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Strengthening of a Bridge with Epoxy Beam and Prestressed Steel

Renforcement d'un pont avec de l'époxi et des fils d'acier précontraints

Instandstellung einer Stahlbrücke mit Epoxyharz und Stahldrahtvorspannung

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SUMMARY

The historical value of a metallic truss-frame "Warren-type" bridge us required a new process of bridge rehabilitation in 1975. Through the profiles that composed the lower chord, an epoxy beam was constructed with 40 steel wires, which was slightly prestressed with the objective of neutralizing the traction in the lower chord due to the structure's own weight. The epoxy mix that filled the space inside the deteriorated metallic profiles and the prestressed wires formed a new composite girder which had the characteristics required by the rehabilitation project.

RÉSUMÉ

La valeur historique du pont métallique en treillis, du genre "Warren", a encouragé le développement d'un nouveau procédé de réparation, en 1975. Sur la longueur des profilés métalliques, qui composent la longrine inférieure du pont, une poutre d'époxis à été construite. Elle se compose de 40 fils d'acier, lesquels ont été mis en légère précontrainte, avec pour objectif de supprimer la traction engendrée par le poids prope de la structure. Le mélange d'époxis a rempli l'espace vide situé entre les profilés métalliques détériorés et les fils d'acier précontraint ce qui forma une nouvelle poutrelle composite munie des caractéristiques nécessaires au bon achèvement du projet de récupération.

ZUSAMMENFASSUNG

Der historische Wert einer alten Stahlfachwerkbrücke des Typs "Warren" führte 1975 zu einer neuartigen Lösung für deren Instandstellung. Zusammen mit den vorhandenen Profilen des Zuggurtes wurde ein Verbundbalken hergestellt, mit einer Epoxy-Zwischenfüllung und einer Längsvorspannung aus 40 Stahldrähten, welche, leicht vorgespannt, die Zugbeanspruchung infolge Eigengewicht neutralisieren. Der neue Verbundbalken verhielt sich in den vergangenen 13 Betriebsjahren äusserst zufriedenstellend.

1. INTRODUCTION

There is a metalic bridge over Nhundiaquara river on the Paraná coast, Brazil, near the Serra do Mar that was built in 1912. This bridge is used for urban traffic in the historical city of Morretes and is the inicial point of Graciosa road a tourist attaction as it is the pioneer way from to the Curitiba highlands. (900 meters of altitude)

Its superstructure consists of a double metalic truss-frame "Warren" type with a 35.20 meters span and rests on a masonry infrastructure of excellent quality. Due to the proximity of the sea, lack of maintenance and total carelessness the bridge structure was so thoroughly eroded by the corrosion that its crumbling was foreseen even without traffic.

In 1964 an attempt to rehabilitate the bridge was carried out by a contractor using conventional methods but soon the results proved inefficient. Again the bridge had to be closed to the traffic from 1972 to 1975 when the Paraná's Highway State Department, D.E.R/Pr, decided to use its own work force to rehabilitate de bridge.

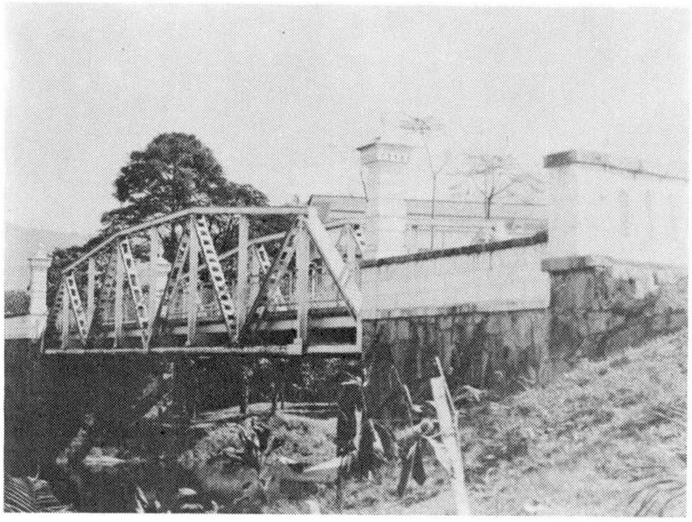


Fig. 1 General View

2. DESIGN AND EXECUTION

The rehabilitation design and execution was carried out in 1975 by engineer Victor L. Engelhardt, following these procedures:

2.1 Careful examination of all the structure showed that

2.2.1 The truss-frame lower chord was almost completely deteriorated due the corrosion.

2.1.2 The truss-frame lower joints were seriously damaged by the corrosion.

2.1.3 The metalic beams which supported the wood road surface were in an advanced stage of corrosion and could not be strenghtened (they were substituted by new parts).

