# Two concrete folded structures for large storage coverings

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Objekttyp: **Article**

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

Band (Jahr): **11 (1980)**

PDF erstellt am: **21.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-11281

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## Two Concrete Folded Structures for Large Storage Coverings

Deux types de structure plissée pour des grandes toitures

Zwei vorfabrizierte Spannbeton-Faltwerke für Lagerhallen mit grossen Spannweiten

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**SUMMARY**
The first structure consists of three-hinged arches with a folded structure. The 60 m span is made up of two thin precast and prestressed concrete units. The second structure has a set of fixed-end frames. The 30 m span is made up of two precast and prestressed elements. The bearing capacity was increased by providing the beams with prestressed tie bars. In both situations, asbestos-cement sheetings were placed between the folded profiles.

**RESUME**
La structure de la première toiture est constituée d'arcs à trois articulations avec section transversale plissée. La portée de 60 m est franchie par deux éléments préfabriqués en béton armé. La deuxième structure est constituée de portiques de 30 m de portée, ayant également une section transversale ouverte. Les deux portiques ont été renforcés par des haubans précontraints. Dans les deux cas les espaces entre les éléments porteurs ont été couverts avec des panneaux en asbociment.

**ZUSAMMENFASSUNG**
Im ersten Beispiel besteht die Tragstruktur aus Dreigelenkbogen mit einem dünnen Faltwerkprofil. Die 60 m Stützweite werden von zwei vorfabrizierten Spannbeton-Elementen überspannt. Im zweiten Fall besteht die Hauptstruktur aus eingespannten Rahmen von 30 m Länge, die ebenfalls mit diesem Faltwerkprofil ausgestattet sind. Die Rahmenriegel werden durch vorgespannte Zugstangen verstärkt. In beiden Fällen werden die Räume zwischen der Tragstruktur mit Asbestplatten überdeckt.

## 1. INTRODUCTION

The field of thin spatial structures is nowadays sensibly enlarged by the applications of shells to the industrial, especially to the chemical, objects, where this class of solutions appears of a high efficiency.

The paper bears on two types of concrete precast and prestressed folded elements, of large spans , designed for chemical depot coverings, in Romania .

The great agressivness of the inside atmosphere was the reason, why the structures had to be situated in the concrete solution field .

## 2. COVERING ERECTED IN BACAU

The structure in this case essentially consists of transversal three hinged folded arches, crossing a 60m span and reaching a height of 20 m, in order to satisfay the specific functional conditions as Fig.1 shows.

