ΓΕΦΥΡΑ ΡΙΟΥ-ΑΝΤΙΡΡΙΟΥ «ΧΑΡΙΛΑΟΣ ΤΡΙΚΟΥΠΗΣ»

21 ΧΡΟΝΙΑ ΥΠΟΔΕΙΓΜΑΤΙΚΗΣ ΛΕΙΤΟΥΡΓΙΑΣ & ΣΥΝΤΗΡΗΣΗΣ

RIO-ANTIRRIO BRIDGE

POWERED BY VINCI HIGHWAYS

11.12.2025

Panos LOUKAS, CEO, GEFYRA SA

Aris STATHOPOULOS VLAMIS, CTO, GEFYRA SA

DISCLAIMER

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Geography	*Γεωγραφία*
History	*Ιστορία*
Idea	*Ιδέα*
Chronology	*Χρονολόγιο*
Metron	*Μέτρον*
Symmetry	*Συμμετρία*

EUREKA

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THE GREEK INFRASTRUCTURES BEFORE THE CONCESSIONS ERA

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The life before the Bridge (just until before 21 years)

- Ferry monopoly situation (level of service & tariffs)
- 45 min to cross the strait with the Ferry (subject to…)
- In case of bad weather, ferry operation suspension
- Heavy traffic jams in holidays, etc.
- Ambulance Service dependence on Ferries operation, even for life-threatening situations

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Rio – Antirrio Bridge
Turning the vision into reality

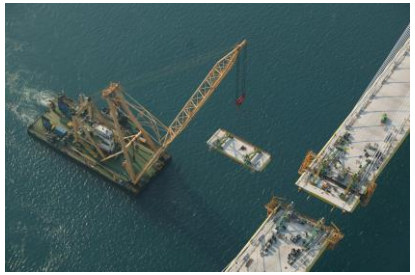
1889
The Vision

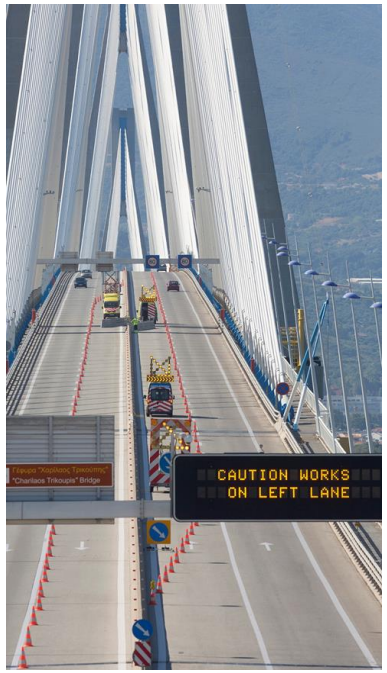
03.01 1996
CA signing

17.12.1997
Financing Documents Signing

12.08.2004
Opening of the Bridge

2039
Concession End





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Rio – Antirrio Bridge
The success of the Concession Model in Greece

- 42-Year Concession term (1997 – 2039)
- 7 years for Design & Construction (1997 -2004)
- Successful long-term Partnerships:
  - CJV led by VINCI with the participation of Greek Contractors
  - GEFYRA SA Shareholders (2023): VINCI Concessions 72,3% and AKTOR Concessions 27,7%
- 9 International Awards by the scientific community
- Investment: €786M (1997)
- Loan:
  - Lender: EIB (370M€)
  - Debt Repayment ends in 2030

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12.08.2004: OPENING OF THE BRIDGE

RIO-ANTIRRIO BRIDGE
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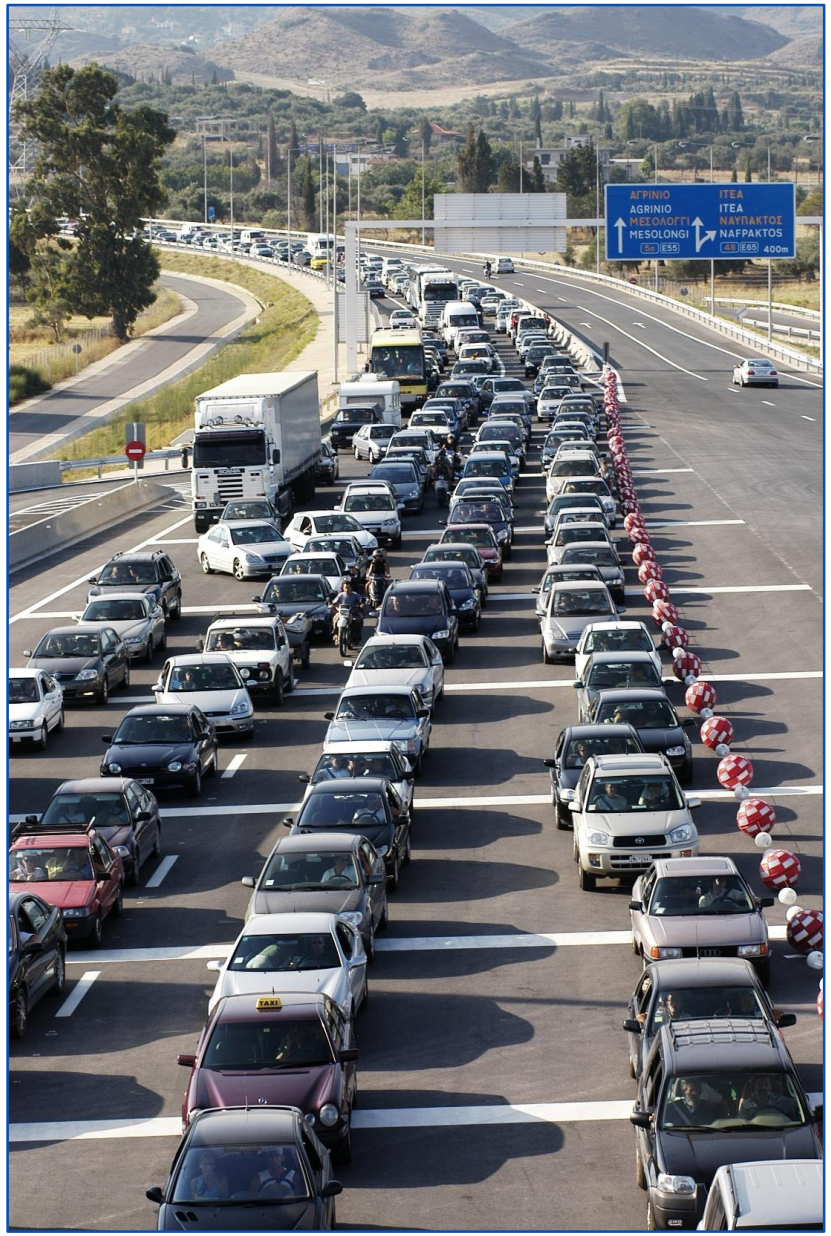
13.08.2004



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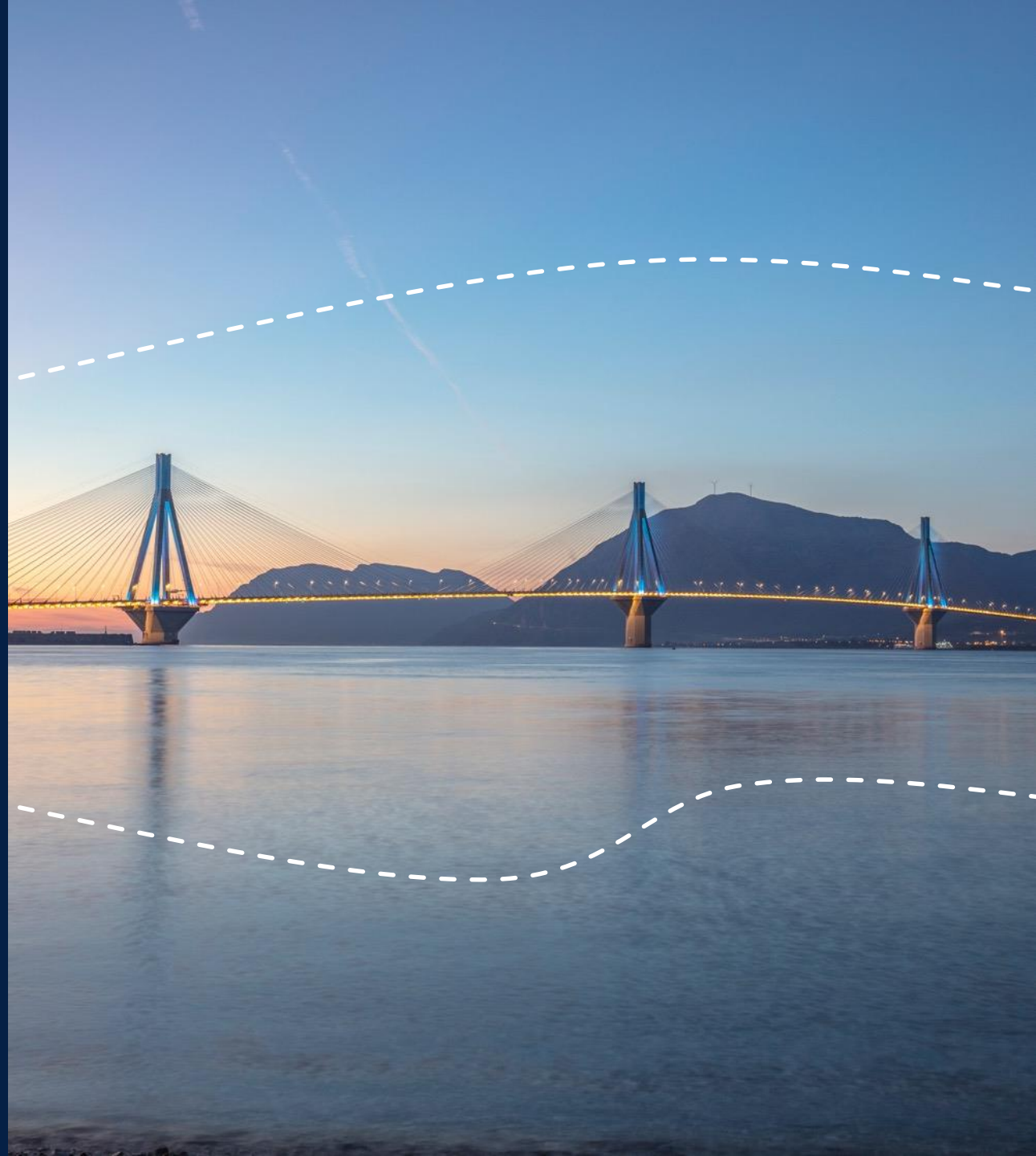
GREEK MOTORWAYS NETWORK

RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

Καινοτόμες Μέθοδοι Παρακολούθησης & Συντήρησης Ειδικών Γεφυρών
Η Περίπτωση της Γέφυρας Ρίου-Αντιρρίου «Χαρίλαος Τρικούπης»

Innovative Monitoring and Maintenance of Major Bridges
The Rion-Antirion Bridge “Charilaos Trikoupis” Case Study



RIO-ANTIRRIO BRIDGE

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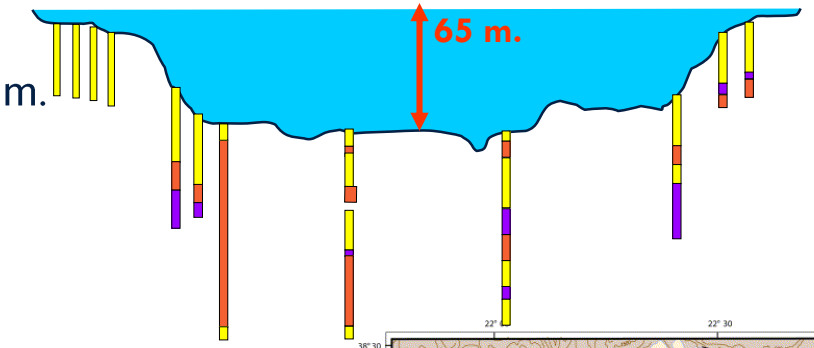
RION – ANTIRION BRIDGE PROJECT DESCRIPTION (1/5)

Environmental Conditions

Weak Sea Bed

No bedrock encountered in first 100 m during soil investigations, while geological studies indicated similar conditions for up to 500 m.

