# A NEW PNEUMATIC TECHNIQUE FOR THE CONSTRUCTION OF THIN SHELLS

by D. Bini *)

The paper describes a procedure for the construction of thin concrete shells that has been invented and patented by the author. The main characteristic of this technique is that the concrete is poured on a membrane in flat position on the ground and is then lifted and shaped by inflating the membrane. Details of the process are given, and questions of reinforcement, weatherproofing and cutouts are discussed.

## 1. Introduction

Thin shells made out of concrete are among the most efficient structures developed today as shown by some of the largest enclosed spaces designed so far, which are covered by thin shells.

The structural advantages presented by such shells would make their application ideal to roofs of all kinds, were it not for the problems presented by the necessity of curved forms. All over the world construction engineers have tried to simplify or to avoid the form problem in order to reduce the cost and simplify the construction of such efficient roofs.

Most persons interested in pneumatic structures are probably familiar with the balloon form, first used by the American architect Wallce Neff as early as 1942, in connection with sprayed concrete. The Neff process was used in a number of instances by Noyes and Salvadori in 1954, but the economy achieved by the repeated usage of the balloon form was not decisive in making thin shells popular, mainly because of the necessity of a scaffold from which to spray the concrete and the high expense of guniting the shell.

The process i vented, perfected, and patented all over the world by the author has most of the advantages of the Neff process and avoids most of its disadvantages. In fact, it seems well adapted to the economic construction of domes varying in diameter from a few feet up to 100 and more feet.

In view of the theme of this conference this presentation will be limited to a discussion of the Bini procedure with particular emphasis on the pneumatic form used for the erection of thin shells.

## 2. Basic Concepts

The Binishell procedure aims at:

(a) abolishing the construction of an expensive form on which to pour the concrete,
(b) speeding up the construction time of domes,
(c) using the same type of concrete regularly employed in shell construction,
(d) avoiding the positioning of reinforcement in complicated patterns,
(e) doing away with expensive special equipment on the site,
(f) performing all the building operations at ground level,
(g) obtaining a finished shell which does not require weatherproofing at a later date.

These goals are simply achieved by the following sequences of operations:

(a) A boundary foundation is prefabricated, in the shape of the perimeter of the shell, together with a slab on grade.
(b) A plastic membrane of great stretch-ability is anchored to the boundary foundation by inflating circular hoses secured to it.

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consisting of either springlike elements capable of stretching or of articulated elements capable of deforming from a flat to a curved shape without stretching (Fig. 1).

(d) Concrete is poured over the plastic membrane so as to cover the reinforcement and to provide the required thickness after forming the dome.

(e) A much thinner, stretchable plastic membrane is anchored to the foundation over the poured concrete with the dual purpose of containing the concrete during erection and of providing a coloured, weatherproofing sheet for the dome.

(f) The entire mass of concrete with its reinforcement and the external membrane is lifted into a dome shape by inflating the lower plastic membrane by means of an electric fan creating a pressure of a few tenths of one pound per square inch.

(g) The concrete mass is vibrated by a vibrator set at the top of the dome and by small vibrators moved over its external surface, in order to obtain smooth internal and external surfaces.

(h) The pressure under the membrane is kept for 12 to 24 hours and the membrane is then deflated.

(i) Openings are cut into the dome by means of a circular saw, unless provided for by templates set on the ground before pouring the concrete.

(j) The hoses at the boundary of the membrane are deflated and the loose membrane is retrieved for further use.

## 3. Technical Details of the Binishells Procedure

The materials most commonly used for the lower membrane are synthetic and natural rubber, elastomers and other plastics presenting high resistance to abrasion, like neoprene. The membrane, with thickness varying between 1/12 and 1/8 of an inch, depending on the dome span, is originally flat and acquires its shape by stretching. Membranes of high abrasive resistance may be reused a large number of times, thus reducing the cost of the pneumatic form per square foot of dome. Less resistant, but less expensive, membranes can also be used, which may be left in place, adhering to the underside of the dome. Such disposable membranes present obvious economical and practical advantages.