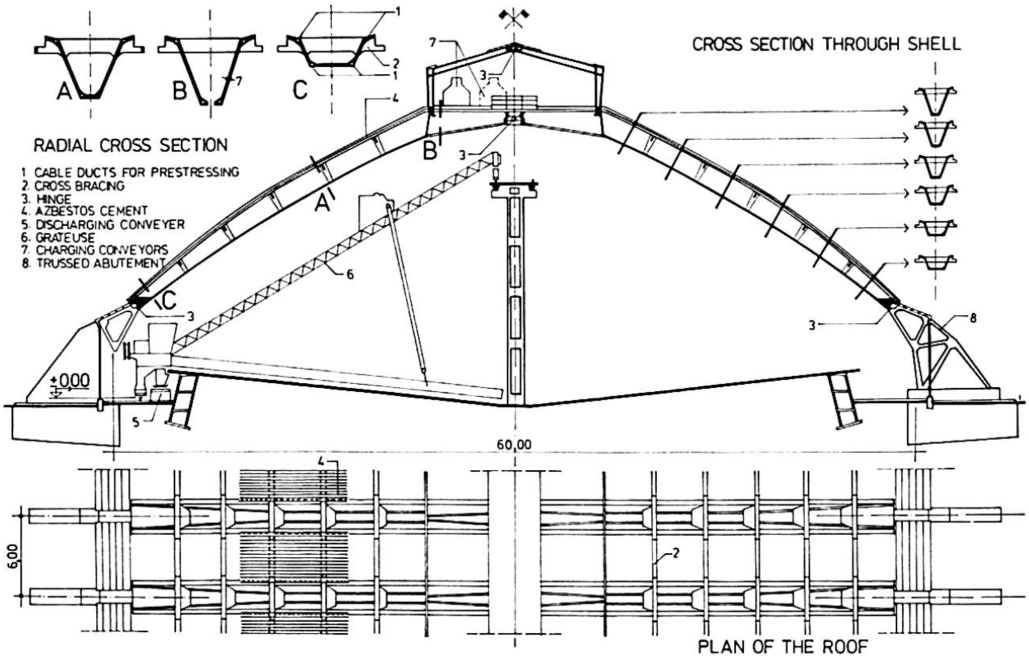
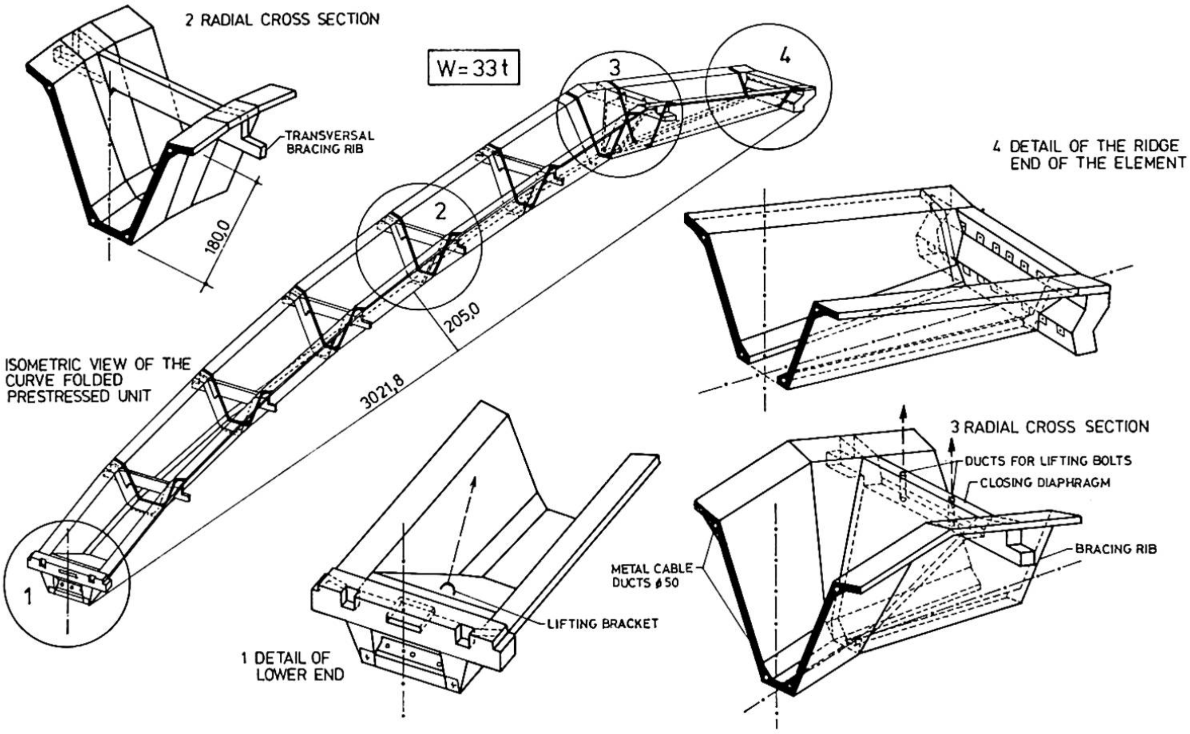



Fig.1. Cross profile of the chemical depot

Fig.2. The longitudinal stiffening system

The arches , each made of two precast thin shell units, of 2.60 m width and variable depth, are placed at 6,00 m longitudinal bay intervals, as seen in Fig.2 ; for their stiffening, in the longitudinal sense bracing ribs and cross bars, were provided, forming two blocks of 85 m each . The intervals between the strips covered by the arches, of 3.40 m, were completed with asbestos cement sheetings and meta-acryl panels, the latter assuring the inside natural lighting , though a 43 percentage economy to the cladding elements was obtained .




