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RÍO PAPALOAPAN BRIDGE: DESIGN AND SUCCESSFUL APPLICATION OF SPECIAL NON DESTRUCTIVE INSPECTION TECHNIQUES

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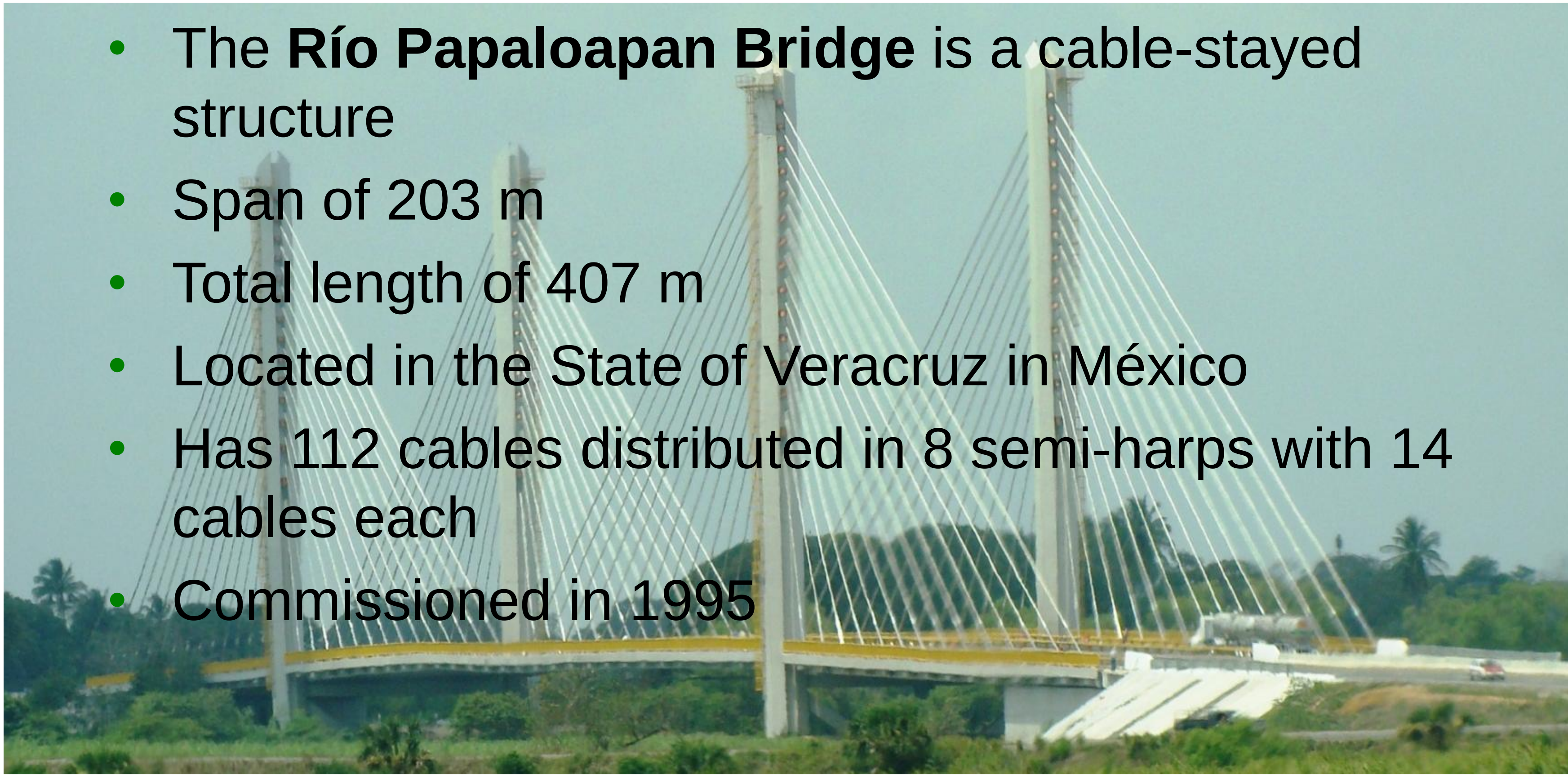
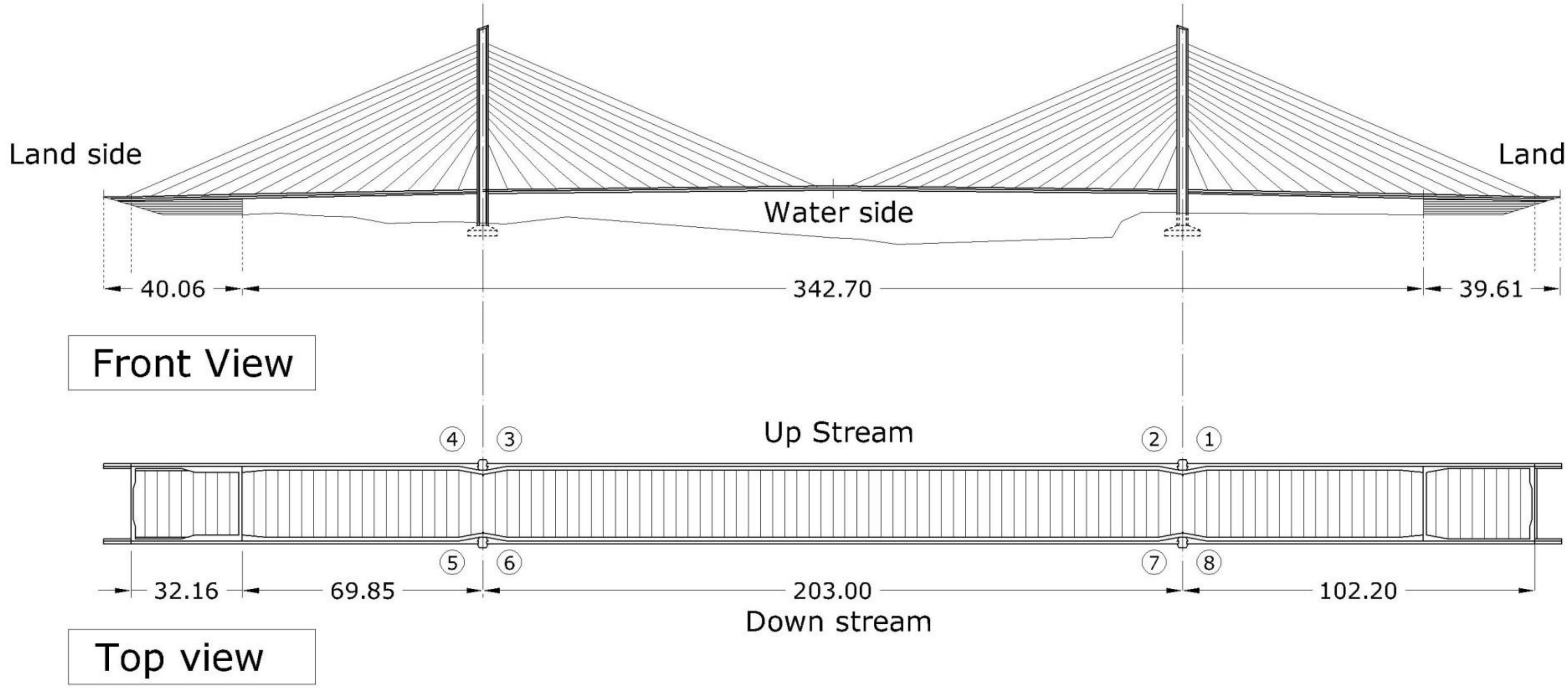
I.- Introduction



