PNEUMATICALLY FORMED REINFORCED CONCRETE DOMES FOR GRAIN STORAGE FACILITIES, BUILT WITH BINISHELLS TECHNOLOGY

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INTRODUCTION

The purpose of these notes is to explain in summary the Binishells patented technology for the pneumatic formation of reinforced concrete domes and some of the main advantages offered by such Binishells structures for the realization of facilities for artificial controlled atmosphere storages of grain.

Our experiences are as designers and builders of reinforced concrete structures and we wish to put them at all the silos experts disposal (International Public Bodies, scientists, designers, consultants, builders and utilizers) who may contribute to the solution of problems concerning the storage and the preservation of cereals in the world.

We do hope that from these information on a technology of construction, collaborations with the experts of different activities may come out.

In fact, instead of suggesting solutions with products and/or equipment already defined, we believe it is great more useful to propose technologies which may be employed with the collaboration of experts and by using the local resources and manpower existing in each country of utilization.

In the areas which are typical of a developing agricultural economy, above all, everybody knows which are the negative economical and social repercussions, deriving from the imposition of outside system and products, which do not involve either the local technicians or workers and then cause instinctive refusals, as the well-known lack of maintenance, etc.

The Binishells technology allows the construction of dome-shaped structures of different sizes, up to 36 - 40 m in diameter (that is a capacity of cu.m 7.500 - 10.000 each) by using local resources (unskilled manpower and conventional materials), reducing the importations to the minimum and offering many advantages, such as :

. building rapidity, i.e.: a complex of 100 domes of 32 m dia., with a total capacity of about cu.m 550.000 is built in Pakistan in 200 days;

cost economy : up to a saving of 40÷60% in comparison with concrete storages built with conventional systems. Further considerable advantages are obtained by making such structures gas-tight.

BINISHELLS PATENTED TECHNOLOGY

Some information on the technology are given here below.

This new building system is based on the pneumatic formation of reinforced concrete structures, i.e. upon the use of the pneumatic dynamic form which lifts all the building materials from the ground, e.g.: fluid concrete, steel reinforcement, etc.

The main special equipment and the different phases of the process are illustrated below.

The Foundation

The foundation consists of a small circular continuous beam (e.g., for a 36 m diameter dome, the section is 60 cm by 85 cm) which is built in a standardized way. The load on the ground is very low, by virtue of the dome's lightness and monolithicity. Before casting, a special tubular form (4 - fig.1) for the anchoring of the internal pneumatic form is inserted in the foundation. This form is inflated before casting and, subsequently, after the concrete has set, deflated and removed (1 - fig.2) to leave an eye-let for insertion of the tubular anchorage connected with the edge of the internal pneumatic form.

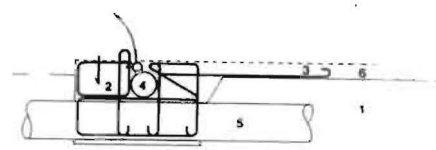


Fig. 1

Internal Pneumatic Form as an uplifting system

The pneumatic form consists of a membrane in nylon reinforced neoprene, with tubular anchorage at the edge (2 - fig.2).It is anchored to the foundations by the above illustrated system and allows both air tightness and mechanical resistance.

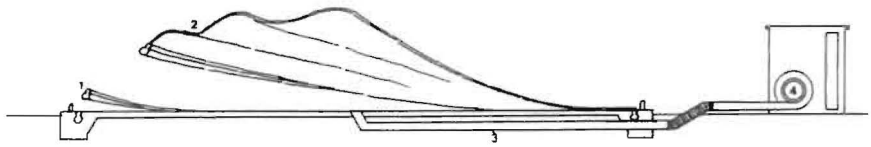


Fig. 2

Pumping Station

The pumping station consists of one or more low pressure electric blowers.

Air inlet and outlet are made through pipes in P.V.C. or other materials (5 - fig.1), under the floor. The shape of the structure is stabilized by air circulation,i.e. by pumping air into the pneumatic form and letting out small quantities to avoid any movement of the structure(1 - fig.7).

