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Contributions to the theory and practice of rehabilitation during exploitation of reinforced concrete structures. Part II-Case Study

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Abstract

In the paper are analyzed, on a specific case, the steps that define the process of consolidation during exploitation of an industrial structure: identification of the technical condition, the choice of rehabilitation solution, aspects of adopted solution calculation, significant details of the execution process, the actual way of execution of the consolidation solution. This study highlights the complexity of the analysis necessary in order to consolidate a structure during exploitation.The study is made on the case of rehabilitation of the load bearing structure of a technological trestle from platform Azomures Targu-Mures. It is restored the load bearing capacity of trestle beams by using metal profiles placed at their base, connected by means of connectors, respectively to shear force by placing of outer stirrups on the beam. Pillars with overhangs are consolidated by the disposition of poles with four branches developed like a pyramid trunk edges, with the base on the respective pillar foundation. After the activation of the system, damaged concrete surfaces are repaired.

Rezumat

În lucrare se analizează, pe un caz concret, etapele ce definesc procesul de consolidare sub exploatare a unei structuri industriale: identificarea stării tehnice, alegerea soluţiei de reabilitare, aspecte ale calculului soluţiei adoptate, detalii semnificative din procesul de execuţie, modul de realizare efectivă a soluţiei de consolidare. Studiul evidenţiază complexitatea analizei necesare în vederea consolidării sub exploatare a unei structuri. Studiul este făcut pe cazul reabilitării structurii de rezistenţă a unei estacade tehnologice de pe platforma Azomureş Târgu-Mureş. Se reface capacitatea portantă a grinzilor estacadei prin utilizarea unor profile metalice dispuse la talpa inferioară a acesteia, conectate prin intermediul unor conectori, respectiv la forţă tăietoare prin prevederea unor etrieri exteriori grinzii. Stâlpii cu consolă sunt consolidaţi prin dispunerea unor stâlpi cu patru ramuri dezvoltate după muchiile unui trunchi de piramidă, cu baza pe fundaţiile stâlpiilor respectivi. După activarea sistemului, se repară suprafeţele de beton degradate.

Keywords: rehabilitation during exploitation, reinforced concrete trestle, bearing structure, conveyor belt, consolidation

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1. Introduction

Rehabilitation during exploitation is the only approach to rehabilitation/strengthening in the case of industrial constructions at which is not possible to interrupt the production process during the process of consolidation of the load bearing structure, due to significant financial losses that would result in the interruption of the industrial activity for the beneficiary.

It is imposed the choice of consolidation solutions that are installed and activated during the operation of the construction or during the current technological disruptions.

Such consolidation systems must fulfill a number of conditions:

• minimize the number of operations that are performed on the spot;

• reduced time period for system installation;

• the possibility of adapting, during assembly, the consolidation system to the deviations of the geometry of the structure that is going to be strengthened (execution deviations, deformations due to advanced deterioration of the structure etc.);

• ensuring easy handling of the consolidation system components;

• ensuring the functionality of the consolidation system, without a significant waiting period;

• the possibility of controlling the efficiency of consolidation measures and the intervention aiming an eventual correction of their effect;

• the possibility of correctly assessing the effect of the consolidation on the state of the efforts in the structure.

Next, is presented the analysis of the rehabilitation during exploitation of an technological trestle from Azomureş Târgu Mureş platform, rehabilitation done according to the principles stated above.[1]

2. Description of the load bearing structure of the original trestle and its initial technical condition

Constructive characteristics: the trestle between the unloading ramp and potassium chloride warehouse sustains the conveyor belt that transports potassium chloride. It has the length in plan of 30 m. The width of the trestle is 3.60 m. It rests at the height of + 9.45 m on the deposit fronton.

The trestle load bearing structure is made of L shaped prefabricated beams with a height of 1.15 m and a core width of 30 cm, on which are disposed, at the lower part prefabricated floor elements (dimensions 2.50 x 1.00 x 0.10 m) which support the conveyor belt. Beams rest on prefabricated pillars with section of 60 x 60 cm, disposed at 9.50 m (between central axes) embedded in pad foundations (2.00 x 2.50 m at the bottom, foundation depth - 3.65 m). Trestle beams resting on the axis 1 fronton is made on an horizontal reinforced concrete element, developed between the central pillars of the fronton, conformed to ensure appropriate resting conditions.