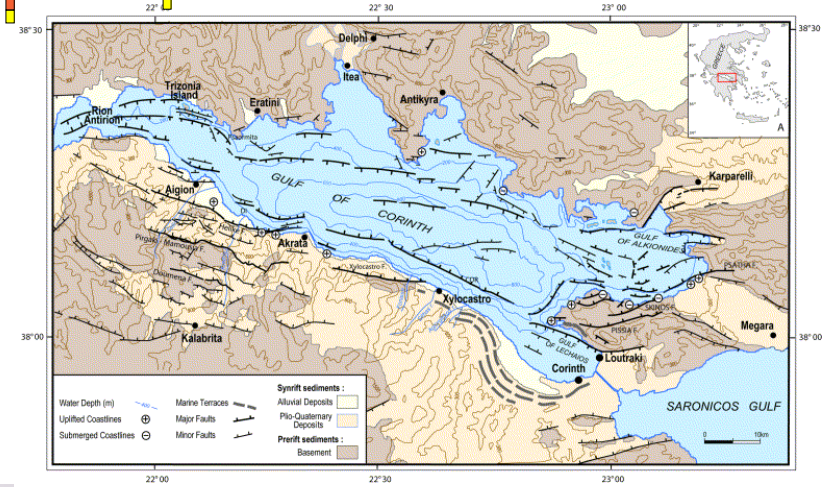


Water depth up to 65 m

Uniform sea bed at depth of 60 m with steep slopes near coast.

High Seismicity & Tectonic movements

Active normal faults on both sides of Corinthian gulf, at the vicinity of Bridge while the tectonic kinematic of area indicates separation of Peloponnese from mainland Greece with rate of ~15 mm/year.



Strong Wind Area

Due to morphology of surrounding mountains, Rion-Antirion strait is prone to the frequent & strong winds with the most frequent winds to have direction perpendicular to Bridge axis.

Corrosivity

Environment Corrosivity Classified C5-M (ISO 12944).

Navigation channel

Significant marine traffic through Rion - Antirion strait.

RIO-ANTIRRIO BRIDGE
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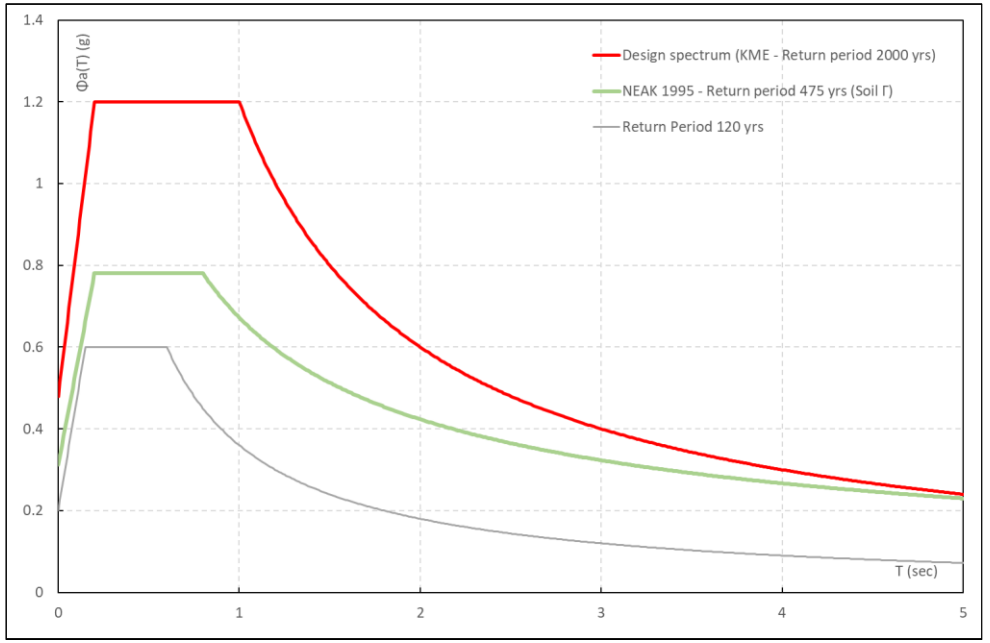
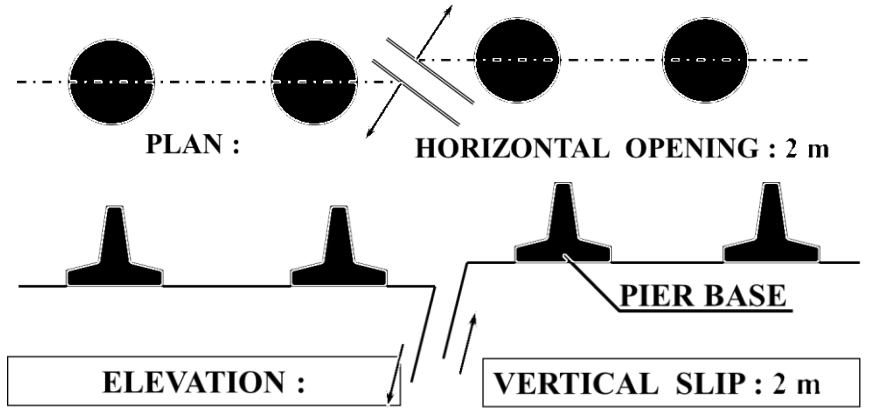
RION – ANTIRION BRIDGE PROJECT DESCRIPTION (2/5)
Structural Design –Design Loads & Requirements

Seismic loads

- Seismic design load (Spectrum: pga 0.48 g, max Sa 1.20 g for T=0.2 up to 1.0 sec) - EQ with 2000 years Return Period.

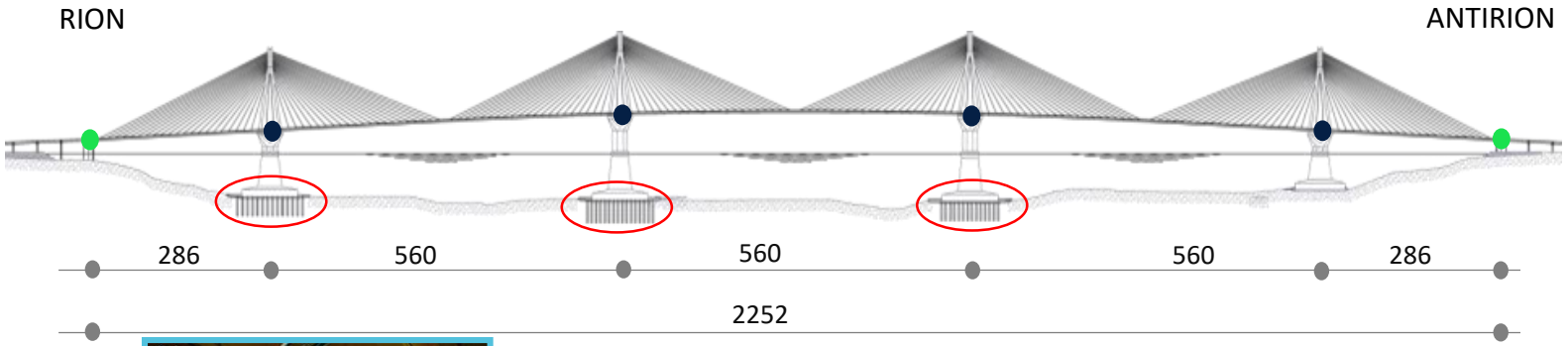
- Tectonic movements:
  - Up to 2m (between adjacent piers) as separate load
  - Up to 1m (between adjacent piers) when combined with specified EQ

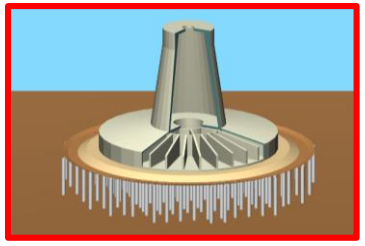




RION – ANTIRION BRIDGE PROJECT DESCRIPTION (3/5)

Main Bridge - Structural Features - Overview





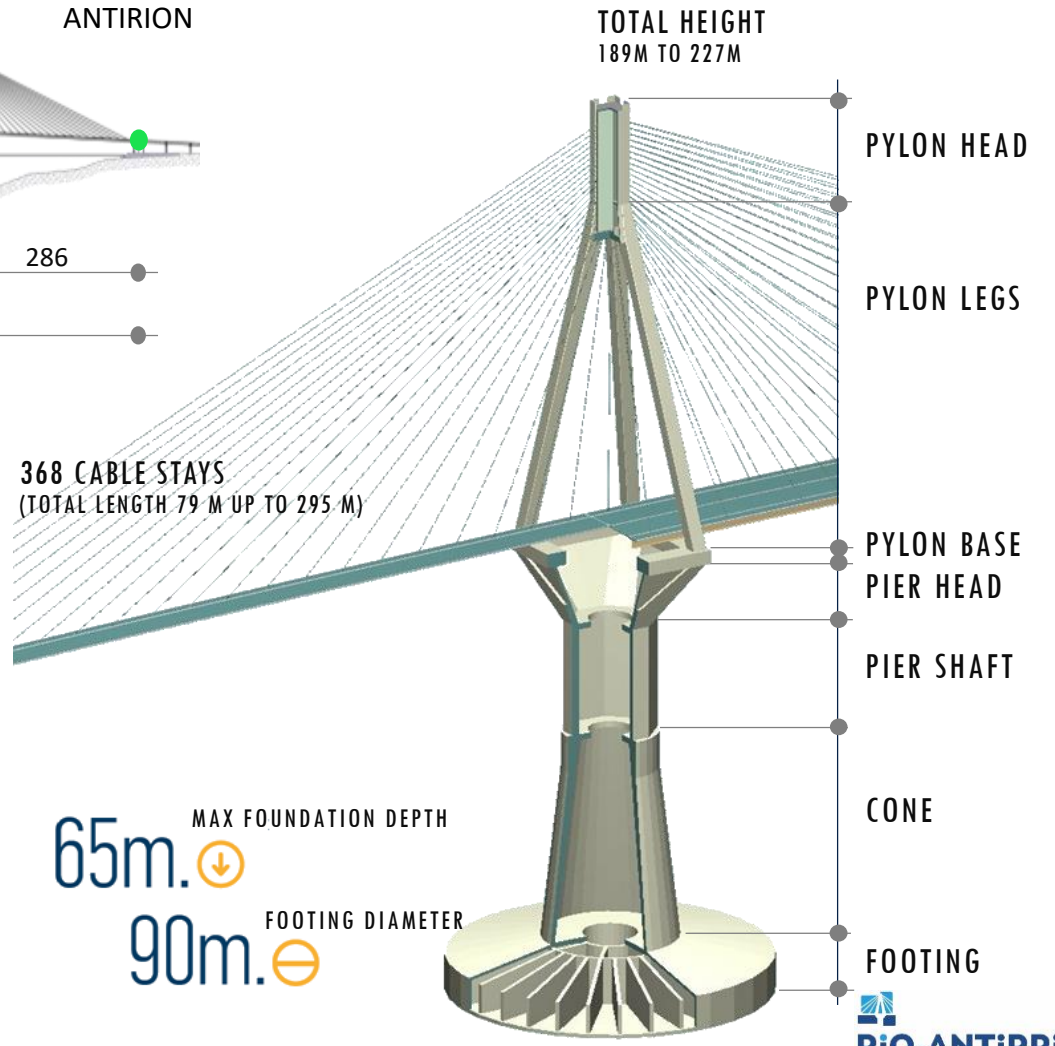
4 DAMPERS ON EACH MAIN PIER & 2 ON EACH TRANSITION PIER (TP)