The internal pressure needed to lift the membrane and construction materials is of few hundredths of an atmosphere (from 0,03 to 0,05 Atm.).

Steel Reinforcement

Steel reinforcement consists of a mesh of spirals (4 - fig.3) plus additional reinforcing bars (5 - fig.3). The mesh is made of steel spirals hooked to an external bar anchored to the foundations (3 - fig.3).

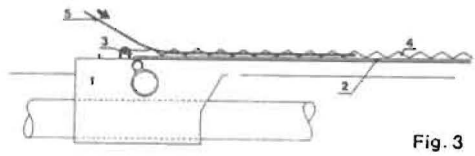


Fig. 3

These spirals are manufactured at close pitch; therefore they take up little space and can be easily packed and carried to the job site. Each structure requires 10-15 types of spiral lenghts (fig.4).

Reinforcement consists of straight steel bars, varying from 5 or 8 mm in diameter. This is placed inside the spirals and left free to slide (fig.4, dark lines).

Placing is easily carried out directly on the membrane at ground level, following a standard drawing and carrying out the same operations for any size of structure. During uplifting the spirals stretch and the bars settle and slide, maintaining the required position with the laps needed to ensure the continuity of the reinforcement.

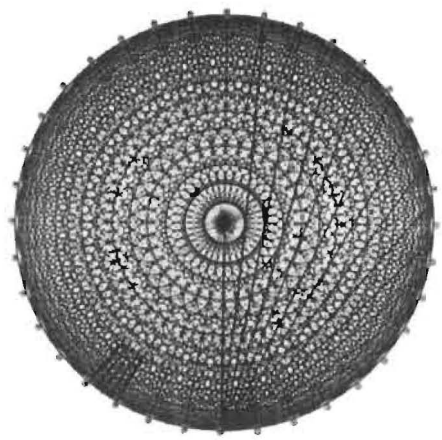


Fig. 4

The spirals have several functions, the most important of which are : - to prevent the concrete from sliding during the uplifting - to guarantee concrete thickness - to uplift and settle the reinforcing bars - to control the uplifting and the shape.

The shape of the structure is defined both by the type of pneumatic form and spirals.Laying of reinforcement takes 1-2 days for structures having dimensions

varying from 12 or 36 m in diameter, with a team of 6-8 workers.

Uplifting of Concrete and its Characteristics

Concrete consists of a regular mix with a high workability and is placed on the pneumatic form at ground level. The characteristics of the mix are usually:

Sand	60%	Water/cement ratio	0,50
Gravel (max 12-15 mm)	40%	Abram's slump	16+18 cm
Cement	400 Kgs/cu.m		

Retarders and plasticizer additives, easily available and in such doses as not to alter strenght of the concrete, are used in order to allow the placing, uplifting and vibration of the concrete.

Placing is usually carried out with concrete truck mixers. Concrete is placed on the membrane at ground level and spread by conventional methods (fig.5).

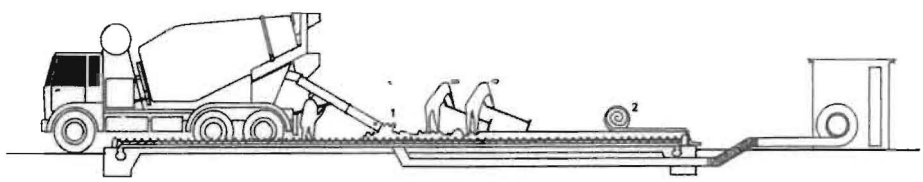


Fig. 5

During uplifting as the surface increases, the thickness both of the spirals and of the concrete decreases.

However, the whole system is calculated in order that the final shape assures the correct concrete thickness for the complete covering of the steel reinforcement.

As already explained, the concrete sliding during the uplifting, is prevented by both the spirals and P.V.C. sheet (external membrane).