Closure of the trestle is achieved with a structure consisting of transversal metal frames (rolled I12 profiles), resting on the upper flange of trestle beams and steel purlins. The roof and side walls are made of corrugated asbestos cement. In the side walls are arranged continuous windows with metal joinery, with mobile sashes of 60 x 60 cm.

Technical condition of load bearing structure: technical condition of the trestle structure, before consolidation, was characterized by the existence of an advanced process of concrete and reinforcement degradation that significantly affected the overall strength and stability of the construction.

The reinforcement concrete covering layer was heavily damaged, up to the point of separation or isolation of the longitudinal and transversal reinforcement. The phenomenon was present at the bottom of the trestle prefabricated beams (in some areas also on the sides of the beams), it was also present at the supporting pillars of the trestle. The longitudinal reinforcement was corroded, with varying degrees of damage also transversal reinforcement. The lower part of the stockade prefabricated plates showed a lower degree of degradation. It was affected by corrosion also the supporting structure of the roof cover and side closures.

Aggressive factors acting on the concrete structure of the trestle: the trestle is located in an area with high intensity of chemical agents. It is an area of "intersection" of currents composed of:

- KCl dry flue gas, carbon oxides, KCl powder;
- fertilizer powder: NH_4NO_3, $NH_4H_2PO_2$, $(NH_4)_2HPO_4$, $CaHPO_4$;
- phosphorite: $Ca_3(PO_4)_2$, which in the presence of nitrogen oxides and water can transform partially in H_3PO_4;
- NO gas, NO_2, nitric acid vapor, NH_3, fluorine compounds.

Their concentration is given by currents, weather conditions, fugitive leaks, etc.

3. Description of the trestle rehabilitation solution

First it was performed the removal of damaged concrete from the trestle longitudinal beams, removal of the rust from affected reinforcement steel bars and neutralization of the corrosion process. Were disposed, at the bottom of reinforced concrete beams thus prepared, along them, fixed with grout, U24 metallic profiles. The profiles are fixed in order to prevent sliding against concrete with punches ϕ25 / 500 mm [7] anchored in holes ϕ32 with resin, drilled on the bottom face of the longitudinal beam. ϕ 14/35 cm stirrups were placed, welded to the U24 profile and L70x70x8 angles arranged on top of the longitudinal beams. It is restored by concrete spray coating the protection layer of the reinforcement [6].

Resting of the beams on the pillars is ensured by the means of 4 pipe steel profiles ϕ219x8 mm resting, through a metallic base on a bearing box of reinforced concrete with a height of 40 cm made on the top of the previous foundation. This avoids transmitting of the trestle actions to the foundation through the degraded pillars, their rehabilitation being difficult during exploitation. Anchoring of the metal base into the previous foundation was made with metallic anchors ϕ25 fixed with resin in ϕ32 holes drilled in the upper surface of the foundation.

After the activation of the metallic trestle supporting construction, the degraded concrete from the supporting pillars of the trestle was removed. The rust was removed from the steel rods, the corrosive process was neutralized, degraded stirrups were replaced and the protective coating of the reinforcement was recreated. The metallic load bearing structure of the trestle enclosure was rehabilitated. A new enclosure was done at the side walls and at the roof of the trestle.

3.1 Restoration of the concrete section characteristics of trestle elements

Interventions on the reinforced concrete structure consisted of concrete spraying, plastering and local concrete pouring. Existing environmental conditions inside Azomureş are intense chemical aggressivity. According to the Standard NE 012-1: 2007 [2], the environmental exposure class of the concrete is therefore XA3, so that the materials used comply with the requirements imposed by this class. Repair mortar and concrete used to repair and / or replace inadequate concrete and protect the reinforcement were applied according to SR EN 1504-1-9 "Products and systems for the protection and repair of concrete structures". [3]

Proposed recipes for the three types of materials are given below:

Concrete for spraying
The type of cement used in concrete recipe for spraying is CEM I 42.5R, the cement having properties that can withstand intensive aggressive chemical environments, according to the standard NE 012-1: 2007 "Code of Practice for the execution of concrete, reinforced concrete and prestressed concrete works ", Part 1: Preparation of concrete.[2]

The aggregates used are river aggregates, according to the standard "Technical instructions for application by spraying of mortars and concrete". The maximum size of aggregate used in the concrete recipe was 8 mm, according to standard C130-78.[4] Concrete class was chosen according to the exposure class and is C 35/45 (Table F.1.2, NE 012-1: 2007). The average dosage of cement is 450 kg/m^3.

