Special session 1: Tensioned structures

Objekttyp: **Group**

Zeitschrift: **IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht**

Band (Jahr): **14 (1992)**

PDF erstellt am: **19.09.2024**

Special Session 1

Tensioned Structures

Structures en tension

Zugbeanspruchte Konstruktionen

Organizer: Ted Happold, UK

Chairman: R. Silman, USA

External Prestressing in Tension Structures

Précontrainte extérieure dans des structures tendues

Aussenliegende Vorspannung von Zugkonstruktionen

Jean-Philippe FUZIER
Technical Director
Freyssinet
Boulogne-Billancourt, France

Jean-Philippe Fuzier graduated in civil engineering from Ecole Centrale de Paris. His experience with Europe Etudes (Paris, France) as International Division manager and with Freyssinet, covers all kinds of outstanding prestressed concrete structures: offshore platforms, nuclear containment vessels and gas storage, large cantilever, cable-stayed bridges.

SUMMARY

The use of external prestressing has proved to be of particular interest for strengthening structures whether for the purpose of adapting them to new loading regulations, or to completely restore their capabilities of resisting environmental loads. This paper deals with tension structures – either new or old – where tension forces are carried by external cables. Three projects are presented: a tension roof structure entirely supported by external prestressing cables; circular tanks prestressed with external individually protected greased strands; cereal silos, which were reinforced by external prestressing.

RÉSUMÉ

L'utilisation de la précontrainte extérieure est particulièrement intéressante pour le renforcement des structures, soit dans le but de les adapter aux nouveaux règlements, soit pour leur redonner leur capacité de résister aux sollicitations de l'environnement. Cet article traite des structures tendues récentes ou anciennes – où les forces de traction sont portées par des câbles extérieurs. Trois projets sont présentés: un toit entièrement porté par des câbles extérieurs; des réservoirs circulaires précontraints par des torons gainés graissés; des silos à céréales renforcés par précontrainte extérieure.

ZUSAMMENFASSUNG

Die Anwendung der Aussenvorspannung erweist sich als besonders nützlich bei der nachträglichen Verstärkung von Tragwerken, sei es zur Anpassung an verschärfte Normenbestimmungen, sei es zur Rehabilitation gegenüber Umwelteinflüssen. Von der Vielzahl jüngerer oder älterer Fälle, bei denen Zugkräfte über aussenliegende Spannkabel aufgenommen wurden, sind drei Beispiele ausgewählt: ein vollständig aufgehängtes Dach, runde Behälter mit Ringvorspannung aus gefetteten Monolitzen, sowie ein Getreidesilo mit äusserer Vorspannung.

1. GENERAL

External prestressing is not a new idea today. Many applications of prestressed structures with prestressing components installed outside the structural material have been realized all over the world during the past thirty years. However its development is more recent.

The use of external prestressing has proved to be of particular interest for strengthening of structures whether for the purpose of adapting them to new loading regulations or to completely restore their capabilities of resisting environmental loads. Today, external prestressing and corresponding techonology are being developed for new structures.

This paper deals with tension structures - either new or old - where tension forces are carried by external cables. Three projects are presented :

- At FELSBERG (Germany) a tension roof structure (after repair works) is entirely supported by external prestressing cables.
- Prestressed decantation circular tanks of a water treatment plant at CHAUNY (France). Use of external individually protected greased strands.
- At SAFI (Morocco), cereals silos, 34 m high, were reinforced by external prestressing.

2. BROADCASTING BUILDING AT FELSBERG (Germany)

2.1 Structure description

The Europe n°1 broadcasting station is housed in a building covered by a prestressed concrete shell, built in 1954.

