The PIARC TC D.3 Bridges Technical Committee is publishing a worldwide compilation of case studies as examples for bridge owners in making critical decisions to ensure the safety of the traveling public during a bridge incident caused by damage and deterioration. This case study compilation has 28 worldwide case studies received from 15 unique countries.

These case studies provide examples of incidents where owners discovered damage or deterioration under two main circumstances. Firstly, damage or deterioration resulting over longer periods of time, and secondly damage or deterioration appearing instantaneously. "Triggers" or causes of this damage or deterioration include environmental impacts, increased live loads, deicing applications, poor detailing in the design phase, poor construction materials and specifications, severe loading events, natural disasters, impacts, construction defects or by human error. At times, this discovery of damage and deterioration may lead to a bridge closure, traffic restriction, or weight restriction. This should result in damage assessment techniques, load carrying capacity calculations, and subsequent remedial works to return the bridge into service.

The PIARC TC D.3 Bridges Technical Committee will publish a report to be presented at the world congress in Abu Dhabi in 2019 referring to this compilation. This report will provide an updated perspective on best practice damage assessment techniques used by bridge owners around the world and produce a decision process for bridge owners to use as a guide during any damage assessment.

Worldwide bridge owners can use the upcoming PIARC produced report decision making process as an important reference with respect to the current damage assessment techniques or to guide them through a bridge incident to ensure the safety of the traveling public.

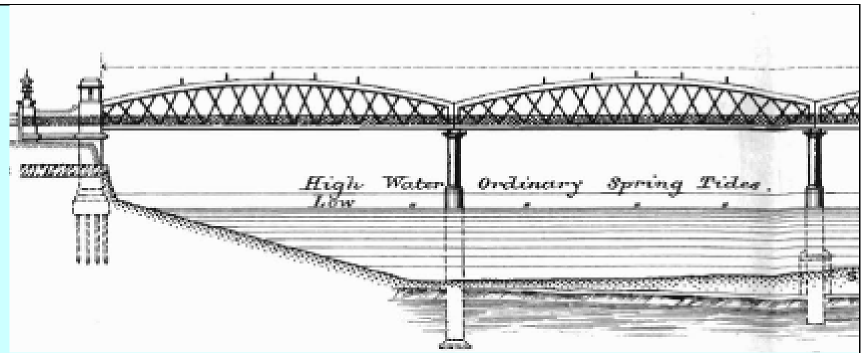
#1 AUSTRALIA (1)

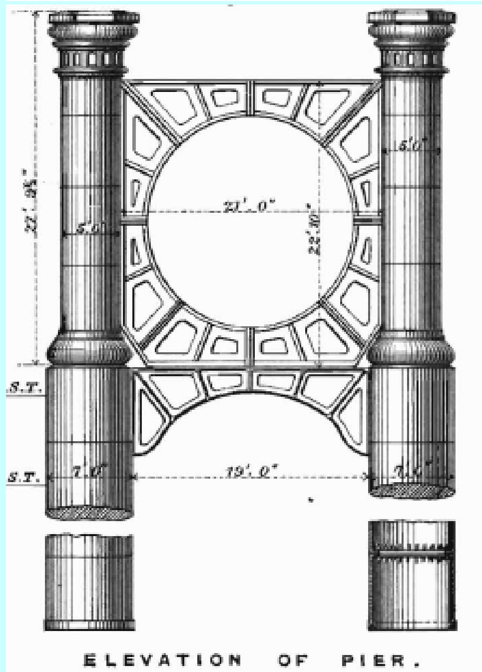
Event Date	Trigger Category: Bridge Impact
March 2017	Vehicle impact with one of the diagonal steel components in the truss

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Arch -Tied Truss	No Immediate Reaction	No	1900	416

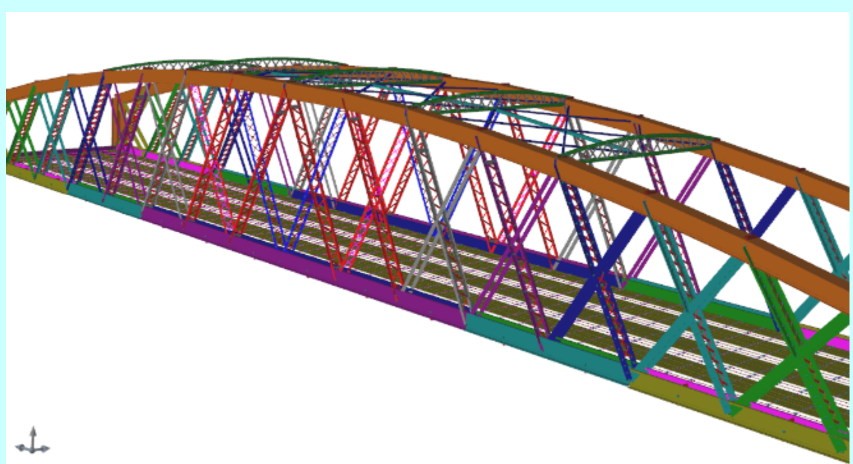
Description: A vehicle impacted one of the diagonal steel components in the truss. The member fractured at the rivet level and deformed. A rehabilitation project was under way, so the FEA analysis model was used to determine the impacts to the capacity. After evaluation, a 30-ton posting sign was installed. The member was replaced and the sign removed in approximately one month.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Australia
Prepared by	Suzanne Brown
Date Prepared	27 April 2017
1.0	Description of Event / Incident
Description of Bridge	Eight span steel bridge constructed in 1900. The Annual Average Daily Traffic is 16,900 with 7% Heavy Vehicles. Each span is approximately 52m long. The superstructure has a hog-back lattice truss either side of the 7.3m wide roadway. The piers are pairs of two cylindrical cast iron piles filled with concrete. It has a steel trough deck that spans between the bottom chords of the trusses. The bridge has been load limited to 42.5t since 2002 due to the corrosion of critical steel components. The bridge is over salt water and is very prone to corrosion.
Picture of Bridge	



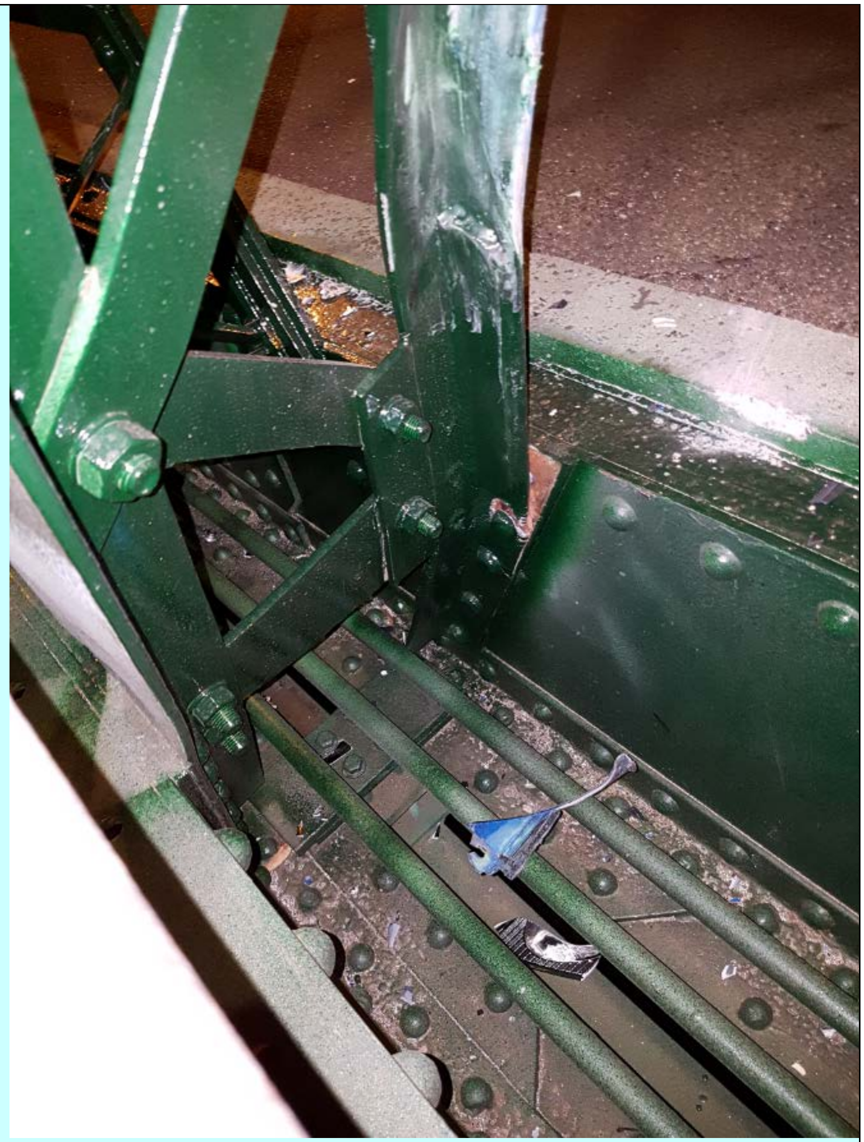


Excerpts from original plans.



3D model

Description of the event and the trigger that caused the assessment	Examples**:** bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	**Answer:** Vehicle impact with one of the diagonal steel components in the truss. The diagonal steel component adjacent to the roadway has fractured at the rivet just below the road level. The component has been deformed for approximately half its height. 



	 A 9.5mm thick steel section fractured around the rivet. Just above the fracture is a welded piece of steel that was added as part of the ongoing bridge repairs to compensate for section loss due to corrosion.
Date of initial event	12 March 2017
Describe your immediate reactions to this event	Examples**:** close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	**Answer:** Inspection of damage and detailed assessment using Finite Element Analysis (FEA) modelling and a 3D SpaceGass model. Leading to a reduction in the load limit from 42.5t to 30t.
Who in your organization made the immediate assessment and what qualifications did they have?	Examples**:** Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.

Answer- Who in your organization made the immediate assessment and what qualifications did they have?	**Answer:** Registered civil engineer and registered structural engineer.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers:	Examples**:** What engineering judgement did you use / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	**Answer:** At the time of the crash, the bridge was already being investigated by a structural engineering consultant to determine strategies for ongoing repairs. After the crash the consultant was able to be immediately engaged to analyze the effects of the damage on the load carrying capacity of the structure. The consultant used the existing FEA and 3D models. This analysis showed that a reduction in the loads using the bridge was necessary to reduce the stress to acceptable levels in the surrounding components. The load limit was reduced to 30t until the damaged component could be repaired.
Answer - Who in your organization made the decision and with what qualifications did they have?	**Answer:** Registered civil engineer and registered structural engineer.
Answer - What pertinent data did you have at your time the decision?	**Answer:** An FEA model that had been verified by field testing and a SpaceGass 3D model.

Answer - How did the timeframe of returning the bridge to full service influence the decision?	**Answer:** It was thought at the time of applying the 30t load limit that the bridge could be repaired by replacing the damaged component within a month. There is also another bridge that is just over 1km away for the vehicles over 30t to use. It was estimated from classified traffic counts that only 145 heavy vehicles per day would be affected.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	**Answer:** Yes, there were calculations done prior to the assessment for the structural investigations that have been ongoing on the structure for many years.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	**Answer:** One other option that was considered was to reduce the speed limit to take out the dynamic affect but compliance with the limit was considered unlikely.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples**:** dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	**Answer:** No special inspections were required as the damage to the component was visible from the walkway of the bridge. Before the repairs were completed monitoring marks were set up to ensure the defects didn't increase.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples**:** 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	**Answer:** The software used for the FEA was ANSYS, Inc. and SpaceGass for the 3D analysis. The FEA model was originally developed to accurately predict the stresses in the individual members of the truss. The individual members had varying levels of corrosion so a non-linear FEA was used to allow for redistribution of load to adjacent members.

Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples**:** reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	**Answer:** To simplify the analysis for the crash damage a linear elastic FEA model was used with the lower portion of the damaged component removed. The 3D SpaceGass model was also checked. A diagonal component of the truss that is adjacent to the damaged component was found to be the critical member of the truss both before and after the damage. The stress level in this member was checked for various vehicle loads. It was found to be overstressed with vehicles above 30t.
Date event resolved or concluded	10 April 2017
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples**:** prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took five days to complete, learned of new process for application of FRP
Answer	**Answer:** A new works procedure was developed and recorded for replacement of the diagonal steel components of the bridge.

This picture shows the newly installed diagonal steel member (in grey). The picture is taken from the roadway looking toward the walkway on the outside of the truss. The bridge was closed to traffic several times in order to complete the repair. The roadway needed to be excavated to get access to where the diagonal steel member was attached to the steel chords that form the base of the truss.

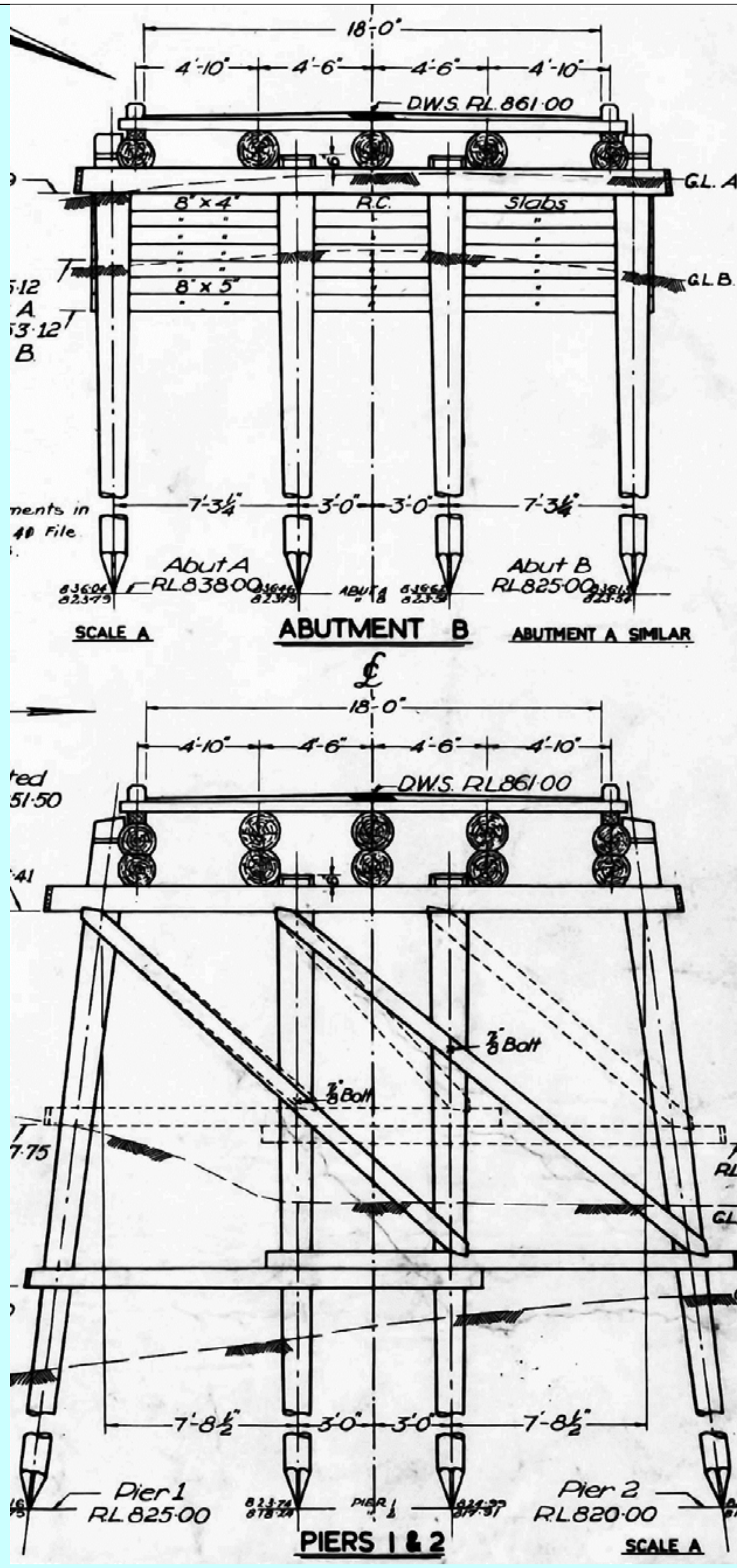
#2 AUSTRALIA (2)

Event Date	Trigger Category: Inspection
September 2010	Inspection after soil washed away discovered rotten timber piles

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Timber Girder	Restricting Heavy Trucks, and a lane	Yes	1961	27

Description: During an inspection after soil had washed away, a decayed timber pile was discovered. In addition, the part of the bridge deck had sunk. The Bridge was restricted to over legal heavy vehicles, one lane, and put on a 3-month inspection monitoring program. The permanent solution was completed in 2016.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Australia
Prepared by	Suzanne Brown
Date Prepared	13 February 2017
1.0	Description of Event / Incident
Description of Bridge	Three Span timber bridge originally built in 1961. The bridge was re-decked in 2003 replacing the transverse hardwood timber planks with bridge plywood. The bridge is on a low order road with a low Average Annual Daily Traffic Volume of 210 vehicles with 17% Heavy Vehicles. Each span is 9m long, so the bridge is only a total of 27m long. Each pier and abutment has four driven timber piles supporting two headstocks (cross beams). The superstructure consists of five round timber corbels and girders per span supporting the plywood deck with asphalt wearing surface.
Picture of Bridge	


18'-0"
4'-10" 4'-6" 4'-6" 4'-10"
D.W.S. RL 861·00
G.L. A
8" x 4"
R.C.
Slabs
G.L.B.
8" x 5"
7'-3¼" 3'-0" 3'-0" 7'-3¼"
Abut A
RL 838·00
Abut B
RL 825·00
SCALE A
ABUTMENT B
ABUTMENT A SIMILAR
18'-0"
4'-10" 4'-6" 4'-6" 4'-10"
D.W.S. RL 861·00
⅞ Bolt
⅞ Bolt
7'-8½" 3'-0" 3'-0" 7'-8½"
Pier 1
RL 825·00
Pier 2
RL 820·00
PIERS 1 & 2
SCALE A

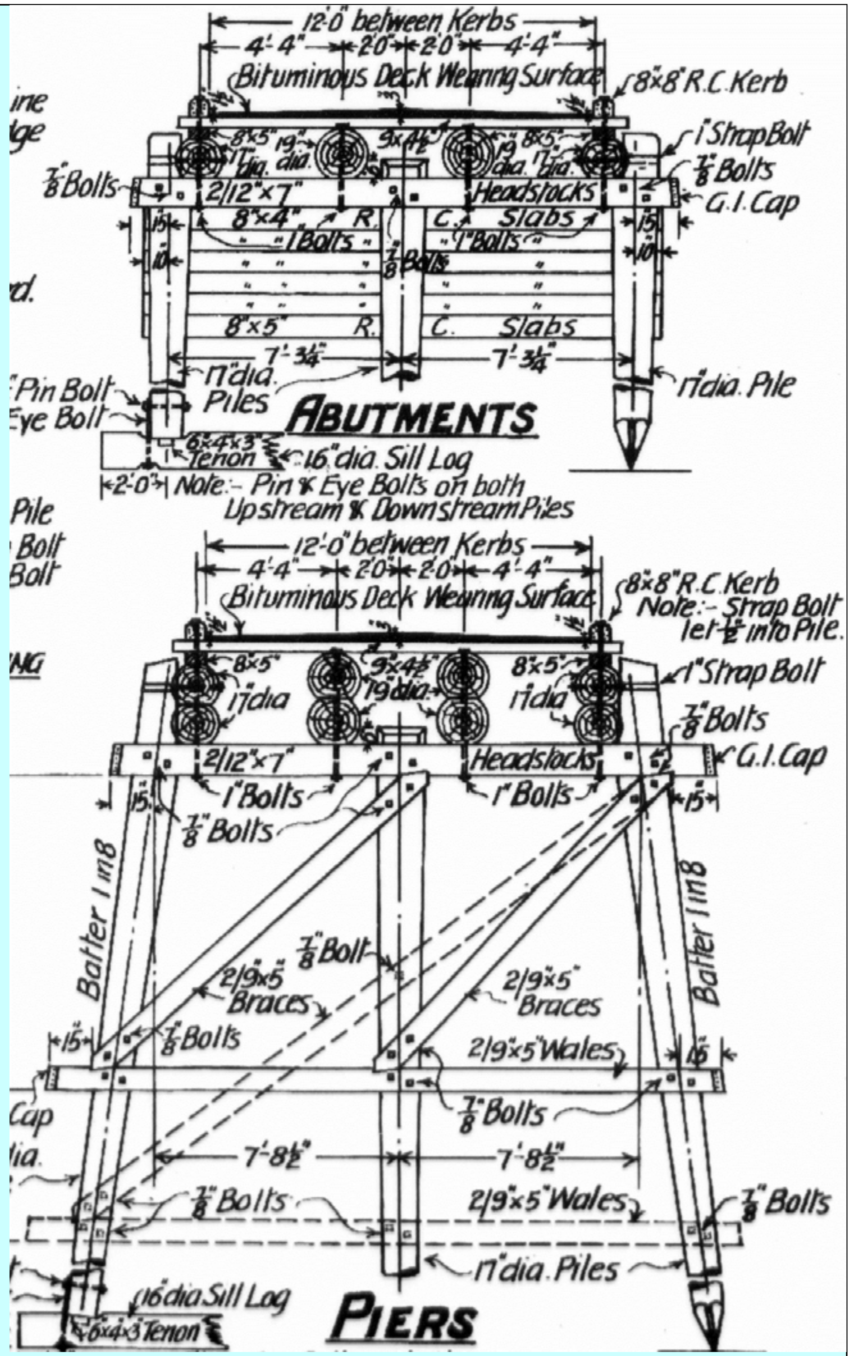
Description of the event and the trigger that caused the assessment	Examples**:** bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	**Answer:** Timber pile gradually rotted beneath the ground, defect discovered after some soil washed away. Then the bridge inspectors dug around the pile to uncover the full extent of the defect. The pile with the most severe rot was in Abutment 2. The bridge deck was also out of shape (sinking) at Pier 1 which added to the issues. This can be seen in the first picture above. 
Date of initial event	September 2010
Describe your immediate reactions to this event	Examples**:** close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	**Answer:**

	• The bridge was restricted to regulation mass vehicles (42.5T) by banning excess mass vehicles requiring a permit to travel. • The bridge was put onto the monitoring program to be inspected every 3 months • The bridge was restricted to one lane operation. Vehicles travelling in one direction had to give way to vehicles travelling in the opposite direction. This was practical due to the low volume of traffic using the road and the short length of the bridge (27m). Traffic was moved on the right hand side of the bridge so that the live load was carried by the other three timber piles. The other three piles in the Abutment were in good condition. Converting the bridge to single lane also prevented the event where two vehicles would be on the bridge at the same time. 
Who in your organization made the immediate assessment and what qualifications did they have?	Examples**:** Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.