Fig, 3. The shape of the concrete precast shell element

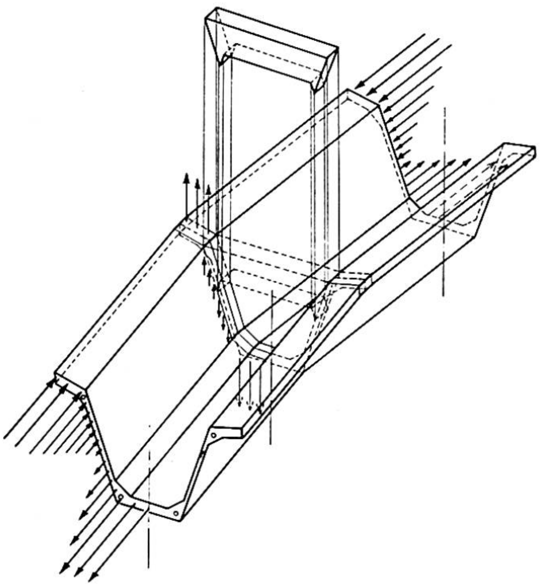


Fig.4.The transversal parasitic efforts .

The curved folded elements of a 32 m axis length, (their fullscale geometry appears in Fig.3) was conceived in a V form, so that the centre of the cross section might be located, as near as possible to half of its depth, making the both extreme flanges to be equally solicited, to alternative bending moments .

The shape of the longitudinal axis of the precast elements, was set in an optimal position against the thrust pressure line, carried out on the three hinged system, for the dead load, considered as a short time action .

It is to be mentioned, as an aucommon feature ( Fig. 3,4 ) , that the longitudinal axis was performed, of straight segments of variable slopes and lengths, having in mind to concentrate the parasitic transverse forces , which normallyappear in the flanges of thin curved elements, induced by the axial efforts , in a short number of transition zones, each stiffenned with bracing ribs, so as to reach a box effect.

Among the advantages of the chosen cross profile, there are to point out:
i- a good lateral stability during handling ( fig.5 ) , a big stability to the Brazier effect, especially for negative bending moments, which may

frequently occur, a satisfactory local stability , of the flanges and webs of the element, as well as, a great economy of the needed materials and manover.

For each shell element, four types of loading hypothesis within the first order theory, were taken to account : (i) the initial prestress forces of 200 K.N. acting in the horizontal casting position, (ii) the initial prestress forces and dead weight, on the static scheme, which occurs during the handling ,(iii) on the three hinged arch-scheme, the loading combinations, wich separately give the maximum compression efforts in the outside or inside extreme fibers ( Fig. 6 shows the first (iii) case).

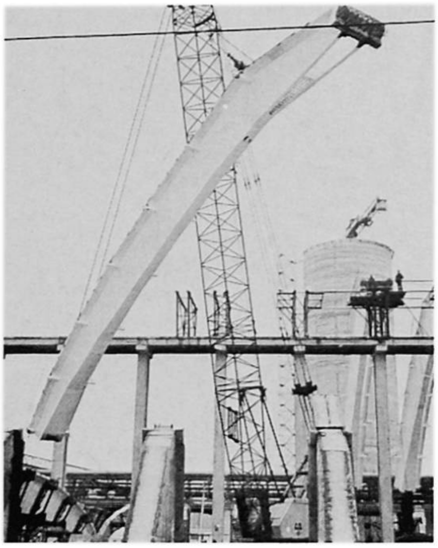


Fig.5. The handling of the precast element

The arch units were reinforced with mild steel bars , and four post-tensioned cables , placed in ducts, with parallel trucks, in the vertical sense, but no longer parallel in the horizontal sense . The bottom hinges Fig.7 made of metal sheets, as to avoid friction against rotation, were placed on metal wedges and finally stiffenned, by welding and in situ poured concrete .

The crown hinges Fig.8 were made of metal cylinders, filled up with concrete, along which, two families of adjustable bolts can rotate,belonging each to one of t he two units .