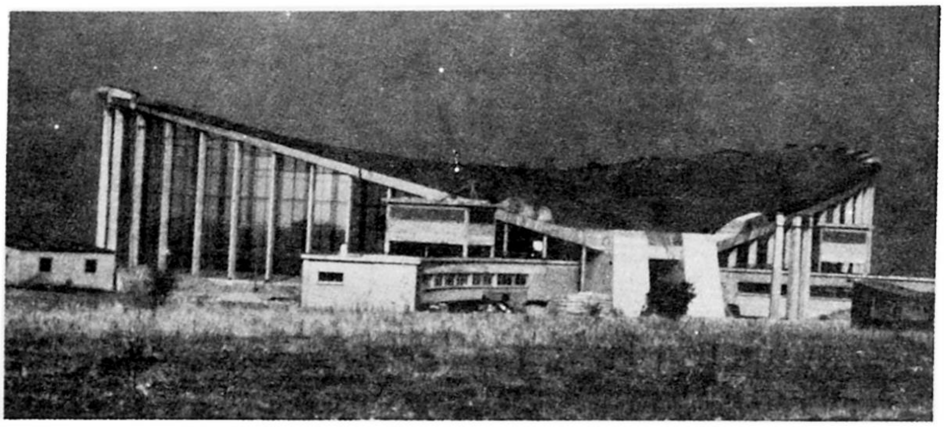

Fig. 1 General view of station building

The building consists of a series of slender columns supporting a reinforced concrete ring beam to which a 5 cm thick concrete shell is fixed. The columns are equidistant and enclose a heart-shaped area, inscribed within a rectangle measuring 86.5 m x 46 m. The walls between the columns consist of full-height glazed panels. The mean line of the ring beam capping the columns is contained within two symmetrical planes in relation to the axis of the heart-shape and inclined at 20 % to the horizontal : the angle of intersection of the dihedron formed by these two planes is inclined at 13 %, the levels of this angle of intersection, with respect to the foundation raft, being at a height of 4.50 m at one extremity and 9.50 m at the other.

The shell is prestressed with cables laid perpendicular to its axis, that is to say across the largest dimension. The surface of this double-cambered shell is generated by parabola corresponding to the cable layout, whereas cross-sections paralell to the symmetry axis of the building present a variable inversed camber due to the shape of the ring beam. The different stresses acting on this ring beam are counterbalanced by means of 6 ties placed in a fan-shaped formation from the point of the heart.

2.2 Analysis of the deterioration

After 25 years of trouble-free service, it was decided to examine the entire structure, following the discovery, in Germany, of defects affecting a similar shell.

The examinations revealed the following defects :

- advanced corrosion of the stirrups supporting the fibreboard panels,
- poor aspect of the ribs housing the prestressing cables and their poor adherence to the concrete shell,
- corrosion of uncovered sheath at the bottom of the ribs,
- superficial corrosion of prestressing wires, the cables being only partially grouted, essentially due to a lack of impermeability of the sheath, a certain amount of grout having probably been lost in the insulating panels, advanced corrosion of certain tie rods in the anchorage zone, at the concrete saddle end.

On the other hand, the shell concrete was found to be most satisfactory.

The client having expressed the request for a complete overhaul of the structure, it was decided to change the prestressing cables and the ties, and to apply a thermal insultation to the outer surface of the shell in order to reduce the risk of internal condensation.

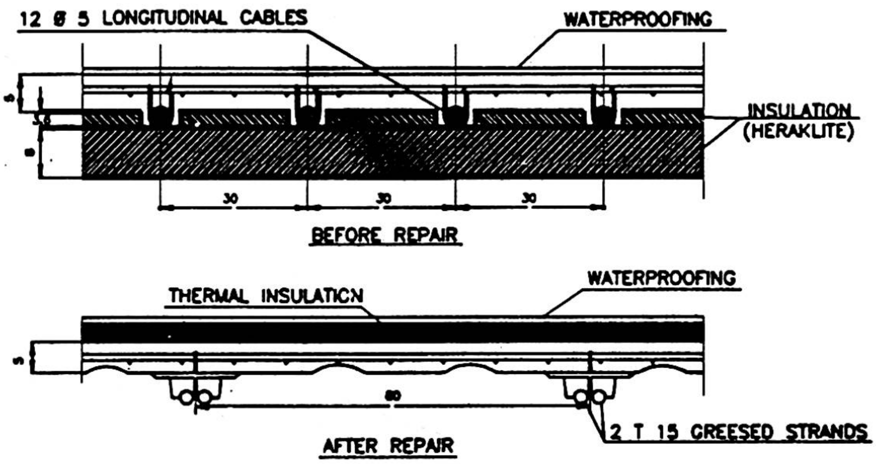

Fig.2 Section through shell

2.3 Rehabilitation of the roof

2.3.1 Replacement of the prestressing cables

Unbonded plastic coated ø 15 mm, strands were adopted to replace the original cables. Placed in pairs at the location of alternate ribs they produced the same prestress as the previous cables.

The operation involved the removal of the fibreboard panels below the ribs, the progressive removal of the ribs and the original cables, made possible by the existence of a low-strength casting joint, the necessary boring in the ring beam in order to pass the new cables, the installattion of these below the shell, the stressing operations being carried out as work progressed. Contact between the strands and the shell was ensured at pin-point locations every 1.50 m, by means of small concrete shims. These shims provided excellent contacts and supported the shell by the curved effect of the stressed cables.