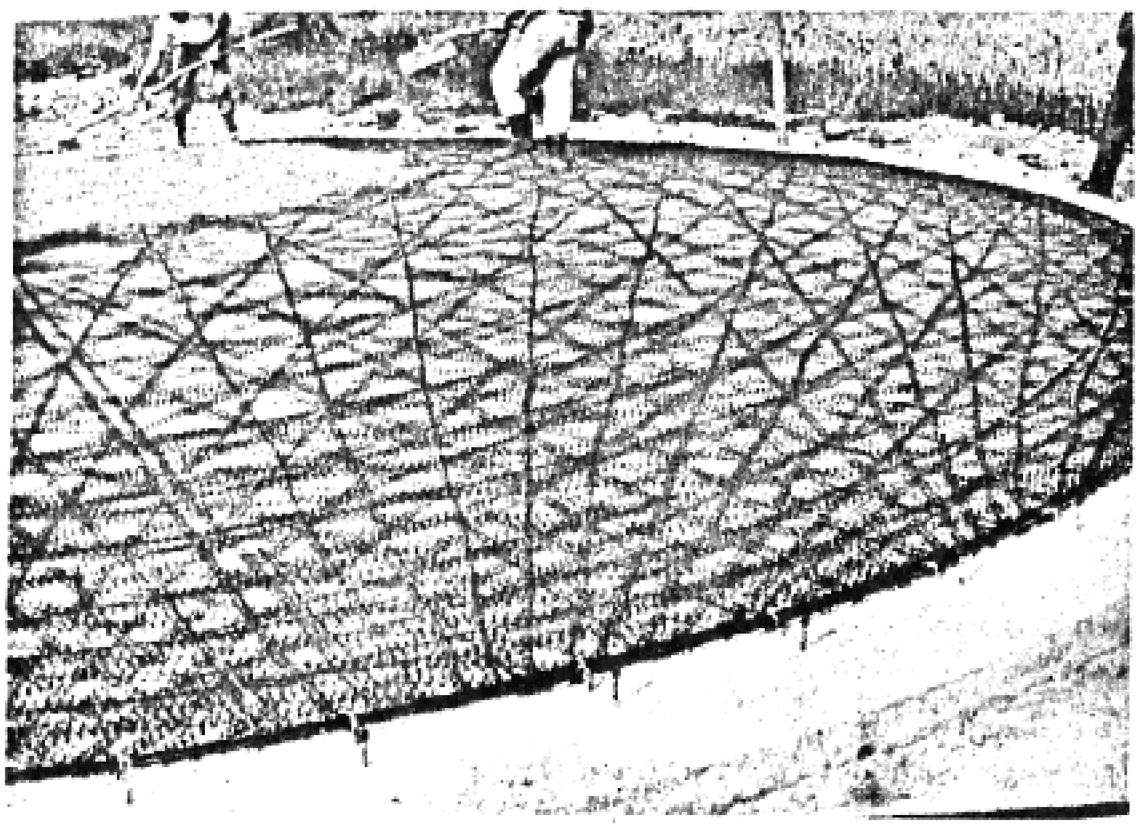

Fig. 1: Springlike reinforcement for Bini-shells

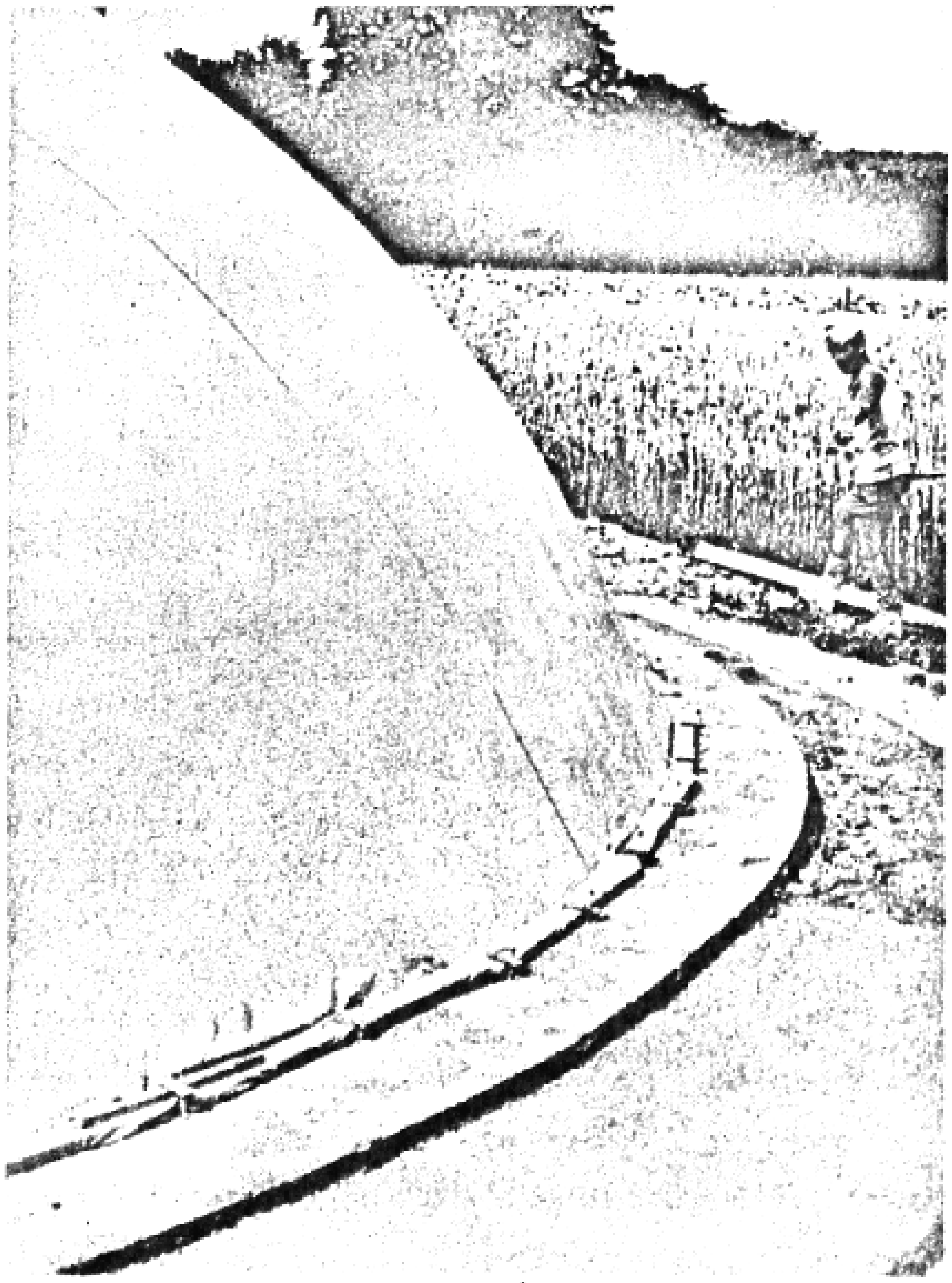

Fig. 2: Anchoring of external membrane

The external membranes consist of a thin sheet of PVC, of Hypalon, or other plastic materials, chosen essentially because of their low cost, their weatherproofing properties and their capacity to be coloured according to the wishes of the architect or the client. The external membrane is always disposable and is anchored to steel rods (set in the foundation during its construction) by wrapping the membrane in wooden slats and by threading the rods through small steel plates which clamp the membrane over the slats (Fig. 2).

The concrete used is of normal strength (anywhere from 2,000 to 3,000 psi), has a high slump (up to 6 inches) and contains is particularly fluid when poured and starts setting within about 1 hour after the start of the pouring operations.

The outside membrane, while facilitating the containment of the concrete and providing weatherproofing for the dome, is not strictly necessary and may be eliminated whenever it is uneconomical or where weatherproofing is not required by exceptionally heavy weather conditions.

The concrete contains a higher percentage of fines than regular concrete, but contains aggregates of up 1/2 inch size. Local aggregates or artificial aggregates may be used, depending on cost. Light weight aggregates have been successfully used in large span shells.

The reinforcing steel may consist of a variety of mesh types and of additional local reinforcement. The basic reinforcement consists of a square mesh of steel springs laid flat on the lower membrane and capable of stretching so as to become automatically positioned on the curved surface when the membrane is inflated (see Fig. 1). An analogous role can be played by a mesh of "chicken-coop" wire, which is laid bunched on the membrane and which is autopositioned by the membrane because of the articulations at the joints of the mesh. The spring mesh may adapt itself to a variety of final membrane shapes, while the "chicken-coop" wire mesh reaches its final position and restrains the membrane to a particular shape.

In addition to the basic reinforcement, double bars are often set around the shell boundary to absorb the minor bending moments created by the compatibility conditions. The same type of bars is also used at times around the boundary of openings in the shell. Finally, purely tensile reinforcement in the shape of thin bars or cables may be threaded through the spring of the spring mesh in order to absorb high tensile stresses in particular areas of the shell, i.e., hoop stresses due to internal loads or stress concentrations in tension around openings. Tensile cables may also be used to restrain the membrane along given lines in order to give the membrane particular shapes not obtainable by internal pressure alone.

The electric blowers required to lift the membrane is usually one 5 HP blower capable of producing a pressure of between matic regulators which actuate an intake and an exhaust valve. The pressure is maintained in the membrane for 12 to 48 hours, depending on the size of the shell, the type of concrete used, as well as on the climate.

The concrete is vibrated immediately after the membrane inflation by means of a vibrating plate set at the top of the shell. The vibration lasts a few minutes and may be followed by local vibration of the shell surface by means of small electric vibrators. As a result of the vibration, the outside and the inside surfaces of the shell are perfectly smooth when the membrane is deflated. The concrete thickness varies from 2 to 5 in for shell sizes varying between 30 and 120 ft. The concrete thickness is slightly greater at the boundary of the shell.

4. Binishells Shapes, Insulation and Weatherproofing

The Binishells technique can be used to build rotational domes on a circular base, but also smoothly curved shells on a square or a rectangular base. The sides of the shells built on a rectangular base are practically vertical. Thus the limitations, due essentially to the expensive requirements of a double form, for shells inclined by more than $30^{o}$ - $45^{o}$ to the horizontal are eliminated.