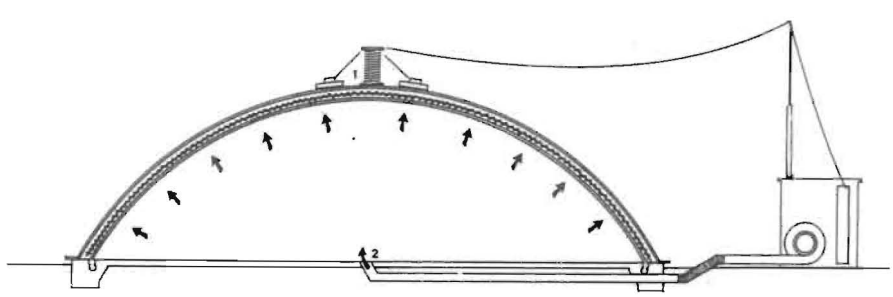


Fig. 6

External Membrane (= P.V.C. sheet)

Before uplifting, a P.V.C. sheet is laid on the concrete and anchored to the foundations in a simple and quick way (2 - fig.5).

During the uplifting, the P.V.C. sheet is put under stress, compressing the concrete (fig.6).

Its functions are mainly: - to protect the concrete both from rain and strong evaporation due to the sun - to help hold the concrete - to allow vibration.

Vibration

The vibration equipment is placed in the centre of the structure before the uplifting and lifted with the other materials (1 fig.6). Vibration is carried out when uplifting is completed, by means of high frequency vibrators fixed on rolling carts (3 fig.8). These rolling carts, anchored to a cylinder placed at the top of the structure, are pulled downwards, drawing paths which are similar to helicoids.

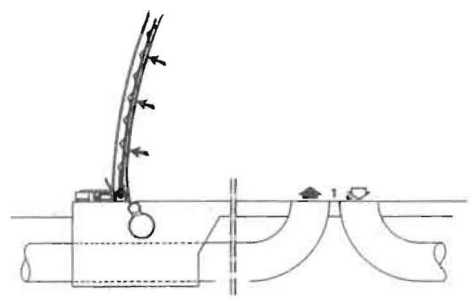


Fig.7

Each vibrator makes a path partially overlapping the one made by the previous vibrator, so obtaining a total tamping and vibration of the surface.

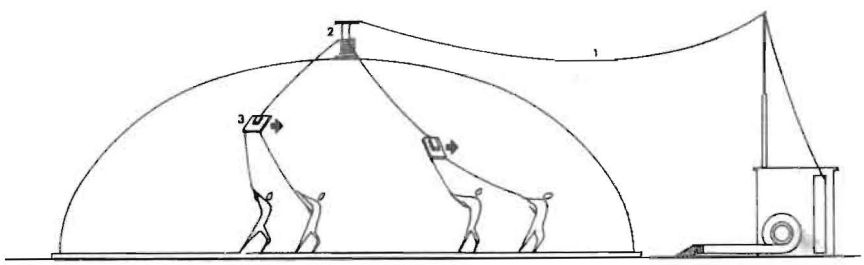


Fig.8

Setting of the Structure and Deflation of the Membrane

After stabilization and vibration, the concrete of the structure sets and hardens between two highly waterproof membranes, which allow a gradual evaporation of water and protect it against atmospheric agents (fig.7).

The device used, the controlled evaporation of water, the acceleration of setting due to both its own heat and sun eradiation,allow the elimination of any shrinkage.

and the obtaining of a perfect monolithic structure.

Usually, the membrane is deflated after 1-3 days,according to the size of the dome and to atmospheric conditions.

Before deflation, tests are carried out on the concrete and hence deflation of the membrane is carried out without risk.

Sometimes, it happens that,due to particular atmospheric conditions and to strong sun eradiation, setting is remarkably accelerated.

After an adequate period of time, an opening is cut in the structure to enter and remove the membrane for re-uses (3 - fig.9).

Opening in the Structure

Cuts are made with normal rotary saws or with other simple tools. Before making the cuts, if so required by calculation, reinforcement may be added in reinforced concrete or steel members (4 - fig.9).