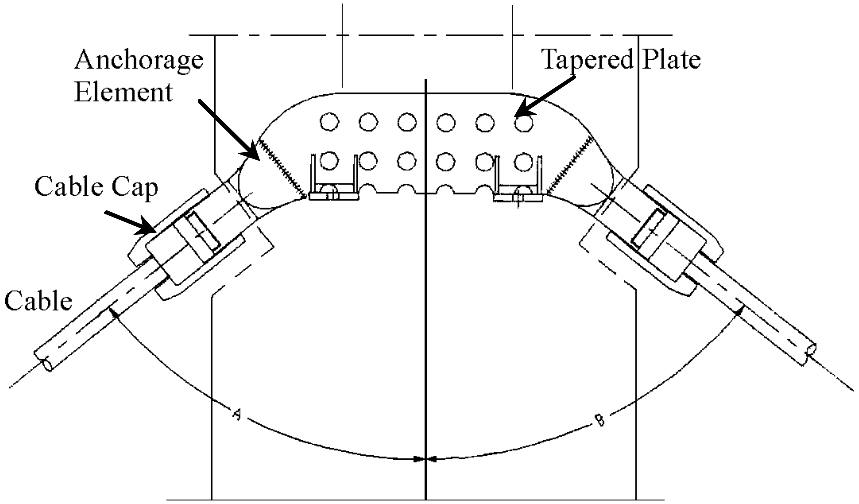
- The **Río Papaloapan Bridge** is a cable-stayed structure
- Span of 203 m
- Total length of 407 m
- Located in the State of Veracruz in México
- Has 112 cables distributed in 8 semi-harps with 14 cables each
- Commissioned in 1995