Insulation and weatherproofing are obtained by the same methods used in connection with any other type of shell. Moreover, thermal insulation may be easily obtained in very cold or very hot climates by building a second shell inside the first, which simply requires the use of the same membrane attached to the same foundation and a very minor amount of reinforcement. The space left between the outside and the inside shells may be filled with insulating materials, like plastic foams, and may be also used to incase the air-conditioning ducts and other components of the electric and mechanical systems.

Weatherproofing, beside being guaranteed by the external membrane, may be obtained by plastic materials sprayed, painted, or rolled on the outer surface of the shell. In mild climates the compactness of the concrete (due to the vibration process) eliminates the need for weatherproofing. Moreover, sealants may be added to the concrete, whenever it is deemed that they may increase the weatherproofness of the concrete in an economical manner.

## 5. Analysis and Tests of Binishells

In view of their novelty, Binishells have been submitted to model and load tests and have been analyzed mathematically. The results obtained so far indicate that these domes satisfy the static requirements of concrete structures with factors of safety of the order of magnitude of those used in accepted practice.

Model tests indicate that shells of 50 ft diameter, with a vertical opening 30 ft wide, have ultimate loads corresponding to a uniform live load of 150 $lb/ft^2$ in addition to the load of a 3 in shell. A 30 ft diameter prototype shell loaded to 30 $lb/ft^2$ through repeated cycles of loading presented an elastic behaviour without any residual displacements. Preliminary stress analyses of domes with large openings under dead load, live load, wind, earthquakes, thermal expansions and concentrated loads indicate that the stresses developed are essentially of membrane type, with minor bending stresses in the neighboorhood of the boundary of the shell and its openings.

## Conclusions

The simplicity of operations required to erect a Binishell dome and its satisfactory static conditions indicate that this procedure is capable of meeting most of the requirements for the economic erection of both small and large concrete domes

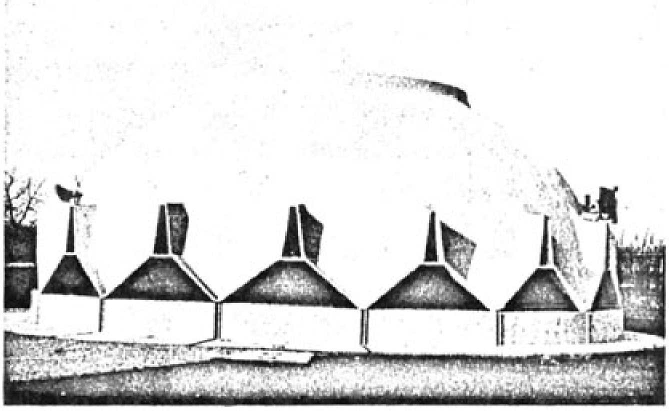

Fig. 3: Shell dome for use as office constructed by means of Binishell procedure

for a variety of uses. The domes already built are used as barns, offices (Fig. 3), one-family houses or multiple dwellings, playground roofs and storage tanks. The potential uses of Binishells are practically unlimited and depend essentially on the imagination of the architect and the engineer.

From the economic viewpoint it is to be noticed that the reduced time of conctruction allows for a fast turn-over of the capital employed in their construction, with essential reduction in financing costs.

From the practical viewpoint, the advantages of performing all construction operations at ground level and without use of particularly skilled manpower result in an increase in safety and in economy.

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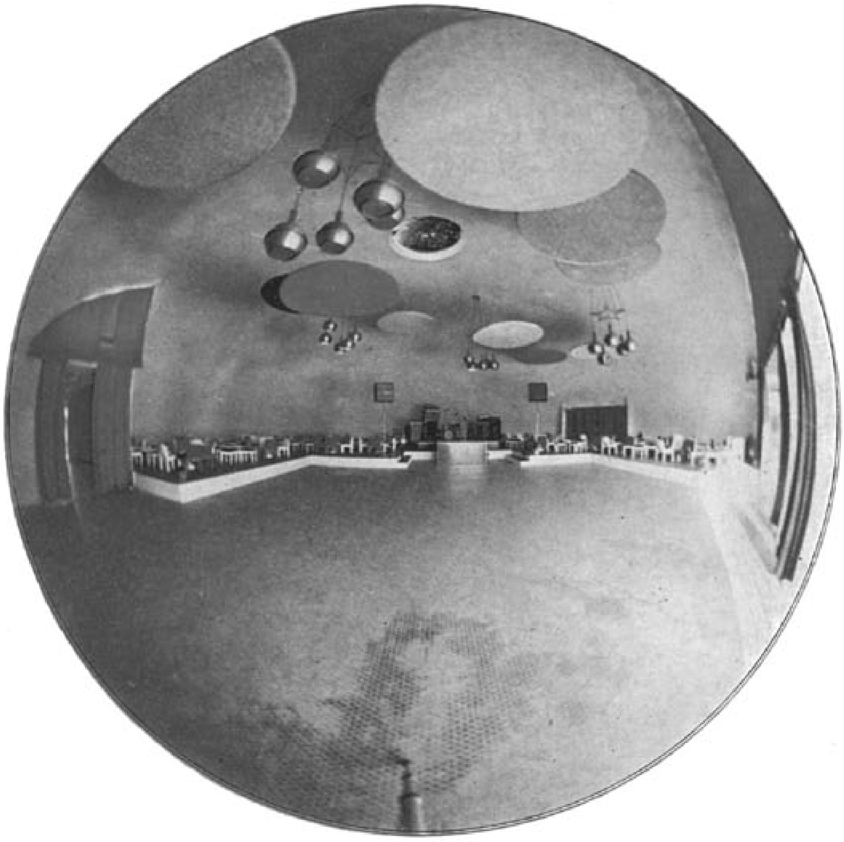
# LA PREFABBRICAZIONE

ANNO 6 APRILE 1970

## Strutture in cemento armato a formazione pneumatica



# 1

# STRUTTURE IN CEMENTO ARMATO A FORMAZIONE PNEUMATICA

NOTA REDAZIONALE

## 1 La novità della tecnologia brevettata Binishells

Questo nuovo sistema costruttivo si basa sulla preformazione pneumatica di strutture in calcestruzzo e cioè sull'impiego di una CASSAFORMA PNEUMATICA DINAMICA che solleva da terra tutti i materiali da costruzione quali per esempio: il calcestruzzo allo stato fluido, l'armatura metallica, i materiali isolanti ecc. (fig. 1).

Il procedimento è stato sviluppato dalla Soc. BINISHELLS di Milano.

In sintesi il procedimento impiega una membrana in neoprene rinforzato che viene ancorata al pavimento.

Sopra di essa si stende l'armatura metallica e si getta, a terra, uno strato di calcestruzzo fluido.

Successivamente si comprime l'aria tra il pavimento e la membrana, la quale si gonfia e solleva tutti i materiali da costruzione portandoli alla forma finale.

Raggiunta e stabilizzata la forma, si effettua la vibrazione del calcestruzzo con appositi carrelli vibranti. Dopo la presa del calcestruzzo si effettua il disarmo sgonfiando semplicemente la membrana, la quale viene reimpiegata per successivi usi.

