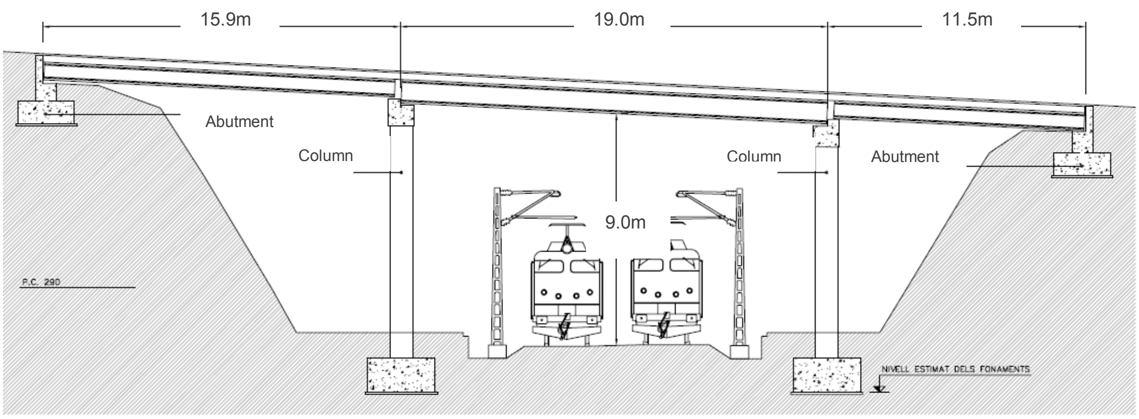


Fig. 4 Elevation of the bridge

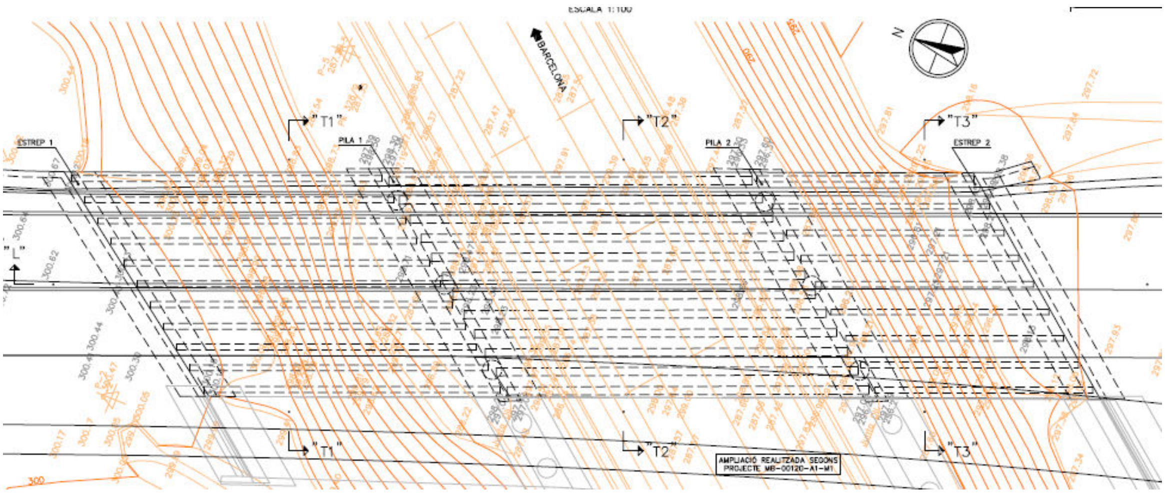


Fig. 5 The plan of the bridge

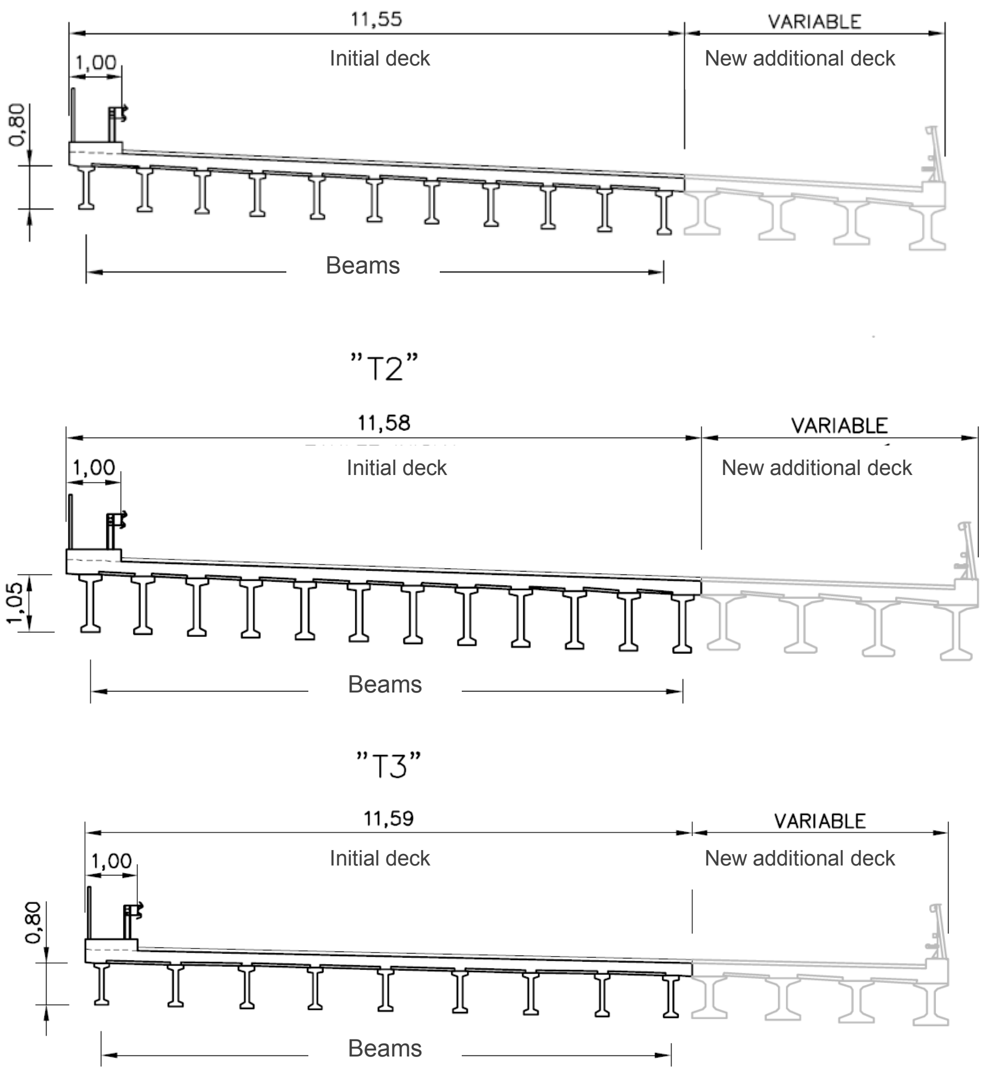


Fig. 6 Cross sections of the bridge following the plant

1.2. TRAFFIC INFORMATION

The bridge is located on the C-58 road considered one of the busiest in Catalonia with an approximate daily traffic flow of 160,000 cars /24h.