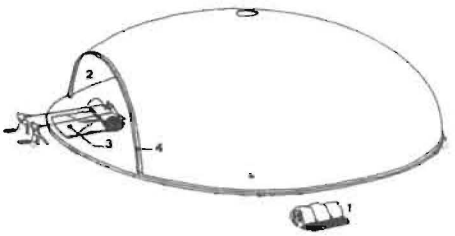


Fig. 9

Transportation and Re-uses of Equipment

All equipment are easily carried on one lorry and there is the possibility of a quick move, with remarkable savings (1 - fig. 9).

Equipment investments are small and their amortization has a low incidence because of their many re-uses.

Insulation and Finishings

Binishells domes are reinforced concrete monolithic structures, and their finishings,i.e. thermal and acoustic insulation, are carried out with materials which are normally available on the market.

Building a dome time

The usual time for the construction of a dome is hereunder outlined :

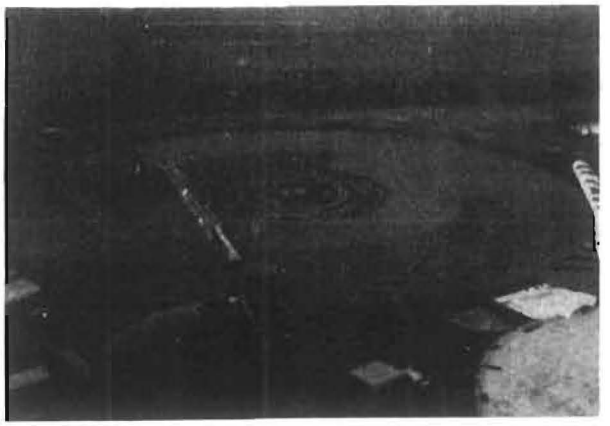
. laying of the internal membrane and equipment, etc.: 1 day,

. laying of the steel reinforcement, etc.:1÷3 days(according to size),

. cast of concrete, uplifting and vibration, etc.: 0,5 days,

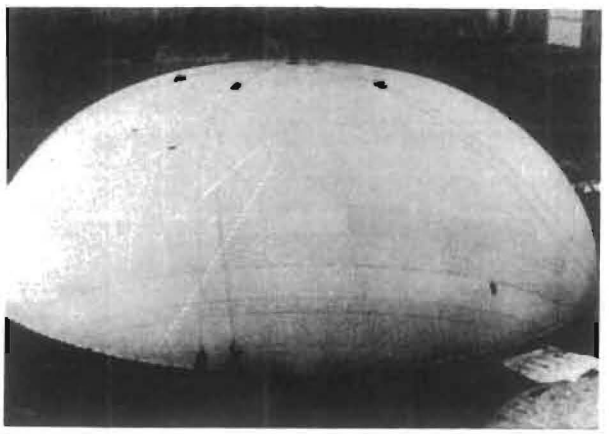
. set and hardening of concrete and deflating of membrane,etc.:1,5÷2,5 days.

A mass production can be organized by a contemporary employ of more than one pneumatic form.For example: a production of 4 domes per week (100 domes in 200 days) can be realized with 4 membranes and three teams of workers.



Casting of concrete at ground upon the internal membrane and steel reinforcing,already laid,for a structure of 36 m dia. Centre:steel reinforcing not covered yet by concrete - Right: folded P.V.C. sheet - Left: truck mixer and concrete pump.

Starting the inflation : P.V.C. sheet not yet under tension. Equipment for vibration is placed on top.



Inflation is completed and P.V.C. sheet is under tension. Vibration is carried out by means of vibrators which are driven one after the other,around the dome surface, from top to base.

The whole work here illustrated lasts from three to six hours.

ADVANTAGES OF BINISHELLS STRUCTURES FOR STORAGE FACILITIES

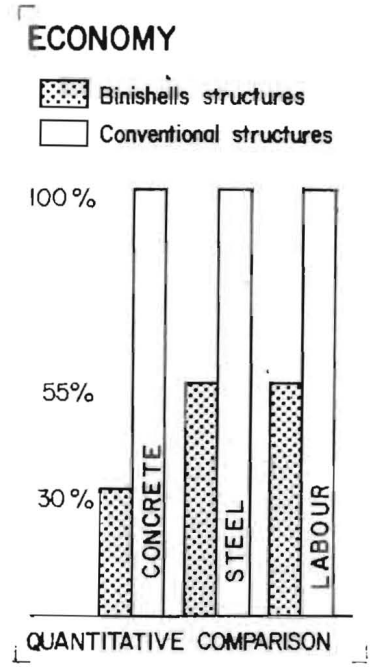
The main advantages are summarized here below.