La novità del sistema consiste appunto nella possibilità di sollevare da terra i materiali, nel dare loro contemporaneamente una forma, con grande rapidità ed economicità esecutiva, e nel consentire la realizzazione di strutture monolitiche gettate in unica soluzione, (anche di grandi dimensioni: 30-40 m di diametro) con semplici attrezzature e con modesta mano d'opera.

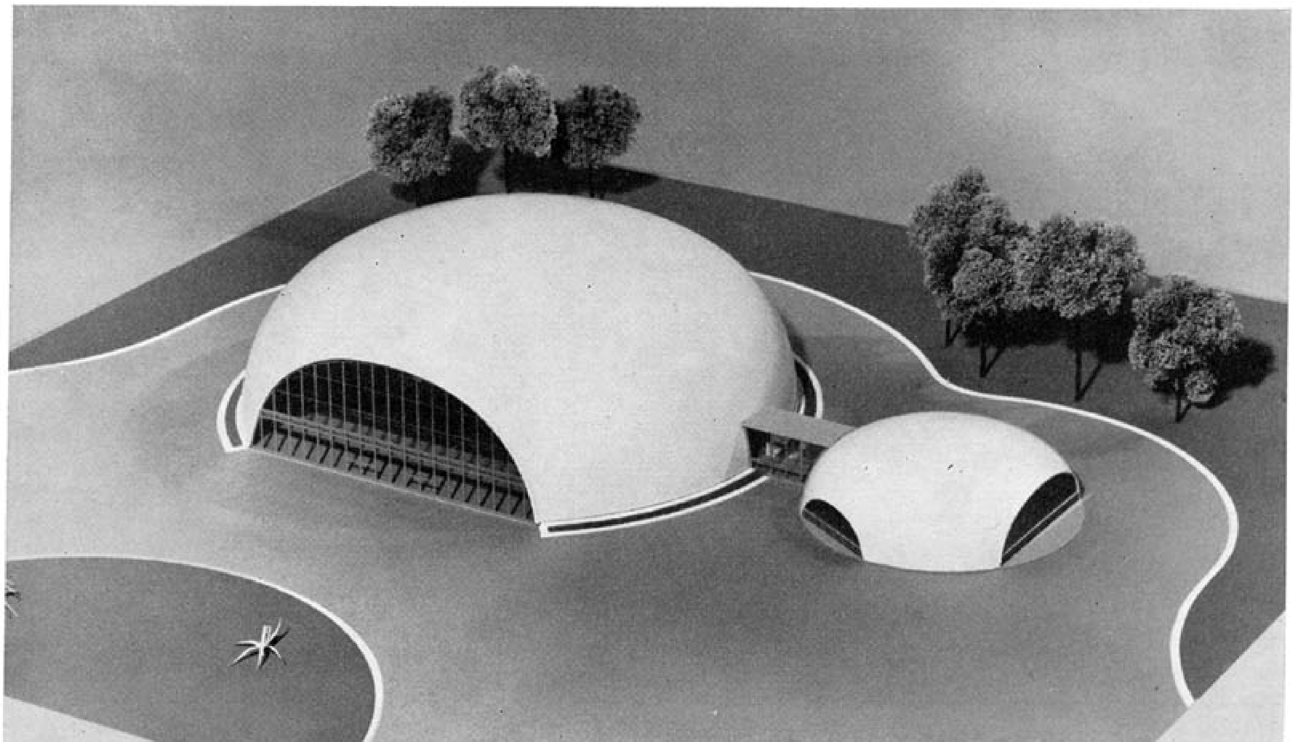


Fig. 1. Modello di palestra polivalente in cupola da 32 m di diametro con servizi indipendenti in cupola da 15 m di diametro

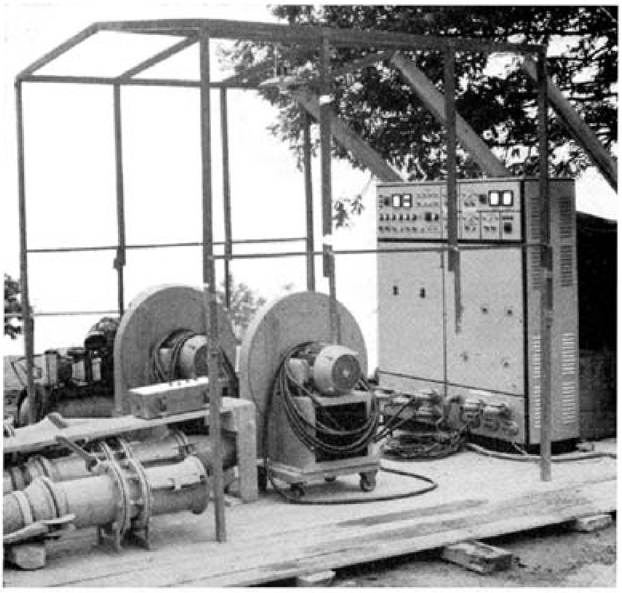


Fig. 2. Stazione di pompaggio

Fig. 3. Posa armatura a spirale

Fig. 4. Distribuzione calcestruzzo

Per esempio una struttura a cupola a base circolare da 30 m di diametro, con altezza di m 10, ed un volume chiuso di oltre mc 4.500 è realizzata in tre giorni da una squadra di 8 ÷ uomini uomini.
Le operazioni richiedono infatti due giorni per la posa della membrana e dell'armatura metallica, mentre nel terzo giorno, in un periodo di circa cinque ore, viene effettuato il getto del calcestruzzo, il sollevamento e la vibrazione della struttura. Normalmente una struttura di tali dimensioni può essere disarmata dopo 36-48 ore, mentre strutture di dimensioni inferiori possono essere disarmate anche in periodi più brevi.
Fino ad ora nella realizzazione di strutture a doppia curvatura erano state usate casseforme in legno o ferro od anche casseforme pneumatiche del tipo statico che avevano soltanto la funzione di sostituire altre casseforme rigide quali appunto quelle metalliche e in legno.
La tecnologia messa a punto dalla Società Binishells è pertanto di assoluta nuova concezione ed è stata brevettata in tutti i principali Paesi del mondo.

## 2 Dettagli tecnici

Volendo approfondire in dettaglio le modalità esecutive si possono analizzare le singole attrezzature e le varie fasi del procedimento:

a) *Cassaforma pneumatica interna.*

La cassaforma pneumatica è costituita da una membrana in neoprene rinforzato in nylon, munita di ancoraggio tubolare al bordo.
Essa viene ancorata alle fondazioni tramite un sistema brevettato che consente sia la tenuta pneumatica che la tenuta meccanica.

b) *Stazione di pompaggio* (fig. 2).