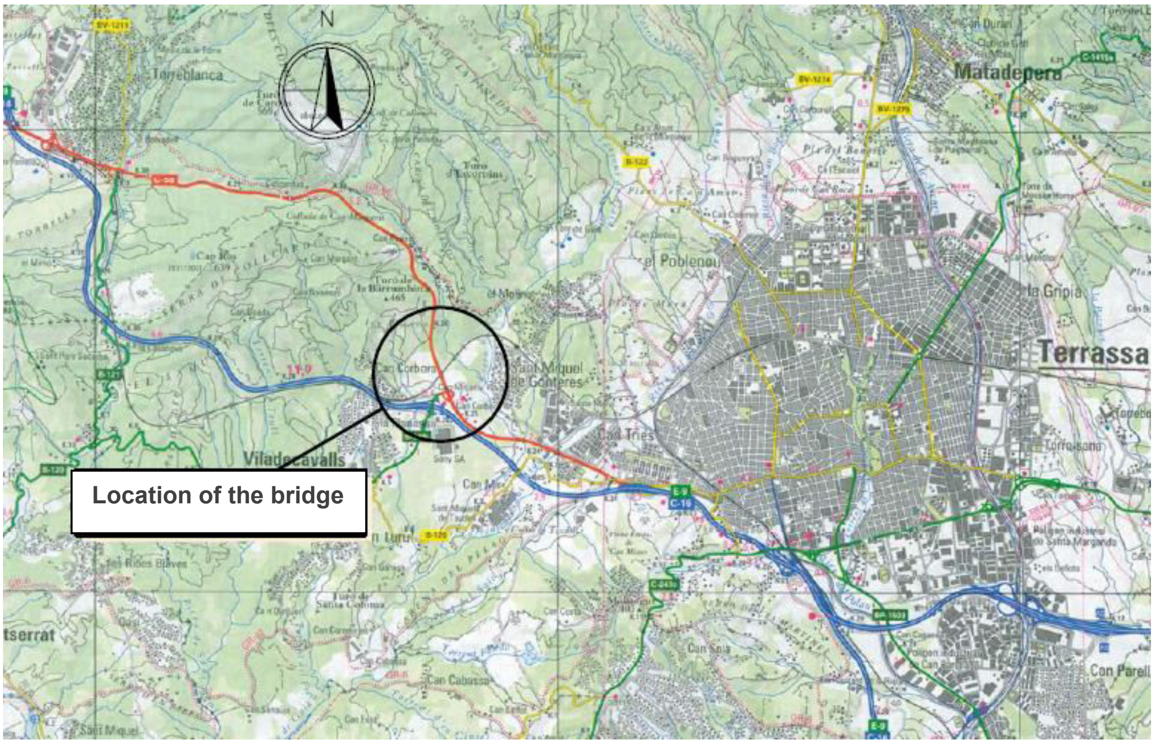


Fig. 7 Location of the bridge

1.3. FOUNDATION

In this inspection the foundations were inaccessible. However, the plans show the type of surface foundation that was used (shallow foundation).

1.4. SUBSTRUCTURE

The substructure is composed of two pillars stretches, separated by a distance of 19 m. each stretch with three circular columns supports the pier cap.