- In service: The deck is laterally supported by means of a restrainer
  (nominal load: ±10,5MN for main piers / ± 3,5MN for TP)
- In ultimate conditions: It fuses allowing the dissipation system to absorb the induced energy
  (dampers stroke: 3,5 m for Main Piers / 5,2 m for Transition Piers)

2 MODULAR EXPANSION JOINTS

+1,26/-1,15 m longitudinal displacements in SLS
(longitudinal displacements in ULS: +2,81/-2,20 m)
+/- 2,6 m lateral displacements in ULS

SHALLOW FOUNDATION ON REINFORCED SOIL



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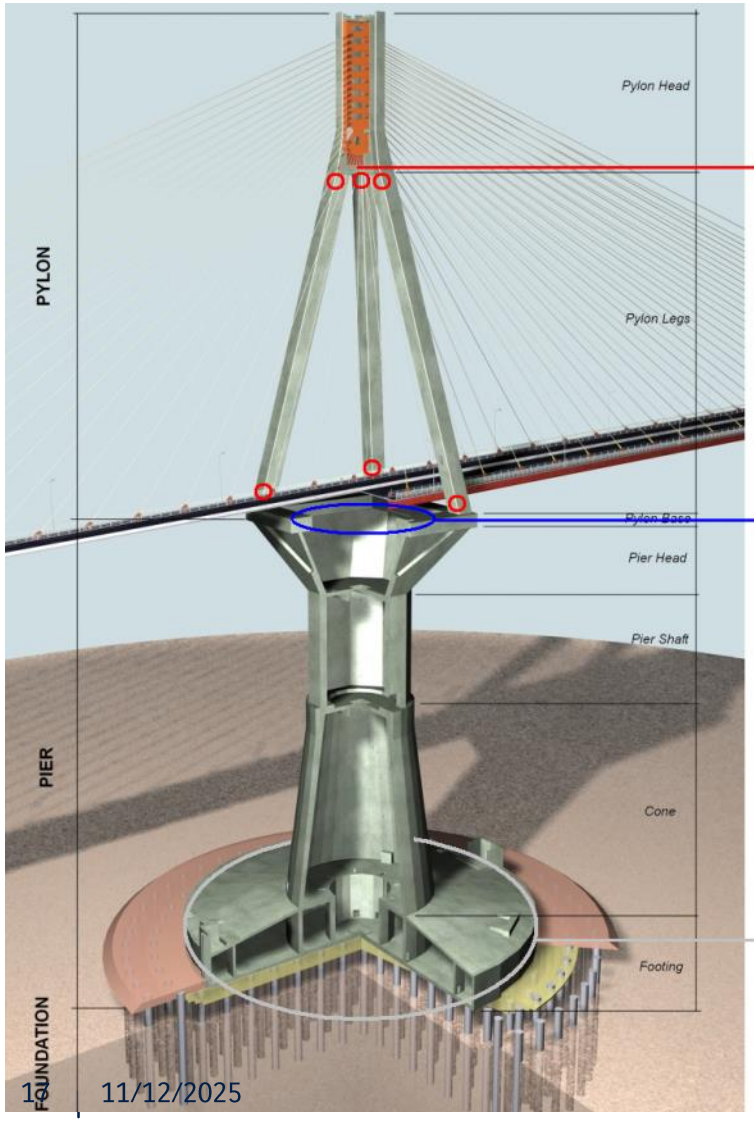
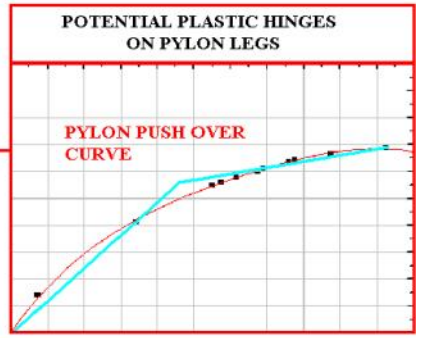
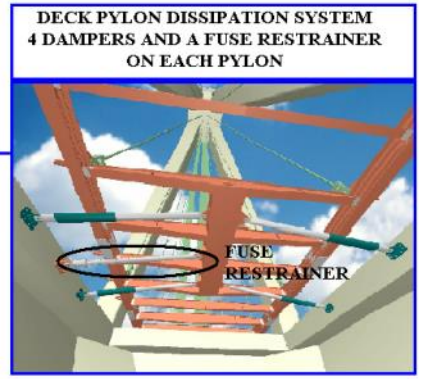
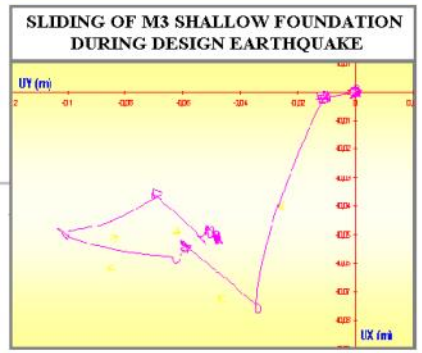
RION – ANTIRION BRIDGE PROJECT DESCRIPTION (4/5)

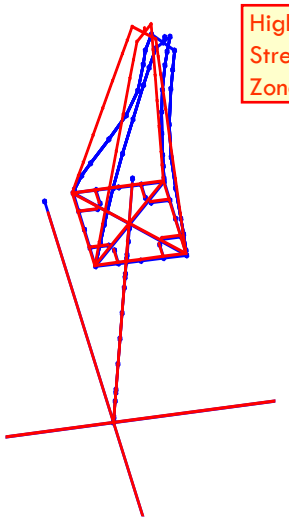
Design Performance-Seismic Design Concept

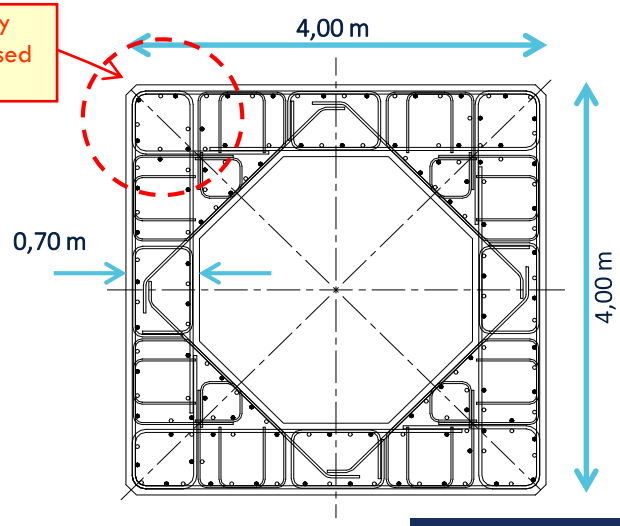


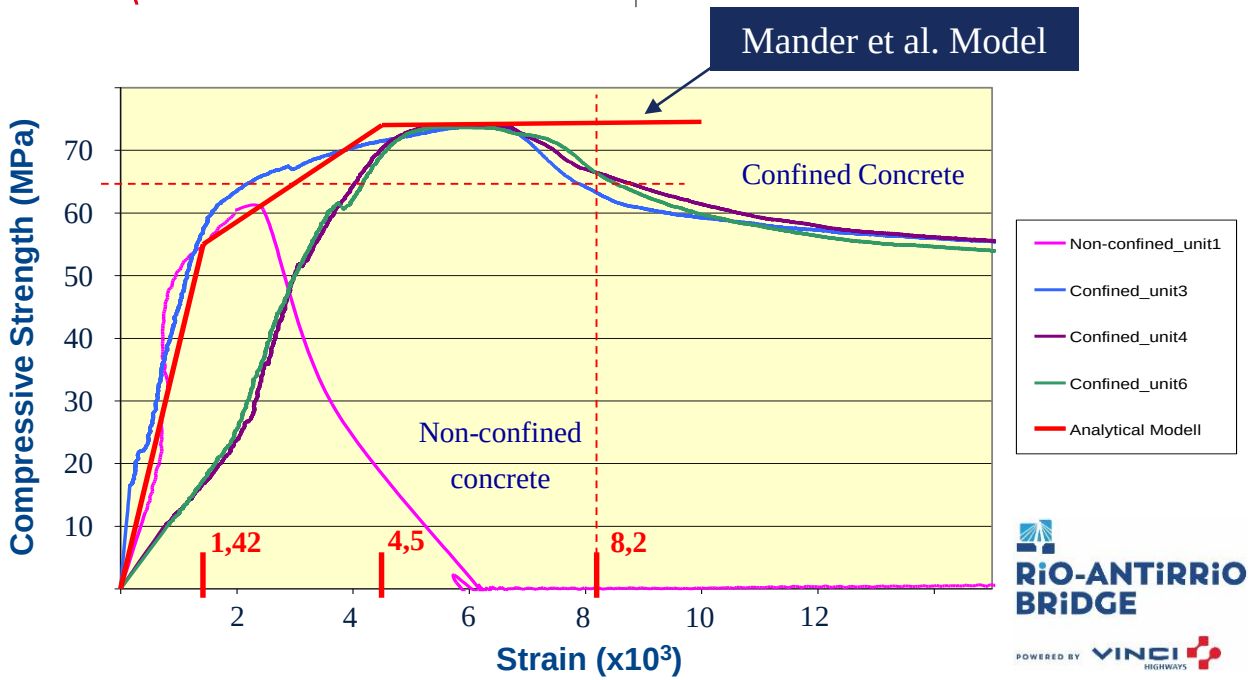












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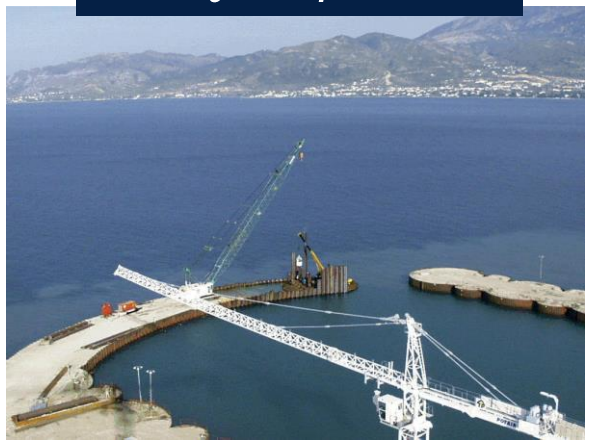
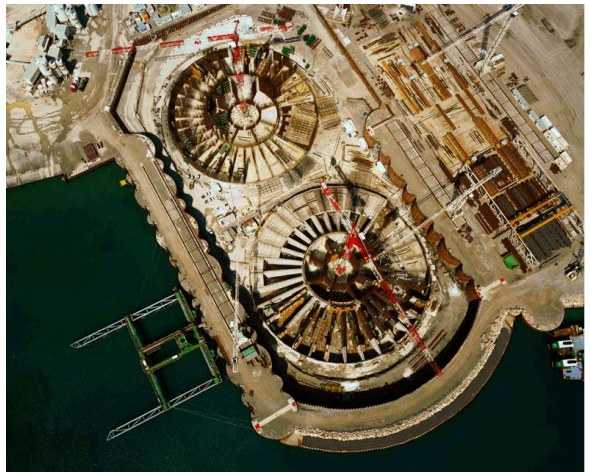
RION – ANTIRION BRIDGE PROJECT DESCRIPTION (5/5)