La stazione di pompaggio è costituita da uno o più elettroventilatori del tipo a bassa pressione che assorbono modeste potenze di 10-15 kW anche per strutture di grandi dimensioni.
La pressione interna per sollevare la membrana ed i materiali da costruzione, è dell'ordine di alcuni centesimi di atmosfera e normalmente varia dai 250 ai 500 mm di $H_2O$.
Il flusso ed il deflusso dell'aria avviene tramite tubazioni in cloruro di Polivinile od altri materiali, che passano al di sotto del pavimento.
Queste tubazioni possono, a costruzione finita, essere impiegate per fognature, passaggio di impianti ecc.
La regolazione dell'aria è fatta tramite normali valvole a farfalla.
La stabilizzazione della forma è effettuata creando una circolazione dell'aria e cioè insufflando aria nella cassaforma pneumatica, e facendone uscire in piccola quantità, onde evitare pulsazioni dell'intera forma.

c) *Armatura metallica.*

L'armatura metallica è costituita essenzialmente da una armatura di confezionamento e da un'armatura di rinforzo.
L'armatura di confezionamento consiste di spirali di acciaio che vengono agganciate ad una barra perimetrale ancorata alle fondazioni (fig. 3).

## Sequenza schematica del sistema

### SCHEMA OPERATIVO

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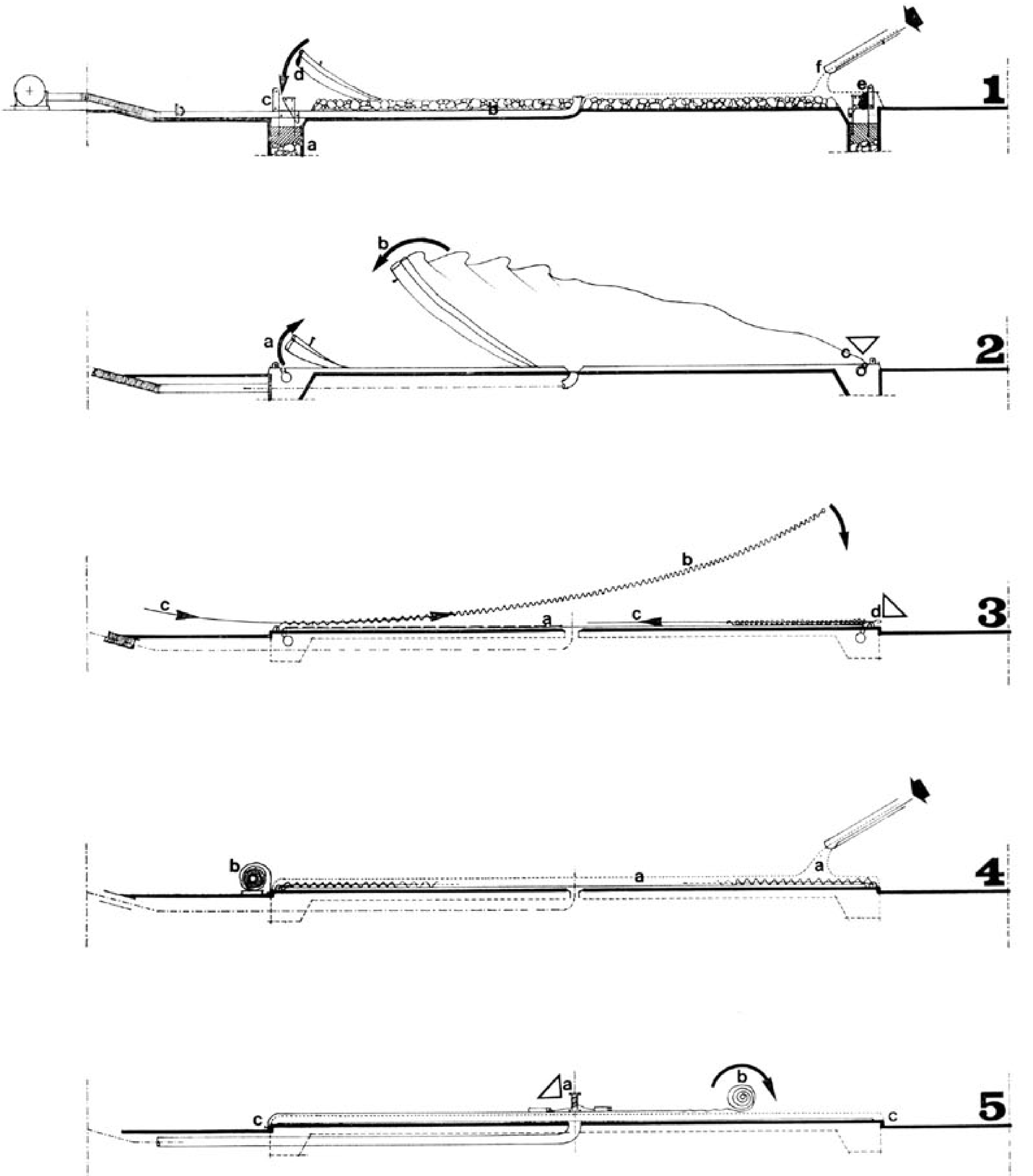
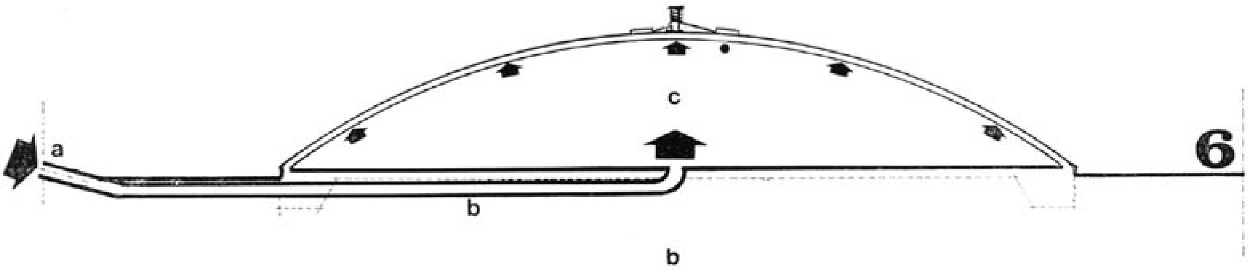


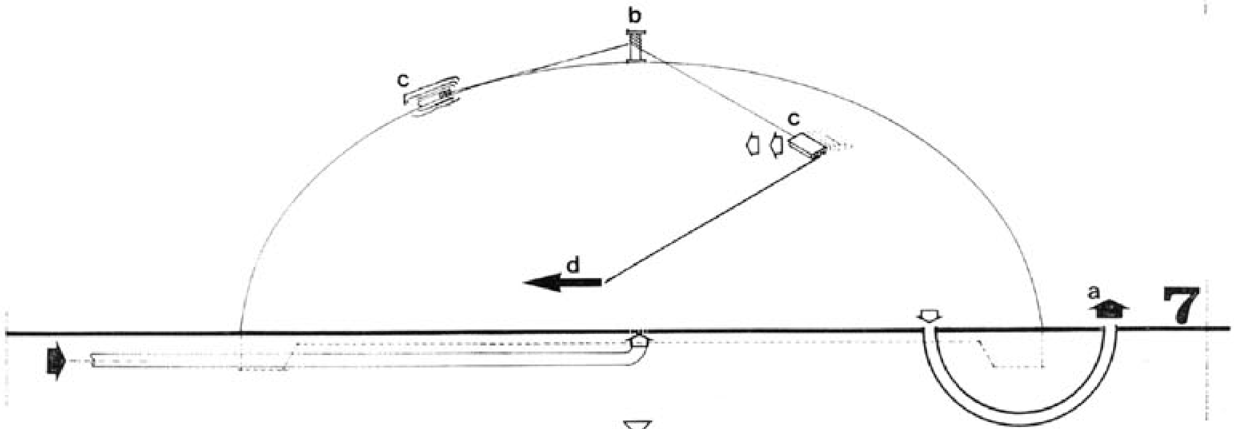

Schema 1)