2.3.2 Replacement of ties

This operation resulted in temporary complementary stresses being applied to the roof, through a lack of synchronization in the stressing of the new ties and the removal of the original ones. In order to limit the parasitic stresses connected with this phase of the operation, the ties adopted were of the "prestressed"type. To reduce their size and weight, the compressed section is that of a concrete-filled steel tube.

The installation of the new ties comprised the following phases : placing of steel tube lengths on scaffolding, butt-end welding of these tubes, threading of the central sheath placed on supports to ensure the correct position, grouting between the tube and the sheath, threading of cables and stressing.

With a mind to simplification and safety, the new ties were all identical and each made up of 19 strands ø 15 mm placed in a 273 mm outside diameter tube with a 10 mm wall thickness. They are stressed to 300 t and their overall capacity is largely above that of the original ties.

The new ties were installed next to the old ones, according to the possibility of boring the necessary holes (ø 100 mm) through the ring beam, on one end and the solid abutment at the other end.

3. DECANTATION TANKS AT CHAUNY

The treatment of the industrial effluents is carried out with the use of aeration and homogenisation tanks. Each of these basins consists of a cylindrical tank whose 22 cm thick wall is fixed to the raft base.

- Aeration tank :
  32.00 m inside diameter ;
  4.75 m high
- Homogenisation tank :
  5.00 m inside diameter ;
  5.00 m high

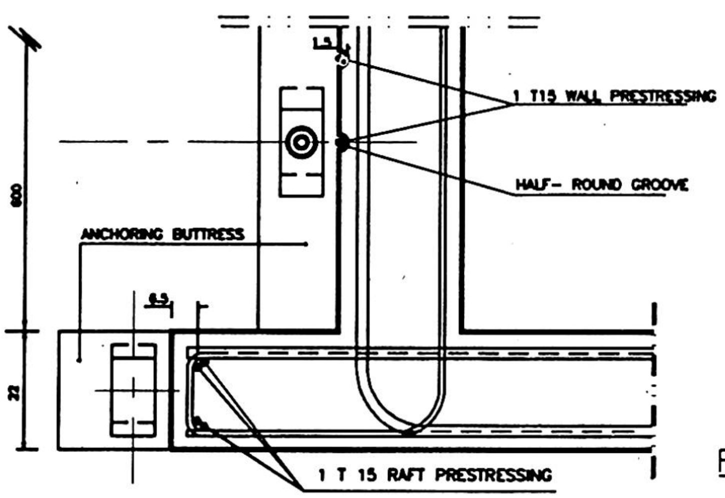

Fig.3 Decantation tanks hoop prestressing

3.1 Prestressing method

The prestressing of these tanks is obtained by means of single greased strands placed on the outer side of the wall and lodged in horizontal grooves formed during concreting. Double protection of the strand is achieved by housing it in a tube which remains visible. Each strand forms one complete loop and is anchored in a vertical buttress. Two buttresses at 180° are used to ensure uniform distribution of the prestressing force.

3.2 Application

The method of applying the prestressing is simple : threading of the strands into a polyethylene tube suspended in front of the groove. When stressing, the tube takes up its permanent position in the groove.

3.3 Advantages

This type of prestressing is particularly advantageous for small storage units. While producing a certain architectural aspect it still remains simple to apply. The structure described above was built with ordinary formwork but the same dispositions can be obtained with the use of climbing formwork. However care must be taken in forming the grooves and their effect on the rebar cover must be reduced to a minimum.

The following method provides a simultaneous solution to the problems of strand protection and proper application of the reactions due to curvature :

- placing the strand inside a larger sized sheath (30 mm minimum int. dia for 15 mm strand),
- grouting the free space between the outer sheath and the greased strand before stressing and then stressing after hardening of the injected grout.

On this site the plastic caps of the anchorage heads remained exposed. Generally they are sealed off and when this is not done they must be protected by painting.

4. STRENGTHENING OF A CEREALS SILO AT THE PORT OF SAFI (Morocco)

The activity of the port of Safi, Morocco's first fishing port, is also for a large part devoted to importation and exportation of cereals. The Safi cereals silo, a large structure built in 1957 which comprises two batteries of three rows of five circular, tangential cells 6 m in diameter and 34 m high, showed serious dilapidation of the reinforced concrete structure : vertical and horizontal cracking due to insufficient rebar and the intensity of the thermal gradient. The design of the strengthening operation led to the adoption of additional prestressing consisting of 40 hoops per cell, evenly distributed over their height. The prestressing force in each hoop is of the order of 20 t.