1.5. SUPERSTRUCTURE

This bridge has three stretches: 15.90, 19.0 and 11.5m in length and 10.60m in width. The deck was structurally resolved with pre-stressed concrete "using double beams -T type", 0.80m and 1.05m from the edge and reinforced concrete upper slab, executed "on-site ", 0.20m from the edge

1.6. ACCESSORIES

The asphalt pavement on the bridge is proximally 10cm thick. The sidewalks are of precast concrete elements. The safety barriers are external on both sidewalks and are of prefabricated concrete.

1.7. VULNERABLE ZONES FOUND

The vulnerable zones found are marked on the bridge drawings:

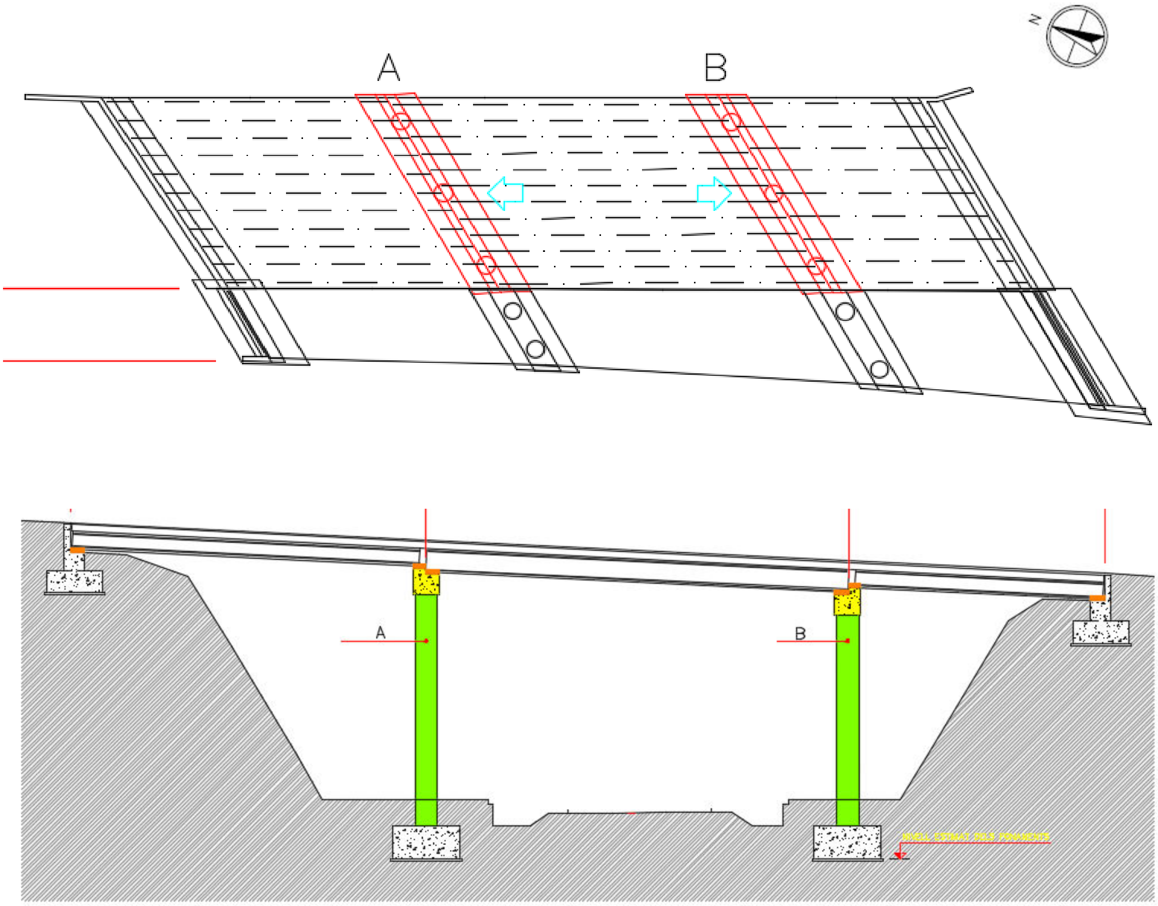


Fig. 8 Plan and elevation of the bridge are showing the porticos analyzed

Portico A

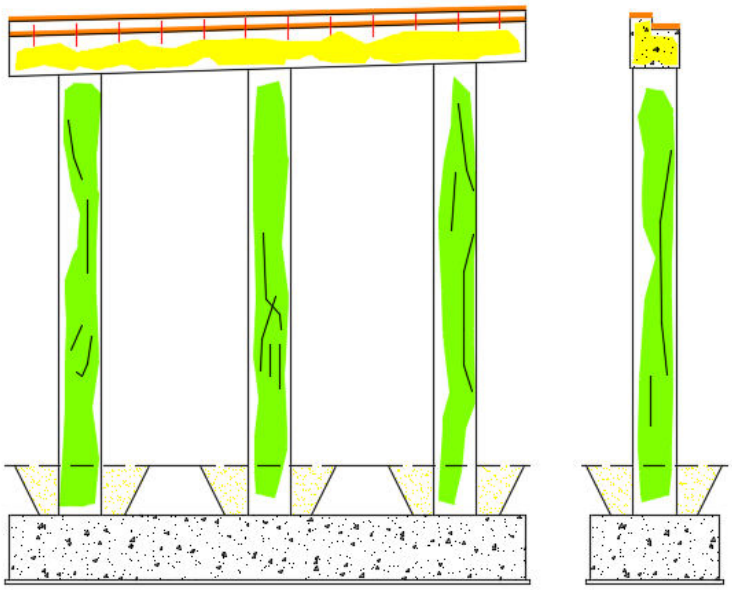


Fig. 9 Vulnerable zones – main truss (**Orange**= Debris accumulation on abutment, **Yellow**= Moisture in the pier cap, concrete detachments and visible armor and Green = External cracks, concrete detachments and visible armor)