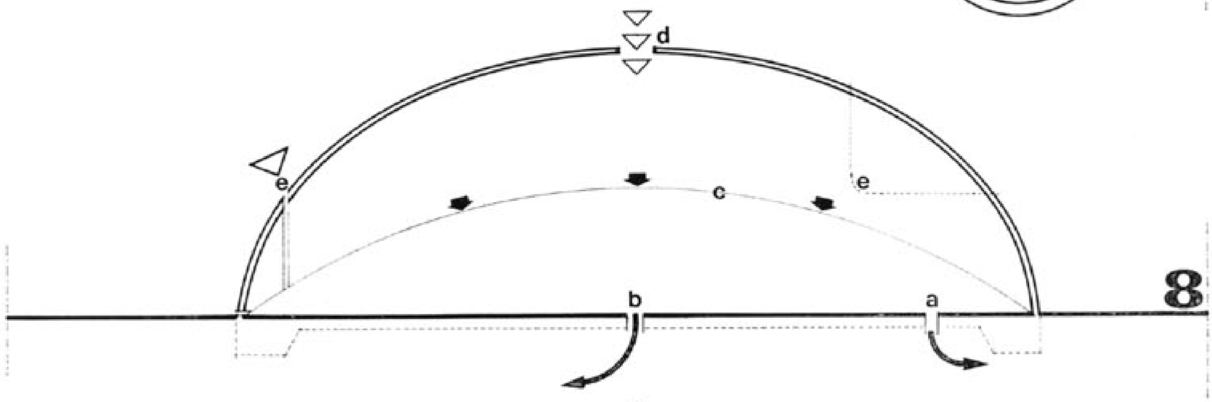
a) Scavo di fondazione circolare a sezione costante;
b) posa tubazioni di insufflaggio sotto il vespaio;
c) armatura della trave perimetrale di fondazione;
d) posa della tubazione pneumatica per realizzare la sede di ancoraggio della membrana;
e) gonfiaggio della predetta tubazione e getto contemporaneo della fondazione e della pavimentazione interna.

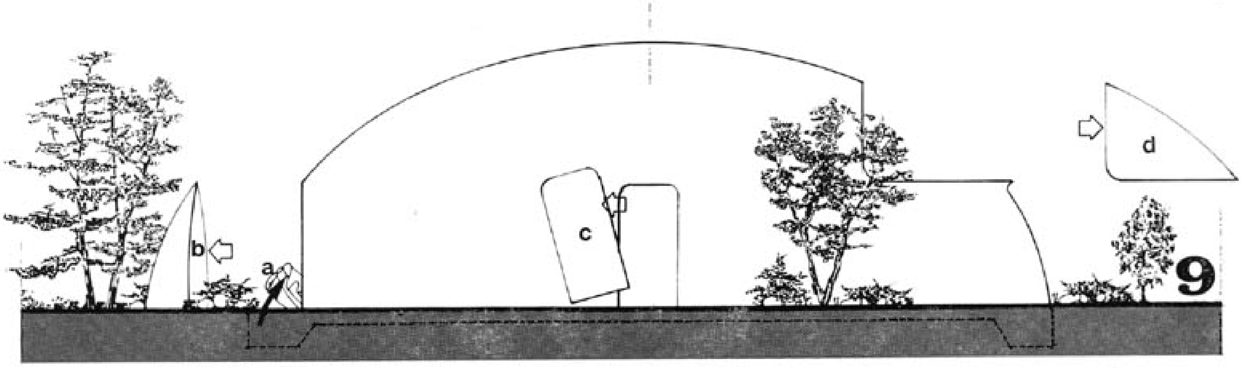
Schema 2)

a) Sgonfiaggio della tubazione pneumatica a presa avvenuta e relativa estrazione della medesima;
b) stendimento e posa in opera della membrana con inserimento del relativo ancoraggio tubolare;
c) gonfiaggio della tubazione di ancoraggio collegata alla membrana alla pressione occorrente per la tenuta pneumatica.




Schema 3)

a) Eventuale disposizione di materiale isolante termo-acustico, da sollevarsi con gli altri materiali da costruzione;
b) aggancio e distribuzione, secondo uno schema prefissato, delle spirali previste nello speciale sistema di armatura dinamica;
c) esecuzione dell'armatura statica mediante inserimento di tondini in acciaio all'interno delle spirali che costituiscono sede di scorrimento degli stessi in fase di sollevamento;
d) aggancio dell'armatura meridiana ad un ferro perimetrale di bordo costituente cerniera.

Schema 4)

a) Getto a terra di normale calcestruzzo additivato di ritardanti di presa;
b) predisposizione della membrana esterna da sovrapporre al calcestruzzo.

Schema 5)

a) Installazione delle apparecchiature di vibrazione collegate in corrispondenza del polo;
b) posa della membrana esterna;
c) ancoraggio della stessa al bordo.

Schema 6)

a) Avviamento dell'elettroventilatore;
b) insuflaggio dell'aria attraverso le predisposte tubazioni;
c) azione della sovrapressione interna (alcuni centesimi di atmosfera) occorrente al graduale sollevamento dell'intero sistema.

Schema 7)

a) Stabilizzazione della forma mediante continua compensazione e ricambio del volume d'aria interna;
b) rocchetto di avvolgimento dei cavi alimentazione dei vibratori elettrici;
c) carrelli vibranti a rulli in azione sulla intera superficie esterna;
d) schema di traino dei carrelli.

Schema 8)

a) Disarmo della struttura mediante apertura delle valvole di uscita;
b) arresto dell'elettroventilatore ed ulteriore fuoriuscita d'aria dalla stessa tubazione di mandata;
c) discesa graduale della pneumoforma;
d) apertura di comunicazione con l'esterno a pressione atmosferica;
e) taglio di apertura.

Schema 9)

a) Disancoraggio e recupero della pneumoforma disponibile subito per ulteriori utilizzazioni;
b) interventi di carattere architettonico.