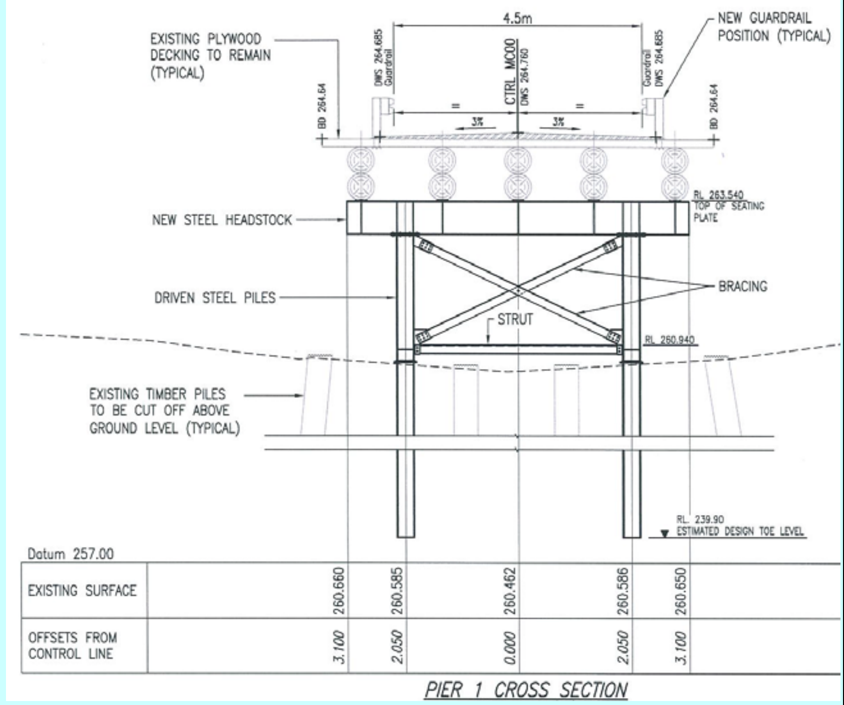
Answer - Who in your organization made the immediate assessment and what qualifications did they have?	**Answer:** Registered civil engineer in the district where the bridge is located and then checked and agreed to by a registered structural engineer in head office.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers:	Examples**:** What engineering judgement did you use / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	**Answer:** As the defective pile was located on the same side of the bridge as the depression in the bridge deck we were able to move traffic to the other side of the bridge by allowing only a single lane of traffic to use the bridge. This was possible due to the low volume of traffic using the road and the short length of bridge. Description of structural process • These old timber bridges were designed in accordance with working stress methodology. When undertaking capacity checks we adopt the same methodology. • Under WS methodology bridge piles inspected and found to be in good condition were assumed to be capable of carrying a safe working load (axial compression) of 20tonne each. This assumes a 17” or 432mm diameter pile. • The abutment reaction for the specified live load was calculated and a simple 2d SpaceGass model used to derive the load distribution to each of the 3 remaining piles.

	• A comparison was then made with the derived load (as per dot point 3) and the assumed capacity of each pile based on pile area (as per dot point 2) • There are also several other single lane bridges on the network that were designed and operate with only three timber piles of the same diameter. These bridges are operating well under current vehicle loads so this gave extra confidence to the decision. An excerpt from the standard drawing is shown below in Section 4.
Answer - Who in your organization made the decision and with what qualifications did they have?	**Answer:** Registered civil engineer in the district where the bridge is located and then checked and agreed to by registered structural engineer in head office.
Answer- What pertinent data did you have at your time the decision?	**Answer:** Detailed inspection by experienced bridge inspectors, including photographs. Plus inspections from each previous year. Classified vehicle counts to show the volume and type of vehicles using the road.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	**Answer:** There are no alternative routes to this road. The road goes to a dam and there are several tourist parks and residents on the road that rely on the bridge being open. The road wasn't used frequently by excess mass vehicles, so banning them didn't have a big impact. Especially as they couldn't cross the next bridge on the road. This would only have a significant impact if major works were required on the dam.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	**Answer:** No as the bridge was built in 1961 and the design matches the Standard Drawing details for timber bridges from the time it was built.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	**Answer:** Implementing a lower load limit or sidetracking the bridge if it showed any further signs of structural issues. Reducing the traffic to single lane and moving it to the side allowed the bridge to be kept open to traffic while a more permanent solution was found.
3.0	Description of special inspections, and damage assessment techniques

Description of the special inspections, assessments, methods, or techniques used.	Examples**:** dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	**Answer:** The monitoring of the bridge including surveyors checking the levels on the pier that was sinking and causing the deck to distort. No further movement was detected once monitoring began. Also experienced bridge inspectors went to the bridge every three months to check for any signs of structural distress in the bridge.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples**:** 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	**Answer:** As described above. Extract from old standard drawing below showing a three pile / four girder arrangement.

	
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the	Examples**:** reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.

special assessment into your analysis models?	
Answer	**Answer:** Removal of the fourth pile from the distribution of load as it was effectively carrying no load due to its condition.
Date event resolved or concluded	The temporary solution of moving the traffic over was implemented within a week of finding the defect. The more permanent solution was completed in 2016.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples**:** prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took five days to complete, learned of new process for application of FRP
Answer	**Answer:** Timber bridges are good at re-distributing load. The final solution involved replacing the timber sub-structure with steel. Many of the timber piles were showing signs of rot and deterioration below ground level. After completing geotechnical investigations it was revealed that the bearing capacity of the ground was low and the piles had to be driven to a depth of at least 20m. It is assumed the ground conditions were the reason for Pier 1 sinking and distorting the deck. Funding was not available for replacement of the bridge in concrete due to other priorities on higher order roads. It was decided to keep the bridge operating as single lane as no issues had arisen since this was implemented in 2010. For the sub-structure replacement, the bridge was sidetracked, the timber components unbolted and stockpiled, old piles cut off at ground level, new steel piles driven and the bridge re-assembled.


4.5m
EXISTING PLYWOOD DECKING TO REMAIN (TYPICAL)
NEW GUARDRAIL POSITION (TYPICAL)
CTRL MC00
3%
3%
NEW STEEL HEADSTOCK
RL 263.540 TOP OF SEATING PLATE
DRIVEN STEEL PILES
BRACING
STRUT
RL 260.940
EXISTING TIMBER PILES TO BE CUT OFF ABOVE GROUND LEVEL (TYPICAL)
RL 239.90 ESTIMATED DESIGN TOE LEVEL
Datum 257.00
EXISTING SURFACE
260.660
260.585
260.462
260.586
260.650
OFFSETS FROM CONTROL LINE
3.100
2.050
0.000
2.050
3.100
PIER 1 CROSS SECTION

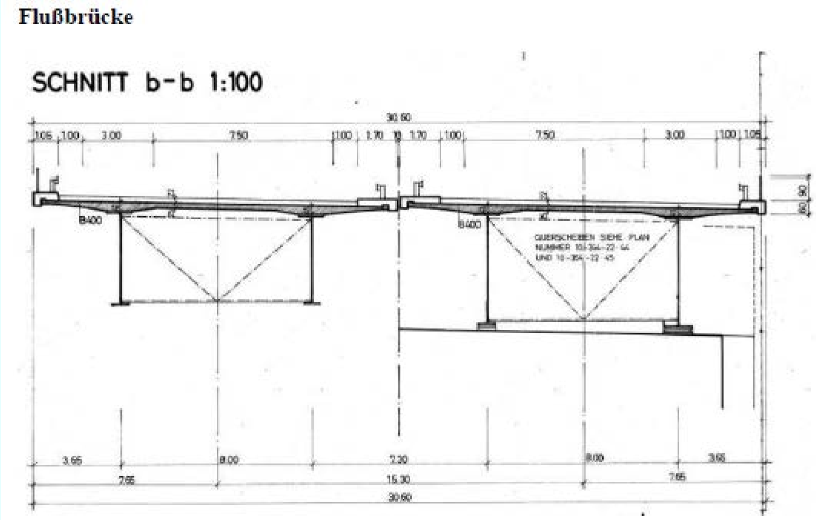
#3 AUSTRIA (1)

Event Date	Trigger Category: Inspection
2009	Floor panel plate buckling

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Plate girder	Lane Closed	Yes	1969	13290

Description: A main bridge inspection identified floor panel plate buckling. The security lane was closed immediately. The decision was made to replace the bridge in a future year and leave the security lane closed.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Austria
Prepared by	Martin Kirchmair
Date Prepared	July 2016
1.0	Description of Event / Incident
Description of Bridge	Name of the bridge: B74 Terfener Innbrücke The existing structure of the B74 Terfener Innbrücke at the A12 Inntal Motorway in Tirol / Austria spans the Inn river with 52,90 and 80,00 m. The bridge is existing of the main structure with an concrete-steel-composite structure and the secondary structures with a reinforced concrete deck. The bridge was built in the years 1969 and 1970. In 1973 occurred the first problems in the floor panel in terms of plate buckling.
Picture of Bridge	

	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	The trigger were the routine inspections and the local problems with the plate buckling. This lead to a recalculation with the code "*Evaluation of load capacity of existing railway and highway bridges*".
Date of initial event	The last main inspection was in 2009.
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	We closed the right security lanes and we initiated some repair works.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The immediate assessments have been from our bridge inspectors and from an external Civil Engineer due to the four-eyes-principle.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what	Examples:

assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Then we made a recalculation based on the Austrian code "*Evaluation of load capacity of existing railway and highway bridges*". To have secure data of the material we tested the steel properties of the structure.
Answer – Who in your organization made the decision and with what qualifications did they have?	The decision has been made from the group of the Asset Management together with the external Civil Engineer.
Answer - What pertinent data did you have at your time the decision?	We had the available data from the bridge inspection.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	The first decision was to close the security lane on the bridge - this had to be done immediately. The second decision was to put the bridge in the reconstruction program.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	The analysis is based on a central grating system and the slab has been calculated by the Finite Elements method.

Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The first fixes were to close the security lane.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	We made some special inspections, a material property evaluation and a recalculation.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	The analysis is based on a central grating system and the slab has been calculated by the Finite Elements method.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The real material properties of the steel has been one of the parameters of the recalculations.
Date event resolved or concluded	
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair.

	This took 5 days to complete, learned of new process for application of FRP
Answer	We closed the security lane on the bridge – we had the same number of traffic lanes and no problem with the traffic. Due to the massive problems with the bridge it will be removed and reconstructed in the next years.

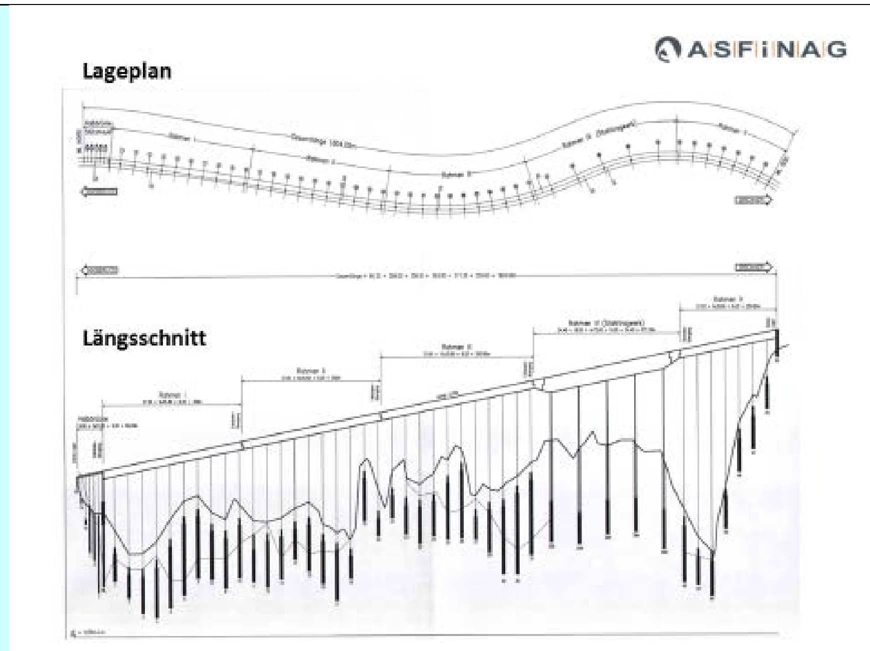
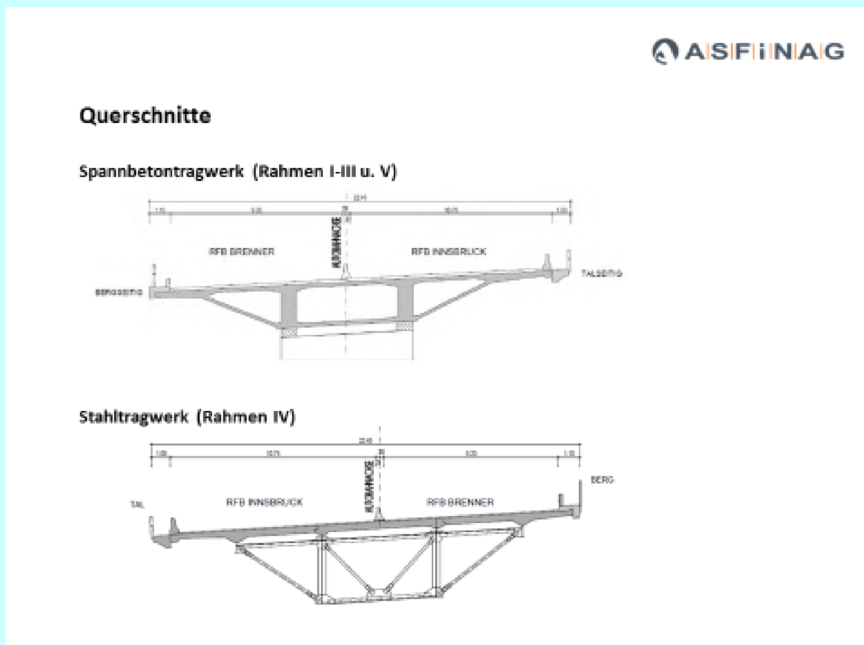
#4 AUSTRIA (2)

Event Date	Trigger Category: Inspection
2013	Gaps near prestressed cable couplers were detected

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Mixed Steel Plate - Prestressed T Girders	Special Inspection	Yes	1968	1800

Description: A main bridge inspection identified open gaps near prestressed cables where they are coupled together. A gap surveillance monitoring system was installed. Some of the members were reinforced after the engineering analysis calculations were performed.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Austria
Prepared by	Martin Kirchmair
Date Prepared	July 2016
1.0	Description of Event / Incident
Description of Bridge	Name of the bridge: BB57 Luegbrücke The existing structure of the BB57 Luegbrücke at the A13 Brenner Motorway in Tirol / Austria is a hillside bridge with a total length of 1.800m. It is subdevided into 5 frames. Four frames have a cross section of T-girders and are pre-stressed. The frame number 4 is a steel bridge with a concrete deck. The bridge was built in the years 1966 to 1968.
Picture of Bridge	

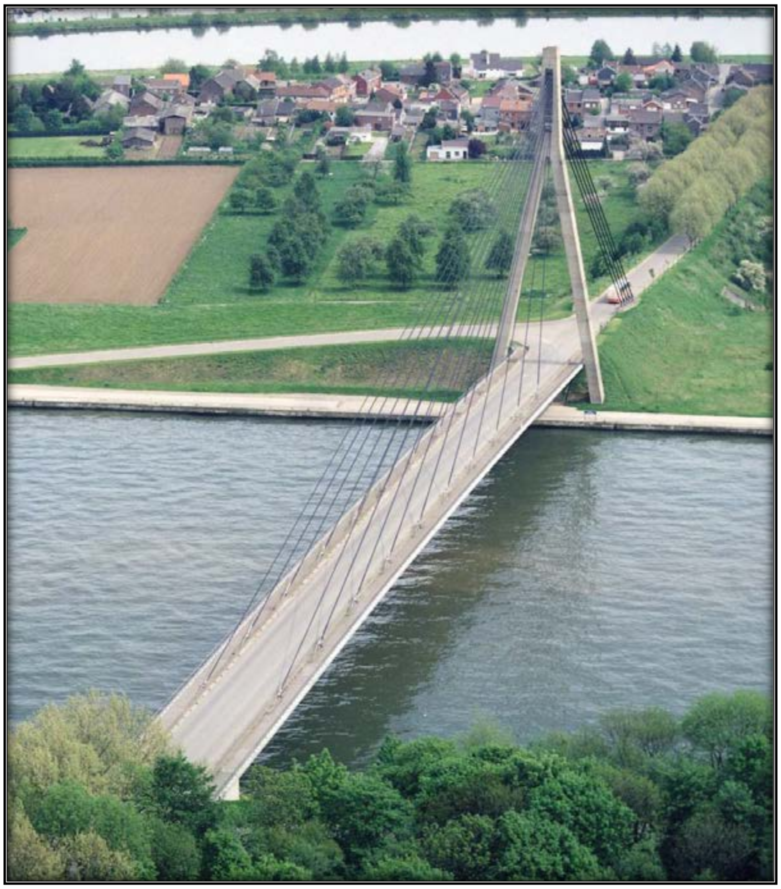
	 
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	In the course of the main inspection some open gaps at the location, where the pre-stressed cables are coupled have been discovered. Thereafter we initiated some special assessments.

Date of initial event	The last main inspection was in 2013.
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	We decided to install a gap surveillance system and to make some special investigations and detailed calculations.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The immediate assessments have been from our bridge inspectors and from an external Civil Engineer due to the four-eyes-principle.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?

fixes considered at the time of the decision?	
Answer	We immediately installed a gap surveillance system with an automatic alarm when increasing a fixed value. After having the first calculations we applied some reinforcements at the critical areas. So there was no need to reduce the traffic loads. Afterwards we made some detailed calculations due to fatigue strength problems of the pre-stressed steel in the gaps.
Answer – Who in your organization made the decision and with what qualifications did they have?	The decision has been made from the group of the Asset Management together with the external Civil Engineer.
Answer - What pertinent data did you have at your time the decision?	We had the available data from the bridge inspection.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	The actions to improve the carrying capacity had to be planned immediately.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	The analysis is based on 3D –frame model. Important was the application of all the constraints and the temperature gradients in the cross section of the structure.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	A surveillance program had been installed.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Applied measurement – system in the gaps. Detailed calculations due to fatigue strength problems of the pre-stressed steel in the gaps.
4.0	Description of load calculation model and the application of damage or deterioration to that model

Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	The analysis is based on 3D –frame model. Important was the application of all the constraints and the temperature gradients in the cross section of the structure.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The deterioration of the pre-stressed steel has been taken into account.
Date event resolved or concluded	
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	Now we are very sensitive due to the open gaps at the location, where the pre-stressed cables are coupled.

#5 BELGIUM

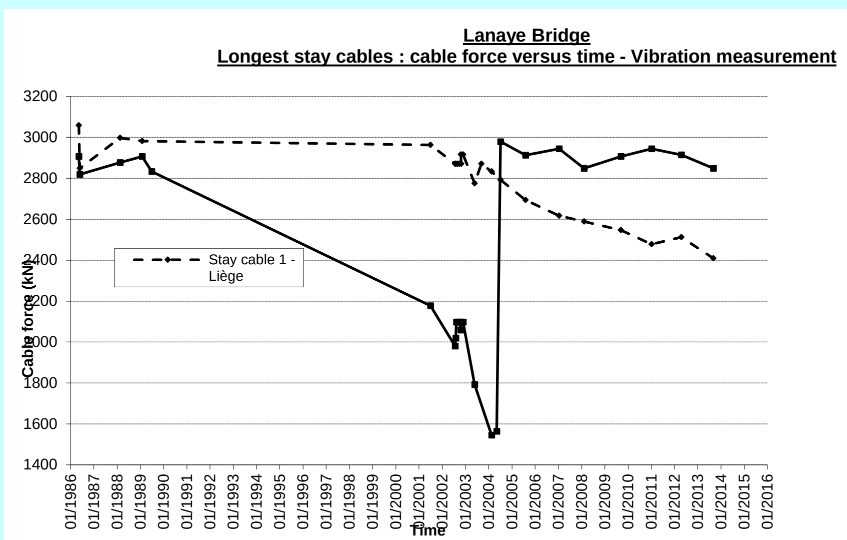


Event Date	Trigger Category: Inspection
2001	Cable partial rupture and deteriorated

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Asymmetrical Cable Stay	No Immediate Reaction	Yes	1986	232

Description: A cable inspection identified a cable with some wires ruptured. Two strands were installed next to the cable in case of complete rupture. An analysis was done to verify the bridge would be serviceable with one less cable.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Belgium
Prepared by	Pierre Gilles
Date Prepared	3.03.2017
1.0	Description of Event / Incident
Description of Bridge	Lanaye bridge, with a total length of 232 m, crosses the Albert canal before it reaches the Dutch border. It connects the areas of Lanaye and Eben-Emael. It is an asymmetrical cable-stayed bridge with a single reinforced concrete pylon at the base. It is equipped with 2 layers of 5 stays anchored into the counterweighting abutment (Lanaye side) and 2 layers of 10 stays anchored to the deck (Eben-Emael side). The deck, in the form of a box, consists of two principal metal girders and reinforced concrete slabs (light aggregates). The main section, which crosses over the Albert canal, is 177 m long and 13.3 m wide and the stays, made from between 104 and 325 parallel galvanised wires (Ø 7 mm), are between 49.25 and 165.79 m long. The wires are protected by HDPE covers which have been injected with bray epoxy resin.

Picture of Bridge	
Description of the event and the trigger that caused the assessment	
Answer	All the cable-stayed bridges managed by the Public Services of Wallonia are checked periodically to record the cable force in the stays. The measurements on the Lanaye bridge were taken in this context. 

Date of initial event	2001
Describe your immediate reactions to this event	
Answer	Bridge assessment with one or two cable less The stability of the cable was also check with different uncertainties. Depending on the kind of corrosion and on the location of the wire rupture, the cable main became unstable and may fall down on the road and/or on the canal. To avoid this risk, two strands where installed beside the cable in order to maintain it even if the cable was completely broken.
Who in your organization and made the immediate assessment and what qualifications did they have?	Structural engineer at the Bridge Department
Answer – Who in your organization made the decision and with what qualifications did they have	It was a common decision between the local department and the bridge department. All were engineer.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the	

assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	
Answer	The main investigation method was the stay cable effort measurement by frequency measurement. We performed also geometrical measurement of the cables in order to confirm the situation. We try different electromagnetic method in order to locate wires ruptures but without real success. In dead after replacing the cable, we open completely the old cable in order to understand what happens and were where the wires ruptures. We observe that prediction with the different electromagnetic method didn't match the reality. The assessement of the bridge was relatively simple. Just check how it believe with one or two cable less.
Answer – Who in your organization made the decision and with what qualifications did they have?	Bridge engineer in the bridge department
Answer - What pertinent data did you have at your time the decision?	Loss of effort in the stay cables
Answer - How did the timeframe of returning the bridge to full service influence the decision?	No real impact because the bridge was still stable with one less stay cable. No big traffic on the bridge.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	Yes 2D
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	stay cable stabilization
3.0	Description of special inspections, and damage assessment techniques
Description of the special	Examples: dynamic tests of members, proof testing, material

inspections, assessments, methods, or techniques used.	property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	With success : stay cable effort determine by frequency method without success : Different electromagnetic method to locate wires ruptures
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	The original calculation notice was enough
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	It is very easy to remove a cable in the model.
Date event resolved or concluded	
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	For stay cables it is essential to monitor stay cable effort during all time live.

#6 CANADA 1(S)

Event Date	Trigger Category: Inspection
July 2016	The impact damaged both exterior girders

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Girder	Closed Bridge	No	1965	

Description: The bridge girders was impacted by an over height vehicle. The bridge was closed immediately by law enforcement. After an inspection, the bridge was open with one lane running in the center portion. A normal repair of the girders was completed in November.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Canada
Prepared by	Bernard Pilon
Date Prepared	January 2017
1.0	Description of Event / Incident
Description of Bridge	Bridge located on highway 343 over autoroute 40 in St-Sulpice (outskirts of Montreal). Consists of four continuous steel beams. Constructed in 1965 and extensively renovated in 2006 (new girders and slab) 20 000 ADT with 4% trucks. The bridge is used to access the City of l'Assomption and St-Sulpice from autoroute 40 and receives a fair amount of traffic during rush hours.
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Bridge was hit by boom truck and both exterior girders were damaged. Worst hit was the last one (west exterior, westbound) Below are pictures of both damaged girders

	 
Date of initial event	July 5th 2016, in the morning
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	Bridge was initially closed to all traffic by law enforcement, so was the autoroute underneath. Traffic was diverted through the exit ramps. In the following hours, a bridge inspection engineer from our local office on Montreal's North shore inspected the bridge from the ground (see following answer). Decision was made to resume traffic normally on both directions of the autoroute underneath (six to 8 hours after impact) and to open one lane of the bridge in the center portion of the deck over the two intact girders. Lane on the bridge was opened approximately 10 to 12 hours after impact.

Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Bridge inspector (engineer) made the initial on-site inspection from the ground and reported pictures and observations to a committee composed of bridge experts (design and rating engineers) and managers
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Since two of the girders were not affected, and a third was damaged locally, reopening to one lane was possible fairly quickly. The position of the opened lane meant that no traffic loads were transferred to either of the damages girders. Also, since the girders were a recent design (less than 10 years), no further analysis was deemed necessary for capacity. A detailed inspection with a lift truck was done in the

	following night (by inspection engineers) and revealed no other damages than those initially observed The opened lane was in the northbound direction. A detour was more easy in the southbound direction so the bridge remained in this condition until the more permanent repair
Answer – Who in your organization made the decision and with what qualifications did they have?	Decision was made by a committee of bridge engineer from our design and rating teams. Also on the committee were the managers from those teams. All agreed with the decision, including the inspector (engineer) on site.
Answer - What pertinent data did you have at your time the decision?	Pictures, as built plans
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Since the detour of the southbound lane on the bridge was not so long and efficient, the repairs were done using our normal tender procedure. Bridge was opened to two lanes in November.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	In order to open one lane, since no traffic loads were transferred to the damaged girders and since those were recently made (10 years), a simple analysis (2D) of the position of the wheel loads on the deck was made.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	A system of high strength bars to reinforce the less damaged girder was considered to open quickly the bridge to two lanes but since the detour route on the southbound lane proved to be efficient, it was not used immediately. This reinforcement was eventually used on a temporary basis to splice the damaged portion of the girder during the permanent repair work.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Not in this case
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.

techniques used.	
Answer	None for the initial one lane opening 2d line analysis for the permanent reinforcement. Done with SAFI. (we also use Advance Design America in our office) Mathcad calculations for the repairs
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	
Date event resolved or concluded	
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	Not the first bridge hit this way on our territory, a fairly well defined procedure of inspecting for damage, identifying potential falling debris, etc. is in place. In this particular case, no analysis was deemed necessary to open the bridge to traffic but in some cases such an analysis is undertaken. Typically, assumptions will then be made to not consider a portion of a steel girder flange or a certain portion of prestressing strands and concrete section depending on the severity of the observed damage.

#7 CANADA 2(C)

Event Date	Trigger Category: Inspection
December 2013	fire reached the girders

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Plate Girder	Closed Bridge	Yes	1972	483

Description: During a repair project, a fire started on the temporary works that reached the girders. The bridge was closed immediately by law enforcement. A inspection was performed and resulting in leaving the bridge closed. A repair and reinforcement of the girders was completed in 14 days.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Canada
Prepared by	Bernard Pilon
Date Prepared	Week of February 6 2017
1.0	Description of Event / Incident
Description of Bridge	Bridge located on highway 175 over the Saguenay river in Chicoutimi. Seven spans, continuous steel caisson beam with four webs supporting a concrete slab. Total length of bridge, 483 meters Constructed in 1972 46 000 ADT with 10% trucks. The bridge is an important regional link between the city of Chicoutimi and the surrounding municipalities. It is particularly used during the morning and afternoon rush hours
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	While repair work was being done on one of the concrete piers (in winter), a fire started in the temporary heated enclosure and burned a wooden access structure and formworks. The flames reached the steel caisson overhead. Below are pictures prior, during and after the fire

Date of initial event	In the night of December 9 to December 10 2013
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	Bridge was initially closed to all traffic by law enforcement and the local fire department. Once the fire was extinguished, a bridge engineer from our local office decided to maintain the closure and contacted an expert engineer from the central office (in Quebec City) Since a bridge collapse we had in 2006, we put in place a telephone number where expert bridge engineers can always be reached by all of the ministry's personnel to make quick assessments in case of events on bridges. By the description of the event and the aspect of the defaults seen form the embankment (15 meters distance), this expert engineer concluded that the bridge must remain closed until further inspection. He then proceeded with a colleague (also a bridge engineer) to the site (approx. 2hr drive) for this inspection. Both engineers, with personnel form our local office, inspected the caissons from the interior and from the exterior (summary inspection using climbing ropes) and noted significant buckling of the bottom plate of the caisson had occurred. Deformation of the webs and stiffeners was also visible. Some welds were also cracked. This lead to a prolonged closure of the bridge and need for further analysis
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Initial decision to close the bridge was made by law enforcement, once the fire was extinguished, the closure was prolonged by a local senior bridge engineer (responsible for bridge inspections on his territory) Experts engineers contacted have at least 10 years' experience in bridge design and/or bridge evaluation
2.0	Description of decision making process
Describe the strategies,	Examples:

actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	There were no immediate fixes possible to the buckling of the bottom plate. Reinforcement would need to be put in place. A simple analysis would not be possible considering the defect (localized buckling). Since the bridge was an important regional link between two urbanized regions, re-opening of the bridge as quickly as possible was necessary. A detour route was organized by law enforcement but it was long (40 km) and was jammed by traffic almost all day. Requests were made to employers to consider allowing work from home. A pedestrian bridge was opened nearby but freezing temperatures (minus 15 degrees Celsius) made the walk difficult. Emergency vehicles were permitted to use the closed bridge if needed in a lane over a less affected area. A 2D analysis of the bridge had been made two years prior to the event in planning for repairs to the concrete deck. Using the

	moments and stresses from this analysis, a detailed analysis, considering the buckling, could verify if the remaining capacity of the bridge was sufficient to open the bridge to light vehicles (5 tons). In order to do this analysis, we had the as built plans with the dimensions of the steel elements noted during the rating inspection and we had relatively precise records of the amount of buckling that had occurred in each panel (measured by the engineers during the special inspection the day after the fire) Steel cores would have to be taken from the bottom plate to assert if the steel had lost mechanical properties or if fatigue could be a problem. These cores were taken the day following the fire and the results were known late on December 11. Results showed the steel material properties were not significantly affected by the fire.
Answer – Who in your organization made the decision and with what qualifications did they have?	Decision to proceed with a more precise evaluation and to keep the bridge closed was made by a committee of bridge engineers from our design and rating teams. Also on the committee were the managers from those teams and the senior manager of the bridges department and a specialist in metal fatigue. The two engineers that had made the inspection after the fire were part of this committee. The assistant deputy minister (also happens to be an engineer) was then informed of the decisions.
Answer - What pertinent data did you have at your time the decision?	2D analysis made in the years prior to the event. Measurements of the buckling made during the special inspection and as built plans. After one day, steel core analysis results. Two engineers had seen the bridge and pictures of this inspection were available.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Re-opening the bridge as soon as possible was necessary. It was initially considered to reinforce a portion of the steel caisson in order to open one lane in each direction. However, the detailed analysis showed some risk in doing so and there were concerns regarding a possible redistribution of loads that could have occurred during the fire caused by the deformations of the bottom plate. It was also found that once the contractor was mobilized on site, it was only a matter of one or two extra days to complete the entire reinforcement.
Answer - Did you do an	A 2D analysis had been made, see previous answers

engineering calculation prior to the assessment, in 2d or 3d?	
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	Other than analysis and testing, no temporary fixes were considered as possible.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	The bottom plate panels buckling were measured using a 3m straight ruler. The cracked welds were observed visually. Steel cores were taken the day following the event, discussed in the preceding answers. The cores were tested for tensile strength and were observed by microscope to see the grain of the steel and evaluate potential defects cause by the heat. A load test was initially considered to assert the capacity of the bridge but due to difficulties in measuring the deformations with enough precision, the idea was abandoned
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	The initial 2D model was done using SAFI (a program similar to SAP 2000) This model was done after an evaluation inspection was defects are noted (such as corrosion) and steel thicknesses of elements are validated in regards with the as built plans. For the detailed analysis, a Finite element model of the bottom plate and the stiffeners was made using Femap-Nastran. The efforts from the 2D model were used in the detailed model (dead loads). The detailed model was used to evaluate the resistance of the bottom plate in its deformed state and determine, once the dead loads were entered, the load reserve for the traffic before

	buckling of the entire caisson
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The detailed model showed that there was insufficient capacity remaining in the caisson to open the bridge to all traffic with sufficient security. The bottom plate in its deformed state could carry loads of 5 tons but other defects in the webs needed to be repaired first. (the model showed that the web stiffeners needed to remain straight and take a sufficient load if the bottom plate was to work adequately) The results of the finite element model were used to calculate the reinforcement. The reinforcement was considered as a permanent fix and consisted in adding stiffener angles on the webs to straighten them out. Top and bottom plates on the bottom flange of the caisson were added locally near the webs to take the traffic loads. The buckled sections of the bottom panels were thus not considered in the sections used for calculation
Date event resolved or concluded	The reinforcement of the web panels were completed on December 20 (10 days after fire) and the bridge was then opened one lane to light traffic (posted 5 tons with continuous law enforcement monitoring at the entries) The bottom plate reinforcements were completed 4 days later on December 24 and the bridge was then opened to all traffic on all lanes. Magnetoscopic inspection of welds was done in the following weeks
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair.

	This took 5 days to complete, learned of new process for application of FRP
Answer	The event pointed out the need to have better procedures for work and inspections in enclosed spaces since there were some delays initially with the access inside the steel caissons for inspection. (Local fire department was needed to access interior of caissons)

#8 CHINA

Event Date	Trigger Category: Bridge Impact
June 2007	Vessel Collision with a Pier

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Cable Stay	Closed Portion	Yes	1988	1675

Description: A vessel collided with a pier and caused a portion of the bridge to collapse. The bridge was closed and a damage inspection was performed. This was major event and a rehabilitation project was completed in three steps. The steps included removing the sunken ship and collapsed portion of the bridge, followed by the final repair and rehabilitation. This was completed by August 2008.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	China
Prepared by	Liu Bo
Date Prepared	July 2016
1.0	Description of Event / Incident
Description of Bridge	o The Jiujiang Bridge of National Highway No.325 over the Xijiang River(Part of the Pearl River), Guangdong Province,China o Total length 1675.2m, bridge deck width of 16m o Main span--2x160m single tower cable stayed bridge Approach span--21X50m Prestressed concrete box girder +20X16m concrete slab o Open to traffic in June 1988,Repair in 2009 and reopen to traffic in Jun 2009
Picture of Bridge	 The Original Bridge completed in 1988  The Repaired Bridge completed in 1988
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc

Answer	Due to the misty weather, a ship loaded with sand deviated from the designated channel, collided with the pier of non-navigable span, and caused a portion 200m of bridge collapse.
Date of initial event	5:00 am, 15th June 2007
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The damaged side of bridge was closed, and inspection and detection were immediately carried out for the damaged portion of the bridge. The Guangdong Province Transport Authority started the repair and rehabilitation of the bridge.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	In our organization the decision is made by the Guangdong Province Transport Authority after consultations with expert team of the State Safty Supervision Bureau which has many years of professional experience
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity.

Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Did you do more in the level of analysis?
Answer	There were no appropriate immediate or temporary fixes other than closing the bridge. The Local Authority organized the expert panel to investigate the possible repair solution for the bridge. In the meantime, the reason of the incident was realized and the responsibility was found as a result of the bridge inspection finding, due to the deviation from the designated channel. The bridge repair rehabilitation design was carried out by original bridge designer. After the occurrence of ship collision incident, the portion of bridge deck inclined over the river was dismantled and removed at the end of July and early August of 2008. The repair and rehabilitation of the bridge were divided in 3 steps, including salvage of sunken ship and removal of broken bridge deck, the third step is the repair and rehabilitation of damaged bridge. The rehabilitated Bridge has the same function and scale as the original bridge, but there are changes in bridge structures and materials used for deck. The collapsed portion was replaced by newly constructed (100m+100m) cable-stayed bridge+ 80m continuous box girder connected to existing bridge I. The deck structure of new cable stayed bridge is in composite structure with steel beam and concrete top slab, and the 80m continuous box girder is in prestressed concrete structure. The interfacing position between the newly constructed continuous box girder and existing box girder was added with external prestressing.
Answer – Who in your organization made the decision and with what qualifications did they have?	The Guangdong Province Transport Authority appointed Guangdong Province Highway and Survey Design Institute and Guangdong Province Transport Research Institute to undertake the bridge repair and rehabilitation design. Both are the existing bridge designers and have the relevant licenses.
Answer - What pertinent data did you have at your time the decision?	The existing bridge detailed design drawings and as-built drawings, bridge damage investigation reports.

Answer - How did the timeframe of returning the bridge to full service influence the decision?	For earliest traffic resumption, damaged bridge portion was dismantled and reconstructed according to a construction period of 12 months.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	The rehabilitation design was done by the original bridge designers. If it was rehabilitated following the original design, additional analysis and calculation would not require but only review of original calculations. However, the new portion of the bridge is changed to a cable stayed bridge structure, additional analysis and design calculations were performed.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	Since entire bridge deck collapsed, the traffic on one side was completely closed and opened again only after completion of bridge repair and rehabilitation. Therefore, there was not any temporary measure for traffic resumption.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	3-dimensional finite element modeling was adopted for the bridge rehabilitation design analysis.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.

Answer	Except for the newly built portion, for the interfacing positions between the newly rehabilitated and existing bridge, it was required to take into account the structural bearing capacities of existing structures where the actual material strengths also considered.
Date event resolved or concluded	The bridge rehabilitation was completed on 10th June 2009 for resumption of traffic
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	1. As for bridges over river, the Marine Department shall impose necessary monitoring measures to make sure the vessels should only travel through the designated navigation channel. 2. In the condition of poor weather, there must be sufficient pilotage to assure not deviated from the navigation channel. 3. In the waterway with frequent ship traffic, the pier number shall be reduced or the foundation to be strengthened enough against ship collision.

#9 FRANCE 1

Event Date	Trigger Category: Inspection
2011	Bending Cracks Discovered

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Prestressed Concrete Box Girders	Special Inspection	Yes	1976	204.50

Description: During an in-depth inspection several bending cracks were discovered. A special evaluation and site assessment was performed. The findings resulted in a permanent fix by adding additional prestressing and composite materials. This work was completed in 2011.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	France
Prepared by	Laurent Llop
Date Prepared	13 April 2017
1.0	Description of Event / Incident
Description of Bridge	Sach's Queven bridges. Bending cracks. Sach's Queven bridges carry the national road 165 between Nantes and Brest. There are 2 straight and independent bridges, 3 spans, prestressed concrete box girders. These bridges were built in 1976. Length : 204,50 meters
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Routine inspections (assessment visit and periodic detailed inspections) shows bending cracks. The regulation for national bridges are ITSEOA (Instruction technique pour la surveillance et l'entretien des ouvrages d'art : Technical regulation for survey and maintenance of bridges). These regulation describe an organization in 3 levels of the management service (decisional, organizational, operational) and survey and maintenance procedures (annual visual inspection, assessment inspection IQOA every 3 years for every bridges, detailed inspection every 6 years for complex or

	important bridges, etc…) and procedures when a problem occurs.
Date of initial event	2011
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	No need to reduce traffic or close the bridge. Slow evolution of disorders and reinforced survey was organized. Special detailed inspection. Concrete characterization. Geometrical measurements. Load analysis. Radar on web to verify reinforcement and prestressing. Recalculation.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Assessment was made by specialist by the CEREMA (technical public establissment) for the manager of the bridge (Ministry of energy, sustainable development and ecology represented by the Regional Directorate of Road of the west region). Theses specialists were engineer and have an internal qualification in CEREMA that allow them to be inspector or engineer in charge of studies (2 levels). Then the representants of the managers were specialized engineers in the DIR West working in a dedicated department in charge of bridge management (CGOA : cellule de gestion des ouvrages d'art : service of management of bridges). In regard of the insufficiency of structural security (ULS), and heavy insufficiency of reinforcement in web, reinforcement of the structure by additional prestressing and composite materials was proposed by the DIR West and decided by the Ministry, taking into account the technical project designed by CEREMA.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in	Examples:

determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Detailed inspection, materials characterization, geometrical control, radars on web to verify reinforcement and prestressing, recalculation with nowadays technical regulations.
Answer – Who in your organization made the decision and with what qualifications did they have?	There are internal qualifications in CEREMA for bridges inspectors, engineer in charge of studies.
Answer - What pertinent data did you have at your time the decision?	Detailed inspection report, recalculation.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	No influence. Bridges were not closed.
Answer - Did you do an engineering calculation	Detailed inspection, characterization of materials, then recalculation

prior to the assessment, in 2d or 3d?	
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	No temporary fixes were considered necessary. Permanent fix was to reinforce the two bridges in regard to bending and shearing force insufficiencies.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Radars on web. Materials characterization. Special detailed inspection.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	2D analysis with ST1 program.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	Excessive pavement thickness, heavy load convoys were considered in regard of load and traffic analysis.
Date event resolved or concluded	2011
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge.

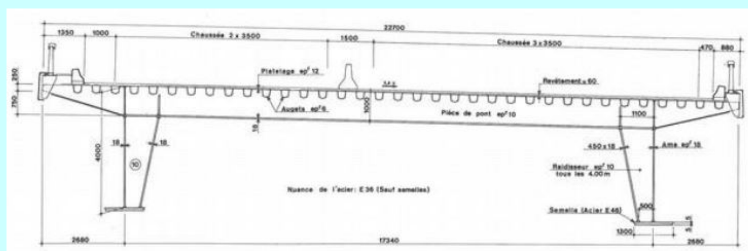
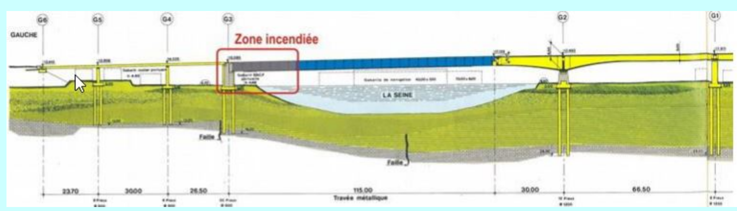
	Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	

#10 FRANCE 2

Event Date	Trigger Category: Bridge Fire
October 2012	Truck overturned and caused a fire on bridge

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Plate Girder – Mixed Concrete	Closed Bridge	Yes	1979	585

Description: A an overturned truck caused a fire on the bridge. This fire ignited parked trucks below the bridge increasing the fire damage and impact to the bridge. The bridge was immediately closed and boat traffic below was restricted. The deck was heated to avoid brittle collapse in cold temperatures. A permanent fix was performed by removing the damaged metallic portion and replacing it. This work was completed in August 2013.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	France
Prepared by	Laurent Llop
Date Prepared	13 April 2017
1.0	Description of Event / Incident
Description of Bridge	Mathilde bridge. Fire on the bridge in 2012. Burned zone was metallic bridge, this bridge was built in 1979. Length : 585 m, multi span, one span is metallic, others are concrete box girders. This bridge is in Rouen. It's not managed by the State but by the department of Seine Maritime (regional organization of France).  

Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	An accident has occurred : A truck carrying hydrocarbons overturned on the bridge and fire began. Then the burning liquid flew under the bridge and several parked vehicles took fire.
Date of initial event	29 October 2012
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The bridge was immediately totally close for the vehicles on the bridge and the boats under the bridge.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Bridge manager of department of Seine Maritime.
2.0	Description of decision making process

Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	A Special committee with experts has been created. This committee had Ministry of energy , sustainable development and ecology experts, CEREMA and IFSTTAR experts, and Departement of Seine Maritime agents. This committee advised : - special detailed inspection, - heating of the first 10 meters of the desk to avoid fragile collapse in cold temperatures, - characterization of the materials of the burned part of the bridge, and in general (steel of the desk and concrete of the pier), - laser measurements (100 Millions automatics measures) of the real geometry of the desk, - recalculation 3D of the bridge. Then the boat were allowed to go under the bridge. The department of Seine Manager accepted and has ordered all these actions.

	The temporary fix was to close the bridge for vehicles and boats, then only for vehicles in a second time. The permanent fix were : - solution 1 – partial replacement of the metallic span, after entire removal, - solution 2 - partial replacement of the metallic span, in situ. Solution 1 was the chosen solution, because the second need to built a temporary pier which was a problem for the boat traffic under the bridge.
Answer – Who in your organization made the decision and with what qualifications did they have?	Department of Seine Maritime with the special committee.
Answer - What pertinent data did you have at your time the decision?	The results of the investigation and studies ordered by the special committee.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	80000 vehicles were using the road each days. Fast opening of the bridge was very important.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	3D calculations were done.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The permanent fix considered was initially the replacement of the metallic desk.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Destructive material (steel) analysis. Very precise laser measurements of the geometry of the metallic desk after the fire.
4.0	Description of load calculation model and the application of damage or deterioration to that model

Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Finite element, 3D calculation were done. In the situation of the burned bridge and after repair.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	Integration
Date event resolved or concluded	26 august 2013 : the bridge was repared and opened for vehicles and boats.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	

#11 JAPAN 1(M)

Event Date	Trigger Category: Inspection
2009	Cracks Spalling and Flaking found led to discovery of fracture of PC Cables

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Precast block segmental	Lane Closed	Yes	1972	300

Description: In 2006, cracks, spalling and flaking in concrete were found in the bottom flange of the PC box-girder during a bridge inspection. Repair work was started in September 2009. When a part of the covering concrete with rust stains was removed for repair, the fracture of some PC cables was discovered. The owner immediately restricted traffic on the bridge by closing the lane above the damage. After the assessment, the traffic was removed by setting up a special monitoring program. The final repair consisted of carbon fiber sheet reinforcement and external PC tendons were installed. This work was completed in 2011.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Japan
Prepared by	
Date Prepared	
1.0	Description of Event / Incident
Description of Bridge	Myoko Bridge on National Highway 18 is located in Myoko city, Niigata prefecture. The bridge is a 4-spanned continuous PC box-girder bridge, and spans over the Ohtagiri River with a total length of 300m. The bridge is comprised of pre-cast blocks. The cantilever election was used when the bridge was built. The construction was completed in 1972. The bridge serves as a major link between Hokuriku and Kanto regions or Hokuriku and Chukyo regions. The bridge carries approximately 15,000 vehicles per day, and among these, the amount of heavy vehicles is 2,400 per day with a share of heave vehicles in the total traffic volume is about 16%.
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	In 2006, cracks, spalling and flaking in concrete were found in the bottom flange of the PC box-girder during a periodic bridge inspection. Repair works started in September 2009. When a part of the covering concrete with rust stains was removed for repair, the fracture of some PC cables was found out.
Date of initial event	December 1, 2009
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions

Answer	Immediately after the detection of the defect, the authority started the single lane, alternative traffic all day.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The immediate assessment was made by in-house engineers. They judged as there was a potential for this bridge to undergo a sudden collapse in the worst case scenario and requested the government research agencies, the National Institute for Land and Infrastructure Management (NILIM) and Public Works Research Institute (PWRI) to give technical advice. These two research institutes are leading agencies for developing and managing the national design specifications for road bridges.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?

What were the potential temporary / permanent fixes considered at the time of the decision?	
Answer	Fiber scope inspections and cover concrete removals were conducted to seek the rapture of PC cables or voids due to poor grouting of PC tendons. As a result, 22 cables out of 215 investigated cables (504 cables in total for the bridge) were found to be fractured. Chloride contents in grouting and concrete chloride ion distributions in concrete were measured, and the growth of gaps between precast boxes was monitored at several cross sections.
Answer – Who in your organization made the decision and with what qualifications did they have?	Investigation policy was decided by in-house engineer with advice from academic advisors and NILIM and PWRI.
Answer - What pertinent data did you have at your time the decision?	In addition to the above mentioned tests and measurements, earlier inspection records and bridge drawings such as PC cable arrangement for the construction of the bridge were found useful in the decision making process.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Removal of traffic restrictions in early stage was desired because of the following two reasons: 1. The bridge was located on a major arterial highway with a heavy traffic of 15,000 vehicles per day. 2. The distress found in winter. The bridge was located in a heavy snowfall area and the bridge has a vertical gradient. A traffic restriction in winter may cause traffic disruption due to skidding accidents and the struck of vehicles stuck on the bridge. Accordingly, fail-safe measures were set up and opened the traffic. After that, additional remedial measures were implemented in a systematic manner.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No numerical analysis was carried out.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The original construction drawings showed the erection cables in the box-girder that could hold the bridge and prevent the sudden bridge collapse. Accordingly, in the emergency investigations, the engineers removed cover concrete at some parts and confirmed if the erection cables really existed.