Portico B

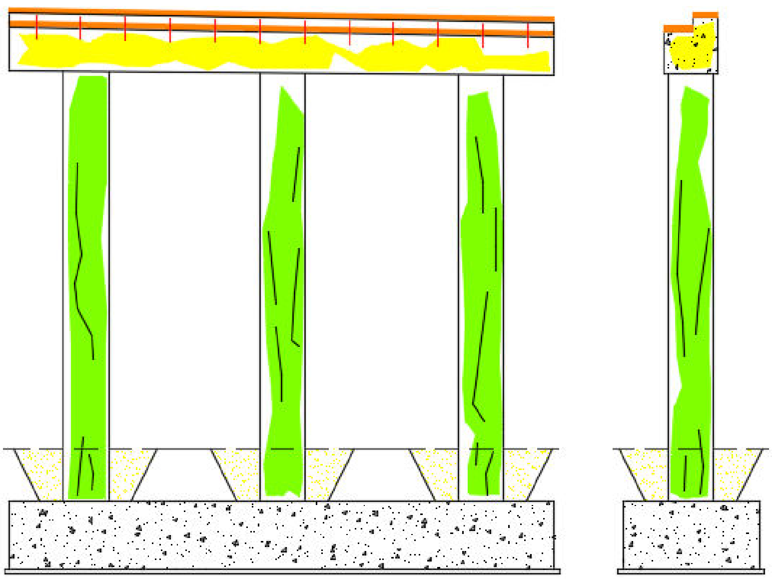


Fig. 10 Vulnerable zones – main truss (**Orange**= Debris accumulation on abutment, **Yellow**= Moisture in the pier cap, concrete detachments and visible armor and Green = External cracks, concrete detachments and visible armor)

2. TECHNICAL CONDITION

2.1. COLLECTION OF DEFECTS

The main types of defects discovered on the bridge inspection were:

Abutment

- Debris accumulation on abutment

Pier cap

- Moisture
- Concrete detachments
- Visible armor

Columns

- External cracks
- Concrete detachments
- Visible armor

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

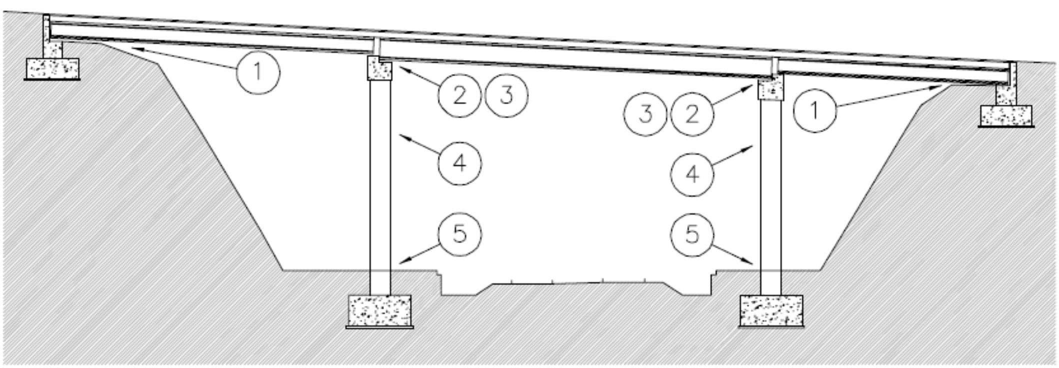


Fig. 11 Defects identification

2.2. DEFECTS OF THE MAIN STRUCTURAL ELEMENTS

Defects 1

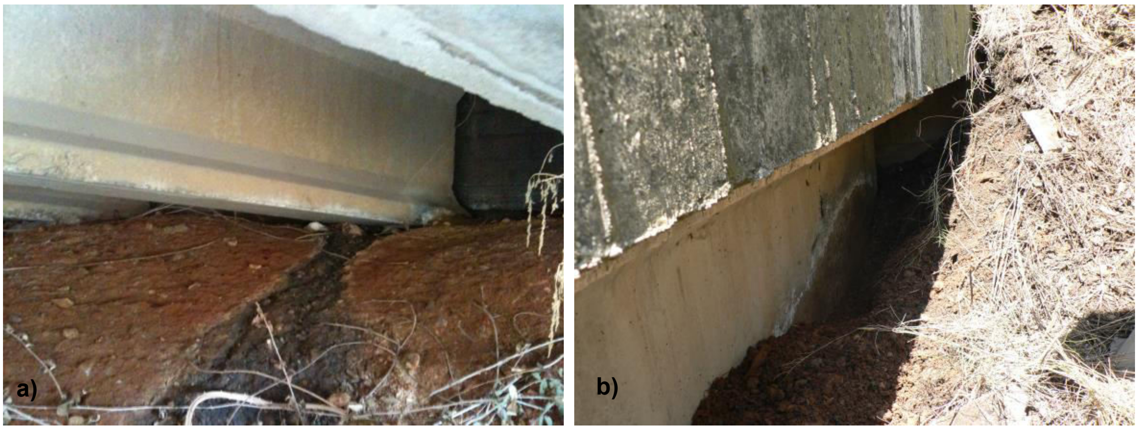


Fig. 12 Debris accumulation of abutment

Defects 2

Fig. 13 Moisture area and possible carbonation

Defects 3

Fig. 14 Visible armor and concrete detachments

Defects 4

Fig. 15 Concrete detachments and visible armor

Defects 5

Fig. 16 External cracks

3. POTENTIAL FAILURE MODE OF THE BRIDGE

In accordance with the current condition of the bridge, the following failure modes are considered:

Abutment

- Debris accumulations on abutment normally are due to the lack of works cleanliness. The origin of the concrete deterioration can be attributed to the moisture content and it could affect the elastic supports.

Pier cap

- The main damage caused by moisture is the carbonation and the concrete detachments with visible armor. They are punctual and do not represent an important problem that could cause failure, but it is important that they are repaired.

Columns

- This problem could cause the columns fail, especially if the steel is damaged by corrosion and the steel bars have their diameter considerably reduced.

3.1. NDT TESTING

It was a visual inspection so no non-destructive tests were used

5. KEY PERFORMANCE INDICATORS AND QC PLAN

This document shows two approaches to evaluate the costs, reliability, availability and safety of the bridge, considered to be a period of 100 years.

Two types of focus are used:

Referenced approach

The defects of the bridge are considered until the bridge fails and it is replaced with a new structure.

Preventive/corrective approach

The preventive approach was carried out using a series of repairs during the lifetime of the bridge. The small reparations are considered every 15 years and general repair every 30 years.

5.1. CURRENT STATE EVALUATION

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

Structure type	Group	Component	Material	Design & Construction	Failure mode	Location/ Position	Damage /Observation	Damage process	KPI	Performance Indicator component level		Performance value R	Performance value S	Estimated failure time [years]
Reinforced concrete	Structural elements	Pier cap	Reinforced concrete	1990	Pier cap Failure	Pier cap	Moisture	Corrosion	Reliability	2	**3**	**4**	**3**	**20**
						Pier cap	Concrete detachments	Corrosion	Reliability	3				**20**
						Pier cap	Visible armor	loss of concrete area	Reliability	3				**20**
		Bearings	Steel	1990	Bearing Failure	Abutment 11 (east)	Loss of rotation ability due to debris accumulation	Corrosion	Reliability	3	**3**			**40**
		Abutment	Reinforced concrete	1990	Bearing Failure	Abutment 1 (west)	Terrain accumulate	Debris accumulation	Reliability	3	**3**			**30**
		Abutment	Reinforced concrete	1990	Bearing Failure	Abutment 1 (west)	Terrain accumulate	Debris accumulation	Reliability	3				**30**
		Columns	Reinforced concrete	1990	Column Failure	Columns	External cracks	detachments	Reliability	3	**4**			**20**
						Columns	Concrete detachments	Corrosion	Reliability	4				**20**

Structure	Group	Component	Material	Design & Construction	Failure mode	Location/	Damage /Observation	Damage	KPI	Performance Indicator component level		Performance value		Estimated failure time [years]
						Columns	Visible armor	loss of concrete area	Reliability	4				**20**
		Expansion Joint	steel	1990	Closing	All joints	Closing of EJ	Deck movement	Reliability	2	**2**			**10**
		Pedestrian Deck slab	Reinforced concrete	1990	Falling chunks	South Edge	Spalling	Corrosion	Safety (Life and limb)	3	**3**			**20**
		waterproofing	Reinforced concrete	1990	Falling of the deck	Safety barrier	Broken, missing parts	Impact	Safety (Life and limb)	3	3			**10**
	Equipment	Pedestrian Handrail	Reinforced concrete	1990	Falling of the deck	Handrail anchoring	Corrosion of structural steel	Corrosion	Safety (Life and limb)	3	3	-		**30**
		Curb	Reinforced concrete	1990	Falling chunks	Curb side	Spalling, delaminations	Corrosion	Safety (Life and limb)	3	3			**20**
		Pavement	Asphalt	Estimated	Sudden disturbance to driver	Expansion joints overlay	Open transvers cracks	Joint reflection cracking	Safety (Life and limb)	3	3			**10**

The estimated failure time is assumed and estimated progress of the defects.

5.2. REFERENCED APPROACH

Due to the lack of major repairs of the substructure, mainly in the column, pier cap, and abutments, leads to progressive deterioration until reaching the bridge failure.

In this document, the estimated failure times are proposed are:

10 years:

• Road pavement failure - due to heavy traffic.

• Failure of expansion joints - due to corrosion and traffic.

• Waterproofing failure - due to poor drainage system.

20 years:

• Severe reduction of the strength in the columns, due to corrosion, detachment of concrete and loss of the section.

• Severe reduction in the resistance to cutting of beams, due to the corrosion of their stirrups.