Complete utilization of local resources :

infact, materials and unskilled labour to be found on-the-spot are utilized. Moreover, the construction can be carried out by local organizations and through licence agreements.

Economy in the costs is due to :

- reduced quantity of labour and materials required for the construction (due also to the reduced thickness of the structures: 4-8 cm);
- small dimensions of the foundations, which have a continuous circular shape, and limited depth (the load on the ground is limited to 0,6-0,8 Kgs/cmq.);
- simplicity of the equipment, their easy transportability and large re-use in subsequent utilizations;
- reduction of the transport costs and investments for building equipment;
- elimination of maintenance costs ;
- reduction of overheads due to the rapidity and simplicity of execution.



Rapidity and simplicity of execution :

A 36 m diameter structure having a capacity of 7.450 cu.m is built in 6-8 days by using simple equipment and by a reduced team of workers.

The simplicity of the foundations, moreover, eliminates unforeseen events and ground consolidation.

Long durability, high resistance and minimum maintenance :

The structures are monolithic, in reinforced concrete, and completed with a conventional and economical external waterproofing and do not require any maintenance. Moreover, the Binishells structures have an enormous natural resistance to all stresses, such as: external loads, earthquakes, typhoons, pressure waves, etc. They can also be covered with earth and camouflaged.

Possibility of utilizing the structures both for bulk and bags storage:

This advantage is shown in two aspects:

- simple warehouses for bags (domes with one or two doors) can be built at the beginning, and subsequently completed with fixed or mobile economic systems for filling and discharging which can be added in a simple way; then changing of a Binishells warehouse for bags into a bulk storage is very simple ;
- if the structures are equipped with the mechanization from the beginning, the same plant can be utilized both for bulk and for bags so that different situations which may occur along the year, can be easily faced.

Possibility of building gas-tight structures :

Such operation simply requires the application of a special paint on the inner surface of the dome. Also such application can be done from the beginning or subsequently. The Binishells structures are monolithic, without any crackings, joints, etc. and thus allow an easy application of the paint and a safe tightness in the future.

The paint employed by us was hardly tested by Snamprogetti and found completely suitable.

POSSIBLE TYPE OF STORAGE FACILITIES

Among the large range of possibilities of utilization of the Binishells structures, some of the most significant solutions are listed here below.

With regard to building (B), we can have the following classification :

B.1. Flat bottom with domes at ground level :

B.1.1. with entry door - B.1.2. without entry door ;

B.2 Flat bottom with dome built on a cylinder (to increase capacity) :

B.2.1. with entry door - B.2.2. without entry door ;

B.3. Inclined bottom :

B.3.1. with only one cone - B.3.2. with multiple hoppers.

With regard to shape (S) of structures, we can have :

S.1. shape with ellipsoidic section (of height H and base diameter D,with H=1/3 D),

S.2. shape with parabolic section (of height H and base diameter D,with H=1/3 D),

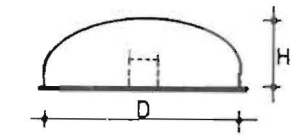
S.3. other shapes (square base, etc.)

With regard to dimensions (D), we can have bins of any dimensions :

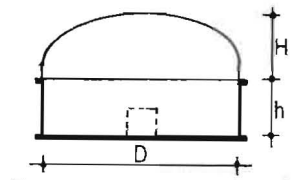
As an example, here below we state dimensions of the ellipsoidic shape standard

structures with relevant capacities for the flat bottom solution.