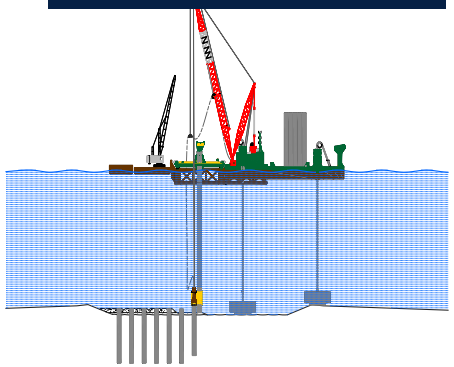
Main Bridge – Construction stages

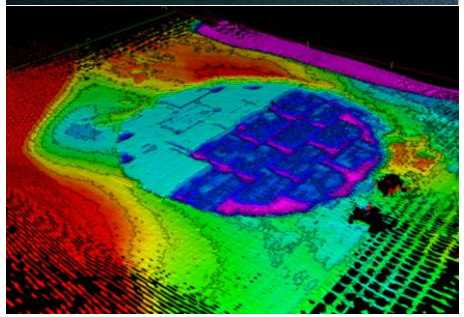
Dry Dock Operation



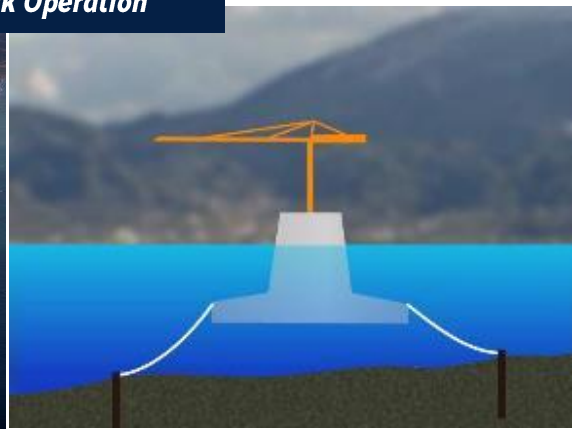


Sea Bed Preparation





Wet Dock Operation



In situ construction

RIO-ANTIRRIO BRIDGE
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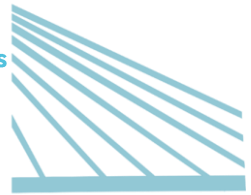
ASSET MANAGEMENT
Technical department Scope of Works

Inspected Assets

Concrete Surface: **190.000m²**

Steel structure surface: **125.000m²**

368 Cable Stays
Including steel stands with total length
3.212 km
(half of Earth radius)



238.330
pre-loaded deck bolts

Pavement Surface
75.400m²

208 Cable Stays
Dampers

Lightning Protection
13.900 m
stainless steel strand

Monitoring	Maintenance	Special Events Structural Management	Other
Visual Monitoring (inspections)	Regular Maintenance (Planned)	Earthquake	Additional works
Material Monitoring	Corrective/Heavy Maintenance	Strong wind	Technical Improvement works
Instrumented Monitoring Structural monitoring system (permanent) Geometrical monitoring		Fire	Remedial works
		Ship collision	Other administrative/ engineering support
		Major accident	

Monitoring & Maintenance

> 750 inspections → **104.400** photos

>1.100 Maintenance campaigns have been registered

>174.000 Photos have been logged and linked to the respective bridge elements & campaigns

Resources

Total (including works with Regular Access & special access means)
>890.000 hours

Alpinists
>34.000 hours in air

U/W & Marine access (including divers)
>11.000 hours on & in water

RIO-ANTIRRIO BRIDGE
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ASSET MANAGEMENT
MONITORING & MAINTENANCE INTERACTION

Monitoring

1. Visual
2. Material
3. Instrumented (SHM,Geometric)

Analysis-Synthesis-Planning

1. Assessment
2. Proposal of actions (Repair/maintenance/monitoring)
3. Works Planning

High level of in-house participation

Maintenance

1. Definition of campaigns (scope , organisation)
1. Preparation (accessmeans, resources, repair methodology, tools, Detailed schedule/Budget)
2. Implementation
3. Monitoring (cost & QHSE)
4. Follow up (reporting, performance, optimization)

RIO-ANTIRRIO BRIDGE
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ASSET MANAGEMENT
VISUAL & MATERIAL MONITORING:PROCESS OVERVIEW AND MAIN FEATURES

Background – Feedback – Data - Resources

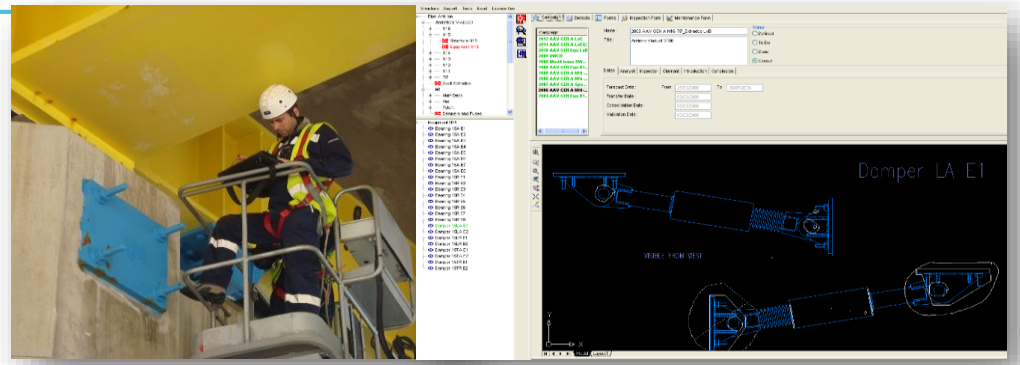
- IMM prepared by Constructor (define visual monitoring content and frequency)-updated upon technical advances and experience
- Concession Perion VM program
- Construction data (WMS, REC, NCRs, etc.)
- Access Means

VM & material testing frequency table for structural elements/equipment

Element	Remarks	Access	Annual	2 Yrs	4 Yrs	5 Yrs	8 Yrs	15 Yrs	20 Yrs
Concrete	Air exp	Regular/Rope	25%						
	Splash	U/W			100%				
	immersed	U/W					100%		
Steel	MB	Regular	100%						
	RAV	Rope or NP/AWP		100%					
Cable Stays	Free length	Rope	25%						
	anchorages	Regular	50%						
	Specialized	Regular		10%					
Scour Protection		U/W					100%		
Structural Equipment	EJ MB	Rope/AWP	100%						
	EJ AV	Regular		100%					
	IDS MB	Reg/AWP	50%						
	IDS AV	Rope/AWP		100%					
Material	Concrete	Regular				test			
	Cable Stays	-						test	
	Pavement	-		test					

VM main features:

- Fully computerized inspections except for specialized means (rope, underwater, supplier)
- Defect Library set up in IMM & populated continuously
- Breakdown of structures into simple elements (5713)
- Simplified ASB drawings for finding location & developed views of all surfaces
- More than 110 types of inspection forms
- >95.000 photos since 2004



RIO-ANTIRRIO BRIDGE
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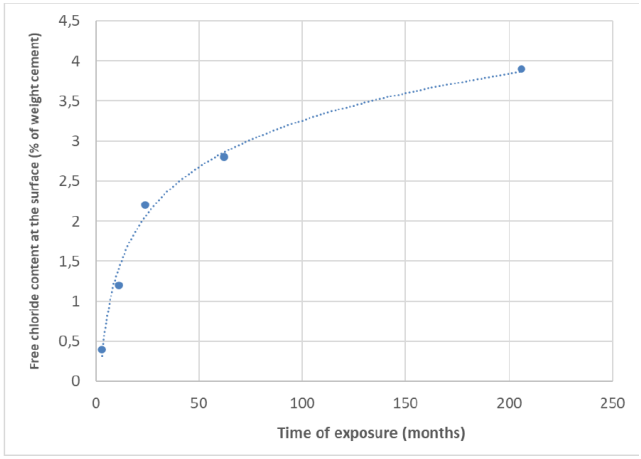
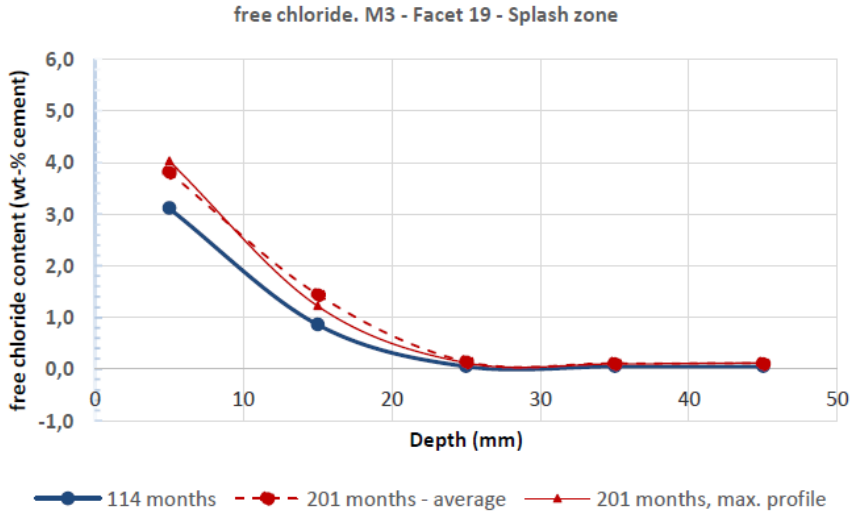
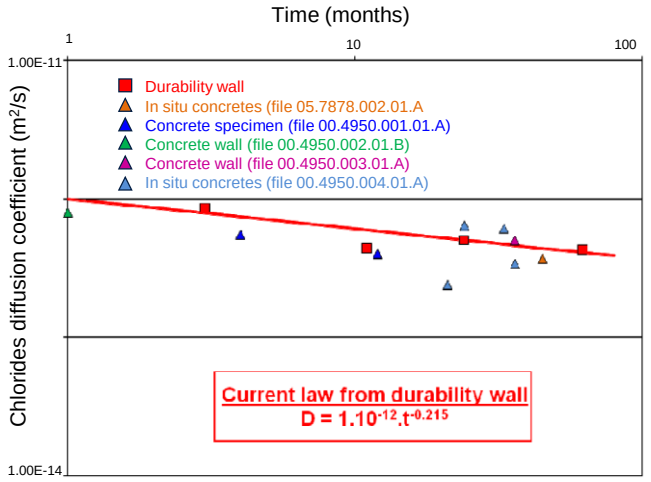
ASSET MANAGEMENT
Material Monitoring: Concrete Durability

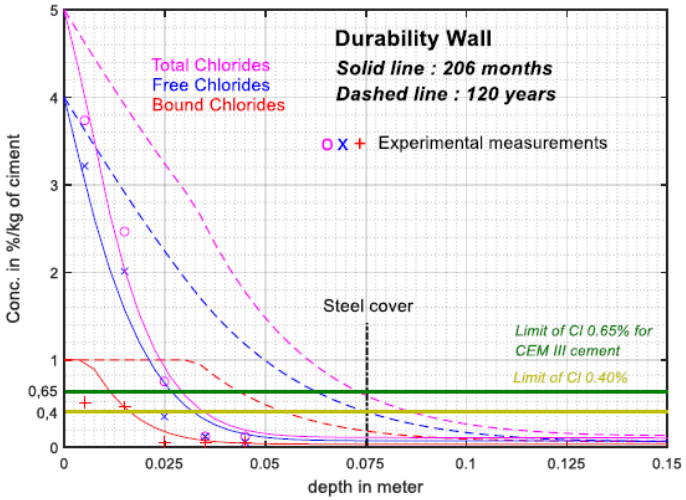
Sacrificial concrete block at P2 of Rion Approach Viaduct for concrete durability monitoring