The water used in the execution of mortars and concrete applied by spraying fulfillled the technical conditions of STAS 790-84.

Regarding the conditions of application, sprayed surfaces have been previously cleaned of impurities and surface layer of grout, achieving a favorable surface roughness favorable for the shotcrete application. The application of shotcrete in concrete repair areas was made only after removal by carving of damaged parts; after removing them, to get to a strong concrete surface, was performed a pressurized water washing and blowing with compressed air.

Spraying was performed in at least 2 layers. The first layer was a primer, to ensure a better grip and the reduction of bounced material. The thickness of the mortar layer ranges between 2 to 5 cm, depending on the local technological conditions.

Mortar for plastering
For the plastering stage it was chosen a cement mortar, class CS IV, mortar mark M100T (SR EN 1015-1011). The maximum size of the aggregates is 4 mm. The amount of aggregate required is 1550 kg/m3. Minimum cement dosage is 385 kg/m^3. Type CEM I 42.5R cement is used.[5]

Metal frame anticorosive protection. For this it was proposed the application of G 4040 AC primer and then painting with GUDROPOL V 3207 paint.

3.2 Calculation of the consolidation solution

Calculation was made for the connectors between the U profile (having the role of longitudinal reinforcement) and the concrete section of the beam to sliding force – see Fig. 1.

The resulted connectors are: ϕ25 / 500 mm and were chemically anchored.

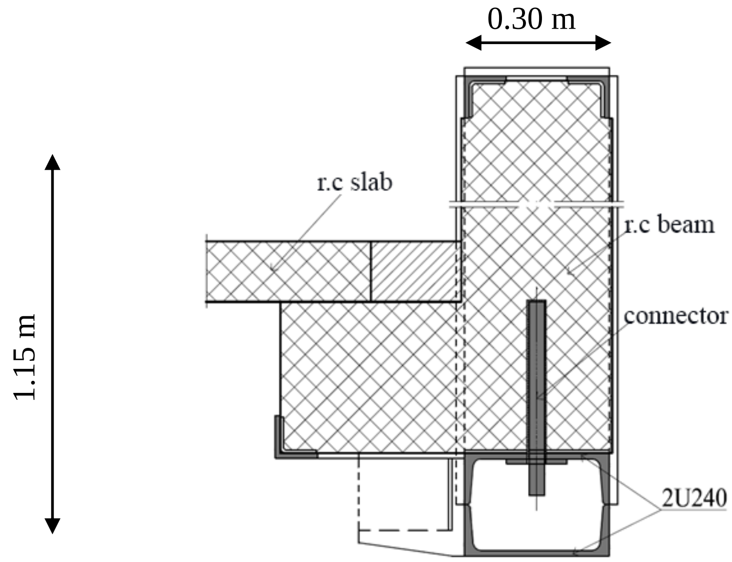


Figure 1. Trestle beam section characteristics

4. Calculation of structure under gravitational and horizontal loads

The calculation was done for permanent loads and exploitation loads. Exploitation loads, coming from the conveyor belt, don't have a dynamic effect, due to the low speed of the belt and due to its structural characteristics. The static scheme for the efforts calculated under gravitational loads is presented in Fig. 2 and Fig. 3.

\Seismic actions were determined on a linear structure (trestle) with fixed supports at both ends (opening of 28.5 m) and intermediate elastic supports (at 9.5 m) represented by the trestle pillars. The large height of the section (3.5 m) in the direction of earthquake loads, makes the structure to have no problem in taking the efforts from this action.