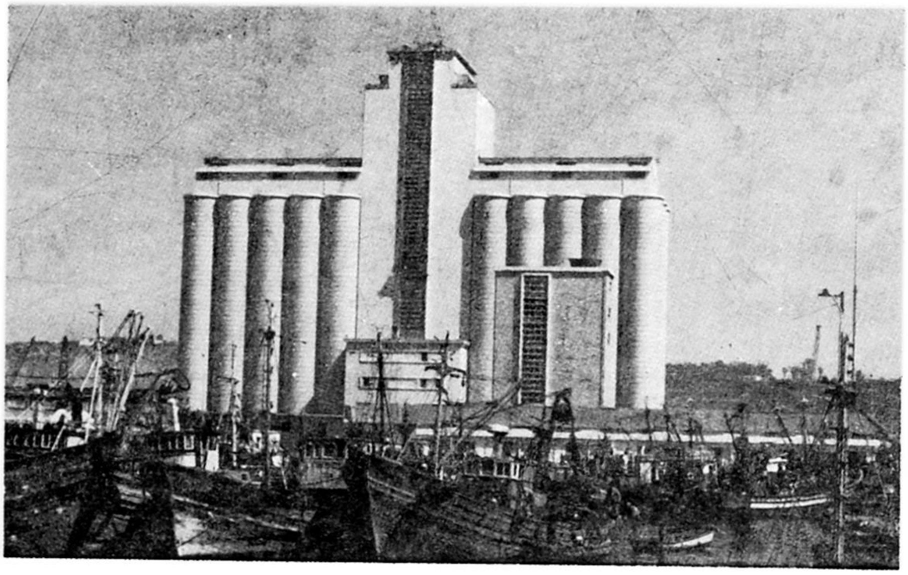

Fig.4 Silo at SAFI after strengthening

4.1 Execution of the works involved several phases :

- successive filling of the cells and sealing of the cracks ; core drilling in the cell walls to allow passage of the cables ;
- placing and tensioning the prestressing tendons ;
- surface treatment and waterproof coating on the entire outer surface.

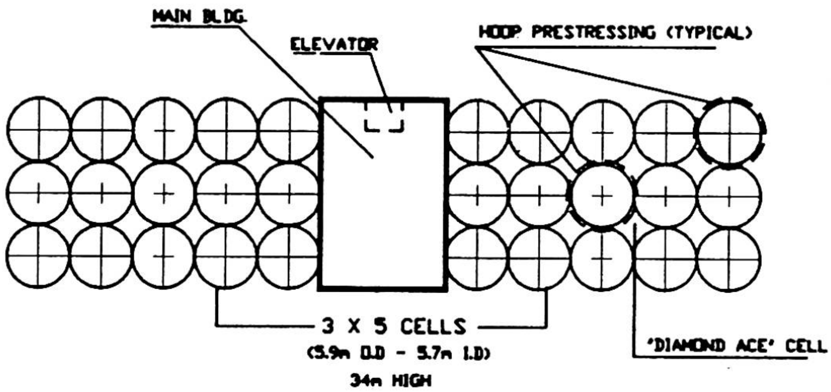

Fig.5 Silo at Safi General layout

The particularity and major difficulty of the operation resided in the fact that the hooped tendons encircling each cell pass through one, two or three other cells, a fact which meant that core-cutting was executed with rigorous tolerances, and the hoops had to be protected, on the inside of the cells, with reinforced micro-concrete, to avoid abrasion by the cereals during filling or emptying operations.

The external prestressing was provided by monostrand T15 greased and sheathed cables, housed in a plastic sheath and then injected with cement grout before being tensioned through "X" type anchorages.

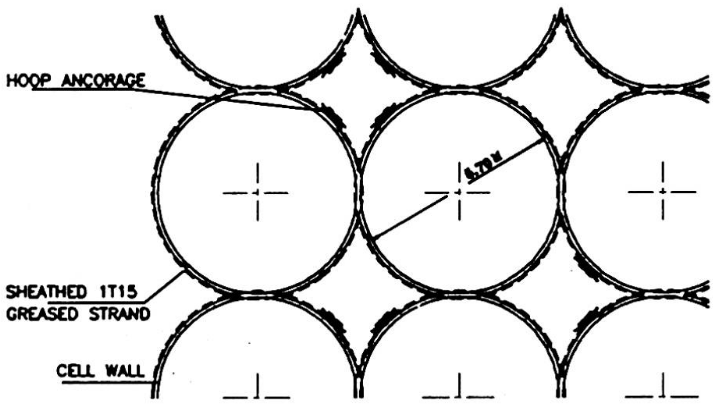

Fig.6 Silo hoop stressing (typical)

4.2 Quantities

- 7040 skew core cuts,
- 1200 hooped prestressing cables,
- 11000 m of sheath protection using micro-concrete,
- 12500 m^2 of surface treatment and waterproof coating.