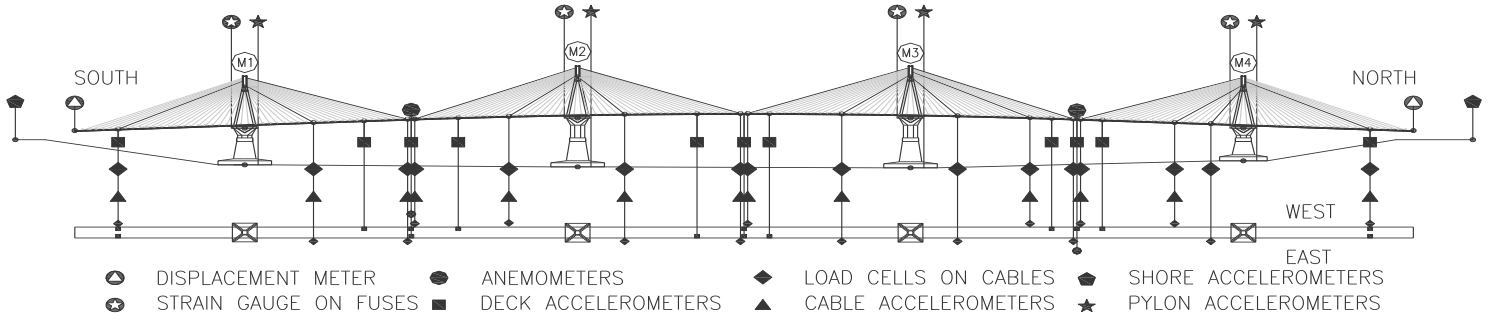


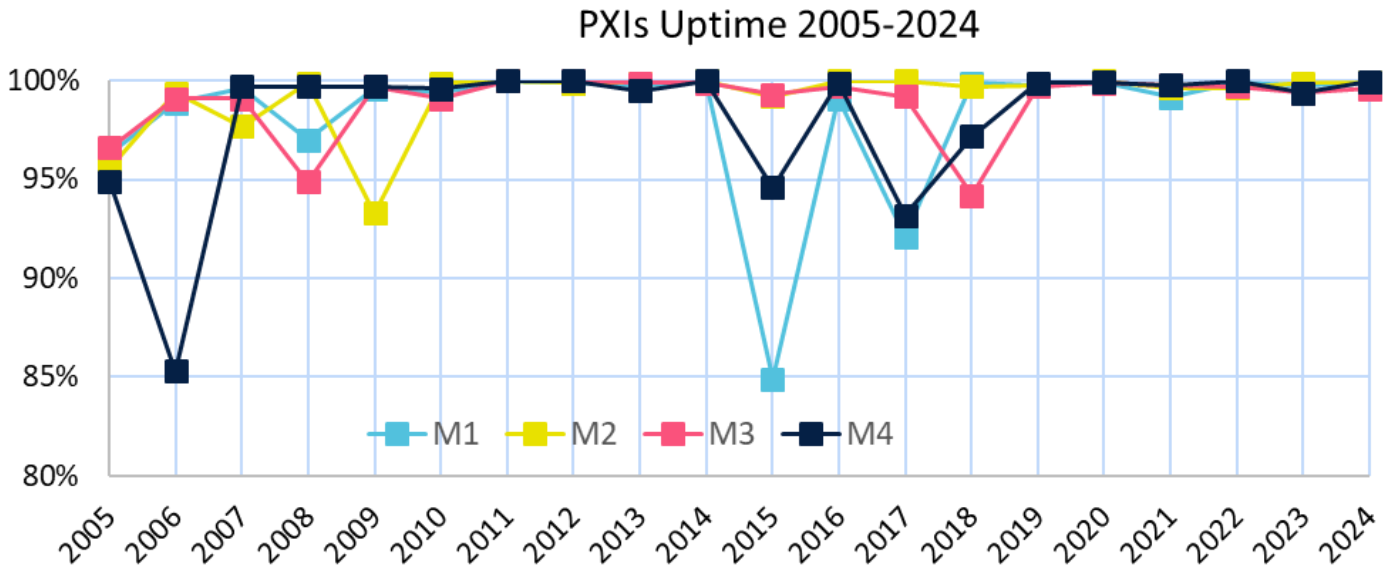
- Measurement of total and free chlorides contents as a function of the depth (from the face of the concrete to 80mm).
- Determination of the chloride diffusion coefficient.
- Life cycle assessment: Simulation through LERM model to assess the free chlorides content at 75mm depth at 120 years.





ASSET MANAGEMENT
INSTRUMENTED MONITORING: SHM-OVERVIEW





Designed and installed during construction period (temporary/permanent instrumentation)

Design based on risk assessment analysis with main objectives:

- Characterization of excitation loads (Earthquake/ Wind/Traffic/Thermal)
- Measuring Bridge Response
- Design verification and feedback
- Provide real time alerts and notification based on configurable parameters
- Assist on operation/enhance user safety (black ice risk/strong winds/seismic events)

Operated since 2004 (2005-2024 average overall uptime > 98%)

RIO-ANTIRRIO BRIDGE
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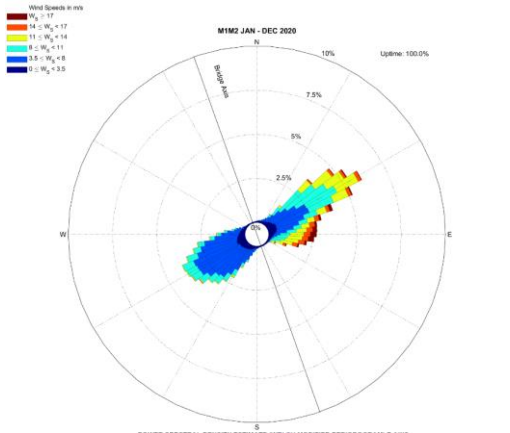
ASSET MANAGEMENT
INSTRUMENTED MONITORING: SHM – OUTPUT & REGURAL ANALYSIS

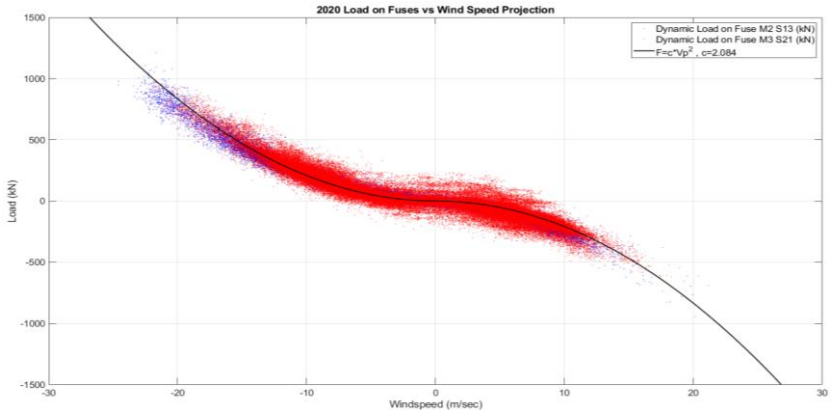
History Files analysis

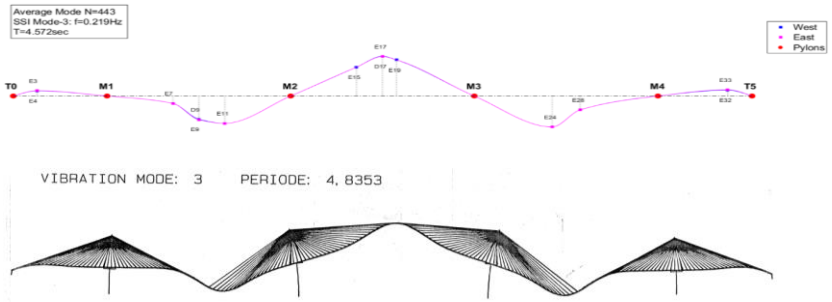
- Slow varying processes/statistical parameters of structural response
- History files: 1 value every 30 sec

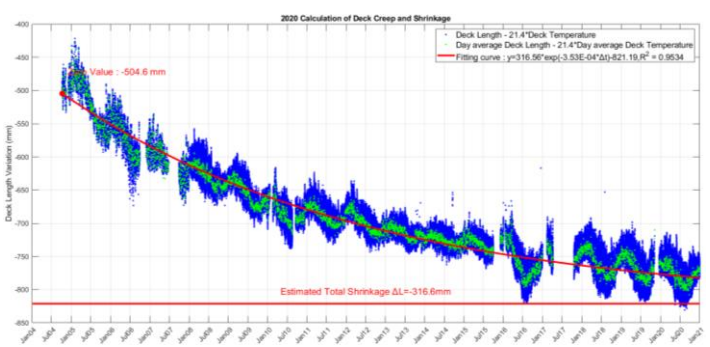
Dynamic Files Analysis

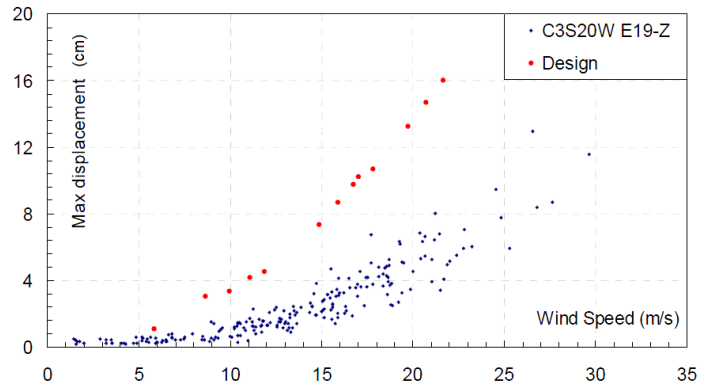
- Dynamic process/actual measurements of structural response
- Dynamic files: High frequency (100 Hz) records of limited duration (typically 3 sec)









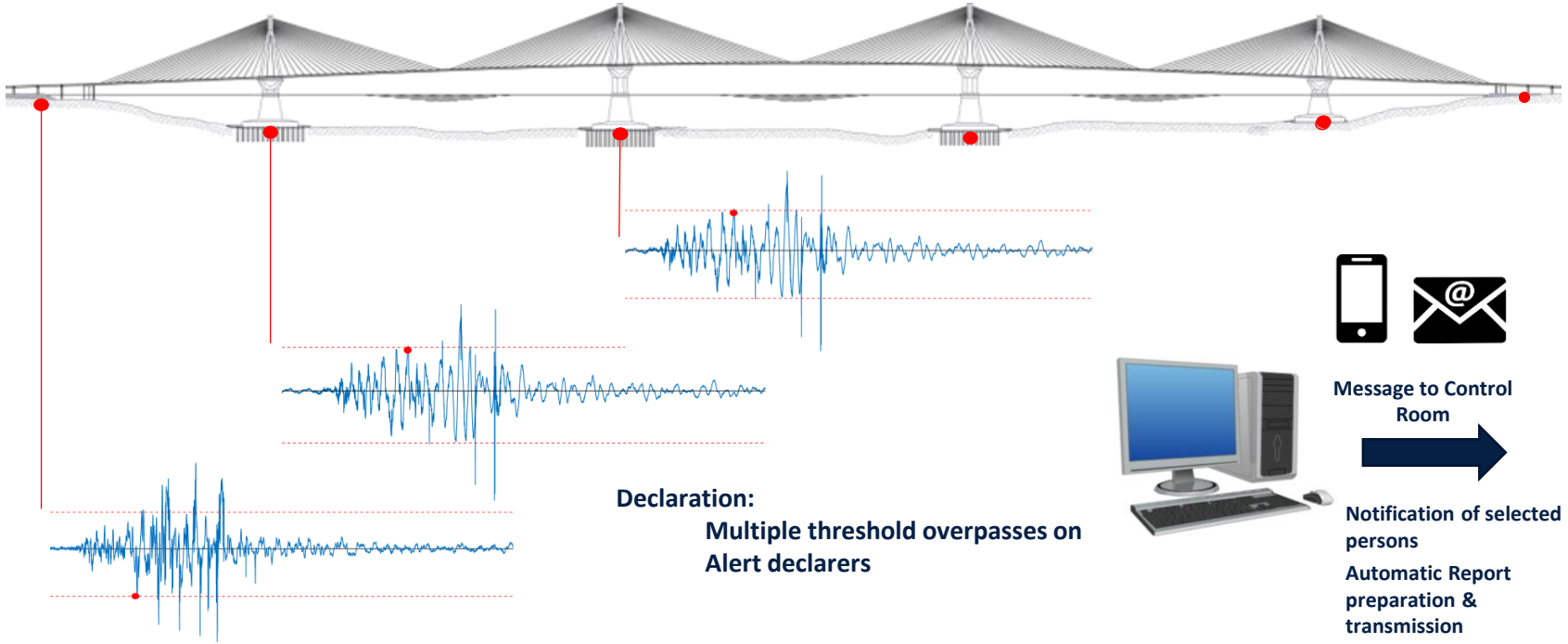


RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

ASSET MANAGEMENT
Instrumented Monitoring - Seismic event follow-up

Automated Event Management (Smart Monitoring)