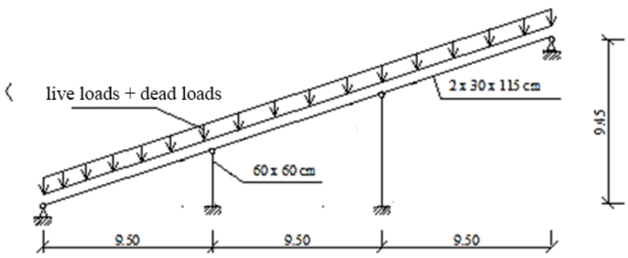


Figure 2. Initial static scheme

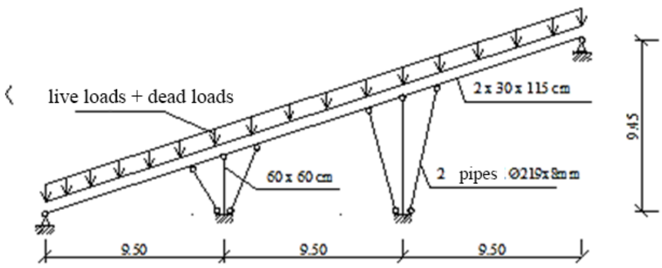


Figure 3. Static scheme after consolidation

Underneath are presented images with the condition of the trestle prior and after the consolidation, associated with details from the execution project.

5. Photo documentation. Initial situation / situation after rehabilitation. Extracts from execution project

The initial state is presented in Photo 1 and 2. Photo 3 shows the image during the rehabilition works execution. Fig. 4-15 are details taken from the execution project.

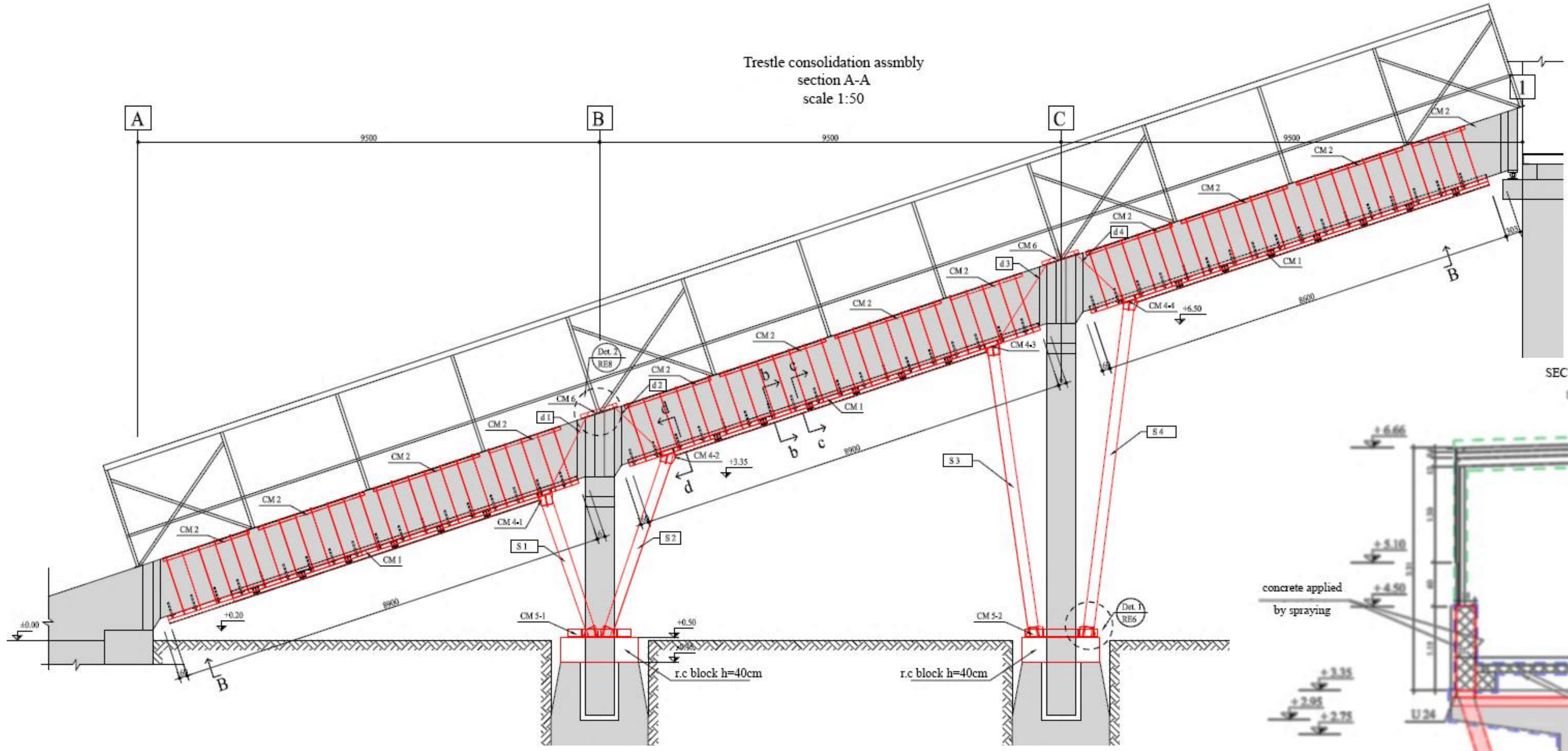
Photo 4-13 are details retrieved during the rehabilitation works execution. Photo 14-16 prezent the trestle’s state after the consolidation.