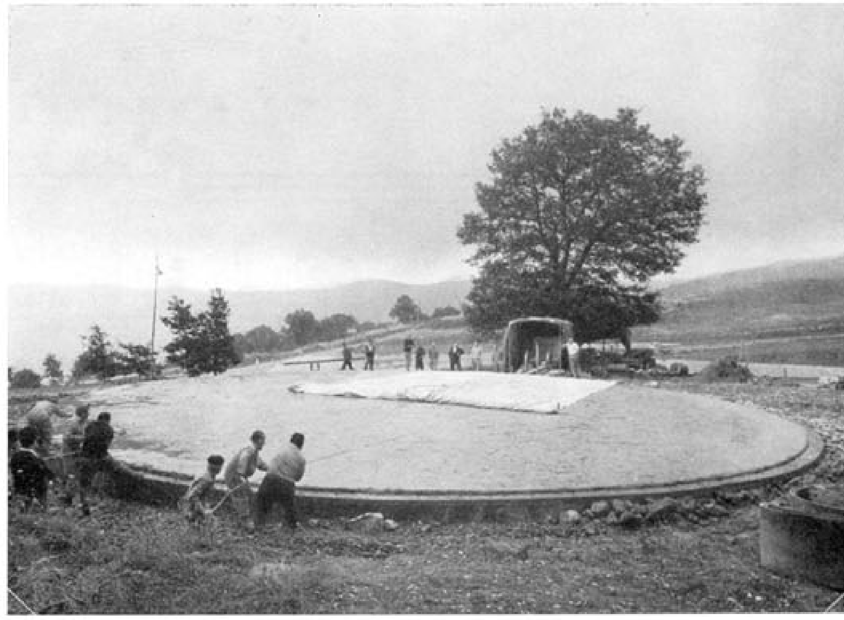


Fig. 5. Posa telo di plastica esterno

Queste spirali sono fabbricate con passo chiuso e quindi occupano un piccolo volume e possono facilmente essere imballate e trasportate in cantiere.
Per ogni struttura si hanno 10-15 tipi di lunghezza di spirali e la posa è effettuata con grande facilità direttamente sul piano di lavoro, secondo un disegno standard ed effettuando sempre le stesse operazioni qualunque sia il tipo di struttura.
L'armatura di rinforzo consiste in tondini rettilinei di diametro variabile da 4 a 8 mm che vengono infilati nell'interno delle spirali e lasciati liberi di scorrere.
Durante il sollevamento le spirali si deformano ed i tondini si autoposizionano e scorrono mantenendo peraltro nella posizione finale le necessarie sovrapposizioni onde assicurare la continuità dell'armatura.
Le funzioni delle spirali sono molteplici ed essenzialmente le seguenti:

— trattenimento del calcestruzzo onde evitarne la caduta durante il sollevamento;
— mantenimento dello spessore del calcestruzzo;
— sollevamento e posizione delle barre di rinforzo;
— controllo del sollevamento e della forma.

La forma della struttura deriva sia dal tipo della cassaforma pneumatica, sia dal tipo e dal lavoro di deformazione delle spirali.
Variando infatti le spirali, si può variare la forma in una vasta gamma di possibilità.
La posa dell'armatura richiede da 1 a 2 giorni per strutture di dimensioni variabili da 15 a 30 m di diametro, con una squadra di 6-8 uomini.

d) *Getto e caratteristiche del calcestruzzo.*

Il calcestruzzo è costituito da un normale impasto di notevole fluidità.
Le caratteristiche dell'impasto sono in linea di massima le seguenti:

| | |
|---|---|
| Sabbia | 57% |
| Ghiaietto (max 12-15) | 43% |
| Cemento | 4 q.li/mc |
| Acqua | 0,50 A/c |

Per consentire il getto del calcestruzzo, il suo sollevamento e la vibrazione, prima della presa, vengono impiegati normali additivi ritardanti e plastificanti, facilmente reperibili sul mercato, in dosi tali da non alterare il costo e le caratteristiche del calcestruzzo.
Il getto viene normalmente effettuato tramite autobetoniere versando il calcestruzzo sulla membrana e distribuendolo con normali frattazzi (fig. 4).
Lo spessore a terra del calcestruzzo è dato dallo stesso spessore delle spirali.

Durante il sollevamento con l'aumentare della superficie, lo spessore dell'armatura metallica diminuisce e così pure lo spessore del calcestruzzo.
Comunque tutto il sistema è calcolato in modo che nella forma finale si abbiano gli adeguati ricoprimenti dell'armatura metallica.

Come già detto, il trattenimento del calcestruzzo durante il sollevamento è fatto dall'armatura metallica,

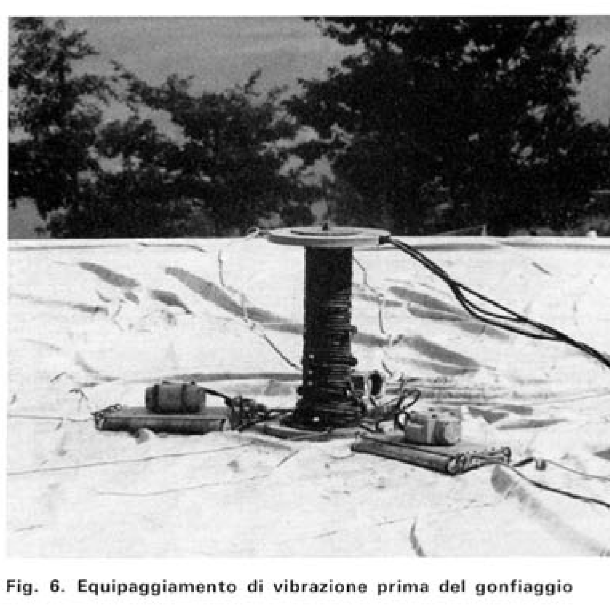


Fig. 6. Equipaggiamento di vibrazione prima del gonfiaggio

Fig. 7. Fase di gonfiaggio - metà sollevamento

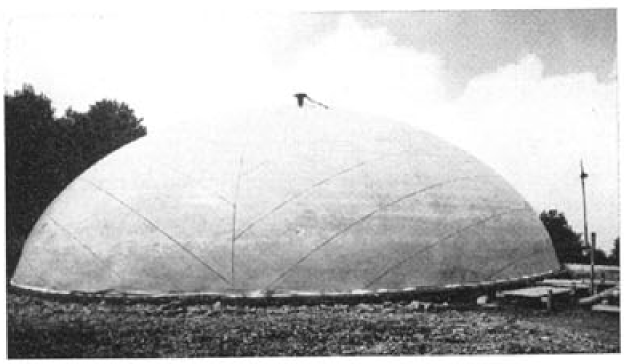


Fig. 8. Cupola a sollevamento ultimato

comunque, per proteggere il getto e consentire la vibrazione, viene posato sopra il getto stesso un telo in PVC come descritto di seguito.

e) *Cassaforma esterna.*

Sopra al getto di calcestruzzo, prima del sollevamento, viene posato un telo di cloruro di polivinile (fig. 5).
Questo telo è ugualmente ancorato alle fondazioni con un sistema semplice e rapido.
Durante il sollevamento questo telo esterno entra in tensione comprimendo il calcestruzzo.
Le funzioni di detto telo esterno sono essenzialmente le seguenti:

— consentire la protezione del getto sia dalle pioggie, sia dalla forte evaporazione dovuta all'irraggiamento solare;
— aiutare il trattenimento del calcestruzzo;
— consentire la vibrazione come descritto di seguito.