Layout of the Río Papaloapan Bridge

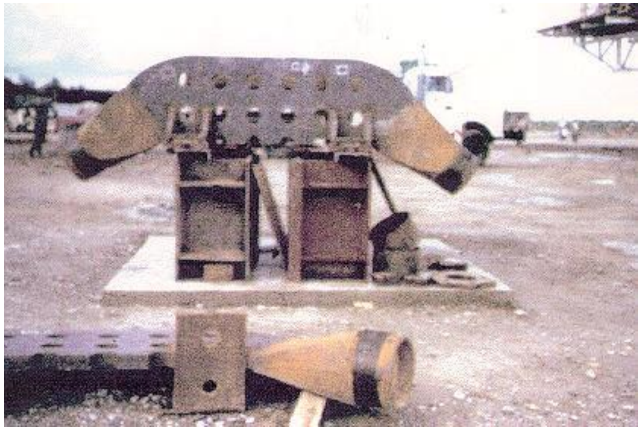


Characteristics of the Río Papaloapan Bridge

- Upper anchorage assembly for the cable system



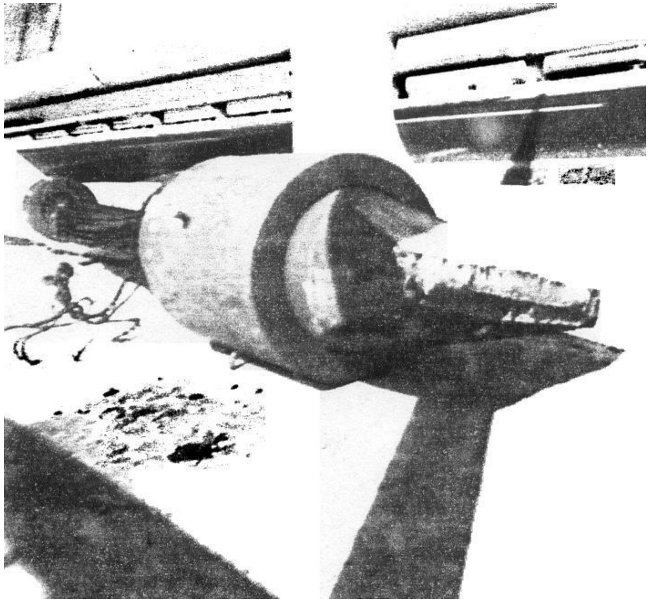
(a) Assembly design



(b) Assembly before installation

II.- Failure analysis (2000)

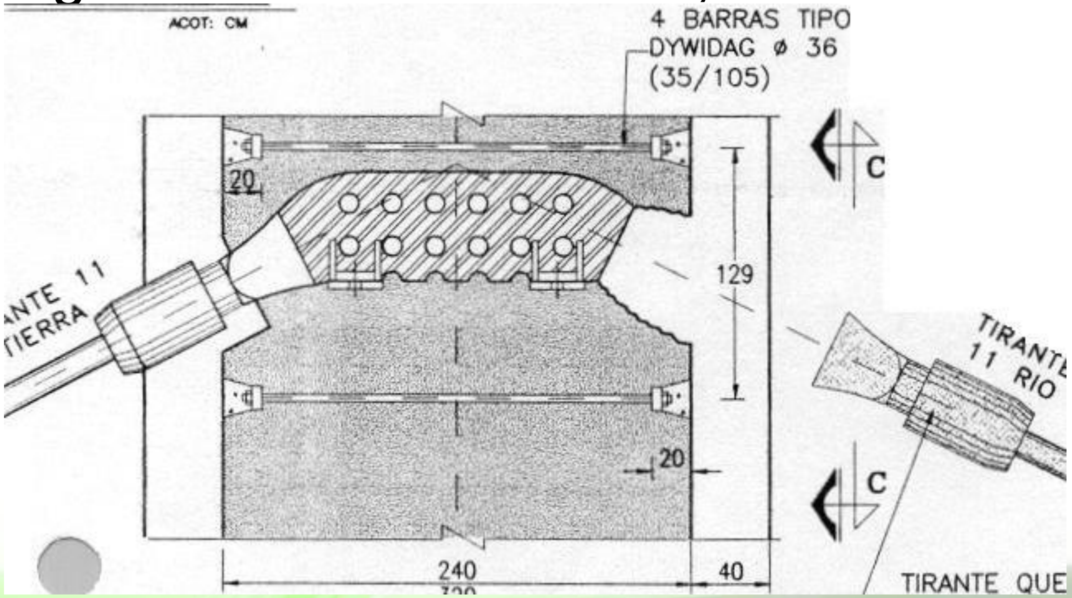
In January 2000, the failure of the upper anchorage element from cable 11, semi-harp 7



- Failure analysis conclusion: Constitutive material was structurally deficient

II.- Failure analysis (2000)

- The fracture took place close to the heat affected zone (HAZ)
- The chemical content of the material, and the yield and ultimate strengths were all within design specifications, according to ASTM A148-80/50, for structural steel.



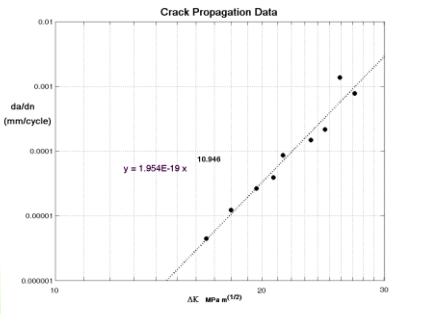
II.- Failure analysis (2000)

- The piece was manufactured from a cast process, 3 main problems were identified:
  - It had a high content of pores
  - The steel was not properly normalized with a large grain size microstructure (ASTM 2)
  - Elongation was 3%, far below to the 22% specification for the tension test.