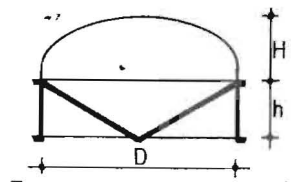
D (m)	H (m)	V (cu.m)
15	5.00	600
20	6.30	1,360
25	8.00	2,580
32	10.20	5,450
36	11.00	7,450
40	12.00	10,050



With regard to combination (C) of several bins there is the possibility of a large range of compositions placing several similar or different domes side by side, i.e.:



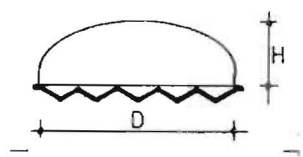
C.1. with Nº 1 bin - C.2. with Nº 2 bins



C.3. with Nº 3 bins - C.4. with Nº 4 bins .....

... C.n. with Nº "n" bins.

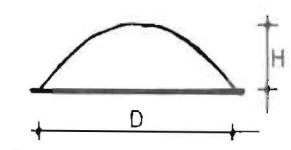
With regard to equipment and mechanization (M) we can have :



M.1.-Simple equipment for:doors, ventilation and/or lighting, but without filling and discharging equipment.

M.2.-Mobile or semifixed simple mechanization :

M.2.1. filling and discharging through screw conveyors in mobile elements assemblable one to the other.



M.2.2.-filling through chain conveyors fixed to the structure - discharging through screw conveyors in mobile elements assemblable one to the other.

M.2.3.-filling through chain conveyors fixed to the structure - discharging through belt or chain conveyors in adit.

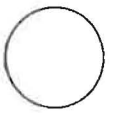
M.2.4.-filling through chain conveyors fixed to the structure - discharging through belt or chain conveyors in adit with turning extractor conveying the material in the discharging hoppers.

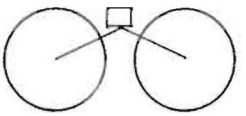
M.3.-High Mechanization

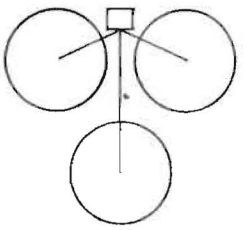
M.3.1.-filling through centralized mechanization with a distribution made through pipes which allow a natural gravitational fall - discharging through belt or chain conveyors running in adit with turning extractors conveying the material

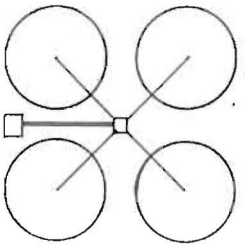
in the discharging hoppers.

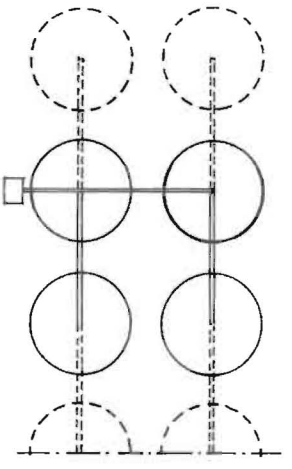
M.3.2.-filling through centralized mechanization with a distribution made through horizontal chain conveyors - discharging through belt or chain conveyors running in adit, with turning extractors conveying the material in the discharging hoppers.











With regard to use of controlled atmosphere (C.A.) : it can be adopted both for the use in bulk and in bags for any kind of Binishells structures.

GAS-TIGHT COATING

"Gas-tight coating" (IDEA-SEBINO) is a transparent varnish especially elaborated for cement gas-tightness. This varnish is an one-component product forming a very hard, elastic film, highly resistant to abrasion and to effect of most chemicals, which finds its application on porous bases (concrete in particular), efficiently permeates those bases and insures a perfect gas-tightness. It is applied preferably with a brush or a roller on a dry and dust-free surface, with normal precautionary rules regarding varnishes. It may be applied in one or more coats, with interval of 12 hours as a minimum and of 24 hours as a maximum . The film becomes hard according to DIN standard 53.157 of about 165" for a thickness of 40 microns.The abrasion is of 5 mg, according to the Taber CS 10 abrasion table for a pressure of 1000 g. The film thus formed, once hardened, is characterized by its high degree of transparence as well as its high elasticity, and its slight yellowing when exposed to light. At the end of 14 days after applying the final coat, under a temperature of 20° C and an ambient relative humidity of 50%, the maximum chemical resistance of the varnish is obtained.