1. Automated ***detection*** of earthquake events
2. ***Classification*** of structural response
3. Proposed ***decision on traffic management*** (Real time)
4. ***Automated report*** preparation and transmission

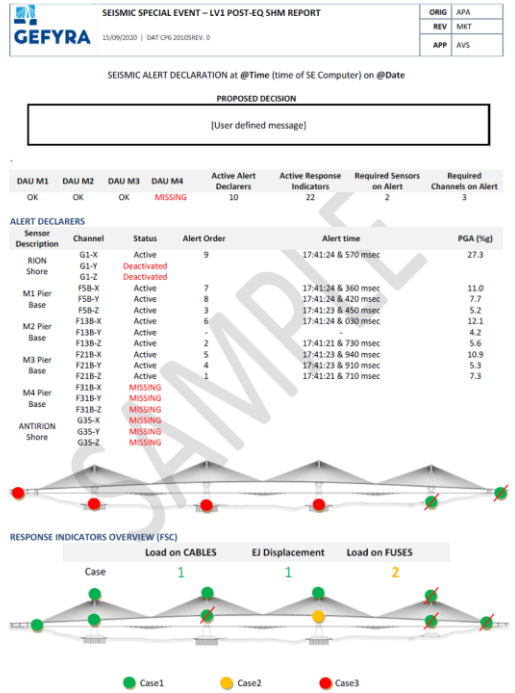


Declaration:
Multiple threshold overpasses on Alert declarers

Message to Control Room

Notification of selected persons

Automatic Report preparation & transmission



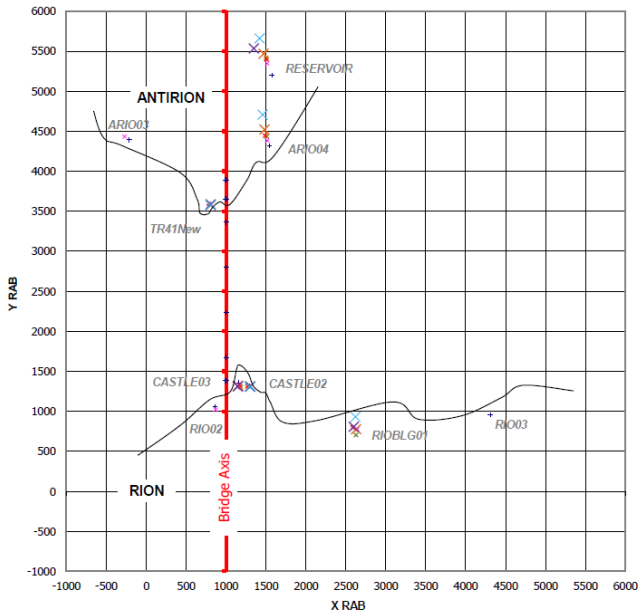
RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

ASSET MANAGEMENT
INSTRUMENTED MONITORING: GEOMETRICAL MONITORING

Measurements and evaluation of:

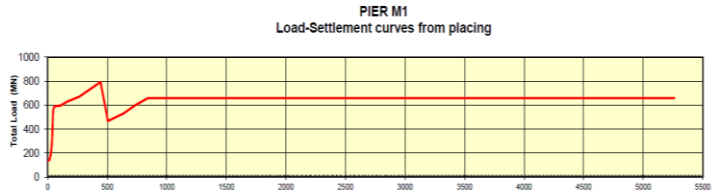
- Automated detection of earthquake events
- Tectonic movements
- Piers tilt & settlement
- Deck geometry
- TP settlement

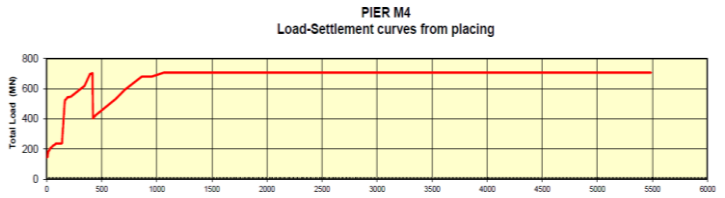
The processed data are analyzed & compared with theoretical res

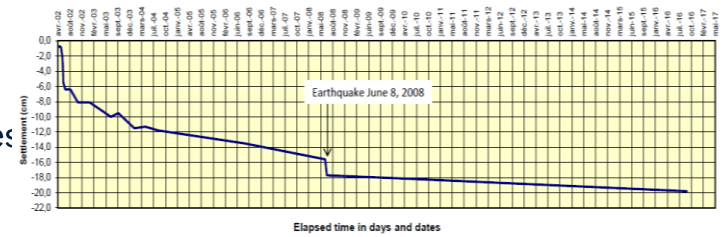


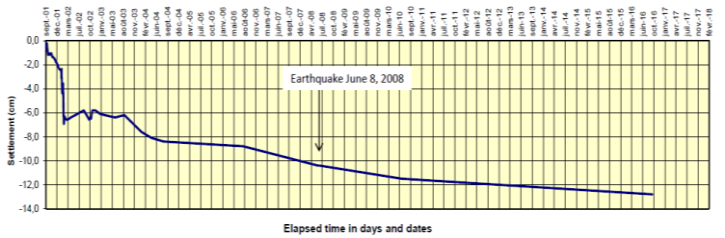
- ZERO POINT 2004
- CAMPAIGN 2006
- CAMPAIGN 2008 Before Earthquake June 8
- CAMPAIGN 2008 After Earthquake June 8
- CAMPAIGN 2010
- CAMPAIGN 2011
- CAMPAIGN 2016

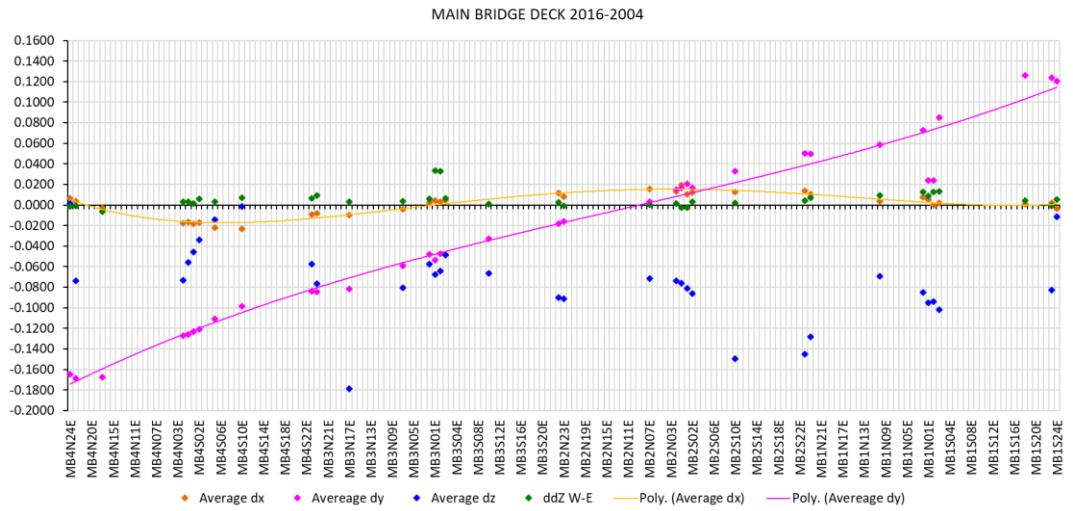
Scale for displacements : 1 square = 50 x 50 mm

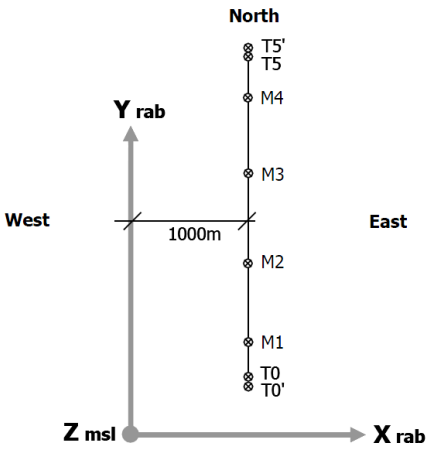












RIO-ANTIRRIO BRIDGE

POWERED BY VINCI HIGHWAYS

Visual & Instrumented Monitoring, HM & SPECIAL EVENTS:
CASE STUDIES

ASSET MANAGEMENT
Visual Monitoring: Underwater inspections case study (1/4)

Scope of Works

- Concrete inspections (e.g. cracks width up to 0,3mm) on the splash zone (from 0 (MSL) to -5m), being an area of 425m^2 per pier
- Check of Earthing System termination at sea
- Check for scouring around pier footing (perimetry of ~285m per pier)

Challenges

- Removal of substantial marine growth from concrete surfaces (Splash zone)
- Weather conditions (waves)
- Strong currents
- Water depth of scour protection
- High turbidity
- Obstacles (fishing nets)

Removal of extensive marine growth

RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

ASSET MANAGEMENT
Visual Monitoring: Underwater inspections case study (2/4)

Scope of Works

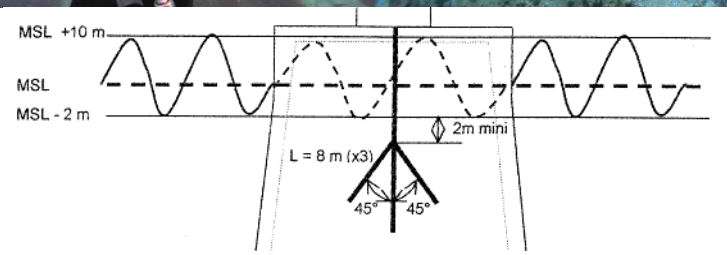
- Concrete inspections (e.g. cracks width up to 0,3mm) on the splash zone (from 0 (MSL) to -5m), being an area of 425m^2 per pier
- Check of Earthing System termination at sea
- Check for scouring around pier footing (perimetry of ~285m per pier)

Challenges

- Removal of substantial marine growth from concrete surfaces (Splash zone)
- Weather conditions (waves)
- Strong currents
- Water depth of scour protection
- High turbidity
- Obstacles (fishing nets)