	In addition, temporary supports were constructed on the slope in front of the A1 abutment and a monitoring device was installed to measure the growth of the gap between box-girder segments. From the viewpoint of traffic management, the following three things were implemented. 1. A special emergency inspection protocol for earthquakes was set up. 2. The snow plow frequency was increased to reduce snow loading effects 3. Monitoring of passing heavy-weight vehicles After that, they designed remedial works using carbon fiber sheet reinforcement. External PC tendons were also installed with little tension forces that can start functioning when the original PC tendon reduce with more breakage of the original PC tendons.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Non-destructive testing for the portion where pre-stressing tendons were not well grouted, and visual inspection using fiber scope were carried out. A loading test using trucks was conducted, and the behavior of the connections between precast segments and existing cracks and the magnitude of vertical displacement were observed. The loading test has been carried out every year to track down the change in the bridge behavior.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Three dimensional structural analysis is performed as needed.

Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	For the portion where pre-stressing tendons is not well grouted, supplemental grouting is needed along with the detailed corrosion survey. However, the bridge is likely to have such defects in a lot of portions and it is difficult to fill all those voids. Plus, it is considered to be difficult to stop the growth of the corrosion once it initiated inside the duct even though the supplemental grouting was carried out. On the other hand, when the load carrying capacity is estimated too conservative, huge compression force may generated in the PC girder by the additional outer cables. Assume that concrete is subjected to a compression stress due to the additional external PC tendons, the concrete may be crushed in the compression side of the cross-section. In addition, it was difficult to estimate the loss of PC tendons. Accordingly, external PC tendons were installed but little tensions were induced, such that the external cables could compensate the reducing pre-stress due to the further breakage of the existing tendons. In addition to that, for the potential breakage of existing vertical PC tendons and the burst-out from the concrete, aramid fiber sheets was applied on the concrete surface.
Date event resolved or concluded	The remedial work was completed in 2011. The bridge is continuously monitored through visual inspection for PC cables using fiber scope and live loading test every year.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge.

	Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	The step-by-step recovery work functioned fairly well. However, it was hard to obtain the exact bridge condition especially inside the concrete. Accordingly the replacement work for this bridge started in 2012.

#12 JAPAN 2(Y)

Event Date	Trigger Category: Inspection
2006	Crack of one meter found from the welding connection

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Girder	Lane Closed	Yes	1971	128

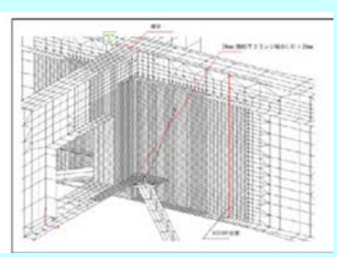
Description: During a routine inspection, the inspector found a crack with a length of 1m developing from the welding connection around the slit between main girder and transverse girder to the girder. The following day in-bound traffic was closed an emergency procedures were executed for 23 hours. The repair consisted of splicing metal plates from both side of the crack. Additional material was added to stiffen lower flanges. This was completed during the closure.

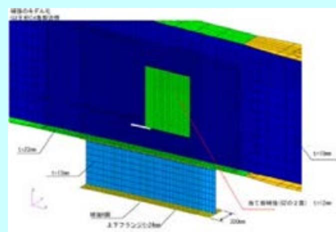
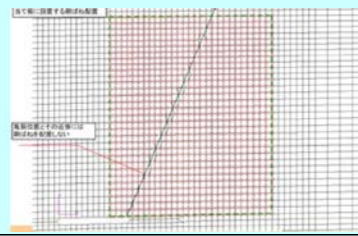
Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Japan
Prepared by	
Date Prepared	January 24, 2017
1.0	Description of Event / Incident
Description of Bridge	Route : National Route 25, Meihan Expressway Type of Road : Motorway Type of Bridge : 3-spanned continuous steel girder bridge Bridge Length : 128m Bridge Deck : Reinforced Concrete Deck Completion : 1971 Traffic Amount : Approx. 60,000 vehicles per day (45% of heavy vehicles)
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	During a periodic inspection, the inspector found a crack with a length of 1m developing from the welding connection around the slit between main girder and transverse girder to the girder web. (picture below)

	
Date of initial event	October 2006
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	- On the following day, the inbound-lane was closed, and emergency measure was executed for 23 hours. - Immediately after the detection of the defect, close visual inspection and magnetic-particle testing were carried out for all suspected welding connections with similar details. - Traffic was backup with an approximate length of 6km at maximum during the road closure. Also, the neighboring roads were congested.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	- In-house engineers - However, in this case, it was difficult to evaluate physical condition of the bridge and further investigation, the government research institutes and academic advisors helped the bridge owners identify the emergency inspections and countermeasures as per the request, where the government research institutes are the leading agencies of developing and maintaining the national bridge technical specifications.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen.	Examples: What engineering judgement did you use to come /

Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	- Fatigue crack is regarded as a major cause. The bridge had carried heavy traffic for more than 30 years, and the bridge had vulnerable substandard details of welding connection. to. And, they concluded that the defect was fatigue crack. - To find other defects in all similar connections, magnetic-particle testing was carried out as well as close visual inspection. - Stop hole with adding splices on the both side of the web. This emergency measure was carried out under the traffic closure because the stress intensity at the tip of the crack had to be reduced as much as possible. - Moreover the lower flange was stiffened by setting an H-shaped steel across over the cracked cross section for the purpose of backup of unforeseeable and

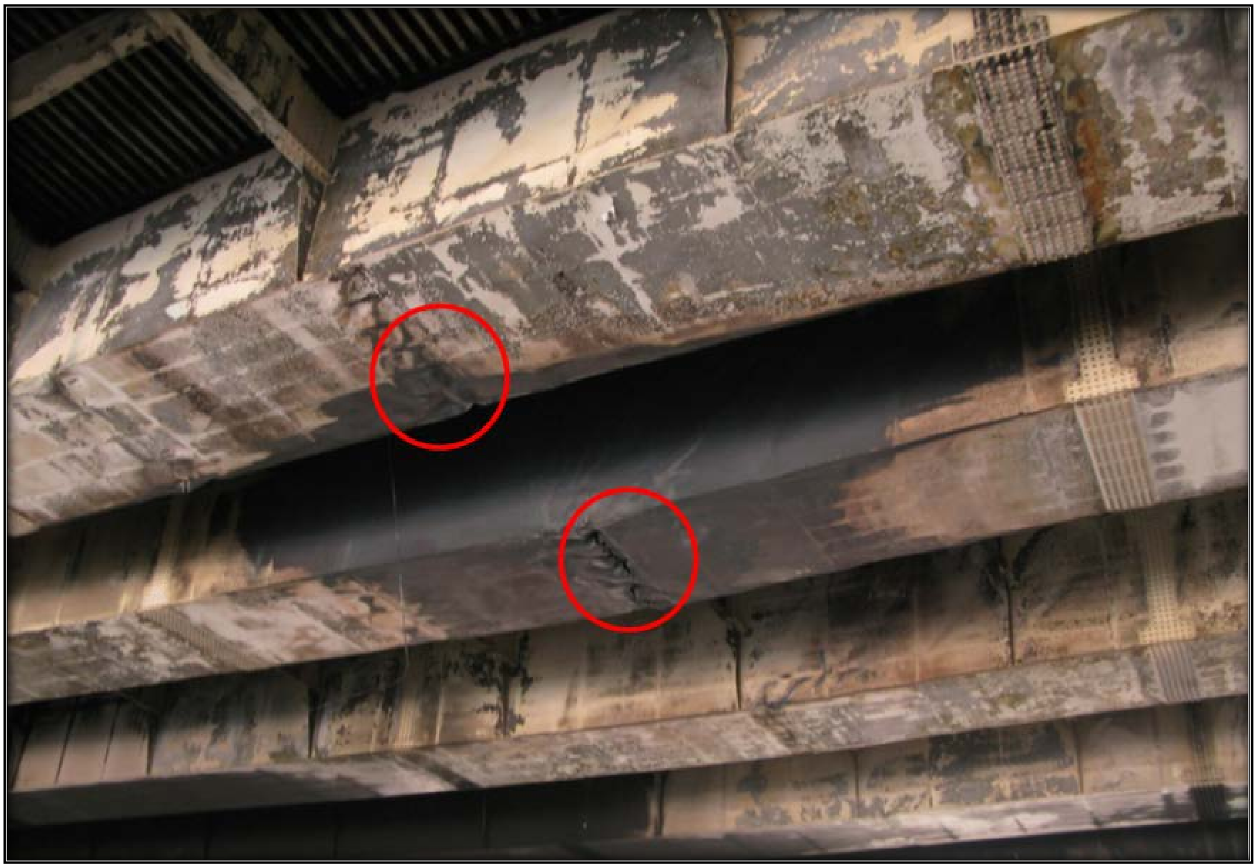
	sudden crack growth. - It was tacked to minimize the traffic closure duration and reduce the impact on road users and residents surrounding the bridge and detours.
Answer – Who in your organization made the decision and with what qualifications did they have?	- The bridge administrative agency made decisions referring to the advice from the academic advisors and the technical experts of the government research institutes.
Answer - What pertinent data did you have at your time the decision?	- In addition to the investigation above, earlier inspection records, bridge inventory data, original drawings were found useful.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	- The closure duration of this vehicle-purpose highway carrying approx. 60,000 vehicles per day had to be minimized as short as possible because it gave a significant impact on economy such as distribution of goods. - Again, the H-shaped steel member was set on the lower flange of damaged steel girder to secure the load carrying capacity for a sudden growth of the crack. This work influence the decision for the traffic resumption immediately after the emergency work without further testing. - After opening the traffic, dynamic load tests and a refined FE analysis are conducted and they confirmed the effectiveness of the measure: stress distribution around the fatigue crack was reduced.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,

Answer	- To find other defects in other part of the bridge, magnetic-particle testing were carried out as well as close visual inspection for the welding connections with suspected defects, such as paint film cracking, which is the typical indicator of fatigue crack. - After the implementation of the measure, they confirmed the effectiveness of the measure by dynamic loading test and FEM analysis. - To analyze the cause of the growth of the fatigue crack, chemical composition testing and charpy impact test were conducted.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	FEM analysis was carried out. - A three-dimensional numerical model covered major bridge components such as main girders, transverse girders and the deck. - The vicinity of the fatigue crack was modeled with fine meshes. - Reinforced concrete deck was modeled with solid elements, main girders are modeled with shell elements, and diagonal and lateral bracings were modeled with beam elements.  
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.

you use to enter the data from the special assessment into your analysis models?	
Answer	- As a retrofitting plan, two splices are fastened over the crack in the web from the both sides. The lower flange was stiffened with splices on the upper side and an H-shaped member om the lower side fastened to each other across the flange plate. A distribution load of modeling live loads was applied on the location such that the maximum bending moment in the main girder appeared at the cross section where the main girder was connected to the transverse girder.  
Date event resolved or concluded	The traffic was re-opened after a 23 hour-closure due to the emergency retrofitting works.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	- All similar welding connections with the low fatigue resistance were retrofitted by bolted cover plates. - A knowledge database has been developed for defect types and portions and remedial measures from the earlier inspection and maintenance reports of all similar steel girder bridges on the same route. - For all similar steel girder bridges on the same route, all welded connections have been databases as a function of connection types with numbers and locations, so that once some major defects happens,

	the road administrator can check other bridges in an efficient and concentrated manner with a short period as the first action.

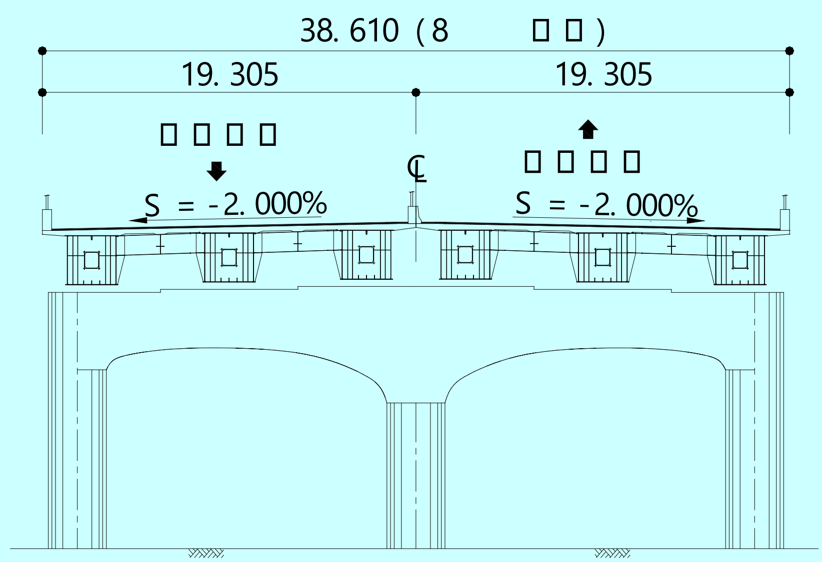
#13 KOREA 1



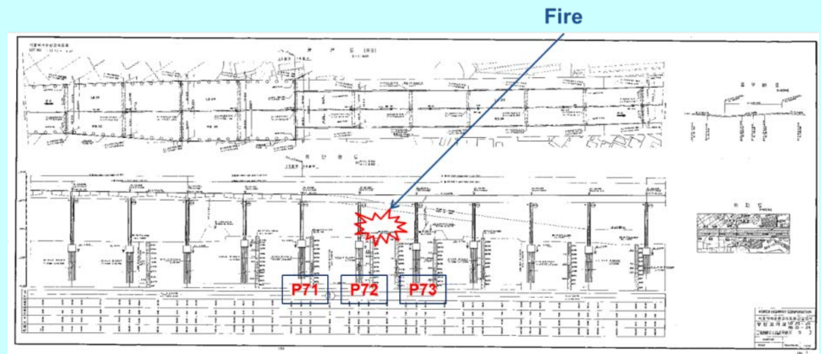
Event Date	Trigger Category: Bridge Fire
December 2010	Tanker truck below bridge caught fire

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Box Girder	Closed Bridge	Yes	1995	380

Description: A tanker truck, which was illegally parked underneath the bridge, caught fire. The fire lasted for about an hour and caused severe damages. The high temperature flames substantially reduced stiffness and strength of steel box girders. The bridge was closed immediately and a special inspection was performed. Temporary supports were placed to avoid larger deformations or partial collapse of the bridge. The damaged portion was removed and precast sections with steel beams were installed to expedite the fix.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Korea
Prepared by	
Date Prepared	
1.0	Description of Event / Incident
Description of Bridge	The Buchon Bridge is a part of Seoul Ring Expressway and was constructed in late 1990s. The total length of the Bridge is 7,754m and composed of 130 spans with the typical span length of 60m. The Bridge carries 4 lanes in each direction and has the total width of 38.61m (19.305m/each direction). Expansion joints are typically installed on every six spans. The superstructure of the Bridge is composed of reinforced concrete deck and three closed steel box girders.  **< Bridge Cross-section>**

Picture of Bridge	 
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	The tanker truck, which was illegally parked underneath the bridge between 72 pier (P72) and 73 pier (P73), caught fire. The fire lasted for about an hour and caused severe damages. The high temperature flames substantially reduced stiffness and strength of steel box girders. This lead to the breakage of the girders and sagging of bridge.


Fire
P71
P72
P73

Date of initial event	December 13, 2010
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The fire occurred in the middle of night. The bridge was immediately closed due to extensive damage (multiple girder fracture, deformation, and sagging) and for the detailed investigation in the next morning. Temporary supports were placed underneath the failed girders to prevent large deformation and sudden collapse of the bridge
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	In-house structural engineers initially made the decision. The special committee made of internal experts and experts from academia and engineering companies was formed to study the extent of damage and make a decision on the closure of the bridge.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity.

temporary / permanent fixes considered at the time of the decision?	Did you do more in the level of analysis?
Answer	Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process
Answer – Who in your organization made the decision and with what qualifications did they have?	The special committee recommended in-depth inspection of the bridge to determine detailed damage extent of the bridge. The inspection company was employed for the in-depth inspection.
Answer - What pertinent data did you have at your time the decision?	
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Because the Buchon Bridge was the part of the busiest highway in Seoul metro area, quick recovery was the one and only concern at the time of the fire.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	The 2 dimensional model was used for the safety evaluation after damage assessment.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The temporary supports were placed underneath the girder to prevent further deflection.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	- In-depth inspection - Non-destructive tests: ✓ Instrumented indentation technique for steel to determine strength of fire-affected steel girder ✓ Concrete carbonation test
4.0	Description of load calculation model and the application of damage or deterioration to that model

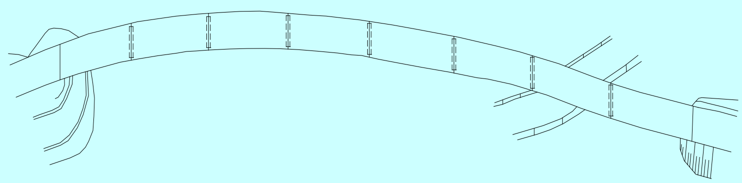
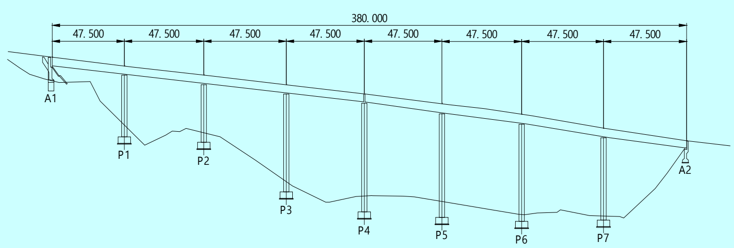
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	In Korea, a grid analysis are typically used to determine bearing strength of the in-service bridges as well as to design new bridges. The commercial softwares, mainly Midas Civil, are used for the analysis.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The material deterioration of heat affected steel girder, e.g. reduction of yield strength, was main concern at that time. However, the non-destructive indentation test showed that the yield strength and ultimate strength of steel girder were not affected. This information was entered into the structural analysis model.
Date event resolved or concluded	March 15, 2011
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	The main priority was quick recovery. While recovery plan was devised, the damaged portion of the bridge was removed. The superstructure, concrete deck and steel box girder, was first cut using a diamond saw cutting method. To reduce time, factory made precast deck as well as steel box girders were employed.

#14 KOREA 2

Event Date	Trigger Category: Bridge Inspection
January 2014	Severe corrosion in box girders from de-icing agents

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Box Girder	Special Inspection	Yes	1990	7754

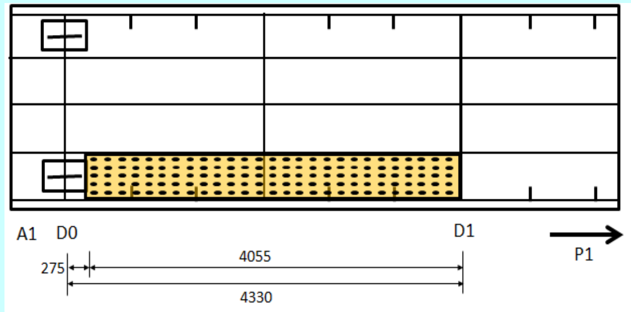
Description: Severe corrosion in the box girders were discovered during an initial inspection. An expansion joint leaked de-icing agents into large areas of the box girders. Traffic was not restricted. A special inspection and model were built. It was concluded to plate the lower members where there was severe section loss.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Korea
Prepared by	Heungbae GIL
Date Prepared	
1.0	Description of Event / Incident
Description of Bridge	The curved Panbu Bridge was built in 1995. The bridge is the part of the Jungang Expressway, which passes through mountainous region of the South Korea The span length of a bridge is 47.5meters and the total length of the two four-span-continuous bridge is 380meters. The superstructure is composed of two closed steel box girders and reinforced concrete decks. As shown in the following figure, the grade of the bridge is 6%.  
Picture of Bridge	

	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	The inspection initially showed the following problems: - The coating for the bottom flanges of the steel box girders was severely damaged over a large area - The bottom flanges were significantly corroded, with section loss. - The top flanges of the box girder under expansion joints were also severely damaged Water and de-icing agent introduced into the inside of the box girder through leaky expansion joints caused these damages.  **< Expansion Joint>**

	 < Inside of the box girder >
Date of initial event	January 2014
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The bridge remained open to traffic because no excessive deflections or vibration was observed. Special detailed inspection was carried out immediately to study damage level and structural impact.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Bridge expert with expertise in steel structures
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field?

What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	
Answer – Who in your organization made the decision and with what qualifications did they have?	In-house bridge expert investigated the damaged condition of the Bridge and made the decision
Answer - What pertinent data did you have at your time the decision?	The section loss was measured using the ultrasonic thickness gauge. The measurement showed that the thickness of a corroded area ranged from 6mm to 10mm while that of uncorroded area ranged 10mm and 12mm. The section loss of the bottom flanges mainly observed near the bridge ends with expansion joints, in which the tensile stress is relatively low.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	The painting damage was widespread and corrosion initially looked very severe. However, the bridge did not show any abnormal behavior and therefore remained open to traffic. The detailed investigation showed that most of the bottom flanges suffered minor corrosion.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	The engineering calculation using a 3d model was carried out after the detailed field investigation.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The corrosion and section loss of the bottom flange was mainly occurred at the ends of the box girders with the lower tensile stress. Therefore, it was decided to retrofit the corroded bottom flange with an 8mm thick steel plate. As shown in following figures, the plate was attached with closely

	spaced high strength bolts.  
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	The section loss of the bottom flanges was measured using the ultrasonic thickness gauge.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	As a part of detailed inspection, a 3-dimensional model was constructed to determine overall structural safety of the bridge and effect of section loss.

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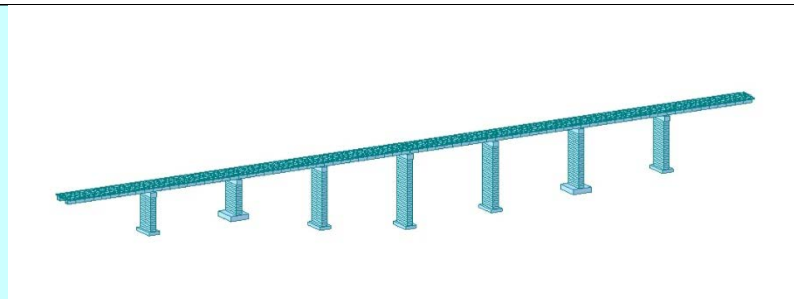
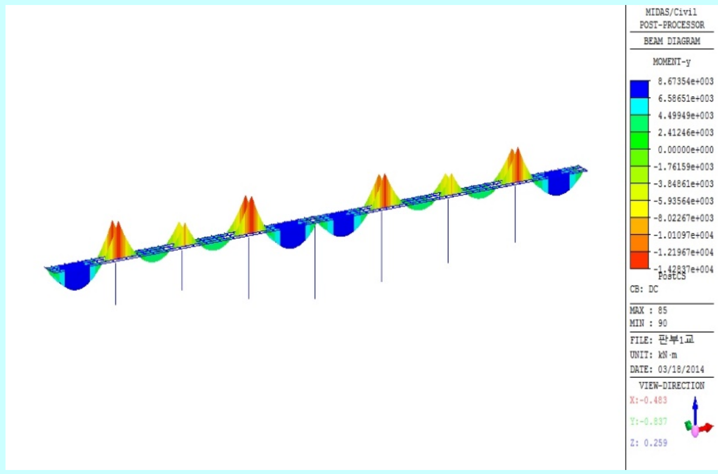
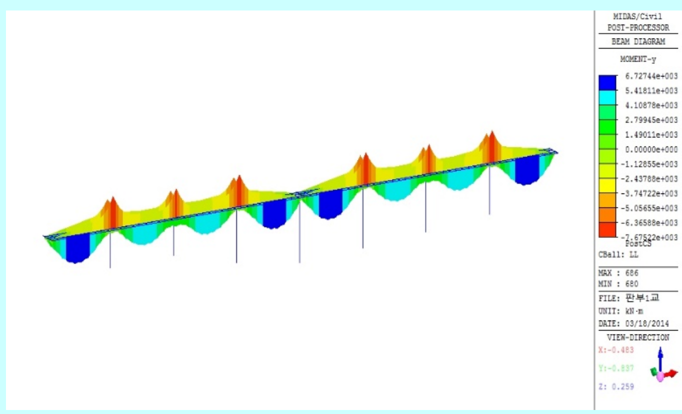


3-D analysis model



Bending moment distribution due to dead load



Bending moment distribution due to live load
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<td>Describe how you applied the results of the special assessment, or techniques to the load capacity calculation.