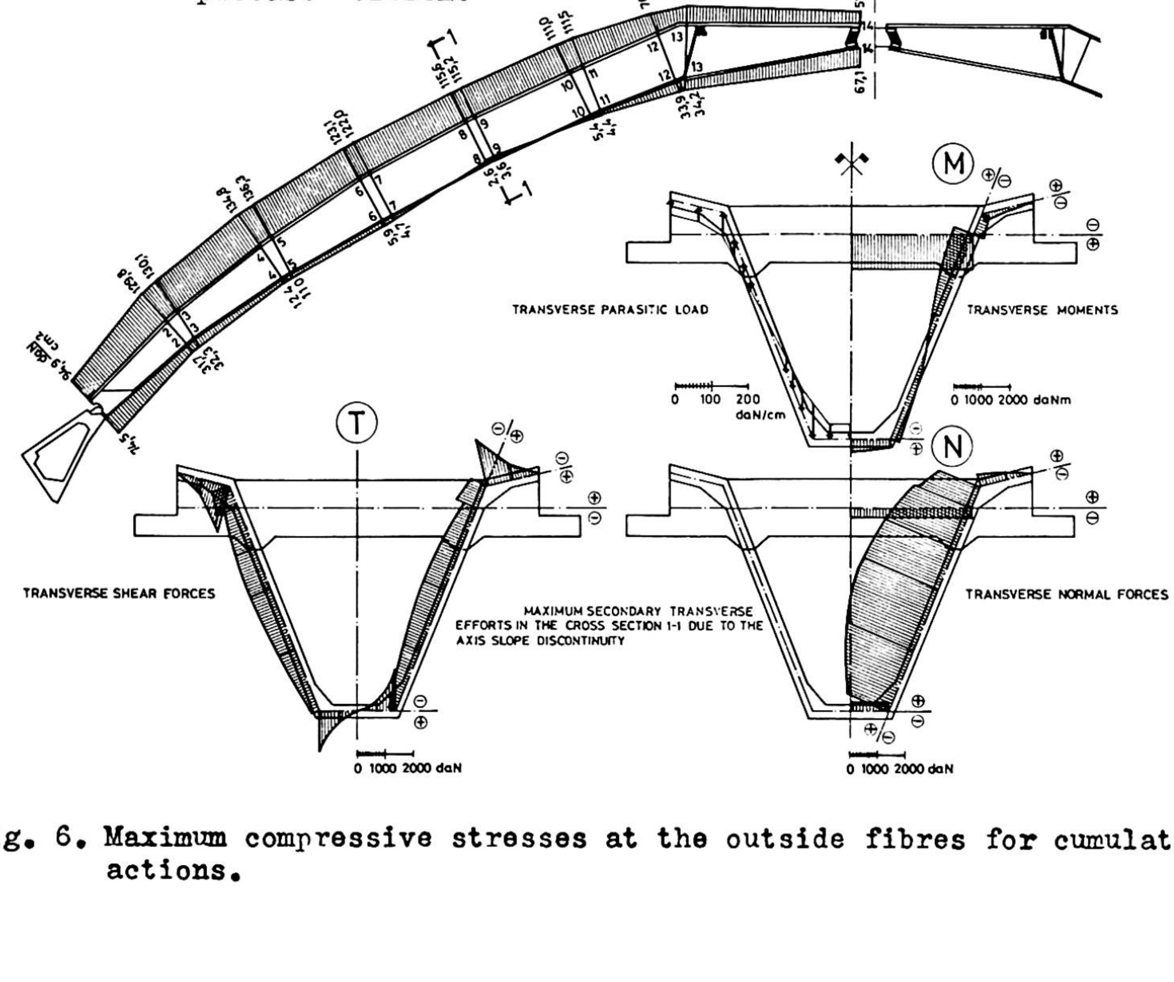



Fig. 6. Maximum compressive stresses at the outside fibres for cumulative actions.

The entire covering material indicators were : - concrete 012 $m^3/m^2$ and total steel - 18,65 $kg/m^2$ . The Figures 9 and 10 show outside and inside views ot the finished depot .