Photo 1a, 1b. Overview of the reinforced concrete trestle - initial situation

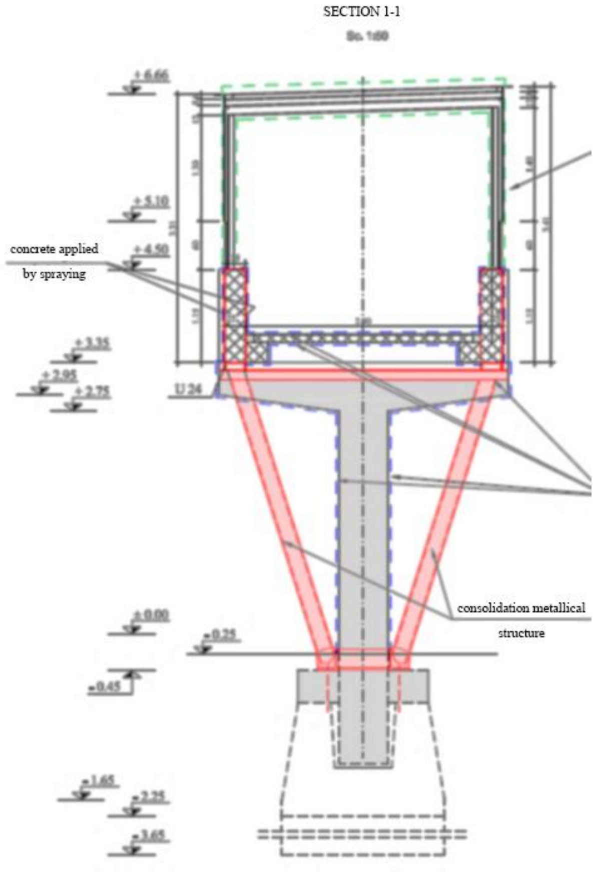
(a) (b)
(c) (d)
(e)

Photo 2. Initial technical condition of trestle concrete elements. a, b, c, d: Concrete corrosion, beams reinforcement; e: Technical state of the supporting console

Photo 3. Execution of the rehabilitation works



(a)



(b)

Figure. 4. Consolidation solution for trestle assembly

a. Side view

b. Section and rehabilitation soltion for pillars

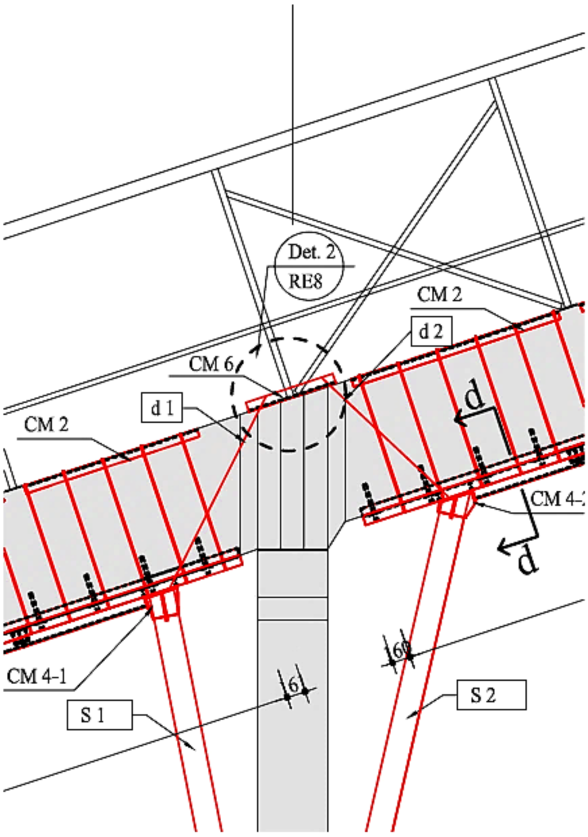


Figure 5. Designed solution - rehabilitation in the area of the support for pillars