Visual Monitoring of Scour Protection

Visual Monitoring of Earthing termination

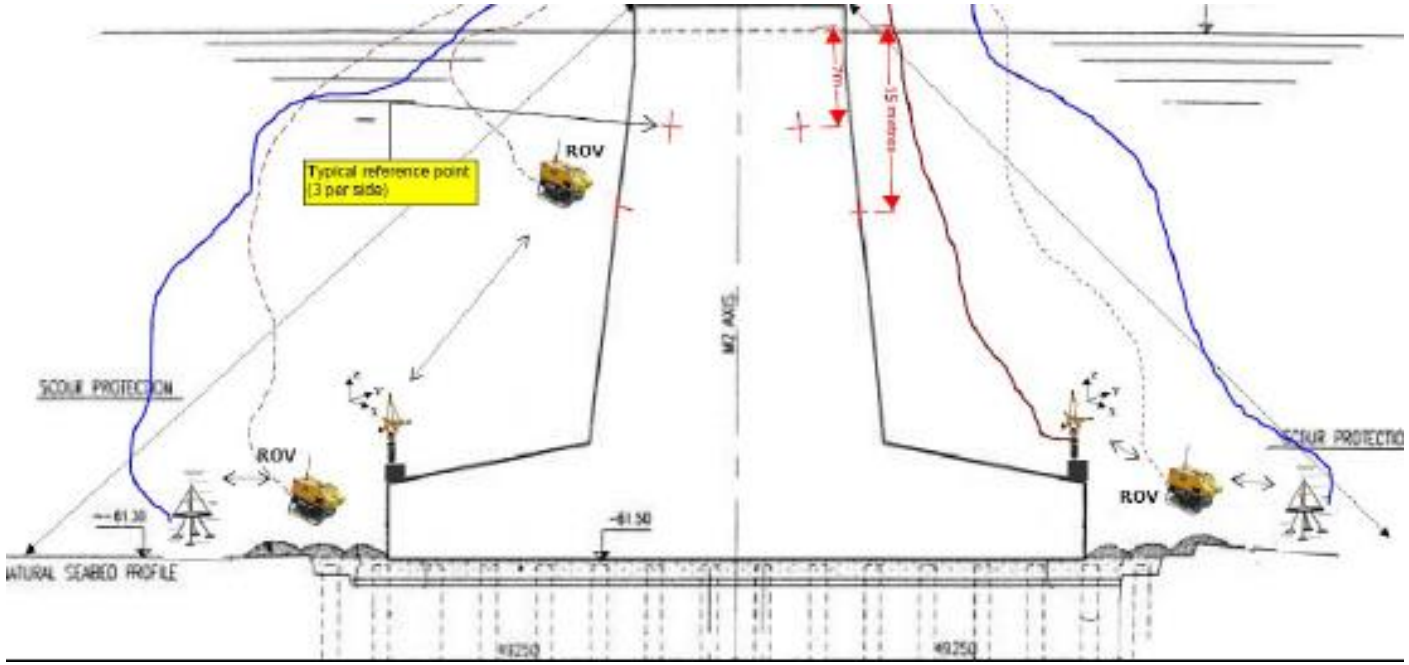


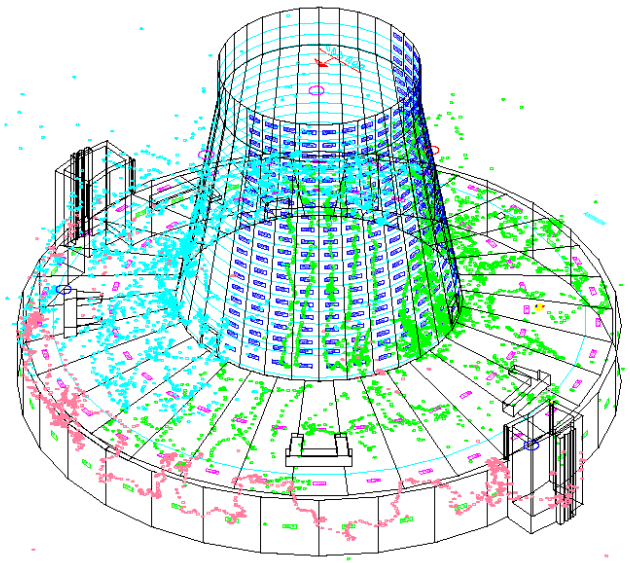
RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

ASSET MANAGEMENT
Visual Monitoring: Underwater inspections case study (3/4)

Means for Underwater Inspections in 2008

- Divers for splash and tidal zone
- ROV equipped with a local U/W positioning system based on USBL. The system was operating using specific CAD software that allowed real time position tracking.

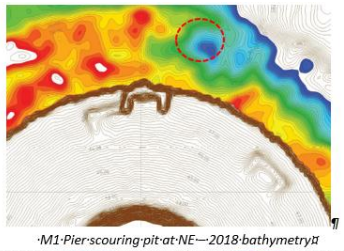




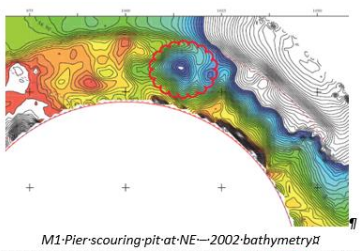
ASSET MANAGEMENT
Visual Monitoring: Underwater inspections case study (4/4)

Means for Underwater Inspections in 2018-2020

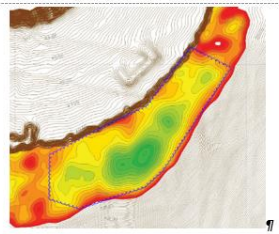
- Divers for splash and tidal zone
- Multi-beam echosounder (MBES) for bathymetry survey
- Photogrammetric method for scour protection w AI driven intelligent data collection system. Real time photogrammetric model creation



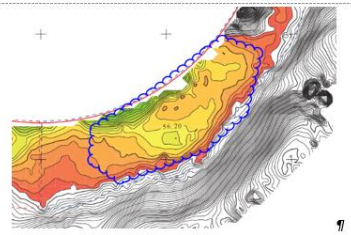
·M1·Pier·scouring·pit·at·NE·—·2018·bathymetry¤



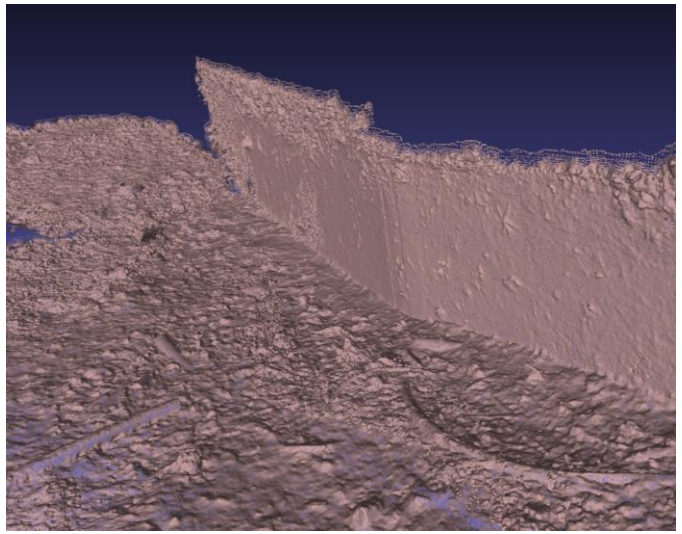
M1·Pier·scouring·pit·at·NE·—·2002·bathymetry¤

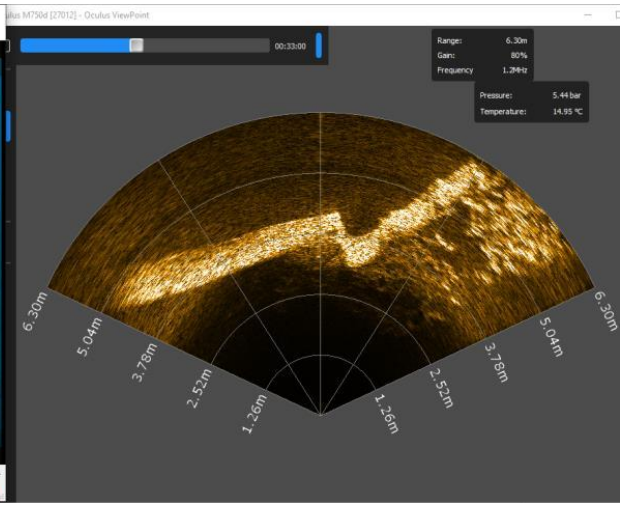


M1·Pier·scouring·pit·at·SE·—·2018·bathymetry¤



M1·Pier·scouring·pit·at·SE·—·2002·bathymetry¤





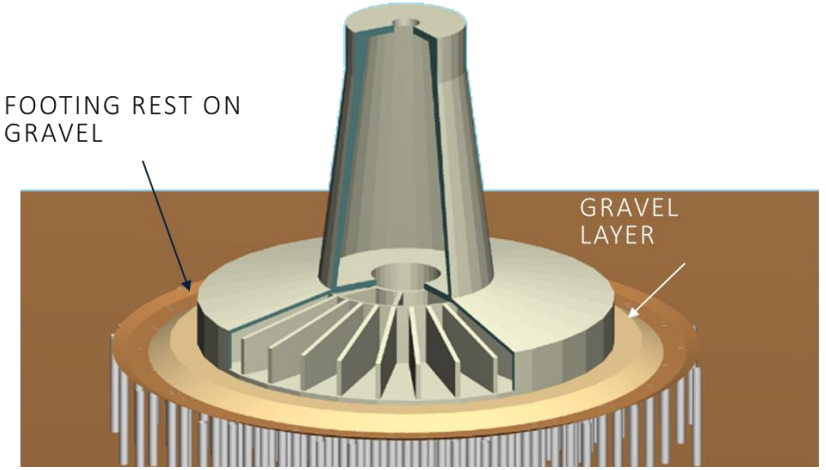
ASSET MANAGEMENT

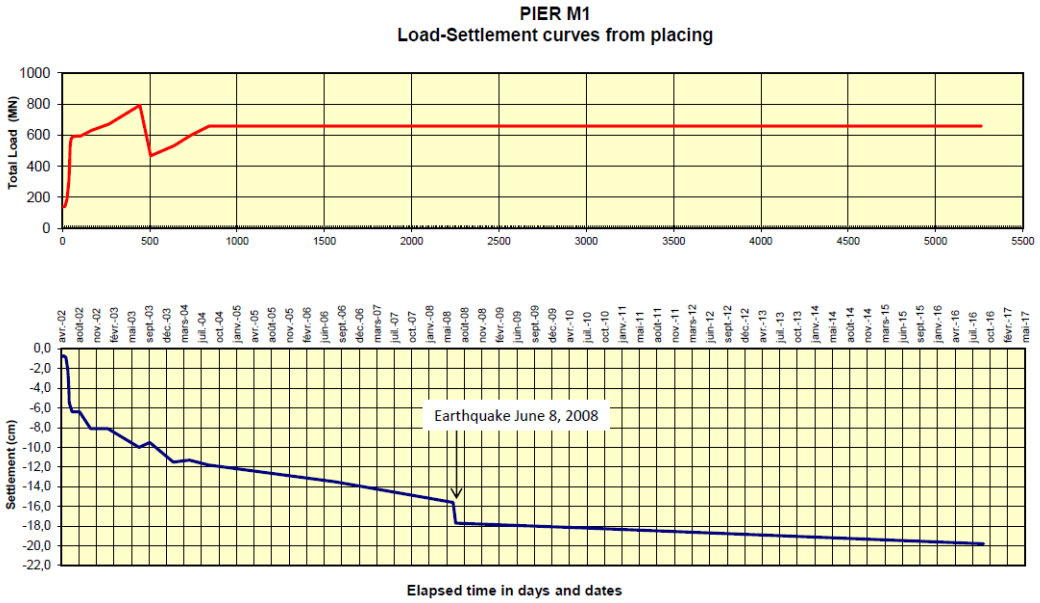
Instrumented (Geometrical) Monitoring –Offshore piers settlement case study

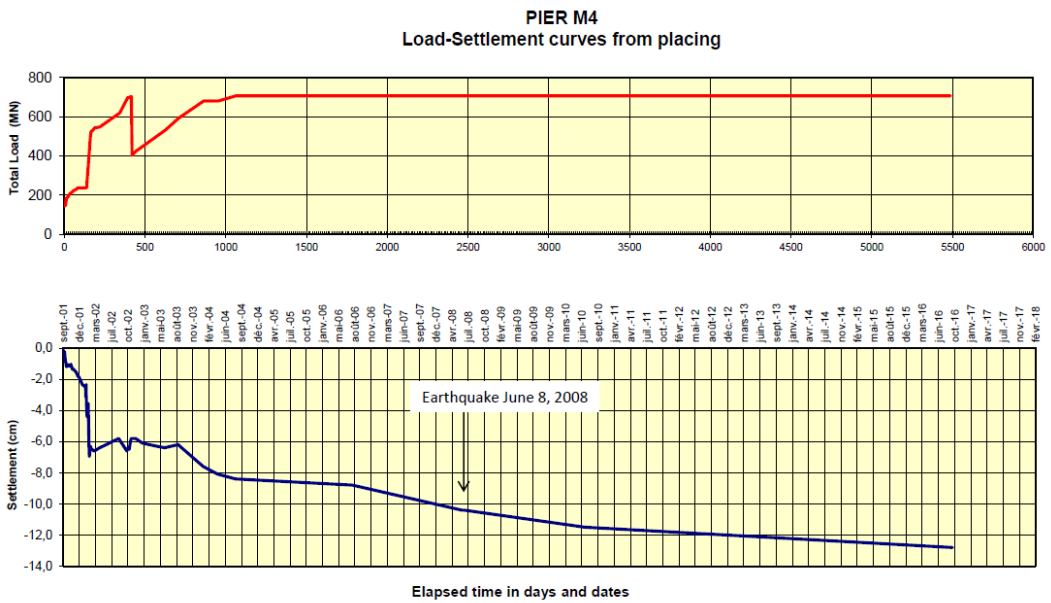
Measurements and evaluation of:

- Tectonic movements
- **Piers** tilt & **settlement**
- Deck geometry

The processed data are analyzed & compared with theoretical results

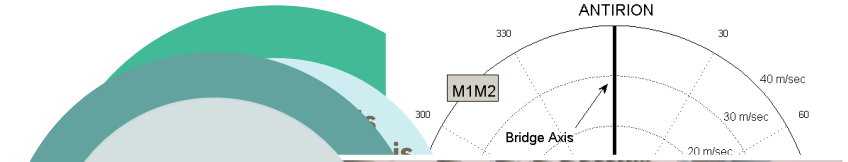




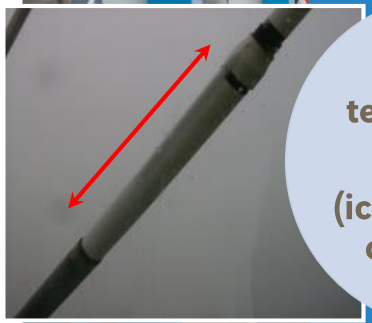


RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

SPECIAL EVENT: WIND STORM JAN 23, 2006



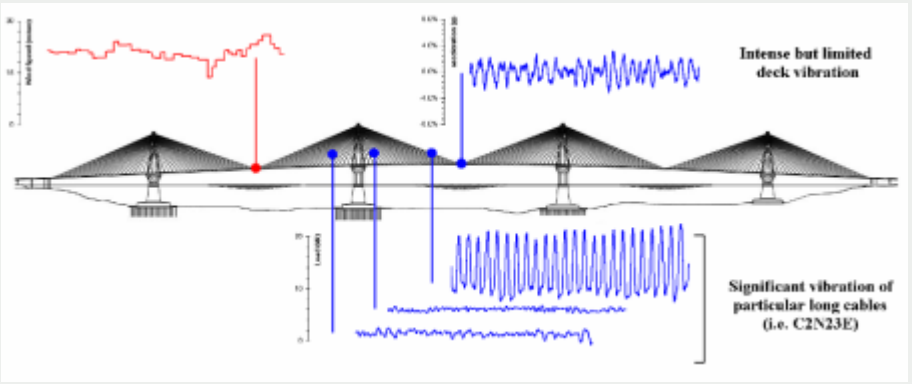
Improvement works: Dampers on long cable-stays



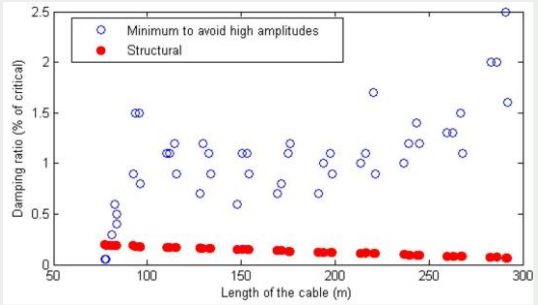
Lower temperature 1.2°C

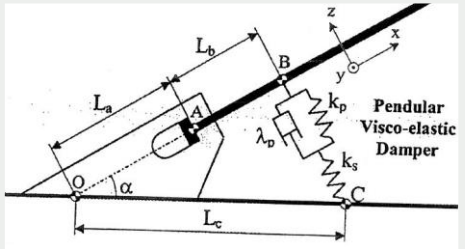
(ice formation on cables)

- Evaluation of Bridge response (Strong wind event)



- Analysis of actual data for required additional damping (CSTB)

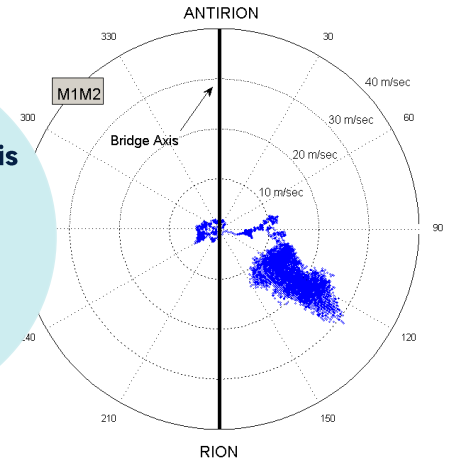




SPECIAL EVENT: WIND STORM/EHD SYSTEM PERFORMANCE EVALUATION

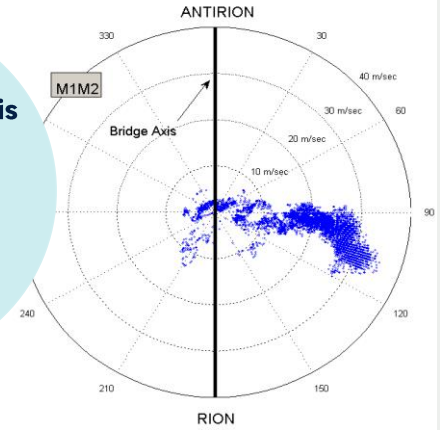
astern winds
°from deck axis

aximum wind speed
' average)
m/sec M1M2
m/sec M3M4

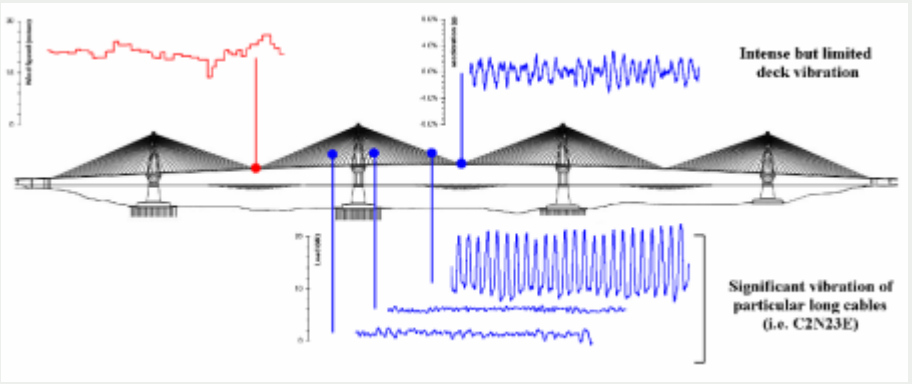


MAR 08, 2010

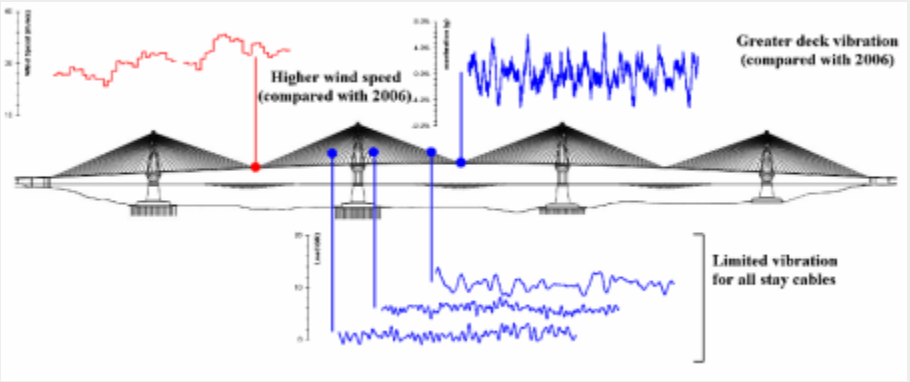
- Eastern winds ~100°from deck axis
- Maximum wind speed (10' average) 35.4 m/sec M1M2 30.7 m/sec M3M4



- Evaluation of Bridge response (Strong wind event)



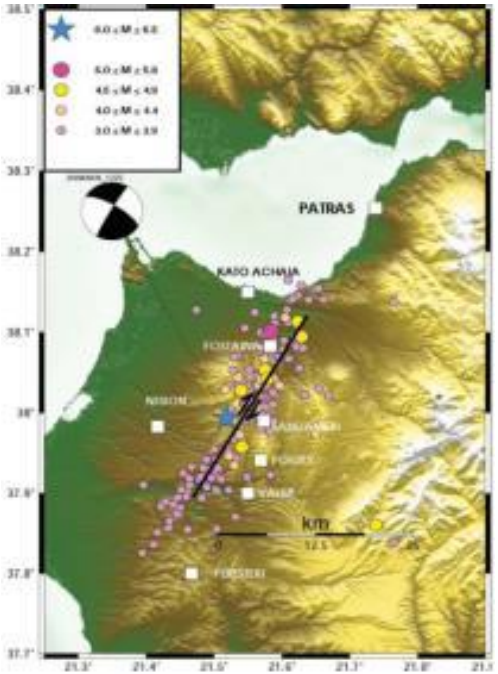
- Evaluation of Bridge response (after improvement works)



RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

SPECIAL EVENT: EARTHQUAKE JUN 08, 2008

- Magnitude Mw=6.4
- 36km from Rion-Antirion site.
- Focal depth:31km
- Max PGA recorded from on-shore accelerometers:0.127g (at Rion bank)



RIO-ANTIRRIO BRIDGE
POWERED BY VINCI HIGHWAYS

SPECIAL EVENT: EARTHQUAKE JUN 08, 2008

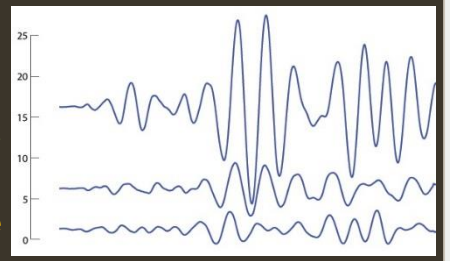
	Level 1 Inspection	Level 2 Inspection	Level 3 Inspection	Level 4 Inspection & geometric control	Final step Remedial works
Elapsed time	**15 min**	**4 hours**	**2 days**	**2 months**	**5 months**
Inspector	**On duty Officer (non technical)**	**Trained structural inspectors**	**Trained structural inspectors**	**Trained structural inspectors and specialized suppliers**	
Findings	**No findings**	**Sign of movement on fuses (Pylon)**	**Minor non structural damage**	**Minor non structural damage**	

Monitoring Report

First review of monitoring data recorded

SLS was not exceeded

Indication of deck release (fuses)

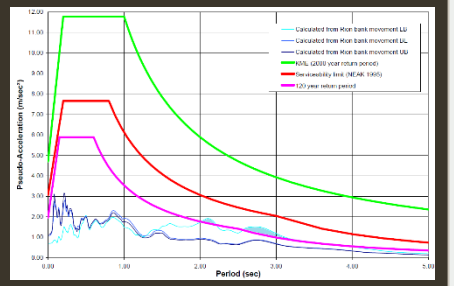


Analysis of Monitoring data

Expertise analysis on collected data

Evaluation of similar EQ's return period

T= 80 to 120 years



Deck re-alignment and fuse replacement

RIO-ANTIRRIO BRIDGE
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RIO-ANTIRRIO
BRIDGE
POWERED BY VINCI HIGHWAYS

RIO-ANTIRRIO BRIDGE

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