What assumptions or</td>
<td>Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.</td>
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techniques did you use to enter the data from the special assessment into your analysis models?	
Answer	The reduced thickness of the lower flanges due to section loss was reflected in the structural analysis model.
Date event resolved or concluded	
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	Special inspection program was initiated to inspect the inside of old steel box girder bridges to determine whether coating damage and/or corrosion had occurred.

#15 MEXICO

Event Date	Trigger Category: Inspection
June 2015	Fatigue crack discovered of anchor system

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Cable Stay	Retrieve SHM Data	Yes	1994	422

Description: A defective weld in the upper anchoring element of one cable, with initial cracks that evolved due to fatigue was discovered after failure. Traffic was restricted to the left side of the bridge. A special inspection was performed in addition to data being retrieved from the structure health monitoring (SHM) system to assess the rest of the bridge. A temporary supporting system was installed. This work was completed in August 2016.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Mexico
Prepared by	Francisco J. Carrion
Date Prepared	February 20, 2017
1.0	Description of Event / Incident
Description of Bridge	The Río Papaloapan Bridge is a cable stayed structure with 203 m span length and 422.37 m total length, and it is located in the state of Veracruz in México. It has 8 semi-harps with 14 cables each; semi-harps.
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Defective weld in the upper anchoring element of one cable, with initial cracks that evolved due to fatigue. Failure took place on June 10th, 2015.
Answer	Failed element was programmed for repair and, since other welds could have the same problems, a general inspection was programmed with acoustic emissions technique, while welds are embedded in concrete pylons. To calibrate the inspection to the defect size in the welds, two welds would be selected with different acoustic emission level (high and medium), then opened for penetrant and ultrasonic inspections and then repaired.
Date of initial event	June 10th, 2015
Describe your immediate reactions to this event	Visit to the bridge and recovery of monitoring data for analysis. The bridge has a SHM permanent system.
Answer	To prevent critical conditions, it was proposed to limit traffic only on the left line on the side where failure occurred, this to prevent load concentrations, and also, at low speed only to reduce dynamic effects. A temporary support system was proposed

	to allow normal operation of the bridge, while repairs and inspections were completed
Who in your organization and made the immediate assessment and what qualifications did they have?	The Bridge manager of the organization responsible for the operation of the highway (CAPUFE). The technical services general direction (DGST) of the transport secretary of Mexico (responsible of the highway) and the *Instituto Mexicano del Transporte* (IMT), responsible for the structural monitoring of the bridge. Innitial actions were recommended by the IMT and supported by the DGST. The IMT is a research institute that has a group working on structural monitoring, inspection and analysis, and it has worked on this bridge for several years.
Answer – Who in your organization made the decision and with what qualifications did they have	Repair was decided by CAPUFE by the bridge manager and taking into account previous repairs in this bridge. Nondestructive inspection and the use of a temporary support system were proposed by the Monitoring Group at the IMT. This group has experience in structural monitoring, nondestructive inspection, FE simulation and analysis.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	The SHM system of the bridge provided information of the structural behavior of the bridge during and after the failure. Temporary support system was recommended form the tension redistribution on neighboring cables to the failed one and to maintain tensions below the maximum design limit. This was done immediately after the failure. Analysis was confirmed from FE analysis using a model already calibrated and being used for the monitoring since it was installed in 2013. Structural monitoring and, in particular, the tensions on the cables form vibrations, continued since failure to the end of the repairs, to warranty the bridge structural safety end integrity. Since the welds of the anchoring elements are embedded in the pylons concrete, the IMT proposed acoustic emissions inspection. The technique was calibrated in laboratory and then applied in the bridge. The correlation from acoustic emissions level to defect size was done by selecting two anchoring elements, where welds were opened for penetrant and ultrasonic inspections. Final results

	identified critical welds that will be repaired in a close future and proposed a monitoring strategy with AE to identify any developing crack in the welds. For repair, the IMT made the failure analysis, proposed the WPS and PQR for the weld, weld qualification was done according to AWS and ASTM (tests made at the IMT or supervised by IMT).
Answer	The operator of the highway (CAPUFE) repaired the bridge through a contractor, including the AE inspection done by the IMT. Repairs and inspections were done according to what it was proposed. The bridge is programmed for a future repair to replace the critical welds identified from the AE inspections.
Answer – Who in your organization made the decision and with what qualifications did they have?	The head of the monitoring group. The group has experience in nondestructive inspections (PT, UT, RX, AE), structural analysis and FE simulation, damage detection and SHM monitoring and prognosis. The IMT has participated with the activities of the ISHMII since 2009, co-organized the SHMII-5 conference in Cancun and has being participating since then in conferences, workshops, and courses. The group has researchers experts in structures, monitoring, instrumentation, software and materials.
Answer - What pertinent data did you have at your time the decision?	The monitoring data, so it was possible to decide immediate actions such as the traffic restriction and the temporary supporting system.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Once the temporary supporting system was built, with the SHM system, it was possible to operate the bridge normaly.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	Yes, a 3D FE model, the monitoring data from 3 years.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	Very important. It maintained the bridge operating normally within safety limits.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	As mentioned previously, a nondestructive acoustic emissions inspection technique was developed to evaluate the welds of the anchoring elements of the

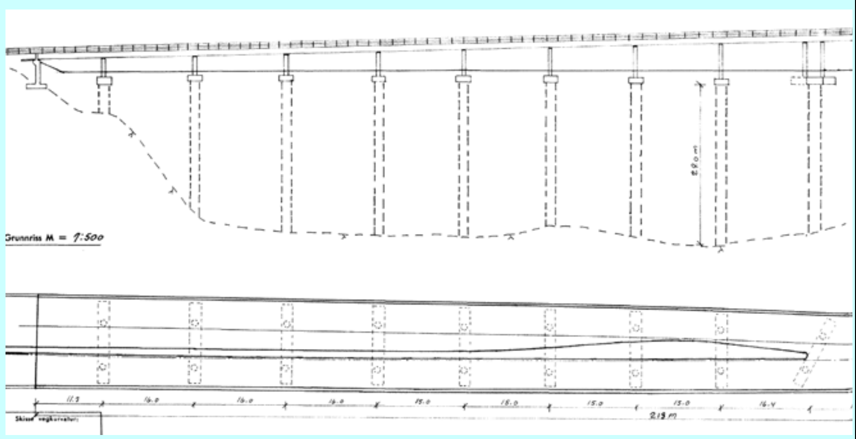
	cables. The IMT had already experience with this technique but main difficulty in this case was that the weld is embedded in concrete and not directly accessible. Cases like this have not been reported.
Answer	The AE technique gave a good indication of the welds condition and it can be used in the future to monitor any developing crack.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	For this bridge, the IMT has 2 FE models. One on ANSYS and the other on StaDyn. The first, commercial software and the second, freeware developed by a professor at Purdue University for dynamic analysis. Both software are normally used and used to retrofit each other.
Answer	Results from FE models permitted the design of the temporary supporting system for the bridge and also to confirm load redistribution on the cables.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Propose repair strategy with a temporary support and monitoring of the cables' tensions. Data was used to calibrate the models, including that obtained during and after the failure.
Answer	We have a FE model calibrated to the actual condition.
Date event resolved or concluded	August 2016
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	The bridge recovered is structural condition to that previous to the failure. Critical welds were identified and planned for future maintenance to prevent future failures. The AE technique can be used in the future to monitor and detect any developing crack.
Answer	A bid is being done for bridge maintenance and weld repairs in 2017.

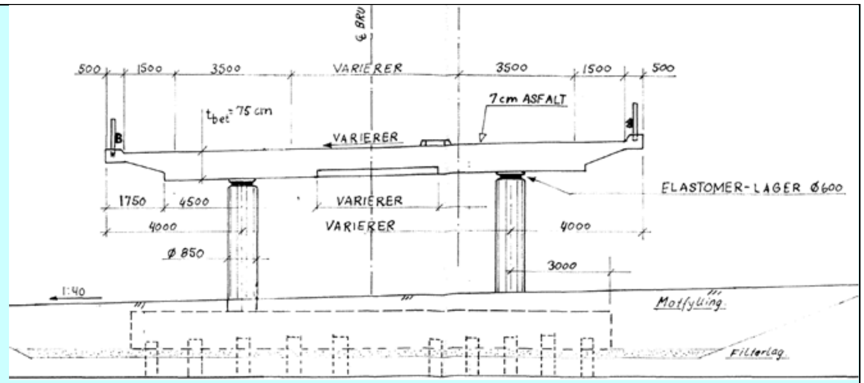
#16 NORWAY

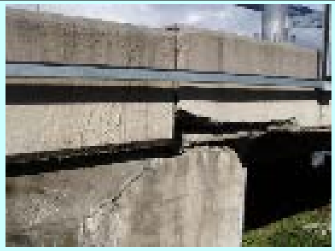
Event Date	Trigger Category: Inspection
2015	Expansion joint failure damaging side wall of abutments

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Concrete Slab	Special Inspection	Yes	1975	214

Description: During a simple inspection in 2015 it was found that the bridge deck had no more expansion room at the joints and that the concrete was damaged along the side walls of the abutments (spalling). The immediate reaction was to remove the back wall and build one 10 cm behind the original one. Traffic was removed during work and special investigations. The permanent fix will include many more repairs and remediation. This work is ongoing.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Norway
Prepared by	Børre Stensvold
Date Prepared	August 2017
1.0	Description of Event / Incident
Description of Bridge	A Norwegian bridge, No. 17-1012 Fiborg bridge, is a concrete slab bridge in 14 spans, each 17.1 m and a total length of 213.5 metres located on highway EV 6 in Northern Trøndelag county. The bridge was constructed in 1975 and has 2 lanes plus acceleration lane with a total deck width of 10.0 m.
Picture of Bridge	 Picture of Fiborg bridge  Elevation and plan of Fiborg bridge The last nine spans are shown.

	 Cross section of Fiborg bridge
Description of the event and the trigger that caused the assessment	During a simple inspection it was found that the bridge deck had no more expansion room at the joints and that the concrete was damaged along the side walls of the abutments (spalling). Such damage is normally caused by absence of expansion room for the deck. Simultaneously it was found that the bearings were heavily out of position at the abutments and at some of the piers. It seems that the bridge deck had moved towards the bridge end where the expansion joint was located. Because of the severity of the damage and the effect it might have on the carrying capacity of the bridge, it was decided to start a more thorough investigation to find the cause of the damage.
Answer	From the simple inspection in 2015, the decision was made to start a planning process with regard to what should be done. The simple inspection resulted in a special inspection to reveal what type of damage we were dealing with. The detection we made from this was that the bridge had extended its length with appr. 15 cm, which had resulted in crushing the edge beams, close to the abutment at axis 15. In addition, it was found that the bearings on the piers were out of position. The combination of these types of damage indicated that the deck probably suffered from Alkali-Aggregates Reaction that normally has such an impact on concrete (Elongation). The decision was made to drill core samples from the concrete to determine if it suffered from Alkali-Aggregate Reaction and the extent of suffering. Conclusions: Alkali-Aggregate Reaction was found in the concrete. During the special inspection also the following defects were detected; 1) Cem-Elastic (Cement-based coating) had some time ago been applied to the edge beam. This has caused the concrete underneath to dissolve 2) The drainage pipes were too short, which resulted in damage to the adjacent concrete. 3) The thickness of the asphalt on the deck was 16 cm, which is far too much and had impact on the carrying capacity of the bridge. 4) There was no waterproof layer on the bridge deck.

	   Damage on kerbs of bearing Displacement
Date of initial event	Simple inspection in 2015
Describe your immediate reactions to this event	The immediate reaction was to make it possible for the bridge to expand by removing the back wall of the abutment and reconstruct a new one appr. 10 cm behind the original one. Additionally, it was decided to reduce the asphalt thickness on the deck to reduce the weight on the bridge. Removing the asphalt revealed considerable and severe damage to the deck. The reaction to this was to perform further investigations.
Answer	In the spring of 2017, it was decided to remove all the asphalt temporarily and to carry out a proper investigation of the bridge deck – a Special Inspection. During this investigation period, the traffic was diverted to another road nearby. When the asphalt was removed, severe damage was detected on the top-side of the deck. The management within the NPRA decided that only the most severely damaged areas should be repaired in order to facilitate safety at present, and that remaining repairs had to be postponed to a later period due to lack of required funding and the fact that there are plans for a new section of the road within approximately 20 years. After the new road section is finished, the plan is to remove the bridge.
Who in your organization made the immediate assessment and what qualifications did they have?	The bridge engineer from the NPRA Regional Office in collaboration with the management of the County Roads Department. Qualifications: A bridge engineer is a structural engineer with relevant experience.
Answer – Who in your organization made the	A special inspection was performed in 2017 by a team comprising two experienced bridge inspectors and one

decision and with what qualifications did they have	structural engineer with a PhD-level degree. Several bridges along the same route in the vicinity of Friborg bridge were also investigated, and the conclusion was that they also suffered from Alkali-Aggregate Reaction. At present, it has been decided to take more tests and a consultant has been hired to follow up the damage and engineer the repairs/rehabilitation.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	
Answer - Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process.	Action activated in February 2017: • Moving the back wall on the abutment 10 cm backwards to admit the superstructure to expand. • Installing a new expansion joint. • Removing the asphalt on the deck completely. • Installing a waterproof layer to minimise moisture penetrating the concrete deck from both Alkali-Aggregates Reactions and de-icing salt.

	• Lifting up the superstructure by jacking to move the bearings on axis 12, 13 and 14 back to the centre of the columns. The supporting area underneath the deck for the bearings and the jack was expanded. • Replacement of the bearings on the abutment on axis 15. • Cleaning the deck after removal of the asphalt revealed big areas with disintegrated concrete caused by frost, bad construction joints and some corrosion of the reinforcement especially on spots where there earlier has been a central reserve. • The water chiselling revealed severe corrosion on the top bars of the reinforcement across the entire bridge deck. It was decided to take 10 core samples and install five reference electrodes to monitor the corrosion speed. The cores were sent to a laboratory for analysis. • The water-chiselled area of 115 m^2 was repaired. The deck was given a waterproof layer and a new asphalt layer.   It was decided to postpone the repairs on the corroded reinforcement of the kerbs until the complete assessment of the bridge was finished. Three other bridges on the same road section have similar damage and will be evaluated during the same process.

	When the results from the core samples and the potential measurements are determined, thorough calculations/assessments will be made for the bridge with regards to load capacity, remaining service life and costs of different actions. At present these actions will be considered: • Repair of the damage on bridge deck and the kerbs • Replace the superstructure by building a new one. • Follow up the deterioration process of the deck via the installed potential electrodes, where the intention is to see if postponement of further actions are possible or not. A new section of the highway E6 will make the Fiborg bridge redundant in appr. 2037 and the bridge can then be removed.
Answer – Who in your organization made the decision and with what qualifications did they have?	A collaboration team between the regional chief bridge engineer, a consultant with significant experience from similar problem areas, and an engineer from the NPRA`s HQ with skills from both concrete and structural behavior. The regional chief bridge engineer makes the final decision.
Answer - What pertinent data did you have at your time of the decision?	At the time of decision, the data at hand included special inspection, results from the alkaline and chloride tests, concrete strength (core samples) and detailed calculations.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	The timeframe for returning the bridge to full service influenced the decision of both temporary and permanent action. Because the bridge engineers were dealing with a highway, it was a priority to keep the bridge open to traffic within the level of appropriate safety.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No engineering calculations prior to the assessment of the preliminary carrying capacity was performed in 2d or 3d. Since the thickness of the asphalt was reduced from 16 cm to 9 cm, the structural engineer considered that the bridge could take service loads at the same level as present without any further calculations. For the final decision thorough calculations must be made in 2d and 3d based on the concrete quality from the core tests.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	In the short term, we considered what effect the damage had on the carrying capacity of the bridge and if the traffic should be restricted temporarily. The issue of permanent repairs will be decided when the results from all the tests are known and calculations have been made. The potential for permanent repairs shall include total costs through extended service life at a level of minimum 20 years. Total costs of permanent repairs must include maintenance through the bridge's entire service life of at least 20 years (According to plan, the bridge will in any

	case be removed in appr. 20 years because of alteration of the road)
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	
Answer	Material property evaluation, special inspections and calculations.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	
Answer	Not decided at present, but we are considering using the following software : Sofistik, RM Bridge,Tekla structure, Abaqus and others
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	
Answer	The results of the data from the tests are entered manually directly into the software.
Date event resolved or concluded	Not available at present.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	
Answer	

#17 POLAND

Event Date	Trigger Category: Inspection
September 2014	Part of bridge portion appeared to have sank

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Double T Post Tension Girders	Restricting Heavy Trucks	Yes	1970	233

Description: During a routine inspection, an observation of the barriers and edge beam showed the portion of the bridge was sinking. The owner restricted heavy trucks immediately. It was determined a default in the girders and the bridge stabilized. Proof testing was performed and no repairs were made. Heavy truck traffic remains restricted.

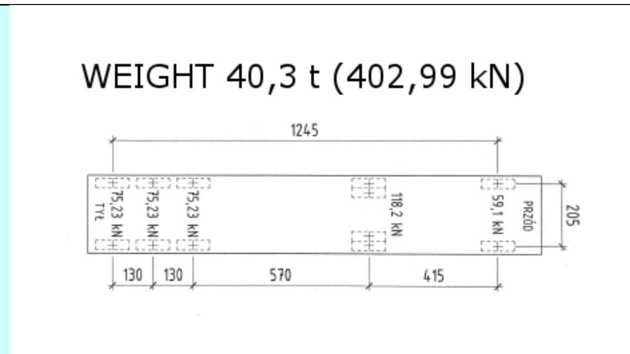
Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	POLAND
Prepared by	ARTUR ROSIAK
Date Prepared	12.11.2016
1.0	Description of Event / Incident
Description of Bridge	The bridge was built in the early 70s of the twentieth century. Six span bridge, static diagram - a simply supported beam. Theoretical span length is 38,75m. In cross-section, there are five post-tensioning girders (double T) combine with reinforced concrete slab by prestressed cables. The nominal spacing between beams is 2.16 m. Beams was made using concrete with compressive strength 40 MPa. The nominal height of the girders, including slab is 229cm. Nominal thickness of the concrete slab - 12cm. Slab was made using concrete with compressive strength 25 MPa and reinforced by steel bars with a diameter of 8.3 mm, placed every 9 cm. Pillars are transmural (massive), made from concrete with compressive strength 40.0 MPa founded on piles Francs. In 2014, due to an emergency condition of the bridge deck was completed its replacement works. Compared to the primary solution the designer increased thickness of concrete plate and bridge concrete class.
Picture of Bridge	

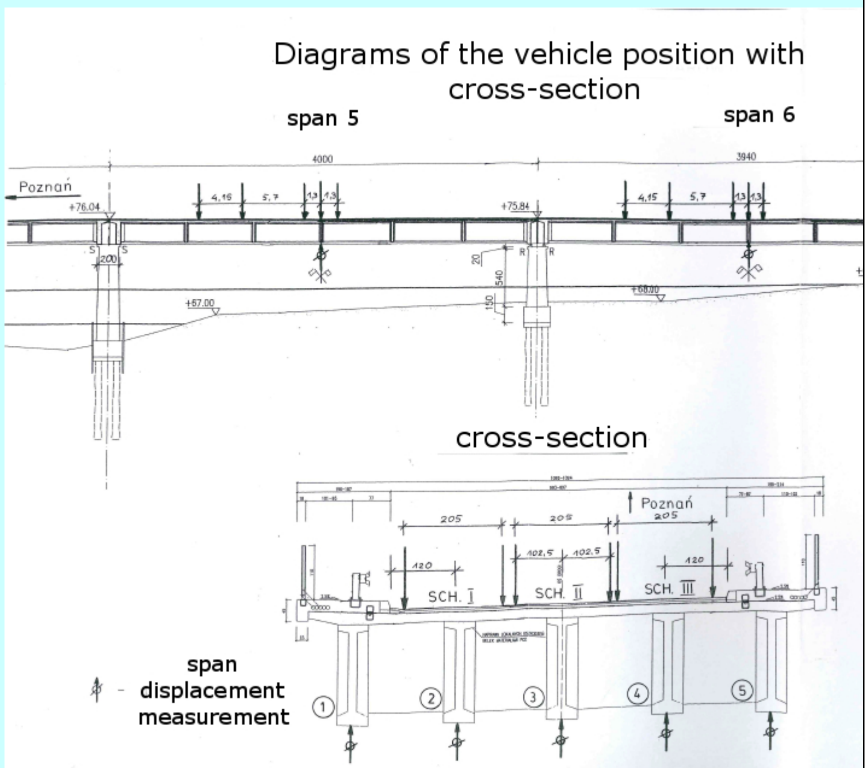
	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	After opened bridge and putting it into exploitation during routine inspection visual observation revealed deflection of protective barriers and edge beam. Detailed observation show progressive changes in the bridge grade line.
Date of initial event	September 2014
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	Withholding oversized tracks (load over 42 tons). Detailed expertise with geodetic measurements was done.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Introduction: In Poland to perform technical functions in the construction industry (i.e. site manager, construction site inspector) person must have a construction license (in most cases unlimited) in our case the specialization must be bridges. Construction license is issued by Polish Chamber Of Civil

	Engineers. The license is valid when person pay annual contributions to Chamber (in fee is included the construction insurance). In our organization the decision is made by the Division Director or Deputy Division Director after consultations with the Head of the Division Department of Bridges which has many years of professional experience. Everyone involved in the decision making process has construction license.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	In most cases / events we purchase an outsource detailed expertise with geodetic measurements and we do detailed inspections with simple tests as Schmidt hammer to measure the strength of concrete. Expertise is made by people with academic and technical professional experience.

	In this case we purchase detailed expertise with geodetic measurements. During this case study after simple engineering 2d calculation was necessary to do complementary examination using proof load testing for bridge assessment. Expertise shows that beams are overloaded due to heavy traffic traveling through bridge. We restricted velocity due to dynamic impact by mounting speed camera close to bridge. During 6 months deflection grow stabilizing in average up to 40 mm, but on two spans was higher, between 60 up to 80 mm. That shows the problem with beams, especially that slab on bridge was already new. Proof test confirmed the problem. In the end was made a 3d calculation to confirm stability of bridge spans by using external tendons. There wasn't temporary or permanent fixes, we restricted oversized tracks (load over 42 tons).
Answer – Who in your organization made the decision and with what qualifications did they have?	In our organization the decision is made by the Division Director or Deputy Division Director after consultations with the head of the Division Department of Bridges which has many years of professional experience.
Answer - What pertinent data did you have at your time the decision?	In the moment of event we knew few things. First of all we knew, that in period of 2 years before the event we built new concrete slab. Second the concrete haven't same parameters as original one (concrete compressive strength - 25 MPa) new one has in average 70 MPa. We checked the data from two located near bridge traffic load stations. We knew that many tracks traveled without permission (load over 42tons). We knew when the bridge was built and beams prefabricated. Beams was compressed post tension with cables. What we didn't know was the tensions / forces used during beams production.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	There wasn't the ordinary timeframe we want to repair the bridge as soon as possible. We restricted velocity due to dynamic impact by mounting speed camera close to bridge. Bridge was monitored daily using visual inspections during ending the tender procedure (purchase the design and purchase the contractor).
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	During the time of expertise developed by Poznan Institute of Technology we had 2d calculations.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	There wasn't temporary or permanent fixes, we restricted oversized tracks (load over 42 tons).