Photo 4. Same as in Fig. 5 – design detail

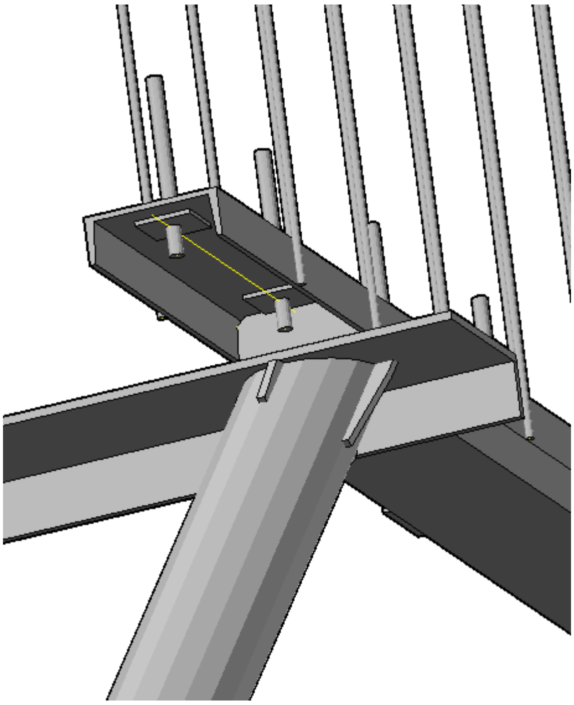


Figure 6. Metallic rehabilitation confection node at pillar resting area

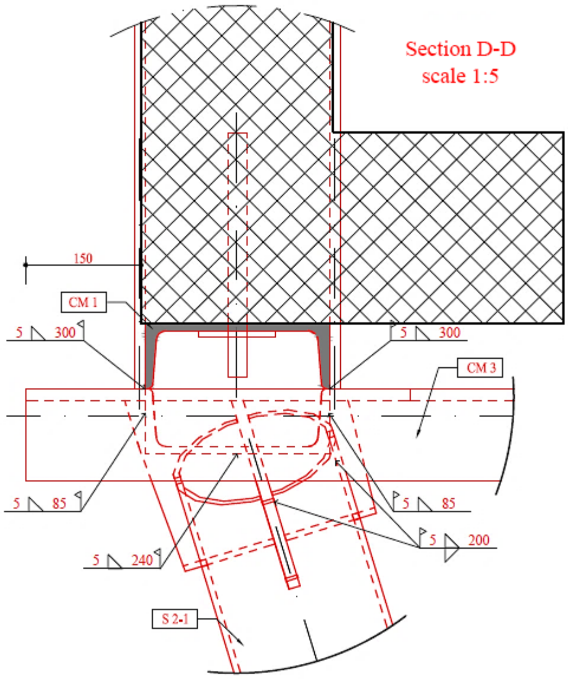


Figure 7. Same as in Fig. 6, execution

Photo 6. Execution details

Photo 5. The same as in Fig. 7, execution

Photo 7. The situation after protection by painting

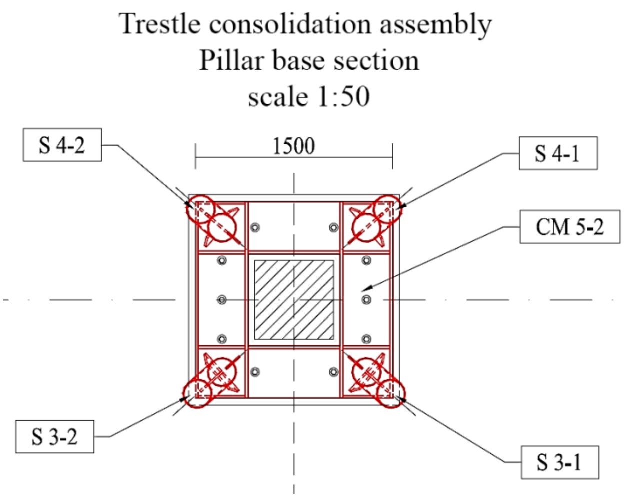


Figure. 8. Metallic confection base for pillar consolidation - project

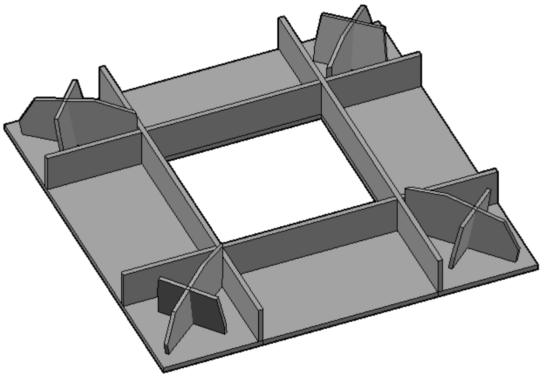


Figure 9. The same as in Fig. 8

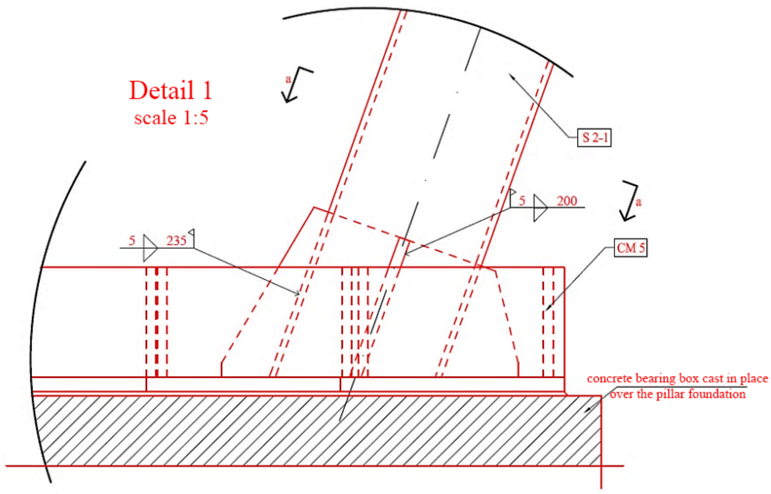


Figure 10. Detail of bottom joint between metallic bar sustaining the tretsle and foundation - project