II.- Failure analysis (2000)

Fatigue crack propagation tests were performed to estimate fracture toughness and the coefficients according to Paris model.

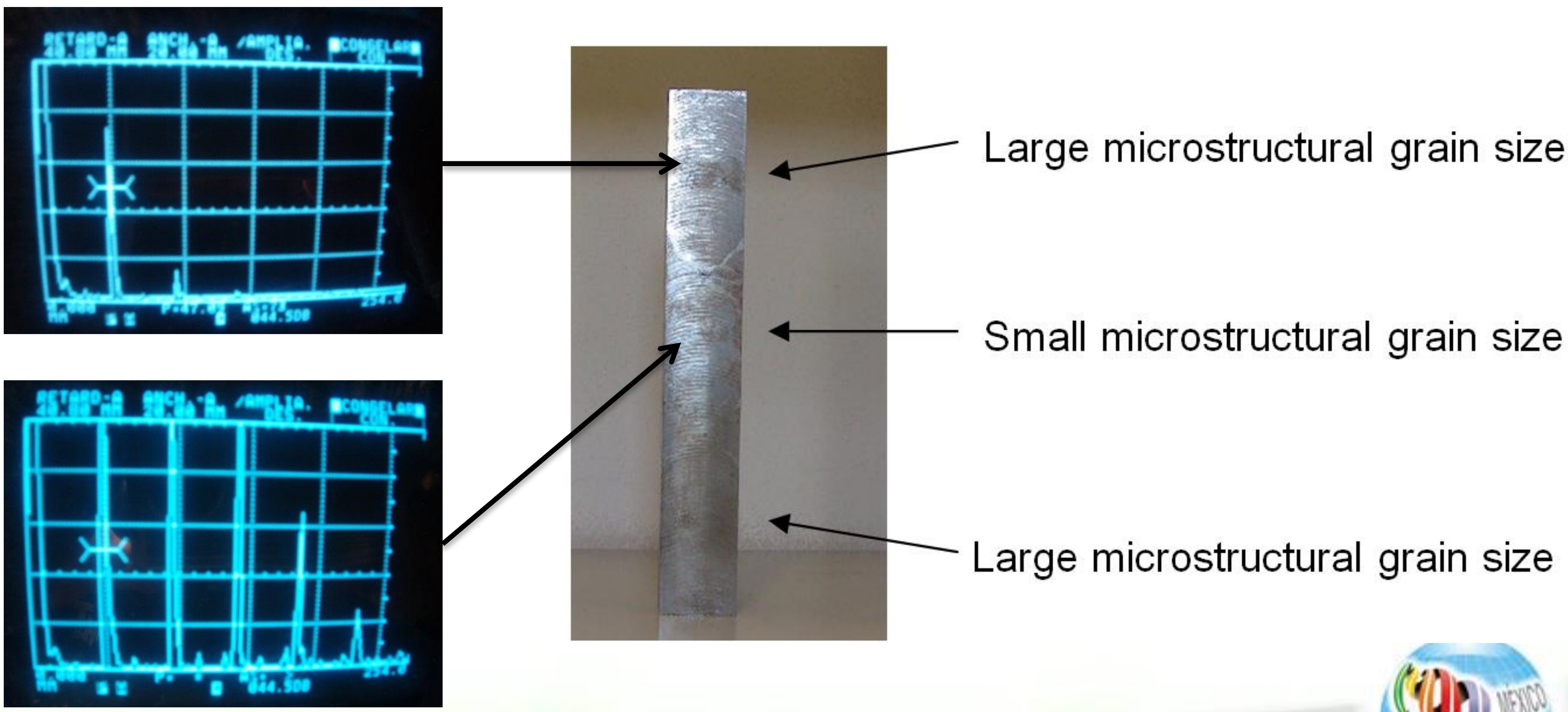
Mechanical property		Experimental Value	Steel
Coefficients to Paris Model Equation	M [MPa √m]	**10.9**	**2-3**
	C [mm/cycle]	1.9×10^{-19}	10^{-11} - 10^{-12}
Fracture Toughness	K_{IC} [MPa √m]	**26**	**30-50**



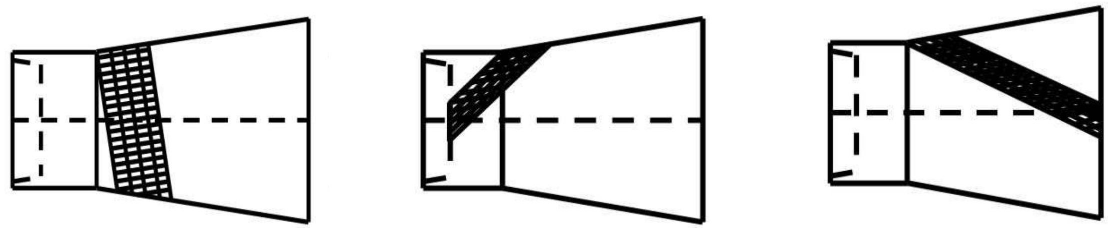
$$\frac{da}{dn} = C\Delta K^{m}$$

III.- Ultrasonic inspection for structural qualification (2003)