2.1.4 The truss-frame components over deck plate were, in general, in acceptable conditions under structural point of view.

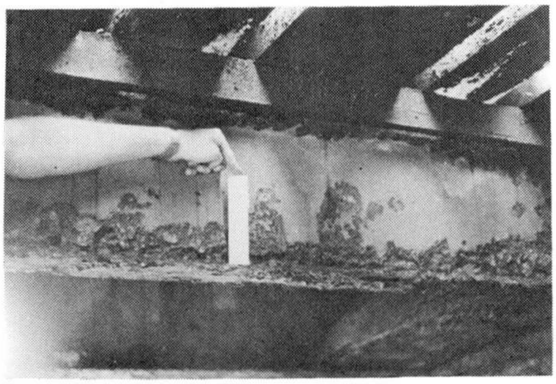


Fig. 2 Corrosion details

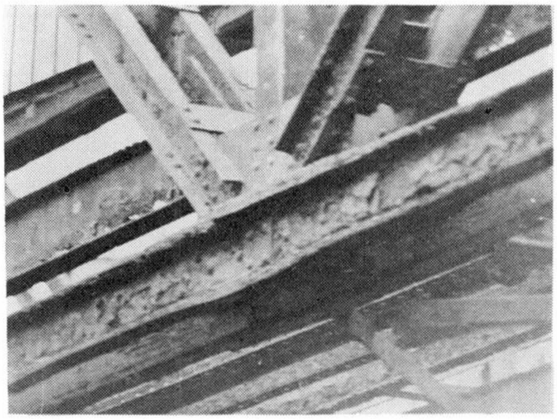


Fig. 3 Lower joints

2.2 Experiments at the DER/PR Laboratory

Several experiments were conducted with resines and epoxy structural adhesives using aggregate in several proportions as well as lightweight aggregate. Several series of samples were tested in different proportions resulting in:

- fcj = average tension of rupture under compression with 'j' days;
- ftj = average tension of rupture to traction with 'j' days;
- τ m = average tension of adherence between steel and epoxy mix;
- γ = specific weight.

2.2.1 Results of the first series of experiments

MISTURE (weight)	fc7 N/mm^2	fc21 N/mm^2	ft N/mm^2	γ g/cm^3
SIKA-DUR 32:SAND 1:0.5	57.4	-	51.7	2.10
SIKA-DUR 32:SAND 1:1	49.3	54.9	40.9	2.22
SIKA-DUR 32:SAND 1:2	28.9	-	-	2.26

Materials utilized:

- Sika-Dur 32
- Sand (from Curitiba)

2.2.2 Results of the second series of experiments

MISTURE SIKA-DUR 32:ISOPROPIL	fc7 N/mm^2	γ g/cm^3
1:3	24.9	1.073
1:4	15.6	1.037
1:5	13.2	0.993

Material utilized:

- Sika-Dur 32
- Isopropil spheres

2.2.3 Results of the third series of experiments

Materials utilized: Sika-Dur 32 - Isopropil Spheres - Steel CP-150 RN
Objective: Obtain the tension of adherence between steel amd mix.
Results: Average tension obtained in the experiments. τ_{ad} = 11.52 N/mm^2

2.3 Solution adopted

- Cleaning with sand blast all the structure.
- Use new metalic reinforcements mainly in knots and superior chord.
- Through the profiles that composed the lower chord an epoxy beam was constructed with 40 steel wires ϕ 5 mm which was slightly prestressed in order to neutralize the traction in the lower chord due the structure's own weight. The epoxy mix that filled the space inside the prestressed wires and the original profiles in addition to its great resistance for compressing and traction effors due ro its high adherence power, worked in order to form an unique block composite by old structure and reinforcements introduced.
- The compression tensions obtained with the samples moulded with the mix utilized in the rehabilitation were greater than ones obtained in the laboratory experiments as shown by the values indicated below:

  Mixed design - 1:4 (Sika-Dur 32:Isopropil Spheres)
  Moulding in 21/11/75 and rupture 28/11/75
  Average tension obtained $tc7m$ = 19.65 N/mm^2
  Standard deviation δ = 1.59
  Maximum tension $fc7max.$ = 21.24 N/mm^2
  Minimum tension $fc7min.$ = 18.06 N/mm^2
  Specific weight γ = 0.965 g/cm^3

  The 1:4 proportion mix volume was the first one indicated in view ot its reduced specific weight, high adherence and facility of execution.