• Pedestrian sidewalks - due to cracks, chipping, induced corrosion.

30 years:

• Failure of safety barriers - due to breakage, cracking.

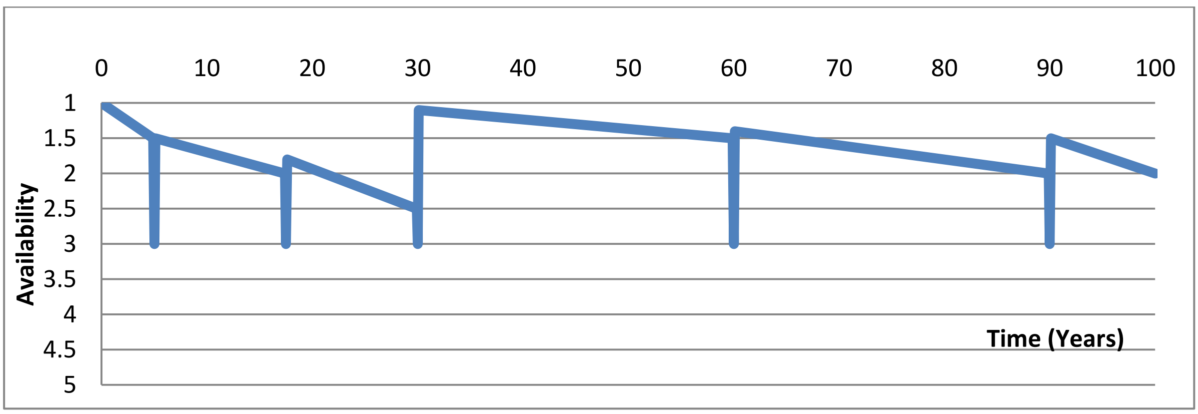
• Sidewalks for pedestrians. due to corrosion of the reinforcement, chipping.

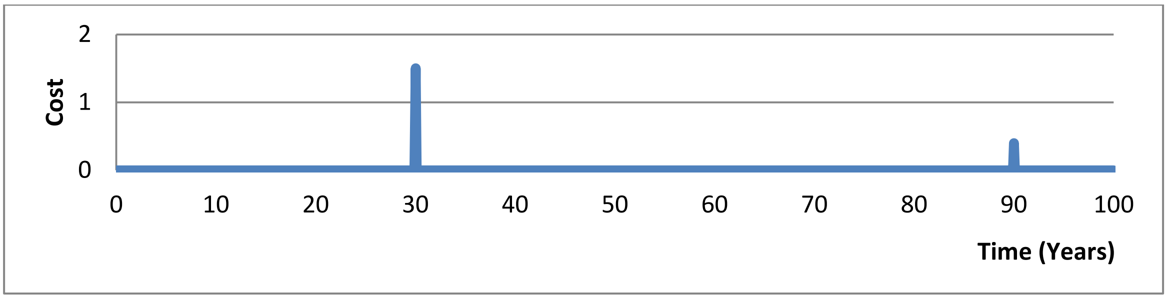
• Structural damage of the heads, due to the ongoing corrosion of their reinforcing bars revealed

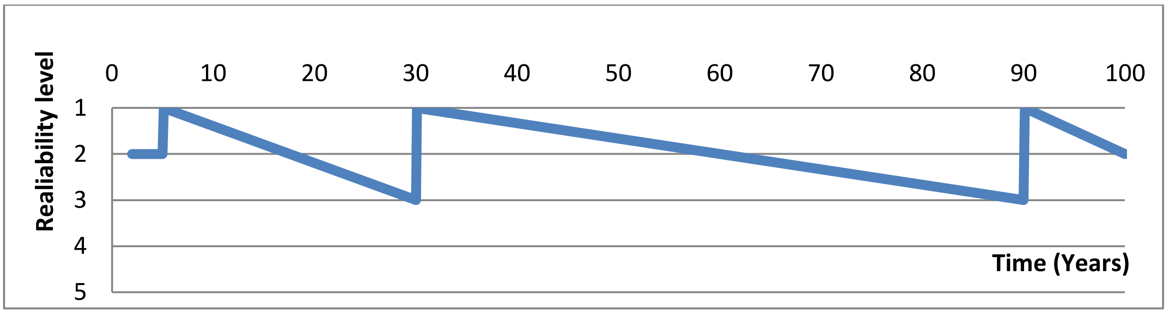
40 years:

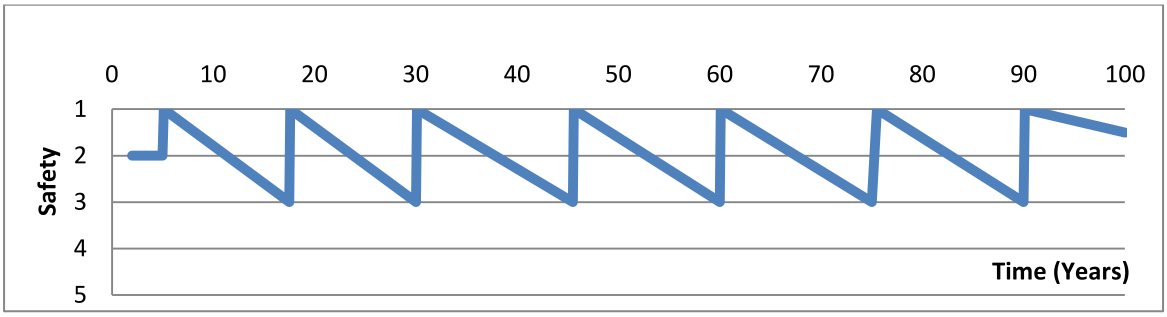
• Condition severe by damping reduction of the supports due to the accumulation of material and moisture in the joints.