Comparison of the back wall reflections of the two different grain sizes in the reference block



III.- Ultrasonic inspection for structural qualification (2003)



(a) Straight UT beam

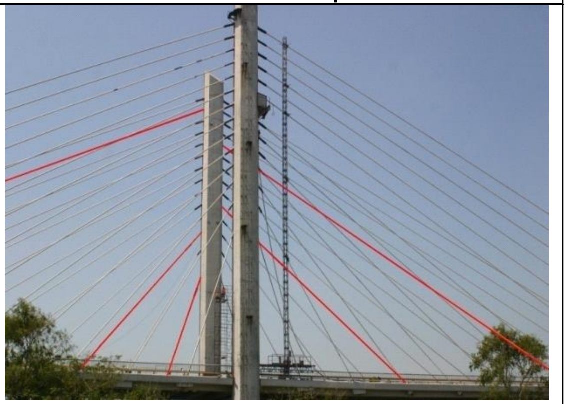
(b) 45° angle beam to internal zone

(c) 45° angle beam to welded zone

Structural deficiency	Number of anchorage elements
Large Grain Size (ASTM 2)	8
High Pore Content	2
Probable large Grain Size	6

IV.- Evaluation of the anchorage elements during rehabilitation (2008)

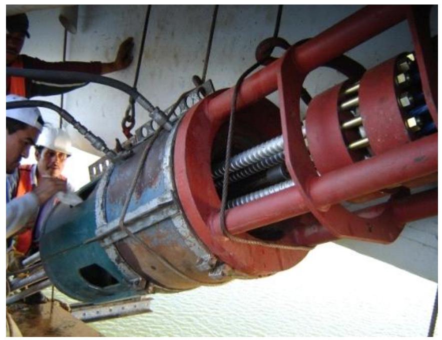
Elements proposed to replace (20 elements)

Tower 2 Semi-Harps 3 and 4	Tower 2 Semi-Harps 6 and 5
	
Tower 3 Semi-Harps 1 and 2	Tower 3 Semi-Harps 7 and 8
	

IV.- Evaluation of the anchorage elements during rehabilitation (2008)