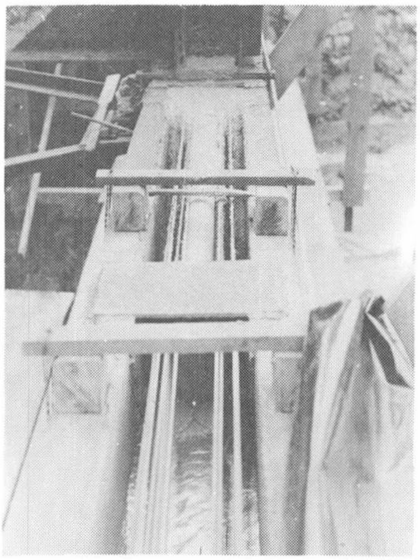
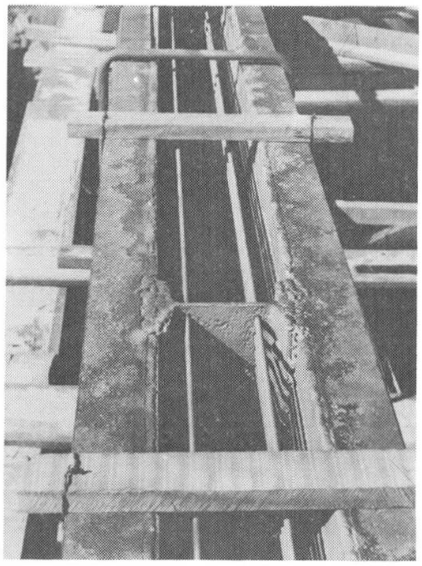
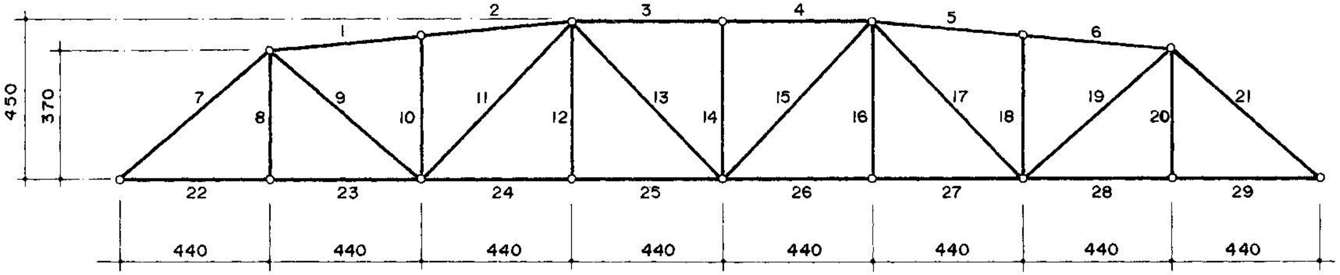
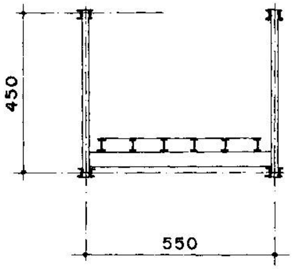
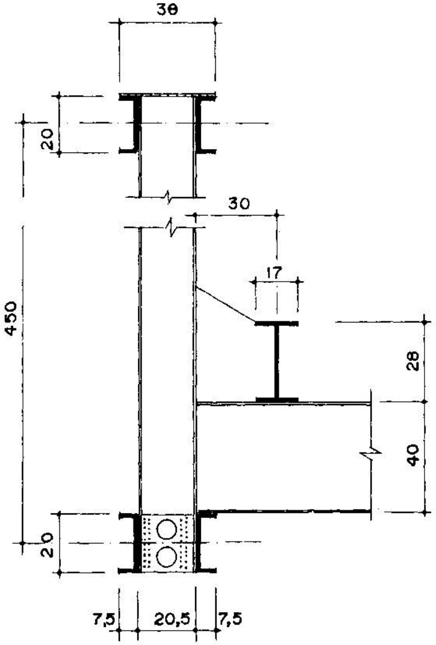