3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	In this case we used proof testing and special inspection. From nondestructive testing we used profometer for searching reinforced bars and cable wires in beams. We already had concrete slab compressive strength from construction time (2 years earlier).
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Expertise of the bridge was made using a software program with 3d analysis. Design of bridge renovation was made using a software program with 3d analysis.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	After the event was verified current load carrying capacity of the bridge. Proof test was made using TIR normative truck (weight = 420kN). Below attached truck and load scheme.





Date event resolved or concluded	Full repair ended in August 2016. Heavy traffic on the bridge is restricted up to 42 tones. Oversized vehicles are directed to alternative routes.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. Work which was done stabilized further spans deflection, the bridge grade line was leveled, shaped like it was before the event. Rehabilitation process start after 1,5 year since the event and

	took four month from the date of signing the contract with the Contractor until the acceptance of works. We learned we should focus more on control the weight of the heavy, overloaded truck (TIR) traveling frequently without valid permission.

#18 SLOVENIA 1

Event Date	Trigger Category: Rating
	200 older bridges designed and deteriorated assessed for safety

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Reinforced Concrete Beams	No Immediate Reaction	Yes	1960	0

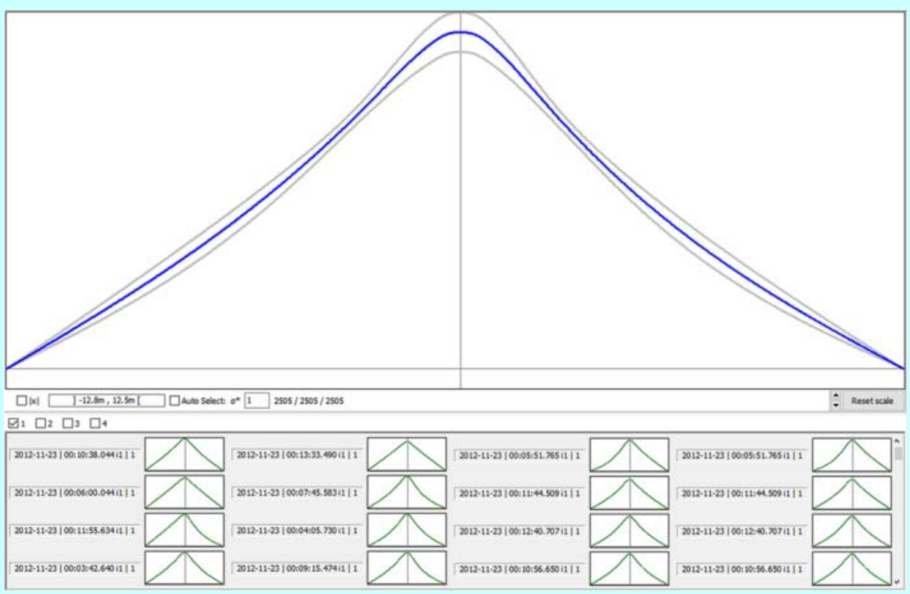
Description: Over 200 older bridges were assessed for structural safety. A program of different analysis and assessment techniques was used to determine what bridges would need posting or strengthening. Load posting of the bridges was to be mitigated based on the program assessment techniques. Of the 200 bridges that were evaluated 13 needed actions in form of strengthening or load posting.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	SLOVENIA
Prepared by	Aleš Žnidarič
Date Prepared	22th March, 2017
1.1	Description of Event / Incident
Description of Bridge	Typical bridge constructed before 1975, many before 1960 or even WW II. They were in majority of cases constructed of reinforced concrete beams with cast in place RC slab. They were designed as simply supported, but have no or have non-functional expansion joints and bearings. For most pre- WW II bridges the designs or drawings do not exist.
Picture of Bridge	 Fig.1

	 Fig.2
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Due to the old design codes these bridges are by definition under-designed. Many of them are deteriorated, they are built with lower strength concrete (below 25 MPa), many have corroded reinforcement. Most are situated on low volume roads with limited heavy traffic.
Date of initial event	Nor relevant
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	As these old bridges deteriorated, at some time it is decided that a specific bridge has to be assessed for structural safety.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The decision is made by the bridge engineer responsible for management of bridges. The actual assessment is outsourced to the specialists organisations.

2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Unnecessary bridge closures or postings have cost implications for the users. In the past (more than 15 years ago), bridge posting was primarily selected based on the judgement of the responsible engineers and using the design rules. Today, a bridge, which safety is questionable, is first checked with simplified analysis, using available information about the bridge and the so-called rating loading schemes that were developed based on extensive weigh-in-motion (WIM) measurements on Slovenian roads. In many cases this is sufficient to prove that a bridge is structurally safe for the present traffic, at least for a limited lifetime. If this is not sufficient, or if an important bridge is being considered, a higher level analysis is performed. This may include:

	– full detailed inspection of the bridge that establishes at least quality and quantity of reinforcement and strength of the concrete, – bridge WIM measurements that not only provide information about loading (static and dynamic, both in statistical terms), but also true influence lines and load distribution factors, which are essential for efficient and optimal structural model calibration, – detailed structural modelling.
Answer – Who in your organization made the decision and with what qualifications did they have?	Decision is made by the responsible engineer, primarily based on results of regular and main bridge inspections.
Answer - What pertinent data did you have at your time the decision?	Condition of the bridge in a form of condition rating of the supporting structure, where each damage is evaluated and the damage numbers are summed together. Bridges on state roads are expected every second year. In addition, year of construction is important to allow the initial estimate of capacity of the bridge or its structural members.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	The primary goal is not to take a bridge out of service or post the traffic loads, if this is not absolutely necessary.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	If possible, yes. Lately, at least a simple 2D structural analysis is performed on level 1 assessment. More sophisticated methods are applied if necessary.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	Occasionally, a temporal bridge posting is applied. But, as bridges are inspected in 2-year intervals, there is generally enough time to perform at least the level 1 safety assessment before the critical stage is reached and posting is necessary.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Analysis starts with a special inspection. Non-destructive methods are used, as necessary. GPR, Ferroscan, electro-potentials and similar are used to assess the capacity and degradation pace of the

	structure. In addition, a unique bridge WIM (B-WIM) system is widely applied. It does not only measure the axle loads, including the dynamic loading as a function of vehicle gross weights, but also measures the true influence lines and load girder distribution factors. These is key information to update structural models and, consequently, to assessing realistic structural safety under the serviceability conditions, which are of the highest concern for these old bridges (is the bridge safe for current traffic conditions?).
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Usually the level 1 assessment involves 2D FE analysis. The model is updated to match as closely as possible the girder factors and the influence lines measured with the B-WIM system. For example, the figure below presents the results of measured influence lines on a 25-m long bridge that by design should be simply supported. The average bending moment influence line, obtained from the individual ones calculated for every vehicle that crosses the bridge, is far from a simply-supported one. Savings can be from a few percent on new bridges to over 100% on bridges like the one on Fig.1. Those bridges in reality behave like integral (frame-type) bridges.  Fig 3 – B-WIM software evaluating the influence lines of all vehicles In a similar way, the B-WIM evaluates, for every crossing of the vehicle, the load distribution over the measured structural members.

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Information is evaluated with mean values (Fig. 4) and standard deviations and is used either to calibrate the bridge model or as girder factors, if simplified analysis is applied.

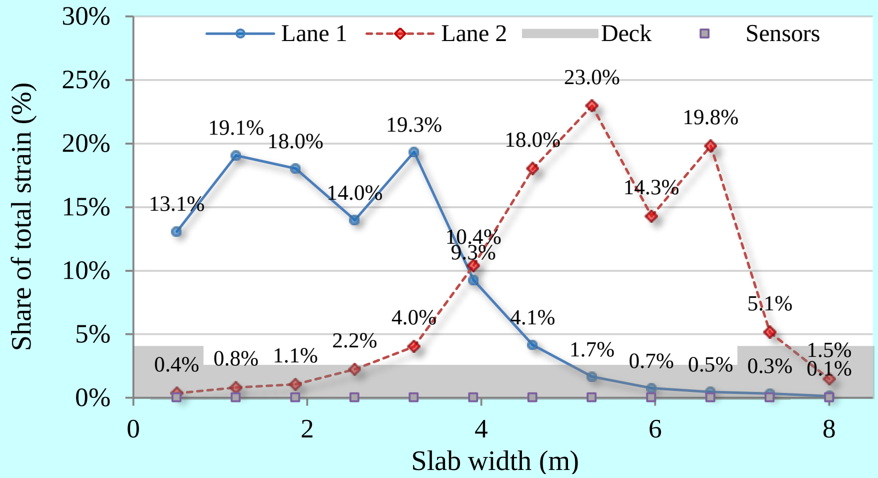

Fig 4 – Measured mean values of sensor (girder) factors

Last but not least, if B-WIM measurements are sufficiently long and capture at least a few tens of thousands of vehicles, realistic information about dynamic behaviour (DAF – Dynamic Amplification Factor, the ratio between the total dynamic and the static loading) is evaluated. Fig.5 gives an example of the results from a very lively bridge. The key and the biggest saving is that the DAF reduces as a function of gross weight.

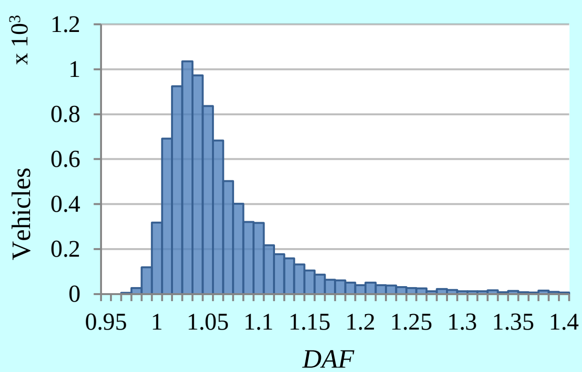

Fig. 5 – Distribution of measured DAF factors on a lively bridge
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<td>Describe how you applied the results of the special assessment, or techniques to the load capacity calculation.</td>
<td>Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.</td>
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What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	
Answer	In all cases, the best possible estimate of section properties is taken. In critical cases the remaining cross section of the re-bars is evaluated on site and is used in calculation of capacity of cross sections. If possible, samples are extracted to test the mechanical characteristics. If this is not possible, the most likely characteristics from the time of bridge construction are taken, as conservatively as necessary. Safety factors are also adjusted based on the quality of information that was used in structural assessment.
Date event resolved or concluded	Not relevant, presented are generic cases based on many years of experience.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	The lesson learned was that out of over 200 evaluated old bridge only 13 needed actions in form of strengthening or posting. Savings are estimated in tens of millions of Euros.

#19 SLOVENIA 2

Event Date	Trigger Category: Bridge Element Failure
2009	An element of the expansion joint failed

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Concrete Box Girder	Lane Closed	Yes	2009	91

Description: An element of an expansion joint failed. The driving and emergency lanes were closed immediately. An expansion joint expert was called in to evaluate all other elements and expansion joints. As an element was not in stock the replacement took four weeks.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	SLOVENIA
Prepared by	Aleš Žnidarič
Date Prepared	11th May, 2017
1.1	Description of Event / Incident
Description of Bridge	A continuous box girder bridge over three spans. Total length 91 m. Width 12 m. On light slope and in curve. Located on a motorway and carries 2 driving lanes and the emergency lane. At the time of the event the bridge was only 8 years old. Bridge is located in the area with relatively harsh climate conditions, with a lot of snow during winters, and consequent show ploughs and salting.
Picture of Bridge	

	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	An element of the expansion joint failed 

	 Fig.2
Date of initial event	Nor relevant
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The driving and emergency lanes were closed immediately. Only the overtaking lane was left for traffic.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The decision was made by the bridge engineer responsible for maintenance of bridges.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge

process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	It was reported during the previous regular inspections that the pace of deterioration of the expansions joints is high. When the failure happened, the driving and the emergency lanes were immediately closed. An expansion joint expert was called from an authorised institution to perform a detail inspection of all expansion joints on the bridge.
Answer – Who in your organization made the decision and with what qualifications did they have?	Decision was made by the responsible maintenance engineer, based on the report from the site.
Answer - What pertinent data did you have at your time the decision?	A report of the inspection from 2 years ago existed. It already reported the accelerated deterioration of the expansion joints.
Answer - How did the timeframe of returning the bridge to full service influence the	The primary objective was to restrict the traffic as shortly as possible and all efforts were put in replacing the expansion joints as quickly as possible.

decision?	
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	A temporal measure suggested was to replace, prior to the complete replacement of the expansion joint, the broken element with one from the emergency lane, and to close only the emergency lane, but this was not done.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	An expansion joint expert performed a thorough inspection of both expansion joints of the bridge, from the top and from the bottom. He prepared a special report, where he described and photo-documented all damages, including torn and delaminated rubber, fractured membrane, corroded elements, missing seal over the attachment bolts, damaged pavement and pot holes around the expansion joints etc., and suggested the remedial measures.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Not relevant.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.

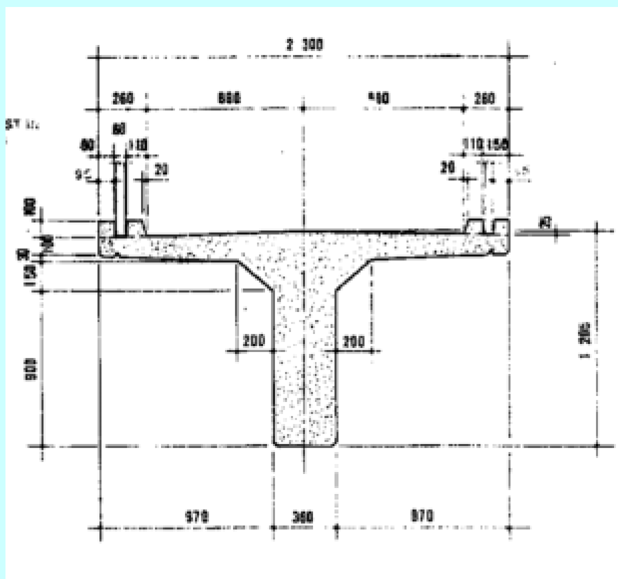
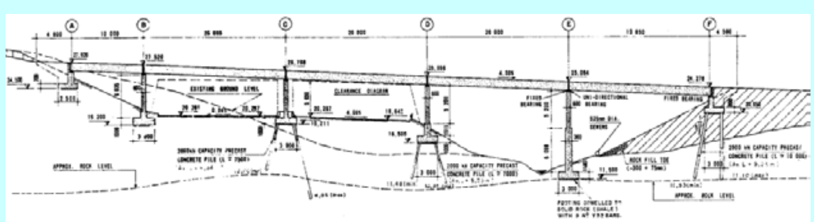
into your analysis models?	
Answer	Not relevant.
Date event resolved or concluded	As there were no appropriate elements in stock, the replacement and full rehabilitation took approximately four weeks.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	The lesson learned was that the owner should keep in stock some typical (standard and easy-to-replace) expansion joint elements, to avoid delays due to the rigid procurement rules, which were the main reason for long-lasting rehabilitation. Also, at the time of construction, the type of expansion joint was changed from steel to rubber, which was an important reason for accelerated deterioration that could have been avoided.

#20 SOUTH AFRICA

Event Date	Trigger Category: Bridge Impact
November 2014	Pedestrian bridge hit above freeway

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Post Tension T Beam	No Immediate Reaction	No	1979	95

Description: A pedestrian bridge was struck by a vehicle. The owner decided to jack up the bridge by .5 meters as a temporary solution before making a permanent repair. The jacking of the bridge was completed in December of 2015 and the permanent repairs of the damaged area was completed in October 2015.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	South Africa
Prepared by	Mohamed Parak
Date Prepared	16 March 2017
1.0	Description of Event / Incident
Description of Bridge	Lamontville Pedestrian Bridge B1326 5 simply supported spans over National Highway and drainage channel. Longest span of 20m. Deck is post-tensioned T-beam 2.3m wide supported on piers and abutments on piles and spread footings. Built in 1979.. 
Picture of Bridge	

	
Picture of Bridge	 
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Bridge deck hit by vehicle in excess of legal height limit of 4.7m on the southbound carriageway. The minimum clearance of the bridge was 5.03m. Resulting damage was loss of concrete section in the web of the deck with exposure of post-tension tendons. 

Date of initial event	25 November 2014
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The immediate concern was the exposed post-tensioning ducts. Should the ducts be severed by an over height vehicle, this will cause the collapse of the span onto the freeway.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Accredited Senior Bridge Inspector with professional registration and extensive bridge design experience made the initial assessment on behalf of SANRAL. The decision was made by SANRAL's National Bridge Network Manager who is also professionally registered and has extensive bridge design experience.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer – Who in your organization made the decision	An accredited senior bridge inspector made the initial assessment that the bridge was still serviceable. This is a

and with what qualifications did they have?	professional engineer with a minimum of 15 years full time bridge design experience accumulated over the last 25 years.
Answer - What pertinent data did you have at your time the decision?	Visual assessments, as-built drawings, site measurements
Answer - How did the timeframe of returning the bridge to full service influence the decision?	The event occurred as the busy holiday season was approaching. Closure of the bridge or the freeway was not an option. It was known that the permanent repairs would not be completed before Christmas, thus a temporary solution to protect the exposed post-tensioning ducts was sought.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	An analytical check calculation was undertaken. Considering the light pedestrian loading, this was deemed sufficient.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	Immediate options considered were: 1. Close the lane above which the damage occurred 2. Remove the damage span 3. Jack the span up to provide an additional 0.5m clearance The bridge is located above a busy freeway and serves as a link for pedestrians between places of residence and employment. Option 1 would cause severe traffic delays which would not be tolerated, especially as the holiday season was approaching. Option 2 would force the pedestrians to cross on the freeway as the detour was 1 km away. Option 3 was chosen as the immediate intervention with permanent repairs to follow in the new year.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	A visual assessment was conducted for the initial response followed by an engineering check calculation. The bridge is due for replacement in 2025 when the freeway will receive a capacity upgrade and so a 10-year solution was sought.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	An analytical engineering calculation was undertaken.
Describe how you applied the results of the special	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic

assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The section properties of the web was reduced to take into account the loss of concrete section
Date event resolved or concluded	The jacking of the structure was undertaken as a specialist sub-contract to the route's routine maintenance contractor. This was completed by 19 December 2014 in time for the Christmas holidays.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	 Jacking of the bridge. The decision to raise the bridge to protect the bridge's exposed post-tension ducts proved to be the correct decision as the bridge was impacted again on 18 February 2015. Had the bridge clearance been lower, the end result may have

	been the collapse of the bridge span. The minimum clearance now is 5.550m.  Completed Repairs

#21 SPAIN 1

Event Date	Trigger Category: Bridge Impact
July 2002	Bridge hit by a vehicle knocking out a column

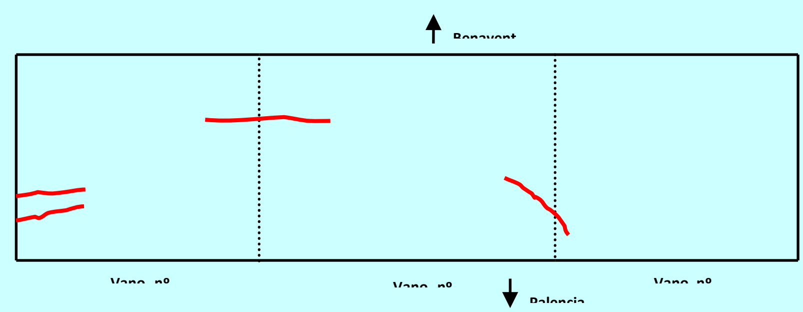
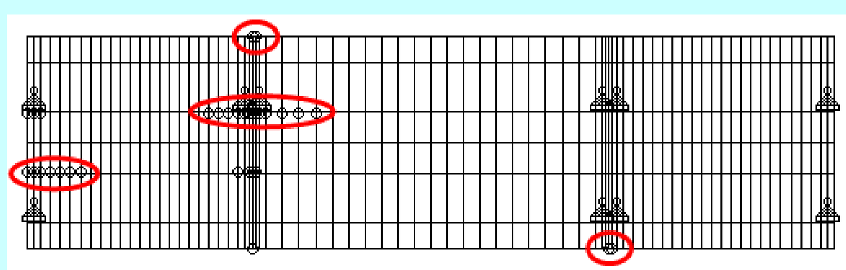
Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Prestress Concrete Box Girder	Closed Bridge	Yes	1995	60

Description: A heavy vehicle hit one of the columns of the pier, causing the collapse of it. The girders supported by this column were hanging on the deck. The bridge was closed and traffic was restricted underneath. Big hydraulic jacks were installed to replace the collapsed column as a temporary fix. A new column was formed and installed and tests were performed for the deck to ensure adequate serviceability. The work was completed in 42 days.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Spain
Prepared by	Gonzalo Arias Hofman (Ines Ingenieros Consultores)
Date Prepared	April 2nd 2017
1.0	Description of Event / Incident
Description of Bridge	3 span bridge crossing over route N-610, near the city of Palencia (Castilla y León, Spain). Each span is a precast pre-stressed concrete box girder (2 girder) with a reinforced concrete deck. Each girder is supported on one precast reinforced concrete column.
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	A heavy vehicle hit one of the columns of pier #1, causing the collapse of it. The girders supported by this column stand on its place and were hanging on the deck. The deck suffered a great deformation and cracking, visible through the pavement over it.

	
Date of initial event	July 18th 2002
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	Traffic was closed over and under the bridge, while decision was delivered: demolishing the structure or repairing it. Big hydraulic jacks where put in place under both girders without support, near the collapsed column. A complete damage map was drawn, while a structural assessment was developed, in order to demonstrate through an iterative process if the damages on the deck where repairable or not. The foundation of the column was discovered, in order to evaluate possible damages on it, but it was in good condition. New reinforcement rebars were anchored on the foundation for the new column. As the original position of the girders was obtained with the lift of the hydraulic jacks, a new on site reinforced concrete column was constructed under the bridge. For the upper part of the column two holes where made on the deck, so the concrete could be put in place.

	A load test was made at the end of the reconstruction, to check the behavior of the deck. The duration of the works took 42 days.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Regional maintenance crew took first measures and informed the Regional Chief Officer (Civil Engineer). Regional Chief Officer informed the National Bridge Maintenance Officer in Madrid (Civil Engineer) who decided to send external specialist (M. Sc. Civil Engineer) in order to evaluate the situation.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?

Answer	After preliminary damage evaluation and holding the deck with two heavy hydraulic jacks, it was decided to develop a step by step structural analysis for the deck, trying to reproduce the collapse of the column and how it affected the deck. By comparison with the crack map of the superior side of the deck, it was concluded that injection of the cracks could made possible the use of the deck, once a new column could be erected on site.
Answer – Who in your organization made the decision and with what qualifications did they have?	External experts made the structural assessment, and the approval of each decision was taken by the National Bridge Maintenance Officer (Civil Engineer) together with the Regional Chief Officer (Civil Engineer).
Answer - What pertinent data did you have at your time the decision?	Original project was obtained in first two days, while there was developed a detailed damage map of the complete structure, once it was supported with heavy hydraulic jacks. Detailed engineering was then developed within 10 days by external experts.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Because of the dates, it was critical to have the structure on service in September, so the fastest way was to keep as much elements of the existing structure and to repair the damaged ones, if possible.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No, detailed 2D engineering was done directly, so to understand the condition of the deck and its possible future use.  

Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Discovering of the upper side of the deck (removing the pavement) was practiced to have a complete view of the cracking. Concrete testing was made in new column, to ensure compression resistance, because the time to rebuilt it was very sort and the materials used were high resistance concretes at first 48 hours. After all reconstruction works, load testing was made to check the behavior of the deck.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Grid analysis with a step by step calculation. Applying minimum displacements to the theoretical supports of the girder, default of the elements was applied to the next calculation step, until real total displacements were obtained in the model. Comparing the collapse elements in the model with the cracks shown in the cracking map at final situation, it was decided which elements was necessary to substitute and which elements could be left in place, injecting the cracks.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.

special assessment into your analysis models?	
Answer	In the step by step process, in a first state (called unplasticized state in the calculations) the percentage of the permanent loads that causes the plastification of the first knot is applied. In a second state (called Iteration 1 in the calculations) a plastic hinge is inserted into the knot of the rod which has plastified in the previous state and another percentage of the permanent load is applied which causes the plastification of a second knot in the new grate. The stresses (bending moments) caused by the percentage of the permanent load in the first state are added to the stresses generated in this second state, in order to evaluate the appearance of a new plastic hinge. The sum of the stresses of both states is compared with the last estimated moment for each bar that exclusively represents the compression slab (cantilever zone and zone between beams). In a third state (called Iteration 2 in the calculations), the same is done by adding the stresses caused by a third percentage of the permanent load to a grid having two plastic ball joints in the knots which have plastified in the previous states, and So on, until 100% of the permanent load is applied to successive iterations
Date event resolved	
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	In case of prestress bridge girder struck by vehicle, in this case with the collapse of a column, reconstruction was possible due to two main reasons: Detailed structural evaluation of the deck in a step by step analysis and, Holding the deck with heavy hydraulic jacks, that gave time to analyze the situation

#22 SPAIN 2

Event Date	Trigger Category: Bridge Inspection
September 2016	Deck moved transversely 20 cm caused from rotational instability from bearing devices

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Prestressed Concrete Beams	Special Inspection	Yes	2004	215

Description: The road maintenance personnel had detected a transverse displacement of the deck. A special inspection and several assessment techniques were conducted to evaluate the bridge. In addition, traffic was restricted from the wider shoulder. The permeant fix consisted of replacing the bearings and the repositioning the deck. The work was completed on January 27, 2017.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	Spain
Prepared by	Damián J. Terrasa Díaz (Ines Ingenieros Consultores)
Date Prepared	April 3rd, 2017
1.0	Description of Event / Incident
Description of Bridge	It is the viaduct that allows the right road of the Z-32 to overcome both the AP-68 toll road and the Zaragoza suburban railroad, at p.k. 246 + 700 of that road. It is a bridge of prefabricated trough-shaped prestressed concrete beams, with seven spans (two trough-shaped beams by span). The spans are variable, in the following order of magnitude: 16, 43, 42, 32, 30, 31 and 21 m. As the bridge has a very considerable skew angle (32º in span 1, 36º in span 2, 41º in span 3 and somewhat higher in the rest) and the above spans are measured to the deck axis, the span of each of the two beams of each stretch differs markedly: for example, in span 1, these beams are 16.40 and 25.37 m long. The deck is about 11.5 m wide and curved in plan, to the left, as it runs from the abutment 1 to 2. Its initial radius of curvature is about 500 m and decreases to the order of 1000 m in E2. The abutments are closed, with walls in turn, and each of the six pillars has two reinforced concrete octagonal-shaped shafts, which top off at a plateau with a rectangular section of 1.50x1.80 m. On these ‘rectangular tables’ we can find the steel reinforcement elastomeric bearing devices, all of them rectangular non-anchored and of different dimensions, according to their location in the viaduct: a single bearing device is located at each end of each trough-shaped beam, whose longest dimension is arranged along the axis of the joints. The heights of the pillar’s shafts are also variable, between 7 and 10 m, approximately. The foundations of all the shafts are direct, by means of reinforced concrete footings. The upper slab is 0.25 m thick, which locally on the pillars reduces its thickness to 0.08 m ("slabs of continuity" of 1.5 m width). As the bridge is curved in plan, the cant is also very marked, with a 5.8% in abutment 1 and slightly lower values in the rest of supports (of the order of 5.2-5% in pillars 2 and 3, descending gradually in the second half of the viaduct, to 2.2% in E2).

<table>
<tr><td></td><td>These strong cants produce an eccentricity between the axis of the beams (measured in the head of these) and the axis of the elastomeric bearings. This eccentricity is 0.20 m in the abutment 1, 0.19 m in pillar 1 and 0.15 m in pillar 3.

In addition to the expansion joints on the abutments, the bridge has a third joint on pillar 3. This joint, by cutting perpendicular to the two beams of the viaduct on each of the two shafts of the pillar (shafts 3.1 and 3.2) and because of the skew angle, adopts a ‘letter Z’ form in plan. This expansion joint was originally made of reinforced elastomer but it had had to be repaired in numerous occasions since the opening of the viaduct (2004). Currently, this joint presents some stretches of reinforced elastomer and other of modified bitumen.</td></tr>
<tr><td>Pictures of Bridge</td><td></td></tr>
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Z-32 pk 246+700 (C.D.)
AP-68

<table>
<tr><td></td><td></td></tr>
<tr><td>Description of the event and the trigger that caused the assessment</td><td>Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc.</td></tr>
<tr><td>Answer</td><td>The road maintenance personnel had detected a transverse displacement of the deck, which translated into carriageway in a twist of almost 20 cm of the white road mark of the edge of its shoulder, when crossing abutment 1. Of course, the traffic railing had also been deformed because of the lateral displacement of the deck with respect to the abutment.

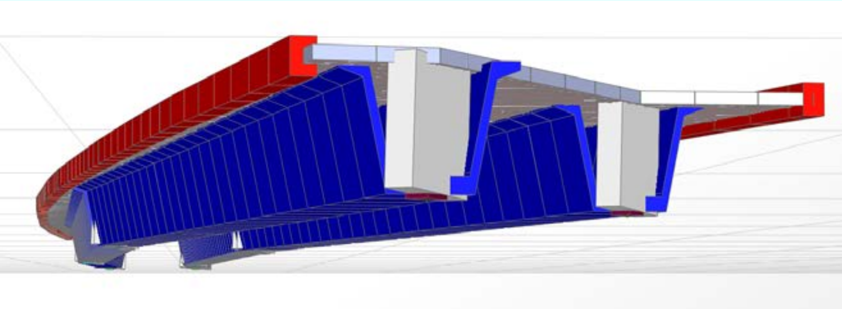
Underneath the deck, in said abutment 1, it was appreciated that it had moved laterally with respect to the neoprene bearings (which remained in place on the front wall of the abutment) in the order of 18 cm. Said displacement was toward the deck's</td></tr>
</table>

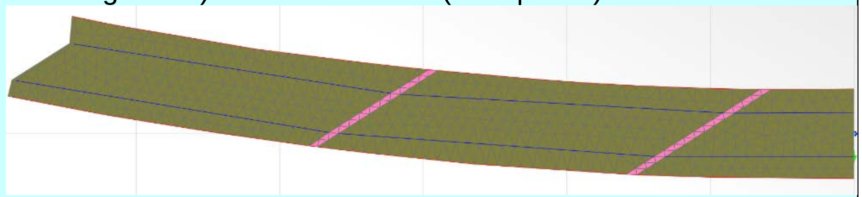
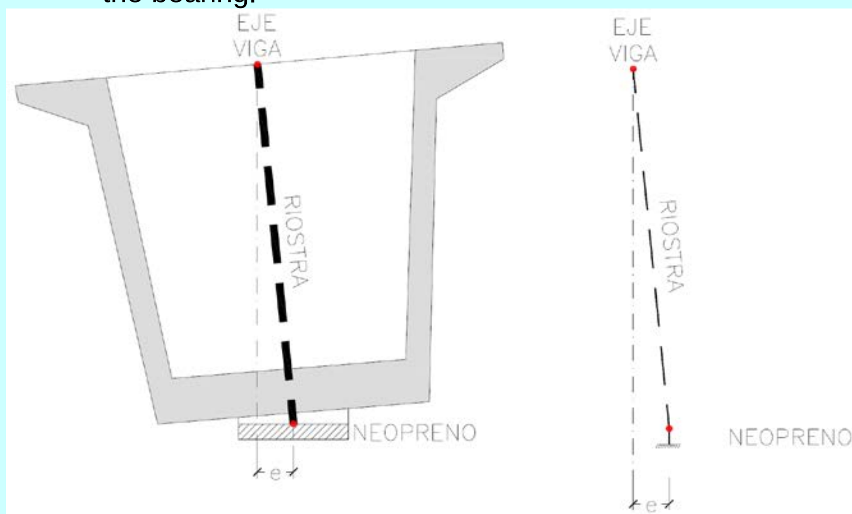
	center of curvature, curved "to the left" in plan. The relative lateral displacement (deck-substructure) had also been in the direction of the cant, a 5.8% to the left in abutment 1.  The white road line had been painted recently and the lateral movement of this viaduct had occurred suddenly between July and September of 2016. It should be noted that the white line did not show any discontinuity as it passed through the other abutment or through the Z-shaped central joint (in pillar 3). In the later inspections, it was possible to verify that the lateral displacement was maximum in abutment 1 and pillar 1, decreasing with a homothetic function towards pillar 3 (the only central expansion joint), where this lateral movement was already null. The lateral displacements at abutment 1 and pillar 1 were a serious danger because the deck was supported by a very small portion of the neoprene bearing and, especially in Pillar 1, a new displacement of the order of the already produced would have left the prefabricated trough-shaped beams without any support, being able to free fall. It should be noted that the reinforced elastomeric bearings of the bridge were not anchored neither inferior nor superiorly, nor was there any type of lateral retention stop of the deck that could prevent greater displacements with respect to pillars and/or bearings.
Date of initial event	September 13th, 2016
Describe your immediate reactions to this event	
Answer	External experts exhaustively inspected the viaduct: • On Sept. 13th 2016 the inspection was made with a basket-type lifting platform. The bearings (and displacements of the deck over these) could be seen and measured in abutment 1 and pillar 1 (both shafts).

	• On Sept. 13th 2016 the inspection could be done thanks to a truck with gangway for under deck jobs, with which it was possible to access absolutely all the bearings of the structure. The lateral displacements observed during these inspections were approximately: • 18 cm in abutment 1 • 12-16 cm in pillar 1 (every pillar has two shafts, as it was already explained) • 5-7 cm in Stack 2 (two shafts) • 0-2 cm in Stack 3 (two shafts)
Who in your organization made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Regional maintenance crew took first measures and informed the Regional Chief Officer (Civil Engineer). Regional Chief Officer informed the National Bridge Maintenance Officer in Madrid (Civil Engineer) who decided to send external specialist (M. Sc. Civil Engineer) in order to evaluate the situation.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?

assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	
Answer	The first immediate action, to avoid greater lateral sliding of the deck over pillars and abutments, was to place side stops on the abutment 1, that is, where it had had more lateral displacement. These steel stops were designed, manufactured and placed quickly.  Another immediate decision was to prohibit traffic on the wide shoulder that the board had on its right side in order to avoid eccentric loads, leaving only two lanes approximately 3.60 m width each. In addition, the speed of traffic, in the section where the viaduct is located, was limited to 60 km/h. This prevented any sudden braking of vehicles on the structure being repaired. With the problem stabilized, it was begun to study, at a theoretical level, possible causes of the displacement of the deck. For this, among other analyzes, the structure was computationally modeled in order to understand the causes of the detected anomalies and to give the best possible technical solution to the emergency situation that had been declared.
Answer – Who in your organization made the decision and with what qualifications did they have?	External experts made the structural assessment, and the approval of each decision was taken by the National Bridge Maintenance Officer (Civil Engineer) together with the Regional Chief Officer (Civil Engineer)
Answer - What pertinent data did you have at your time the	[1] As built plans of the structure (2004). [2] Annex of calculations (2003, during the project phase). [3] Report "Displacement Z-32's modules" (comparing photos of

decision?	the status of the deck between July and September 2016). [4] Cants measured by the conservation company (September 2016).
Answer - How did the timeframe of returning the bridge to full service influence the decision?	There was no influence, because the bridge was always in full service, except the right shoulder.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	Yes, we did a 3D model of the structure.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	• Stabilize lateral movement of the deck by means of steel stops (temporary, permanent and urgent fix). • Clad of the shafts of the pillars (permanent fix). • Permanent remove of elastomeric bearings, turning the viaduct into an integral structure, for which it should be fully verified by a whole new calculus (permanent fix). • Lifting, stabilization, and transverse movement of the deck; removal and replacement of existing bearings by new and anchored ones; controlled descent of the deck (permanent fix that was finally chosen and executed).
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc.,
Answer	Special inspection (with a truck with gangway for under deck jobs) 

4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	The two models of the viaduct (one for each half, before and after the expansion joint in pillar 3) were made in the finite element program SAP2000. It should be noted that the reinforced elastomeric bearings were modeled and checked completely according to what is indicated in point 5.3.3.7 of the standard EN-1337-3. The following figure shows a view of the model of stretch 1 (from abutment 1 to pillar 3). 
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The structure was represented by a spatial model with the following elements: • Bar elements for trough-shaped girders. They are introduced with their eccentricity with respect to the deck's slab. In order to adequately represent its torsional stiffness, its inertia was calculated as a closed section, and a correction coefficient was applied to the torsional inertia automatically calculated by the program for an open section.

	• Plate-like elements for the slab. Plates of 0.25 (in general) and 0.08 m thick (over pillars) were used.  • Bar elements for the struts. These elements have a large rigidity (similar to that of the section of the real strut) and connect the beams to the bar of the elastomeric bearing device. The cant was taken into account, introducing the eccentricity between the axis of the beam and the axis of the bearing.  • Bar elements for elastomeric (neoprene) bearings. These elements have a rectangular section with their dimensions equal to the real ones, a material with G= 0.9 N/mm² and E= 3 N/mm² and modification factors for the mechanical characteristics of axial and bending stiffness, in order to obtain the characteristics described in detail in Annex 3, always according to EN-1337.3. These bars are oriented with their greater dimension according to the axis that joins the pillars (direction of the joint).
Date event resolved or concluded	January 24th, 2017
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms,

	procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	According to the calculations made, the most probable cause of the failure observed in the bearings was the rotational instability of some of the elastomeric bearing devices of the section of the viaduct between the abutment 1 and the expansion joint in pillar 3. These were supports with a ratio of plan dimensions unusually decompensated, which, together with the strong skew angle and cant of the structure, produce significant moments on the bearings and excessive turns. This conclusion is reinforced by the turns and eccentric application of the load on the elastomeric bearings that were observed during the inspection. The bearings were banded neoprene devices, not anchored. The constructive detail of wedge, which ensures that the bearing receives the reaction on a horizontal plane, was correct. The elementary checks, which are usually made in projects, were positive. That is, the dimensions in plan and height of each analyzed bearing met the criteria of maximum and minimum vertical tension, in addition to the angular distortion in service (lower than 0.7). Likewise, the non-slipping checks were favorable too: both the aforementioned minimum tension and the friction check were favorably verified in all cases. However, the supports of dimensions 400x700 mm, present in the first part of the bridge (but not in second) are not normal. They are excessively long supports. These dimensions are outside the standard measures (in EN-1337-3) and are not found in any current trade catalog. The problem they present is the high flexural stiffness according to their larger dimension. In principle this should not be a serious problem in a straight bridge as the larger dimension is arranged perpendicular to the deck axis. However, in a very skewed bridge, such as this, the largest dimension was arranged along the axis of pillars (axis from one shaft of the pillar to the other one) and finds the axis of the beams with a large angle. In this way, the beam-bearing device linkage presented a strong flexural rigidity, especially in the bearings with small heights of neoprene, and therefore there appeared a strong bending moment on the support. The checks made included those of stability to rotation. This verification is not usually done in the project since it implies an elaborate modeling and is not usually a conditioning factor. The usual thing is that the hypothesis of very small bending moments in the bearings is fulfilled. This case, however, was not usual for the two reasons above mentioned: the strong skew angle of the bridge and the 700 mm dimension, very large with respect to the smaller dimension. The calculated moments in

	the bearings turned to be unusually large (up to 1000 kN.m) and the checks according to EN-1337-3 indicated that some bearings were unstable to rotation. This result was got in section 1 (model 1), but not in section (model) 2, in which there are not 700x400 mm bearing devices. This coincided with what had been observed during the truck-walkway inspection: in section 1 there had been seen relative slides of up to almost 20 cm between deck and bearings and, above all, it had been observed that the bearings were receiving the load eccentrically, with one of its edges discharged, which would indicate a failure by excessive turning. The chosen solution was to generally act in section 1 (between abutment 1 and the expansion joint in pillar 3) but only partially in section 2, between P3 joint and abutment 2. In this second stretch was sufficient to replace a support that had been 'spit' at shaft 5.1. For all of the above, new anchored bearings were to be used (in A1, P1, P2 and P3 -first section of the viaduct- and P5 -second section of it-). In section 1 (E1-P3) two actions should be carried out: • Replace all bearings by new anchored others, not necessarily of the same dimensions as the previous ones. Consideration was given to the provision of supports of standard dimensions that met all the checks and were geometrically compatible with the head of the pillars and the dimensions and orientation of the beam's strut. • Reposition of the deck. This was necessary since the movements had been of up to almost 20 cm and the arrangement of the anchored bearings needed to take advantage of the wedge plate under the trough-shaped beams. Moreover, if the deck had not been repositioned, the reaction would have remained eccentric with respect to the axis of pillars' shafts. In addition, when repositioning the deck (by horizontal translation), a better performance of expansion joints in P3 and A1 was ensured. Finally, the anomalous position of the deck also was affecting the safety of traffic. In summary, a technical explanation of what was happening could be achieved: rotational verification for bearing devices had not been not done in project phase, and those bearings were consequently not anchored neither inferior nor superior. They also had unusual width/length ratios. As a general learning, problems were detected that could be

	repeated in other viaducts in curve with prefabricated beams. In such cases, it seems appropriate to project all bearings as anchored or arrange them double (two under each trough-shaped beam, instead of only one).

#23 USA – FHWA (1) (276)

Event Date	Trigger Category: Inspection
January 2017	Inspector During Painting Work Discovered a Full Depth Fracture

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Arch Through Truss	Closed Bridge	Yes	1956	2058

Description: A construction inspector during painting of the truss noticed a full depth fracture of the top chord on one of the spans. The bridge and roads underneath were closed to all traffic. The determined repair was to splice the chord to restore it. The bridge was repaired and returned to service in March, 2017.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	United States
Prepared by	Joey Hartmann
Date Prepared	09.06.2017
1.0	Description of Event / Incident
Description of Bridge	The Delaware River Bridge carries I-276 across the Pennsylvania/New Jersey border, the Delaware River, PA State Route 13, several local roads, and Amtrak. The bridge opened in 1956 and is owned jointly by the New Jersey Turnpike Authority (NJTA) and Pennsylvania Turnpike Commission (PTC), with each state owning up to the state line. The bridge has 31 spans, with a total structure length of 6,751-feet and a main river span of 682-feet. The overall deck width is 80-feet. As shown in Figure 1, the main river span is a distinctive arch-shaped through truss, with suspended deck and vertical clearance of 135-feet. In 2014 the average daily traffic was 42,000 vehicles.
Picture of Bridge	 
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	A construction inspector for an active painting job noticed a full-depth fracture in the top (tension) chord on one of the Pennsylvania deck truss approach spans, where the truss is continuous over the pier. The fracture had initiated at the site of a fabrication defect, two holes drilled through a flange that had been partially filled with weld material.

	
Date of initial event	January 20, 2017
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The bridge and roads running under it were closed to all traffic.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The Bridge Inspection Program Managers for NJTA and PTC made the decision to close the bridge. Both have advanced degrees in structural engineering and professional engineering licenses.

2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Engineering judgment was used to justify closing the bridge. Although no simplified analysis was documented, the engineer quickly reasoned that a rigorous analysis would be needed to demonstrate the failed structure was stable and had the capacity to resist legal loads. The entire bridge was re-inspected to verify whether any other fractures existed and to document the damage caused by the initial event. Also, after the cause of the initial event was identified, ultrasonic testing (UT) was used to identify similar fabrication errors. Again, using engineering judgment, the UT was confined to the first 3-feet of any member entering a connection. The Program Managers agreed that the likelihood of fabrication errors elsewhere on the member where no fabrication took place was very small. Material was also collected from several members of the bridge to perform property testing on. This testing and the

	results of the inspection where then used to tune an analytical model that supported the repair actions and ultimately justified the reopening of the bridge.
Answer – Who in your organization made the decision and with what qualifications did they have?	Engineers from the Federal Government, State Government and consulting community informed the decision. However, the ultimate decision on all actions was made by the Program Managers at NJTA and PTC. Most involved had an advanced academic degree, professional license, and significant bridge design and management experience.
Answer - What pertinent data did you have at your time the decision?	At the time of the decision to close the bridge, the data on hand included visual inspection documentation of the condition of the fractured girder.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Although a number of options were considered in detail, the only pragmatic repair solution was to restore some load to the fractured chord and splice it back together. Also, confidence in the remaining members had to be reestablished using UT. The bridge remained closed until the repair and testing were complete.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No. The structure was behaving in a complex and non-linear manner which required much more rigor than can be captured in a typical engineering calculation.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The 3 options considered included (1) repair the fractured chord, (2) replace the fractured chord, and (3) replace the 4-span unit that included the fracture chord.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing, special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	The special inspection consisted of a detailed visual inspection of the remaining bridge and the use of UT. Material testing was also performed to support the analytical modeling.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.

Answer	Finite element software was used to model the damaged structure, and through all the various stages of repair.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	The special inspection was used to verify the competency of the undamaged members and the condition of the damaged members. Where appropriate, the condition of the damaged members was used to tune the analytical model.
Date event resolved or concluded	The chord was repaired and the bridge returned to service March 11, 2017.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair.
Answer	Although no new lessons learned were generated during this investigation, what was reinforced was, at a minimum, the need to have more than one senior engineer involved with prior experience in addressing similar issues in addition to several junior or mid-level engineers that can both learn from their exposure to the incident and to the senior engineers.