Rehabilitation process for the upper anchorage elements


(a) Cable in service


(b) Hydraulic jack for direct weighting


(c) Cable distension


(d) Concrete removal

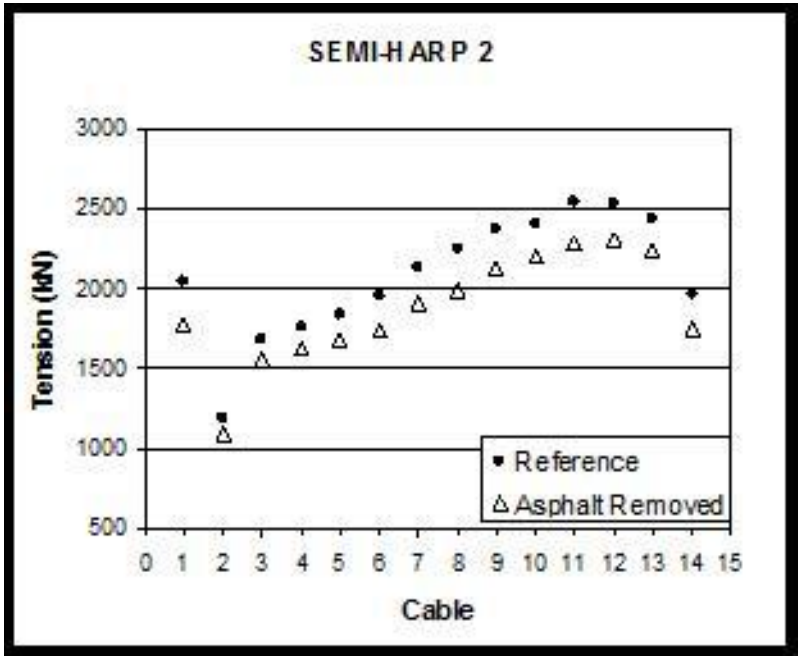

(e) Non destructive evaluation

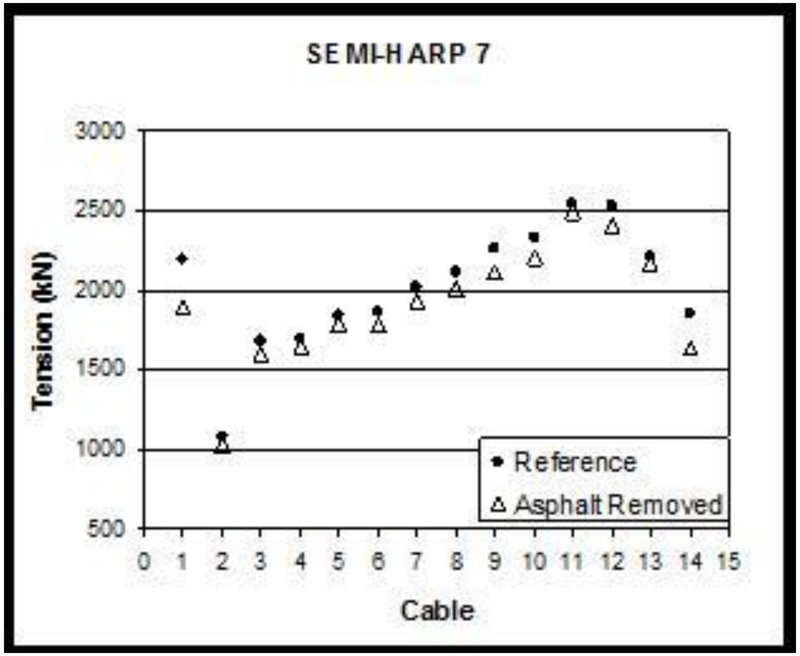

(f) Elements in laboratory ready for inspection


Vibration measurements

V.- Results

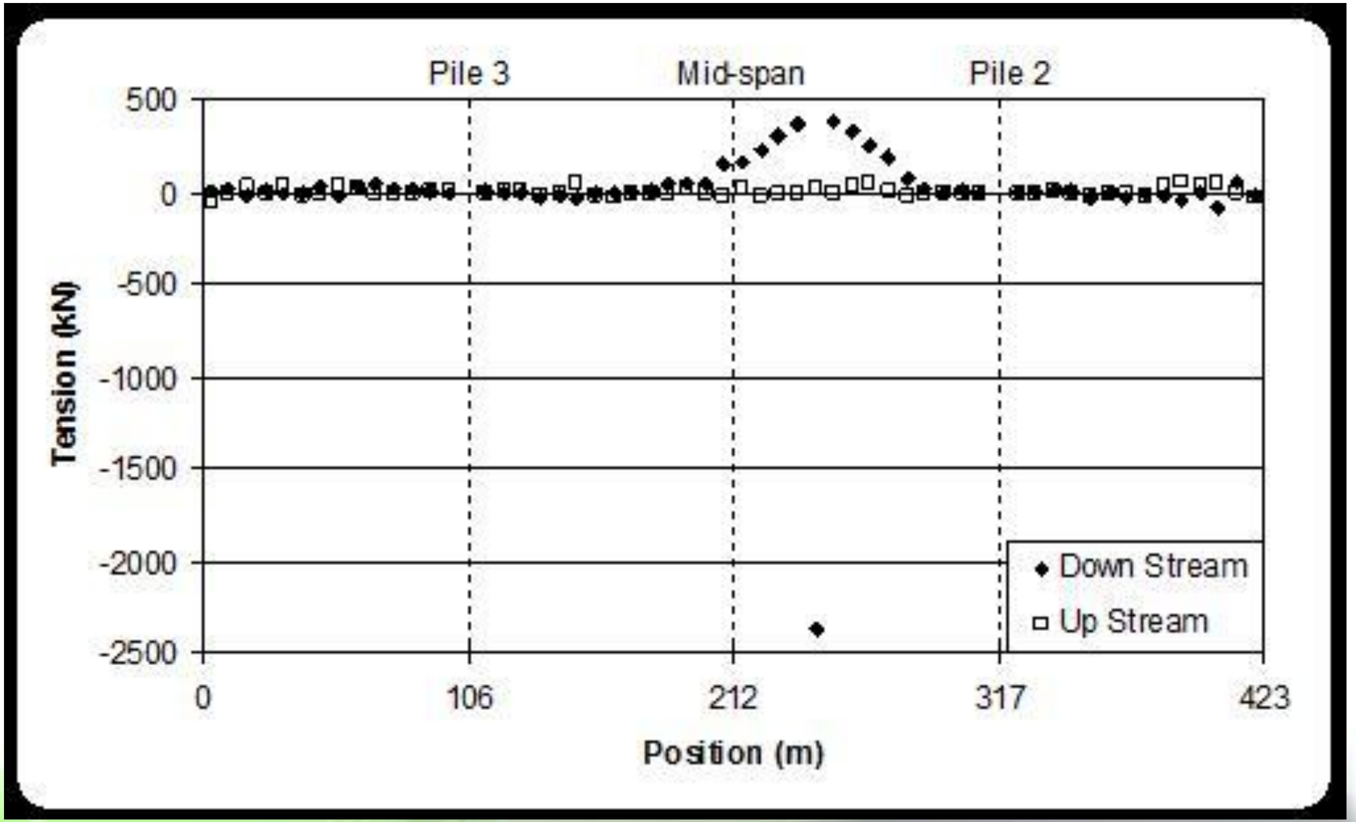
Tension loads **after asphalt removal** on cables in semi-harps 2 and 7, with respect to the initial reference tensions