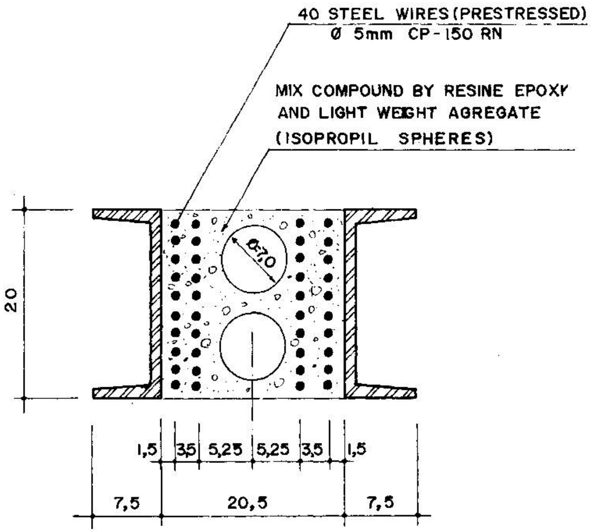
Fig. 4 and 5 Execution details

3. STRUCTURAL PLAN



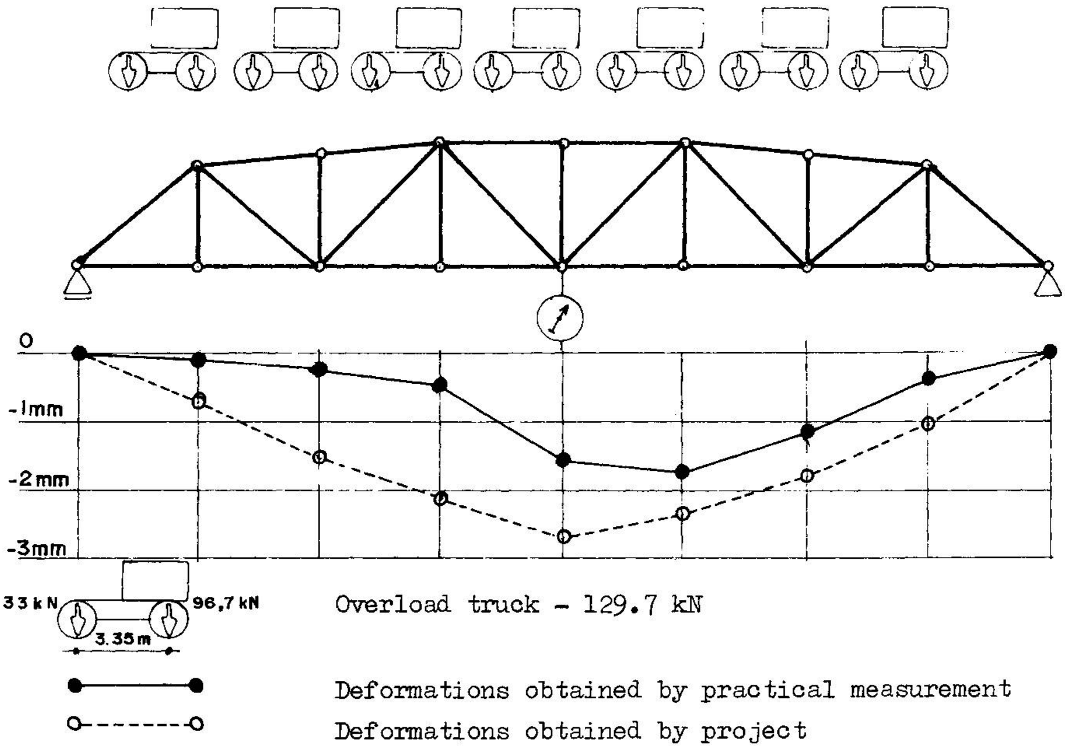






ELEMENTS	ORIGINAL		WITH REINFORCEMENT	
	S	I	S	I
	M2 * E-4	M4 * E-5	M2 * E-4	M4 * E-5
1 a 6	79,54	3820	119.70	7.852
7 = 21	80.89	3.820	115.10	6.111
8 = 10 = 12	62.55	4.320	62.55	4.320
14 = 16 = 18	"	"	"	"
20	"	"	"	"
9 = 19	75.34	2.797	93.35	2.797
11 = 17	63.87	1.890	79.01	1.890
13 = 15	48.48	1.234	55.64	1.234
22 a 29	183.30	22.770	183.30	22.770
30 a 37	32.20	1.850	32.20	1.850
38 a 45	—	—	7.86	
46 a 53	—	—	315.17	9.33

4. THE STRUCTURE BEHAVIOR



In order to check the structure's behavior another serie of tests were executed with an overload truck weighting 129.7 kN, in january 1989.
The tests were realized with the truck parking in 7 stations, at same time the deformations were indicated through a deflectometer (accuracy 1/100 mm) installed in the middle of the bridge.
With these results were possible to confront the deflections obtained by project and practically. We can observe in figure above that the deformations measured were always smaller than the theoretical deformations, consequently showing the good performance of the structure.

5. CONCLUSION

The structure has been constantly observed for 13 jears, subject to normal loads and its performance has proved excellent in regard to deformation and also to the knots rehabilitated and the adherence between epoxy resine and metalic parts.