#24 USA – FHWA (2) (75)

Event Date	Trigger Category: Inspection
June 2014	Fracture in Web and Bottom Flange Discovered

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Steel Plate Girder	Lane Closed	Yes	1968	146

Description: A routine bridge inspection identified a fracture in the web and bottom flange of an interior girder. Traffic was immediately restricted above the affected girder. The girder was repaired by removing the crack tips and plate over the section. The repair was completed by the end of June and the traffic restriction was removed.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	United States
Prepared by	Joey Hartmann
Date Prepared	04.08.2017
1.0	Description of Event / Incident
Description of Bridge	The I-75 Bridge at Mile Post 27.9 over Lynn Camp Creek (I-75 Bridge) near Laurel-Whitley County Line in Corbin, Kentucky consists of three continuous steel girder spans (140 ft – 200 ft – 140 ft). The bridge, which was originally constructed in 1968, is a concrete slab on girder construction with 4 longitudinal beam lines, cross-frames at 20 ft intervals and a lateral bracing system in the bottom of the center bay. The 2 lanes of the bridge carry over 22,000 ADT.
Picture of Bridge	

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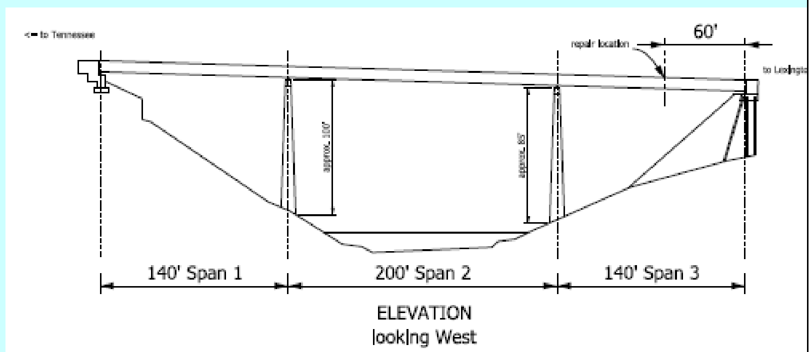

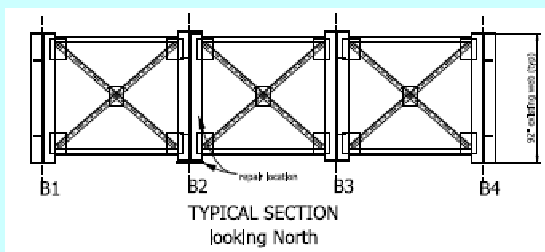

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<tr><td>Description of the event and the trigger that caused the assessment</td><td>Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc</td></tr>
<tr><td>Answer</td><td>A routine bridge inspection identified a fracture of the web and bottom flange of an interior longitudinal girder. The fracture was approximately vertical and originated in the area of an intersecting weld detail.</td></tr>
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	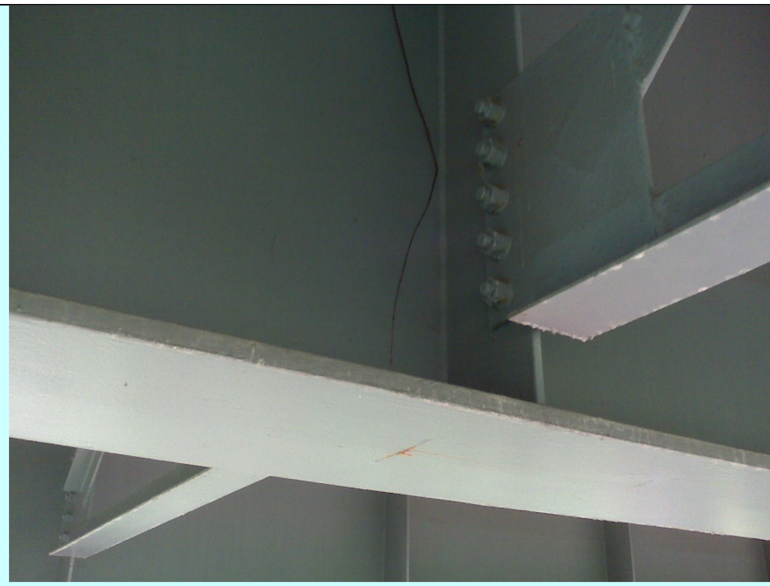
Date of initial event	June 4, 2014.
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The lane directly above the affected girder was immediately closed. A rigorous inspection of comparable details on the rest of the bridge and the similar parallel structure was initiated.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	The Bridge Inspection Team Leader informed the Bridge Inspection Program Manager who ordered the bridge closed.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the

the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Engineering judgment was used to justify closing only the lane above the girder with the fracture. Although no simplified analysis was documented, the engineer quickly reasoned that the remaining open lane was supported by two competent girders and any transverse distribution of load could easily be accommodated by the third remaining competent girder. Once the bridge was restricted to a single lane, inspectors rigorously examined each similar detail for signs of distress or fatigue cracks. The bridge and its parallel twin had previous cracking issues. a fracture was discovered on the same bridge girder near a si intersecting weld detail. That discovery led to an inspection of parallel twin bridge, where another fracture near a similar deta discovered. Repairs consisting of drilling crack arresting holes splicing over the cracks were performed at that time to bring b bridges back into full service. The 2012 cracks were determined to have been constraint ind fractures originating at intersecting weld details, informally refe in the U.S. as Hoan-like details. The fractures initiated at the intersection of a longitudinal web stiffener with either a vertica connection plate or web stiffener, likely as the result of a heav (the bridges had just been resurfaced). Constraint induced fra result from high stress concentrations in the base metal that c relieved through yielding due to the tri-axial constraint supplie intersecting welds.
Answer – Who in your organization made the decision and with what qualifications did	The State government member of the collaborative decision was made by the State Bridge Engineer; advanced academic degree, professional license, and significant

they have?	bridge design and management experience.
Answer - What pertinent data did you have at your time the decision?	At the time of the decision, the data on hand included visual inspection documentation of the condition of the fractured girder and knowledge of the previous fractures in the same girder of this bridge and in the parallel twin bridge.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Although a number of options were considered in detail, the only pragmatic repair solution was to remove the crack tips and plate over the fractures. The bridge remained restricted to one lane until that repair was complete.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	The only temporary fix considered was restricting the bridge to one lane of traffic only.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing, special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	The special inspection consisted of a detailed visual inspection of similar details with intersecting welds. Where surface breaking cracks were suspected, magnetic particle testing was used to verify their existence.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Magnetic particle testing consists of inducing a magnetic field across a suspected crack which, if a crack exists, allows the magnetic flux to leak since air cannot support as much magnetic field per unit volume as metals. To identify a crack, ferrous particles are applied to area with the suspected crack. These particles are attracted to an area of flux leakage and form what is typically known as an indication.

Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	No analysis was required for this event.
Date event resolved or concluded	The girder was repaired within by the end of June 2014, less than one month after the fracture discovery, and the affected lane of the bridge was reopened to traffic. Retrofitting of the remaining similar details on both this bridge and its parallel twin were also completed by the end of June 2014.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair.
Answer	This event highlights the need for the identification and close inspection of intersecting weld details on bridges. Further, bridge owners are strongly encouraged to consider the retrofitting of these details to reduce the occurrence of future fractures, especially on bridges where constraint induced fractures have previously occurred.

#25 USA – FHWA (3 SM)

Event Date	Trigger Category: Inspection
February 2011	Cracks in Tension Tie Discovered

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Tied Arch Truss Bridge	Special Inspection	Yes	1960	488

Description: The Bridge was under a fracture critical arm's length inspection when cracks were discovered in the tension tie. It was decided to manage the bridge with a special inspection and engineering analysis while the repairs were being made. During this monitoring period a crack was discovered and the bridge was closed until the repairs could be made over the next 6 months. These repairs included plating the members and some post tensioning. This work was completed on February 7, 2012.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	United States
Prepared by	Joey Hartmann
Date Prepared	15.11.2016
1.0	Description of Event / Incident
Description of Bridge	The I-64 Sherman Minton Bridge over the Ohio River in Louisville, Kentucky, consists of two 800' tied arch truss main spans that were constructed in 1960-1961. The 6 lanes of the bridge carry over 75,000 ADT on two decks. The bridge serves as a major artery for the City of Louisville and the Region (one of three Ohio River Crossings in the Louisville Area). The tie chords and some vertical and upper chord members of the arch rib of the bridge were fabricated from T-1 steel (high-strength quenched and tempered steel). T-1 steel of this era was difficult to weld and highly susceptible to cracking if proper welding procedures were not followed.
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	A fracture critical (rigorous) inspection identified several cracks in the tension ties of each span. These surface

	breaking cracks were perpendicular to the primary stress range and typically adjacent to and parallel with butt welds. Any failure of the butt welds in the tie chord could result in a fracture of the tie chord and the potential collapse of the superstructure span itself. 

	
Date of initial event	February 15, 2011.
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	The immediate reactions discussed included closing the bridge, restricting load from the bridge, and managing the bridge with a special inspection and engineering calculation. It was decided that a special inspection would be conducted to identify all relevant defects in the tension ties and engineering calculation (fracture mechanics) would be used to manage the status of the bridge will repairs were made.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Due to the lack of redundancy, the management approach taken required establishing a high level of confidence in the fitness for service of the structure. As such, the decision to use special inspection and engineering calculation was made collaboratively by the State owners and the Federal government. The engineers involved had advanced degrees, were professionally licensed and were highly experienced in similar situations.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in	Examples:

determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	There were no appropriate immediate or temporary fixes other than closing the bridge. The only judgment exercised was a consensus that the defects/cracks identified had likely been the result of poor hydrogen control during fabrication and, as the cracks were found during an inspection that occurred in the early spring during warming temperatures, that rupture was unlikely in the near future if there was no more growth. As the extent and severity of the issues were unknown at the time of the decision, the process going forward was designed to consider newly developed data to inform actions. Analyses were conducted to establish safety (strength and fracture) and understand the potential for crack growth due to live load fatigue. To establish material properties and as-built geometries, cores were taken and tested, and plate sizes documented. In addition, the tie chords were monitored for live load stress range and thermal stress range. These results were used to refine strength and fracture calculations.
Answer – Who in your organization made the decision and with what	The Federal government member of the collaborative decision was made by the chief bridge engineer; advanced academic degree, licensed Professional Engineer and significant

qualifications did they have?	experience as both a bridge engineer and failure analyst. The State government member of the collaborative decision was made by the State Bridge Engineer; advanced academic degree, professional license, and significant bridge design and management experience.
Answer - What pertinent data did you have at your time the decision?	At the time of the decision, the data on hand included visual inspection documentation of the condition of the tie chords, some physical testing results for material properties and a history of inspection reports that, although inconsistent, documented the condition of the ties.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Although a number of options were considered in detail, the only pragmatic repair solution was to plate over 3200-feet of tie chord. Both acquiring the materials necessary and installing the plating were projected to take 6 months. A desire to avoid a closing of this length for an ADT of 75,000 in an already congested metropolitan area motivated a sophisticated approach that could result in maintaining the bridge open at an appropriate level of safety.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	Yes. A component level (2D) engineering calculation to quantify strength was completed. The assumptions used in this quantification were debated at length to be sure that the result was useful and appropriate.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	As the tie chords lacked redundancy, the potential repairs all considered adding mitigating a potential fracture motivated by a progressing defect or change in conditions and adding redundancy to the tie chord. To increase redundancy, the options included (1) post-tensioning of the tie chord, (2) partial plating of the tie chord, and (3) full plating of the tie chord.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	The decision to move forward managing the bridge using fracture mechanics relied on developing significant confidence in the knowing the type, orientation, size, quantity and extent of cracking on the bridge. To develop that confidence, Magnetic Particle Testing (MT), Phased Array Ultrasonic Testing (PAUT), Radiography (RT), and High Energy X-ray Testing (HEX) was used. PAUT inspectors were performance tested using known flawed specimens suspended from the side of the bridge. A sampling of testing results were confirmed by collecting additional and examining steel cores

	that captured the defects defined.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	A fracture mechanics calculation was constructed to determine the maximum stable crack size at the Lowest Anticipated Service Temperature (LAST) for each of the types and orientations discovered in the chord tie. Inherent to that calculation were conservative assumptions about the stress intensity at the crack tip, the material properties of the steel and the expected temperature range in which the crack would need to remain stable.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	Once the critical size for each type and orientation of crack were identified for the LAST, any cracks identified by the special inspections were compared to the critical crack sizes to justify keeping the bridge open to traffic.
Date event resolved or concluded	On September 8, 2011, a crack was discovered that exceeded the critical crack size for its type and orientation as determined by the fracture mechanics calculations. As a result, the bridge was closed and traffic detoured until the retrofit/repair was completed. The bridge reopened on February 17, 2012 after 6 months of closure.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair.
Answer	By using the results of a special inspection, the owner was able to confidently keep the bridge safely in service for 6

	additional months before the combination of defect size and the approaching cold temperatures forced a closure. Although the procurement of high strength steel and bolts was always considered a challenge, one lesson learned is that the procurement of trained iron workers in the numbers needed to affect a timely repair was also a challenge on such a large project without foreknowledge.

#26 USA – WISCONSIN (1)

Event Date	Trigger Category: Inspection
September 2015	Excessive Pier Cap Deterioration

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length
Prestressed Girder	No Immediate Reaction	No	1959	176

Description: Excessive deterioration was discovered during a routine visual inspection under a pier cap. The bridge was not closed or have traffic restriction. A 2d analysis was performed to ensure the pier cap had adequate load carrying capacity. The bridge will be rehabilitated in the near future.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	USA
Prepared by	Andrew Smith (Wisconsin Dept. of Transportation)
Date Prepared	11/8/16
1.0	Description of Event / Incident
Description of Bridge	Multi-span concrete prestressed girder bridge over waterway. With expansion joints at select piers.
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Excessive deterioration along underside of pier cap

	
Date of initial event	Request for evaluation Fall 2015
Describe your immediate reactions to this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	No immediate action was taken as it was not deemed to be a critical find. It was being monitored over time through inspections. A request for evaluation was submitted to the bridge rating group.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Bridge Inspector
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen.	Examples: What engineering judgement did you use to come / Special assessment / technique?

Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer – Who in your organization made the decision and with what qualifications did they have?	Bridge inspector requested an evaluation. Evaluation request was sent to me.
Answer - What pertinent data did you have at your time the decision?	Original design plans, inspection photos, and % section loss of reinforcing were provided.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	This deterioration was being previously monitored, and got to a point where it was deemed important to quantify the effect of deterioration on the structure rating. There was no immediate consequence to traffic, and the timeframe for evaluation was not quick.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No calculation done prior to assessment. The load rating on file was recorded as being somewhat low. The first step was to determine what that rating was controlled by. The second step was to assess the pier to see how it rated out assuming a certain percentage of section loss in the bottom reinforcement.
Answer - What were the potential temporary /	Possible fixes included temporary shoring, and fiber reinforced polymer (FRP) wrap.

permanent fixes considered at the time of the decision?	
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	This was a visual assessment by the inspector.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Given the location and nature of the deterioration this section was treated as a beam and focused on the positive bending moment capacity at mid-cap. Force reactions were determined using a 2D frame model, utilizing the finite element analysis program CSI Bridge. A Mathcad sheet was developed to calculate the capacity of the pier cap section, the calculations of which were based on traditional reinforced concrete beam design methods. (See attached calcs)
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	A table of results was developed in which a rating was assigned based on a percentage of section loss in the bottom reinforcing. From the table someone in the field could determine when the rating might control, or drop below the design vehicle based on the percentage of average section loss.

Date event resolved or concluded	September 2015
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP
Answer	Because the level of section loss in the reinforcement was minimal, and the reinforcement was still anchored near the column interfaces it was determined that the pier cap in its current condition was not controlling the rating. It is likely this structure will be replaced in the near future. No remedial action was taken.

#27 USA – WISCONSIN (2)

Event Date	Trigger Category: Bridge Impact
February 2016	Bridge Hit Severed Prestress Strands

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Prestressed Girder	Closed under highway	No	1966	52

Description: The Bridge was hit by a back hoe on a trailer and it damaged girders severing prestressing strands. deterioration was discovered during a routine visual inspection under a pier cap. Bridge inspectors closed the ramp pending further evaluation. The bridge was re-opened to legal traffic after an engineering analysis. The final repair was FRP and completed in the summer of 2016.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	United States
Prepared by	Alex Pence
Date Prepared	November 8, 2016
1.0	Description of Event / Incident
Description of Bridge	2 spans, 85' each Prestressed concrete deck girders Built 1966 Concrete overlay and superstructure repairs in 1986
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Bridge hit by backhoe on a trailer damaged exterior girder and center girder (among 9 girders). Strands severed and significant loss of concrete section. 

Date of initial event	February 16, 2016
Describe your immediate actions from the result of this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	Bridge is located where a ramp merges onto highway. On-ramp was closed due to the worst damage occurring on exterior girder where there is very little shoulder and the ramp caused traffic to become close to exterior girder.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.
Answer – Who in your organization made the decision and with what qualifications did they have	Bridge inspector with professional engineer qualifications made the initial assessment of the bridge condition, then report and photos were sent to the Bridge Hit email list, consisting of managers and bridge rating engineers for analysis and posting/repair recommendations.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?

Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	
Answer	Inspectors made initial decision to close the ramp, pending further evaluation. Load rating engineer performed analysis to determine remaining strength of girder after strands are severed. It was then decided to re-open the bridge to routine traffic, however overweight loads would be restricted until repair is complete.
Answer – Who in your organization made the decision and with what qualifications did they have?	Inspectors with professional engineering licenses and inspection experience as their primary job duty made initial sight evaluation and decision to close the ramp until computational analysis could be performed.
Answer - What pertinent data did you have at your time the decision?	Photos, measurements, and prior bridge rating calculations along with as-built construction plans.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	An access ramp to the highway was closed, therefore it had a high traffic impact. When the bridge had the potential to be re-opened with additional evaluation, the engineers aimed to complete the evaluation as quickly as possible.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	2D line girder analysis with redistribution of loads and loss of strands were severing or debonding occurred.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	Temporarily, the bridge was kept open but permit traffic was restricted. FRP was used as a permanent repair.
3.0	Description of special inspections, and damage assessment techniques
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,

Answer	Visual inspection for initial response, then load rating analysis to determine strength of damaged girder with severed strands. The bridge was already planned for 2017 replacement so short-term repair options were considered. FRP repair was decided.
4.0	Description of load calculation model and the application of damage or deterioration to that model
Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	AASHTOWare BrR was used to perform analysis with severed prestressing strands. Results from analysis were used to perform FRP design with spreadsheets and MathCAD calculations. Calculations are attached.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	Analyzed the prestressed girders with thinner web and bottom flange to account for concrete section loss, and also removed strands from model to account for severed strands. This was the first FRP design that was not contracted out to the FRP supplier. Our agency designed and specified the FRP repair.
Date event resolved or concluded	Same day as bridge hit: traffic restriction removed, leaving only a restriction on overweight vehicles. Summer 2016 – repairs under way
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions.	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair.

	This took 5 days to complete, learned of new process for application of FRP
Answer	A procedure for FRP repair design was established within our agency. Our agency had an engineer with significant experience in researching FRP on its staff to lead this effort. Also, this bridge will provide an opportunity to do laboratory testing on the strength of the FRP repairs when it is replaced with the new bridge in 2017.

#28 USA – WISCONSIN (3)

Event Date	Trigger Category: Bridge Impact
February 2016	Truss Member Hit and Fractured

Bridge Type	Immediate Reaction	Special Assessment	Construction Year	Total Length (m)
Mixed Truss Bridge	Closed Bridge	Yes	1930	424

Description: The Bridge was hit by a back hoe on a trailer and it damaged the bottom chord at nine locations on two truss spans. The Bridge was closed until additional inspection and evaluation were completed. The bridge was opened under a 20 ton limit the next day. Members were fabricated and replaced the damage members in July of 2016.

Issue: D3.3 – Special inspections and Damage Assessment Techniques	
Country	United States
Prepared by	Alex Pence
Date Prepared	November 8, 2016
1.0	Description of Event / Incident
Description of Bridge	11 spans: • 3 concrete flat slab spans • 7 truss spans with one bascule/truss 1391' total span lengths Built 1930 with several rehabilitation projects, most recently in 2010 with misc superstructure/truss repairs
Picture of Bridge	
Description of the event and the trigger that caused the assessment	Examples: bridge hit, excessive deterioration, flood, scour, Routine Inspection resulting in critical finding, emergency, moving super load, etc
Answer	Bridge hit by backhoe on a trailer damaged bottom chord of lateral bracing at 9 locations through two truss spans.

	 
Date of initial event	April 21, 2016
Describe your immediate actions from the result of this event	Examples: close bridge, reduce traffic lanes, and determine the need for special assessments, investigations, or special inspections. These initial assessments would lead to follow up actions
Answer	Bridge was originally closed upon initial response on a Friday evening, until additional inspection and evaluation occurred. Inspectors and structural engineers immediately responded, re-opening the bridge with a 20-ton weight limit on Saturday morning. Additional assessments to determine repairs and adjustments to load restriction would occur the following week.
Who in your organization and made the immediate assessment and what qualifications did they have?	Examples: Bridge inspector, maintenance crew, law enforcement, structural engineer, field personal, etc.

Answer – Who in your organization made the decision and with what qualifications did they have	Bridge Inspector (program manager with licensed professional engineering qualifications) on call performed initial damage inspection, decided to close bridge in collaboration with city officials and law enforcement. Structural engineers on call performed initial evaluation to determine if bridge could be reopened.
2.0	Description of decision making process
Describe the strategies, actions, or outcomes in determining what assessments or special inspections were chosen. Describe the decision making process Specific items to describe answers: Who in your organization made the decision and with what qualifications did they have? What pertinent data did you have at your time the decision? How did the timeframe of returning the bridge to full service influence the decision? Did you do an engineering calculation prior to the assessment, in 2d or 3d? What were the potential temporary / permanent fixes considered at the time of the decision?	Examples: What engineering judgement did you use to come / Special assessment / technique? Items to highlight you considered immediate or temporary fixes, including cost, disruption to traffic or service of the bridge Did you do some simplified analysis prior to the use of the Special assessment / technique Did you do more in the field? Example - Material Property Cores were taken to determine the actual material properties to include in load carrying capacity. Decision outcome- The bridge may not have to be load posted if the actual properties provide a higher estimation of load carrying capacity. Did you do more in the level of analysis?
Answer	Initial closure occurred due to extent of damage as a conservative response. Inspector sent photos to structural engineer. Structural engineer determined damage had only occurred to secondary members, so bridge could carry routine traffic and emergency vehicles (20-ton load limit). Within the following week, another more extensive inspection occurred with additional photos and measurements, accompanied by 3-D finite element analysis and calculation of wind load effects on the damaged lateral bracing members. Time was critical due to this bridge being one of 3 servicing a popular tourist area, and the busy season coming soon.

	One of those bridges was already out due to construction, so closing this bridge left only one in service. Consideration was given to straightening vs replacing members. Since they were secondary members and road closure was to be avoided as much as possible, most of the damaged members were replaced a few weeks after the incident.
Answer – Who in your organization made the decision and with what qualifications did they have?	Licenses professional engineers with inspection experience made the initial field observations. Structural engineers experiences with load rating and repairs performed the analysis. Decisions were made collaboratively with consensus reached among engineers and management.
Answer - What pertinent data did you have at your time the decision?	Bridge plans, field measurements, photos, and impact on traffic.
Answer - How did the timeframe of returning the bridge to full service influence the decision?	Efficient, approximate methods were used in initial analysis. After initial closure, the bridge was reopened, yet conservatively at 20 tons, then the posting was removed. The traffic impact and need for quick decisions resulted in the initial conservative decisions which were relaxed after more detailed analysis was performed.
Answer - Did you do an engineering calculation prior to the assessment, in 2d or 3d?	No calculations prior to the initial assessment. 3-D analysis was performed for the final assessment.
Answer - What were the potential temporary / permanent fixes considered at the time of the decision?	When analysis showed that the damage to these secondary members primarily influenced lateral (wind load) capacity and not live load capacity, the repair consideration of replacing damaged members vs. heat straightening was influenced by minimizing traffic impact, with the heavy tourist season coming soon.
3.0	Description of special inspections, and damage assessment techniques.
Description of the special inspections, assessments, methods, or techniques used.	Examples: dynamic tests of members, proof testing, material property evaluation, Nondestructive testing , special inspections, acoustic, ground penetrating radar, sonar, etc,
Answer	Visual inspection for initial response. However due to many superstructure repairs through the years and mismatched lateral bracing members, LiDAR scanning was used to expedite measurements and fabrication of elements used to replaced the damaged ones.
4.0	Description of load calculation model and the application of damage or deterioration to that model.

Description of the load model, calculation, 3d, verses 2d, analytical or methods, or techniques used.	Examples: 2d line analysis, Grid analysis, 3d analysis or Finite element analysis. Software programs, and capacity calculations. Provide attached calculations if possible.
Answer	Speed was essential in this case, due to this being only 3 bridges allowing traffic into a major tourist destination, and one of the other two to be closed for rehabilitation in May and June. The initial analysis methods were approximate, but the results provided sufficient confidence to lift the load restriction on the bridge until repairs could be made. Evaluation focused on 3D finite element analysis of the portal frames with wind loads. This is where the worst damage occurred to the most essential elements contributing to bridge stability. Calculations are attached.
Describe how you applied the results of the special assessment, or techniques to the load capacity calculation. What assumptions or techniques did you use to enter the data from the special assessment into your analysis models?	Examples: reduced section properties for calculations, identified structural mechanisms to change, areas of elastic or plastic deformation, etc. Specifically outline changes you made to models or calculations if applicable.
Answer	No special assessment techniques modified the load capacity calculation. For repair, the timeline and importance of minimizing closure time led to the decision to use LiDAR scanning to take measurements and quickly fabricate replacement members, instead of heat straightening.
Date event resolved or concluded	Thursday, April 28 – load posting removed. July – damaged members will be replaced.
Describe the results and outcome and any lessons learned including other factors that may have influenced your decisions.	Examples: prestress bridge girder struck by vehicle, closed lane of traffic on bridge, removed loose concrete, added FRP patched bridge, and opened bridge. Other factors may include contracting mechanisms, procurement of materials, and familiarity with repair. This took 5 days to complete, learned of new process for application of FRP

Answer	Older trusses have significant redundancy in lateral bracing elements, and these contribute very little to live load capacity. This is the first time our state is employing the LiDAR system to expedite repairs, but the initial measurements appeared to be within acceptable tolerances and may be used again.