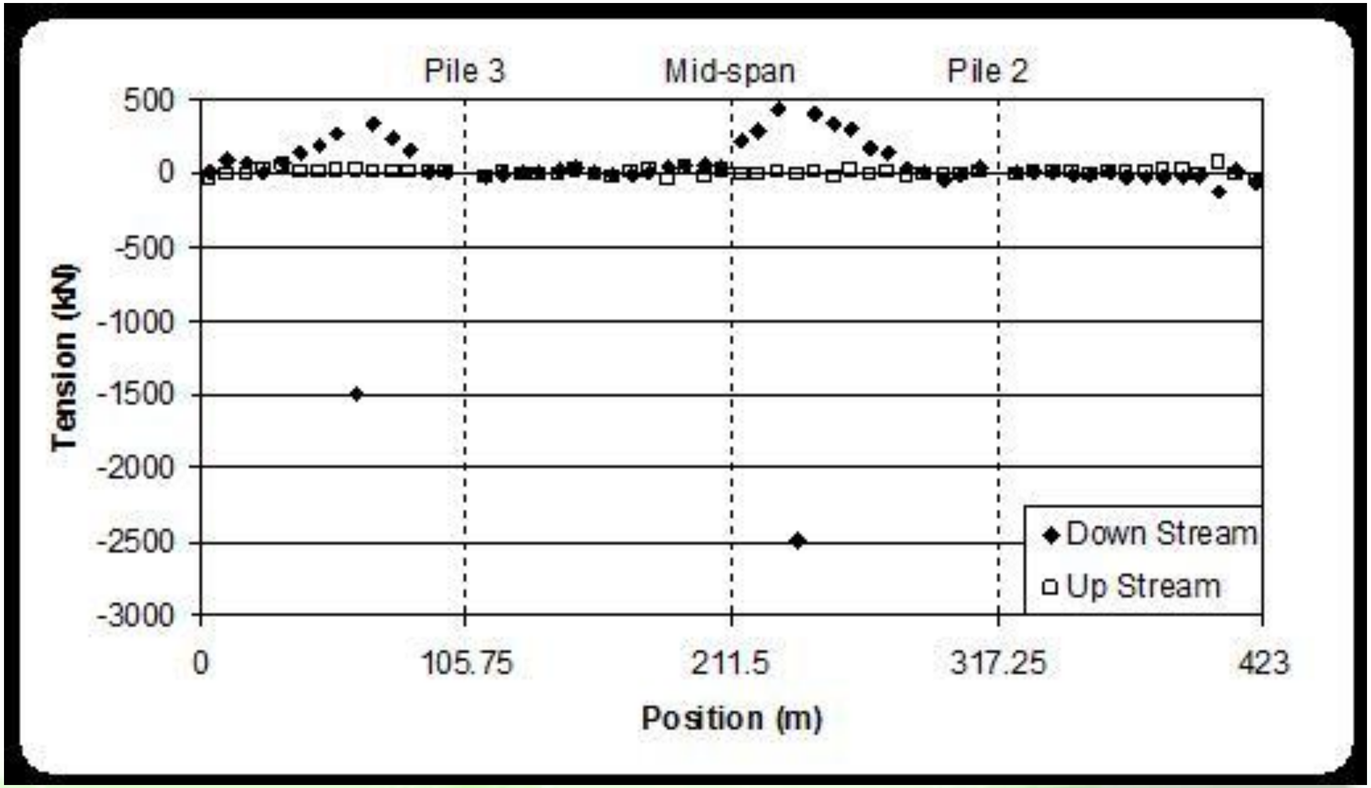
V.- Results

Variation of the tension on the cables along the bridge **after distension of cable 10 in semi-harp 3** (the x axis represents the position of the lower anchorage of each cable)