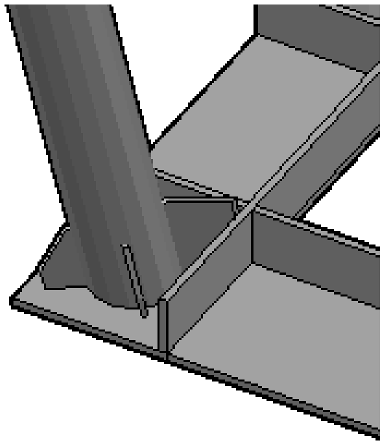


Figure 11. The same as in Fig. 10

Photo 8. Execution of the system to support trestle on the foundation

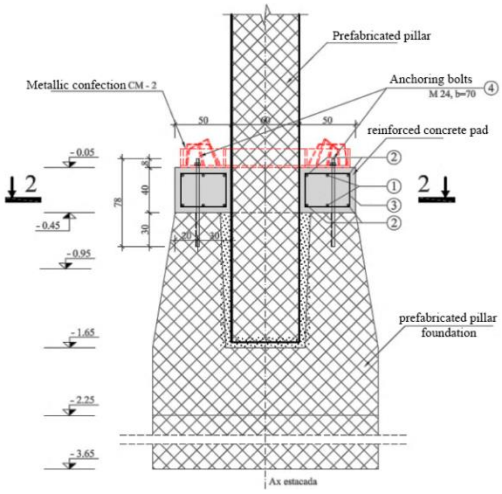


Figure 12. Solution designed for resting on the foundation

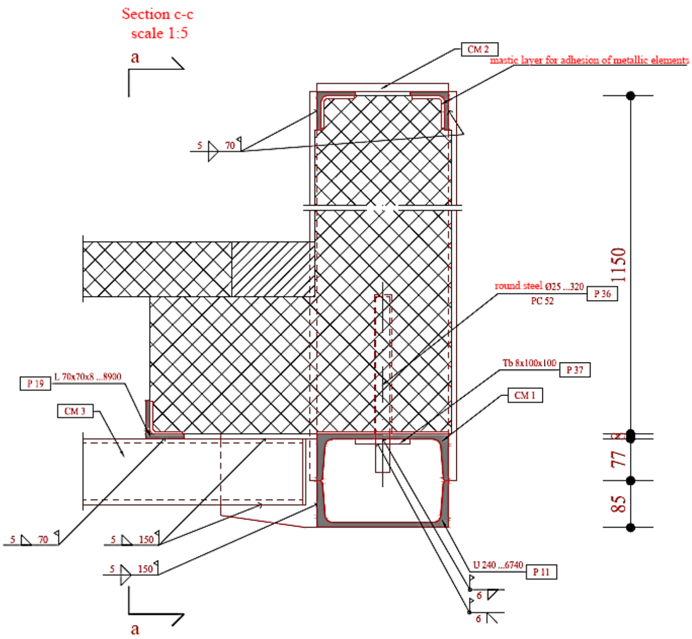


Figure 13. Trestle beams rehabilitation solution - design

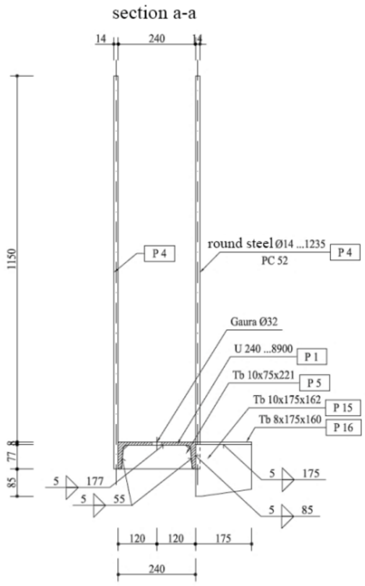


Figure 14. Metallic confection done in workshop – longitudinal profile+stirrups

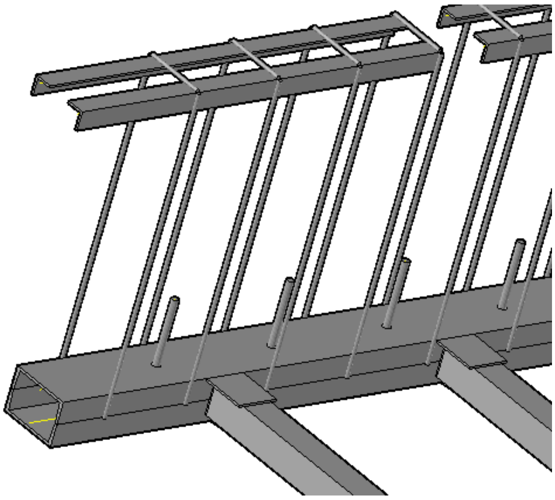


Figure 15. The same as in. Fig. 14

Photo 9. Execution of the beams consolidation

Photo 10. The same as in Photo 9, connectors view

Photo 11. The same as in Photo 10, overview

Photo 12. Fixing of the stirrups at the top of the beams

Photo 13. The same as in Photo 12

Photo 14. Post rehabilitation trestle

Photo 15. View of the rehabilitated trestle in the pillar area

Photo 16. View of the rehabilitate trestle near the conveyor belt stretcher

6. Conclusions

This case study allows the analysis, on a particular case, of the steps that define the consolidation process during the exploitation period of a structure, from the identification of the initial technical state, to the analysis of the possible rehabilitation solutions, characteristics of the adopted solution computation, execution details and effective in-situ application of the consolidation solution.

The case study highlights the complexity of the analysis required to consolidate a structure during its exploitation.

7. References

[1] SC UCTRA EXPERT SRL Cluj-Napoca Structural Designer, *Potassium chloride deposit and trestle rehabilitation*, 1325 Object, Azomureş Tg. Mureş, *Trestle rehabilitation*, project 2013
[2]NE 012-1:2007: *Code of practice for the execution of concrete, reinforced concrete and prestressed concrete elements*
[3] SR EN 1504 -1-9: *Products and systems for protecting and repairing the concrete structures*
[4] C 130-78: *Technical instructions for applying mortars and concretes by gunite*
[5] SR EN 1015: *Determining the bending strength after the mortar solidification*
[6] SR EN1992-1- *Concrete structures design*
[7] SR EN 1994 Eurocod 4: *Design of composite steel and concrete structures*