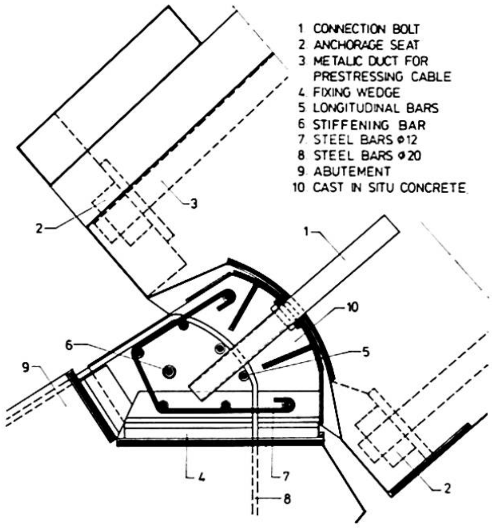



Fig.7 . Bottom hinge

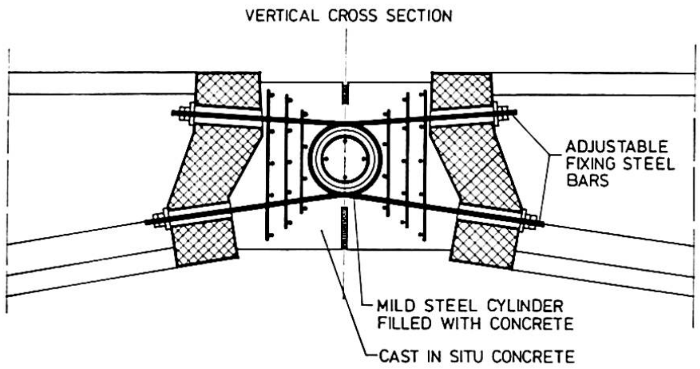



Fig.8. Ridge hinge

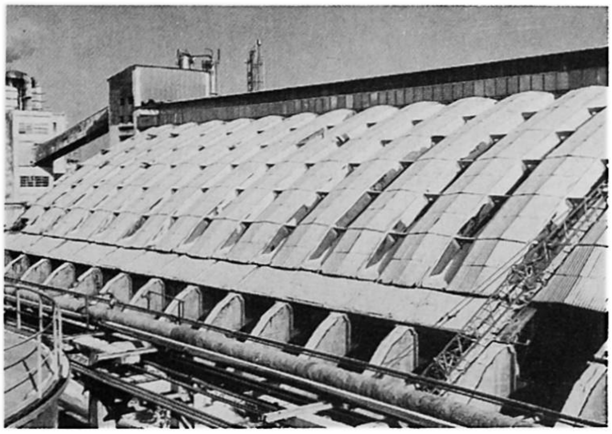


Fig.9. Out side view of the finished depot

Fig.10Inside view of the depot

3. THE COVERING LOCATED IN FAGARAS

The second type of chemical depot in Făgăraş , mainly consists of a set of simple fixed frames disposed at 9,00 m bay intervals , each crossing a 30,00 m span , and having a 2.60 m width .

As Fig.11 shows , the geometrical data were chosen, as to satisfay the technological requirements . As mechanical specific loads, there be mentioned two vertical life loads of high values, about 1ot each, placed at the quarters of the midle span , as well as the horizontal pressure, induced by the stored chemical material, at t he half of the column height .

For efficiency purposes, the frame elements were precast , Fig.12-13, showing the individual pieces. In order to increase the bearing capacity of the horizontal members, the beam effect was supplemented with a tension carrying action, providing a suspended diagonal cable system. Also it was investigated the possibility to minimize, the construction material amount, by conceiving : the columns as truss elements, prestressed at the ouside line, and the beams as thin folded shaped shells.