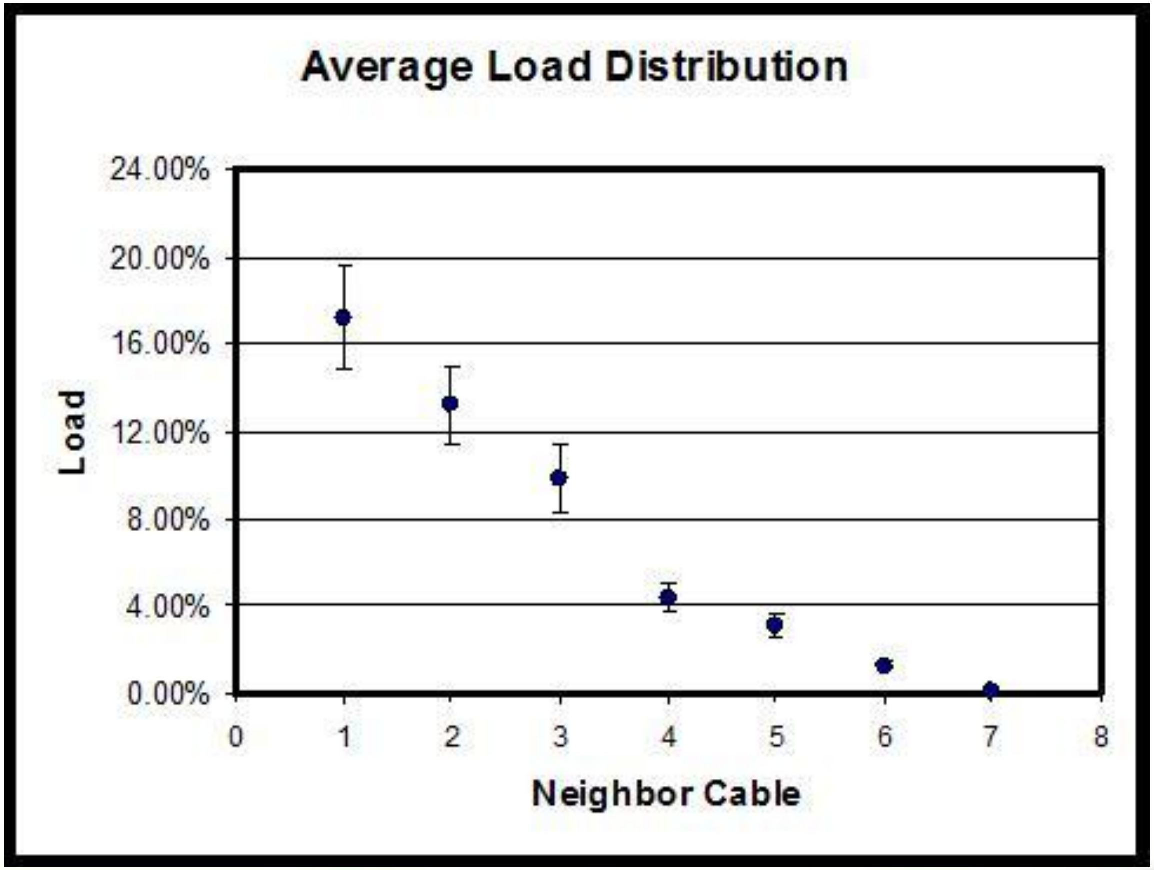
V.- Results

Variation of the tension on the cables along the bridge **after distension of cables 6 in semi-harp 1 and 11 in semi-harp 3** (the x axis represents the position of the lower anchorage of each cable)



V.- Results

Average load distribution to neighboring cables for a released cable



V.- Results

Id. No.	Semi-Harp	Cable No.	UT Grain Size Qualification		UT Flaw Detection		PT Crack Detection	
			Embedded elements 2003	Uncovered elements 2008	No. flaws	Total length [mm]	No. cracks	Total length [mm]
1	1	13	Large	Large	----	----	cluster	31.0
2	2	12	Large	Large	----	----	----	----
3	2	13	Large	Large	----	----	----	----
4	3	10	Probable large	Large	----	----	----	----
5	3	11	Large	Large	2	18.5	1	63.0
6	3	12	Probable large	Large	----	----	----	----
7	4	8	Probable large	Large	----	----	1	76.0
8	5	10	Probable large	Large	----	----	----	----
9	6	3	Fine w/pores	Fine w/pores	----	----	----	----
10	6	13	Large	Large	----	----	----	----
11	7	1	Fine w/pores	Fine w/pores	----	----	1	83.0
12	7	8	Large	Fine w/pores	----	----	----	----
13	7	9	Probable large	Large	----	----	----	----
14	7	10	Large	Large	----	----	----	----
15	7	12	Large	Large	----	----	----	----
16	7	13	Probable large	Large	----	----	----	----
17	1	6	Good condition	Fine	----	----	----	----
18	2	4	Good condition	Fine	----	----	----	----
19	5	5	Good condition	Fine	----	----	5	66.0
20	6	1	Good condition	Fine	1	14.0	1	50.0

V.- Results

Cracks detected with liquid penetrant testing in the anchorage elements

(a) Element Id. No. 5
Large grain size

(b) Element Id. No. 7
Large grain size

(c) Element Id. No. 11
Fine grain size w/pores

(d) Element Id. No. 19
Fine grain size

VI.- Conclusions

The ultrasonic inspections for grain size evaluation on the embedded elements

- Accuracy of 95%, that is, 19 elements out of 20 were accurately identified.

Inspections on the uncovered elements

•Flaws were identified in 6 upper anchorage elements with ultrasonic testing and with liquid penetrant testing.

•In 4 elements, cracks were found near the welding area or the heat affected zone (HAZ) using the liquid penetrant technique.

•Large cracks in 2 upper anchorage elements with fine grain size were detected.

•In general, there is some relation between the microstructural characteristics (grain size, pores and inclusions) and the cracks; but the most significant factor is given by welding and post heat treatment processes.

VI.- Conclusions

Measurement of the cables vibration

•Structural behavior of the Río Papaloapan cable stayed bridge was fully monitored during rehabilitation and it was possible through the measurement of the cables vibration and analysis using a non linear model.

•The complete rehabilitation of the Río Papaloapan Bridge was fully monitored and its structural behavior was secured, even if two cables were replaced simultaneously.

•Load distributions from the removed cable to the immediate neighbors were in average 17.2%; and the load redistribution affected only to the seventh closest cables.

For your attention, Thank You

Questions?