• Severe reduction of the resistance of the abutments due to damage in the reinforced concrete produced by dampness due to the collapse of adjacent land.





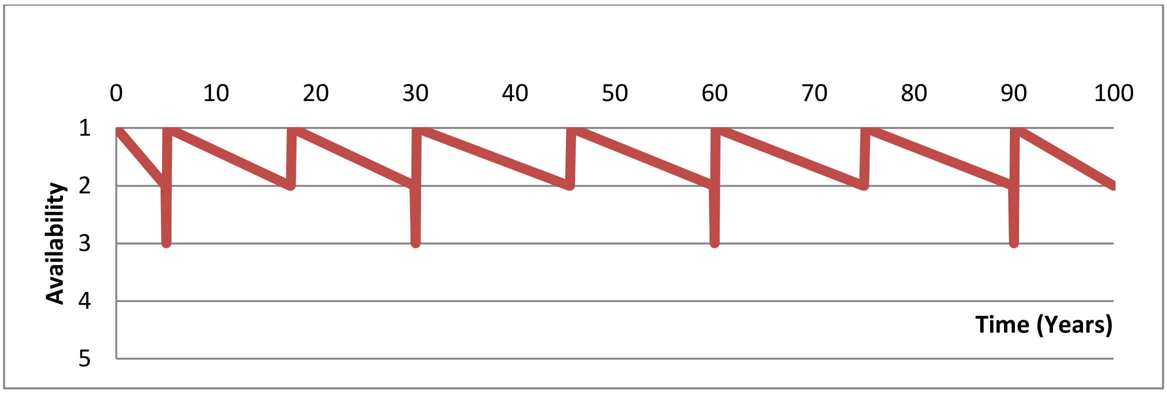


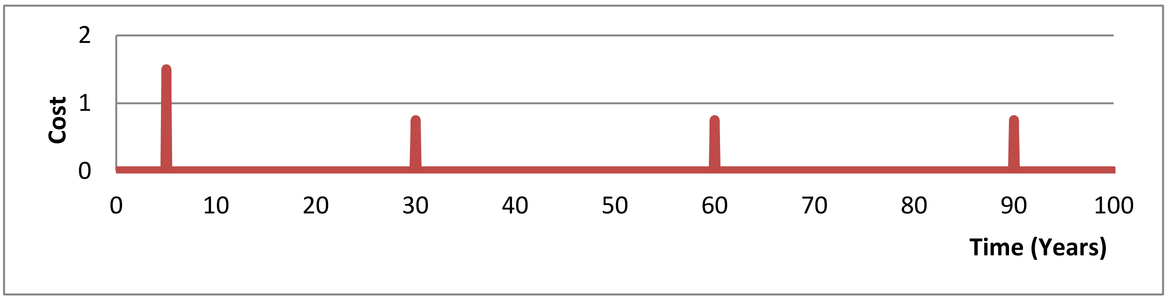


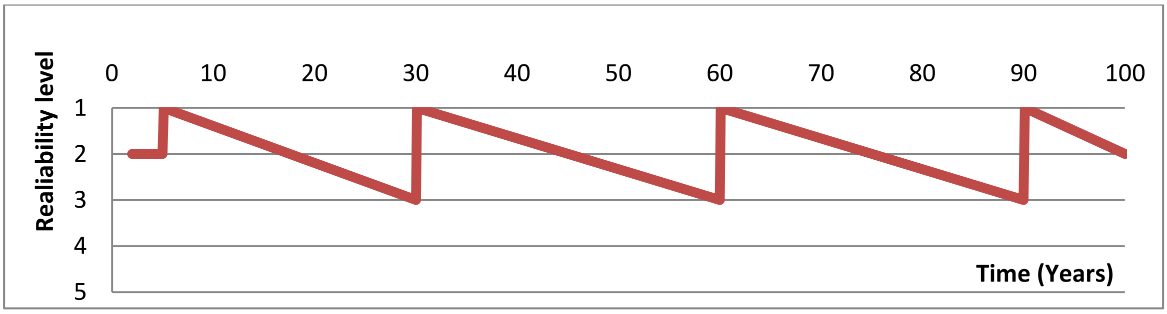
5.3. PREVENTIVE/CORRECTIVE APPROACH

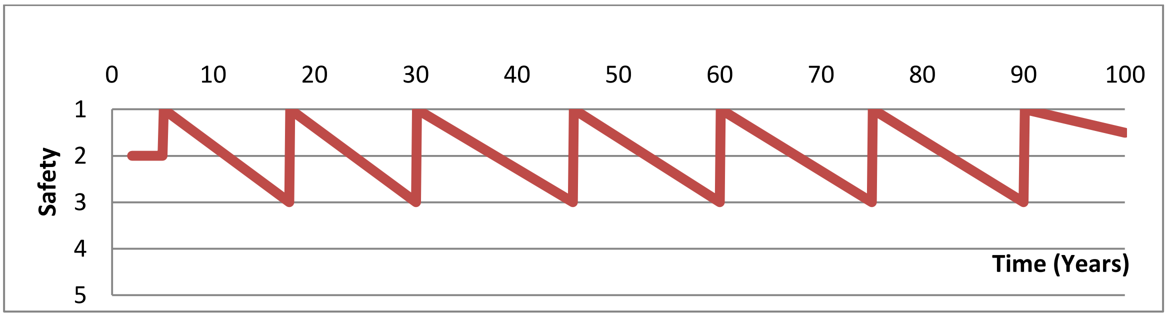
The preventive approach for bridge maintenance is considered a period of 5 years (as first maintenance), repairing the visible deteriorations in all the structural elements, and is proposed a general maintenance every 30 years.

The evolutions of the KPIs versus the remaining life of the bridge (100 years) are the following:


Availability
Time (Years)
0 10 20 30 40 50 60 70 80 90 100
1 2 3 4 5

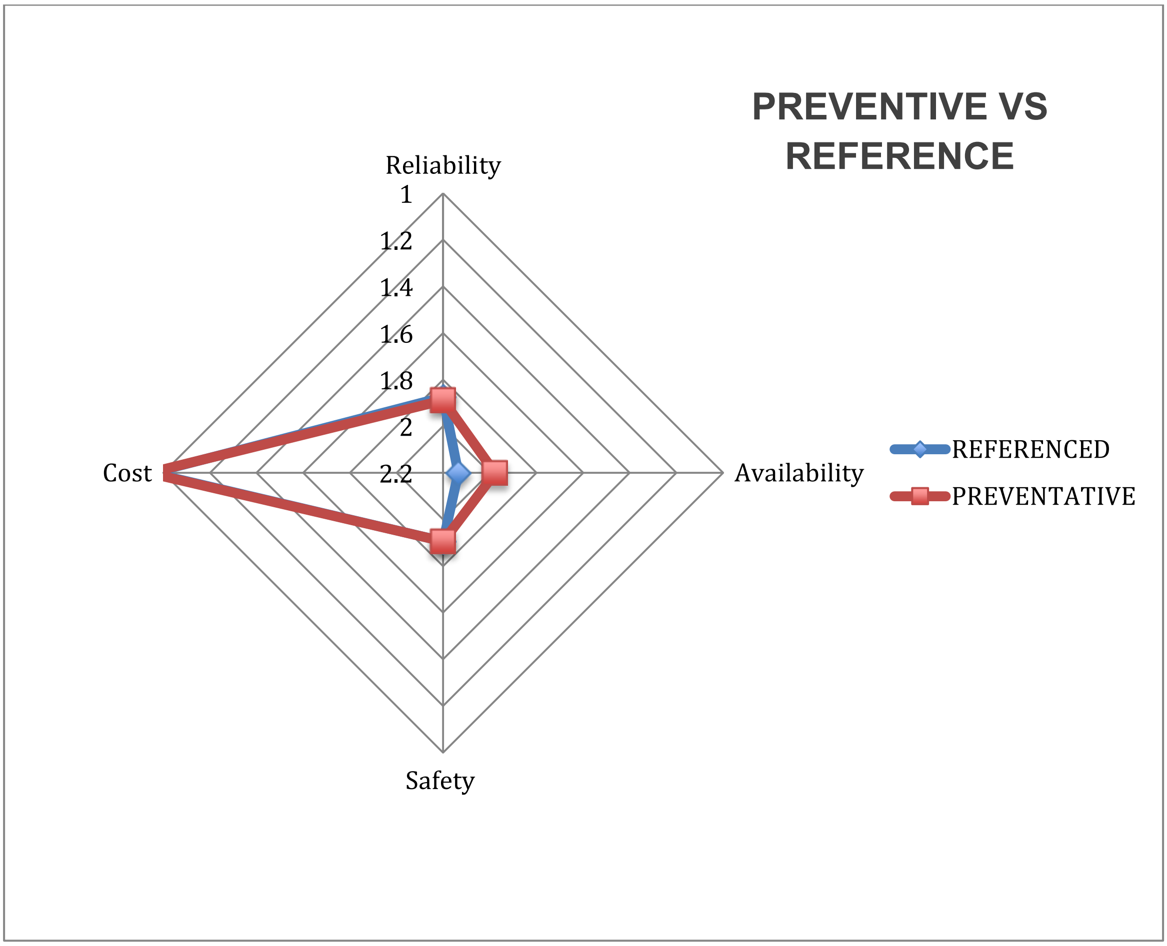

Cost
Time (Years)
0 10 20 30 40 50 60 70 80 90 100
0 1 2


Realiability level
Time (Years)
0 10 20 30 40 50 60 70 80 90 100
1 2 3 4 5


Safety
Time (Years)
0 10 20 30 40 50 60 70 80 90 100
1 2 3 4 5

5.4. COMPARISON OF THE APPROACHES

A comparison of the referenced approach and preventive approach is shown in diagram below.



According to the analysis carried out, the preventive approach is clearly advantageous, as can be seen in all the indicators show more favorable results for all aspects.

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