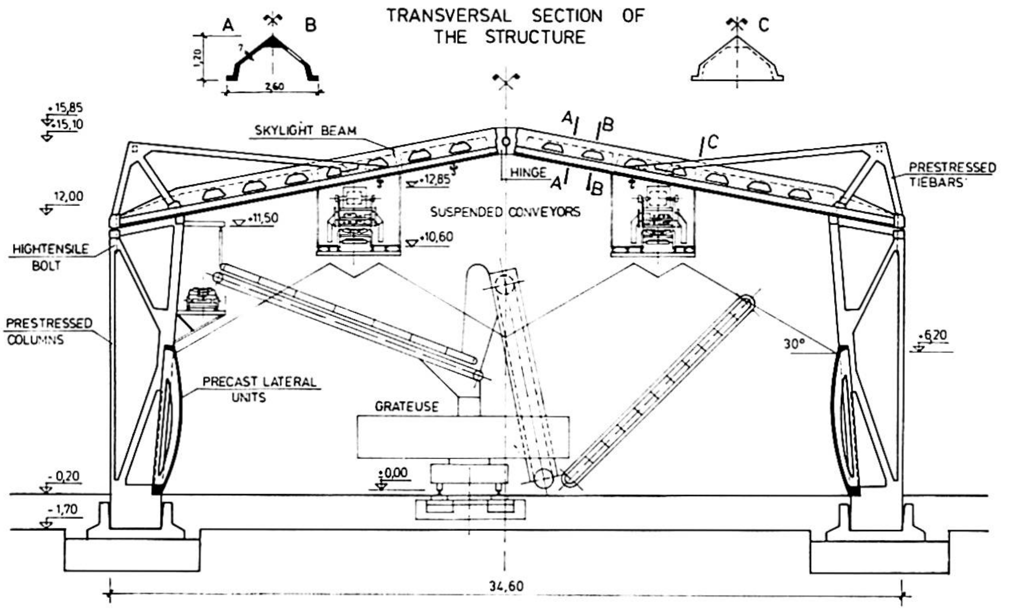



Fig.11. Cross section of the depot structure

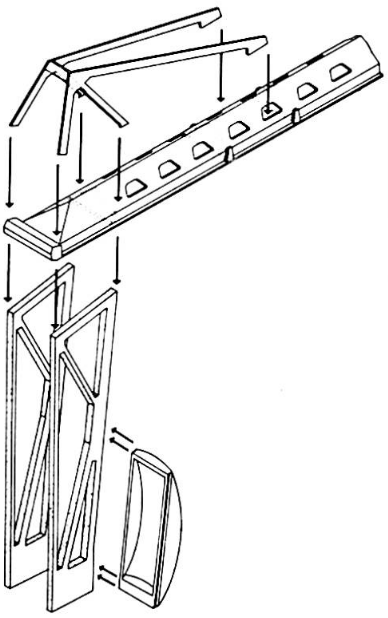


Fig.12.Axonometric view of the precast elements

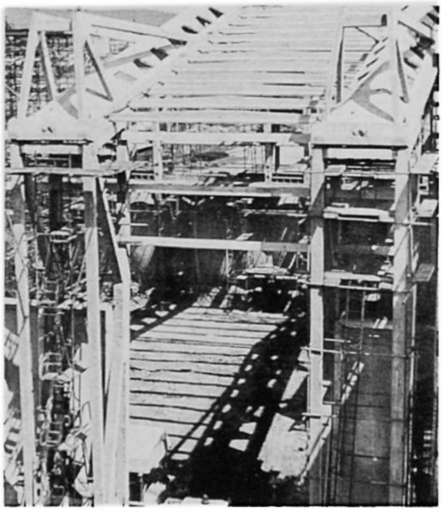


Fig.13.Ouside view during the erection

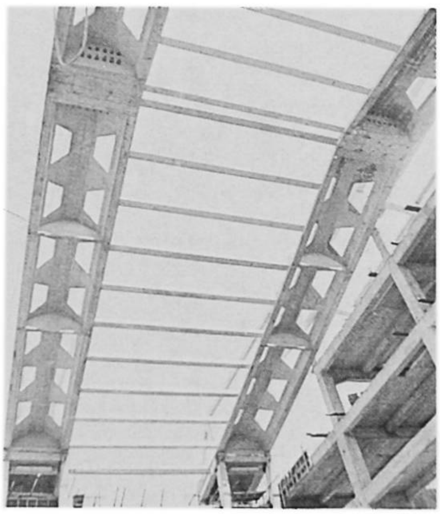


Fig.14.Inside view of the precast beam

The spatial development of the main bearing system enabled :(i) a 22 percentage economy in the cladding cement-asbestos sheetings,which cover by pannels only the strips between the beam flanges (ii) a good lateral stability during the erection time assuring meanhile a convenient stiffness in the longitudinal sense to the earthquake action. The main indicators for the entire upper structure are:concrete 0176 $m^3/m^2$ and total steel 29,2 $kg/m^2$.

4. ACKNOWLEDGEMENT
The first structure was advised by Mr.Ing.Mircea Georgescu,the second one has been controlled by Mr.Ing.Ion Găvozdea .