f) *Vibrazione.*

Prima del sollevamento, nel centro della struttura, viene posato tutto l'equipaggiamento di vibrazione che viene sollevato unitamente alla struttura (fig. 6-7-8).
La vibrazione è effettuata dopo l'ultimazione del sollevamento, tramite vibratori ad alta frequenza (6000-8000 Hz) montati su carrelli a rulli.
I carrelli ancorati ad un cilindro posato nella parte polare della struttura, vengono trascinati verso il basso, descrivendo delle striscie simili ad elicoidi.
Ogni vibratore descrive una striscia che si sovrappone parzialmente alla striscia descritta dagli altri vibratori così da consentire una totale costipazione e vibrazione della superficie (fig. 9).

g) *Presa e disarmo del getto.*

Il calcestruzzo della struttura, dopo la stabilizzazione e vibrazione, effettua la presa e l'indurimento tra due membrane ad alta impermeabilità, con una graduale evaporazione dell'acqua ed assolutamente protetto dagli agenti atmosferici.
I dispositivi usati, l'evaporazione controllata dell'acqua, l'accelerazione di presa dovuta sia al calore proprio sia all'irraggiamento solare, consentono di eliminare i fenomeni di ritiro e di avere strutture perfettamente monolitiche e prive di fessurazioni.
Normalmente le strutture vengono disarmate dopo 1-3 giorni a seconda delle dimensioni e delle condizioni atmosferiche.
Prima del disarmo si effettuano le prove di indurimento del materiale e quindi si procede allo sgonfiaggio della membrana ed al disarmo della struttura senza alcun pericolo.
A volte particolari condizioni atmosferiche ed un forte irraggiamento solare consentono una notevole accelerazione della presa.
Trascorso un adeguato periodo di tempo si esegue una apertura nella struttura, si entra all'interno e si recupera la membrana per successivi reimpieghi.

h) *Aperture nella struttura.*

Le aperture nella struttura vengono fatte con normali seghe circolari (fig. 10).

Fig. 9. Vibrazione della struttura a sollevamento ultimato

Fig. 10. Taglio delle aperture con flessibile

Fig. 11. Esempio di cupola da 10 x 10 m su pilastri

Naturalmente ove possibile, si può evitare di porre l'armatura di rinforzo nelle parti da eliminare e la si concentra ai bordi dei tagli.
Qualora il calcolo statico lo richieda, prima di effettuare le aperture, vengono fatti dei rinforzi statici sia con piccoli getti di calcestruzzo armato, sia con elementi di ferro.

i) *Trasporti e reimpieghi delle attrezzature.*

Tutte le attrezzature sono facilmente trasportate su automezzo e si ha quindi la possibilità di un rapido spostamento del cantiere di lavoro anche a grandi distanze con notevoli economie.
Gli investimenti delle attrezzature sono molto modesti ed il loro ammortamento ha una bassa incidenza, sia a causa del limitato costo, sia per la loro alta reimpiegabilità.

## 3 Forme ed utilizzazioni

Questa tecnologia consente di realizzare solidi a doppia curvatura ottenuti dalla deformazione di sistemi elastici o aventi forme geometricamente definite.
Naturalmente sono state sviluppate per prime strutture geometriche più elementari quali appunto settori sferici, ellissoidi di rotazione, cupole a base quadrata (fig. 11).
Come già accennato la forma della struttura può essere variata sia variando le caratteristiche e la composizione delle spirali metalliche su una stessa membrana, sia può essere data anche con una diversa forma e diverso ancoraggio della cassaforma pneumatica stessa.
Queste strutture possono essere realizzate direttamente su fondazioni e pavimenti partenti da terra (fig. 12) oppure possono essere *realizzate su strutture tradizionali in elevazione*, precedentemente costruite (fig. 13).
In questo secondo caso il sistema costituito da membrana e armatura metallica, anzichè essere ancorato ad un perimetro di fondazione, sarà ancorata ad una trave portata dalle strutture sottostanti.
Le caratteristiche della tecnologia, i bassi investimenti richiesti nelle attrezzature, la duttilità di applicazione delle medesime, consentono di affrontare programmi di diverse ed opposte caratteristiche quali:

— *produzioni di massa:*

generalmente produzione di strutture di piccole e medie dimensioni nello stesso cantiere per villaggi, coperture ecc.

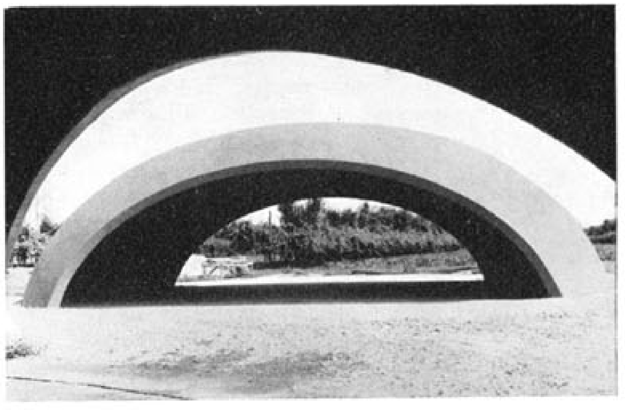


Fig. 12. Esempio di cupola con imposta a quota terreno

Fig. 13. Esempio di cupola costruita su elementi prefabbricati

— *produzioni singole:*

generalmente di costruzioni di grandi dimensioni e di strutture speciali.

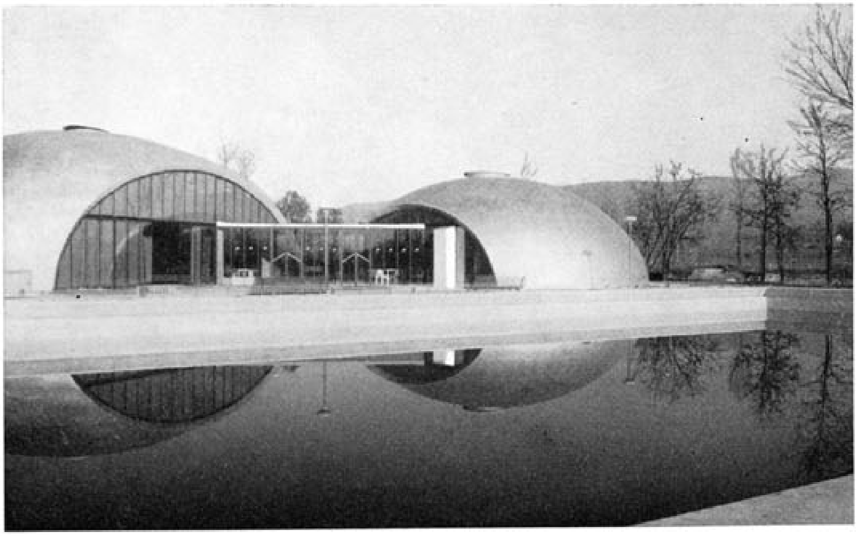
I campi di applicazione sono molteplici e si citano quelli che si prospettano i più interessanti:

— Case di abitazione: ad uso turistico e per nuovi villaggi, ecc.
— Edifici sportivi: palestre, piscine ecc.
— Edifici sociali: scuole, asili, centri ricreativi ecc.
— Edifici ad uso commerciale: saloni di vendita, ristoranti, supermarket.
— Edifici ad usi industriali ed agricoli — sia con il sistema della cupola partente da terra, sia con la produzione di massa di cupole a base quadrata su pilastri.
— Edifici a scopi militari.

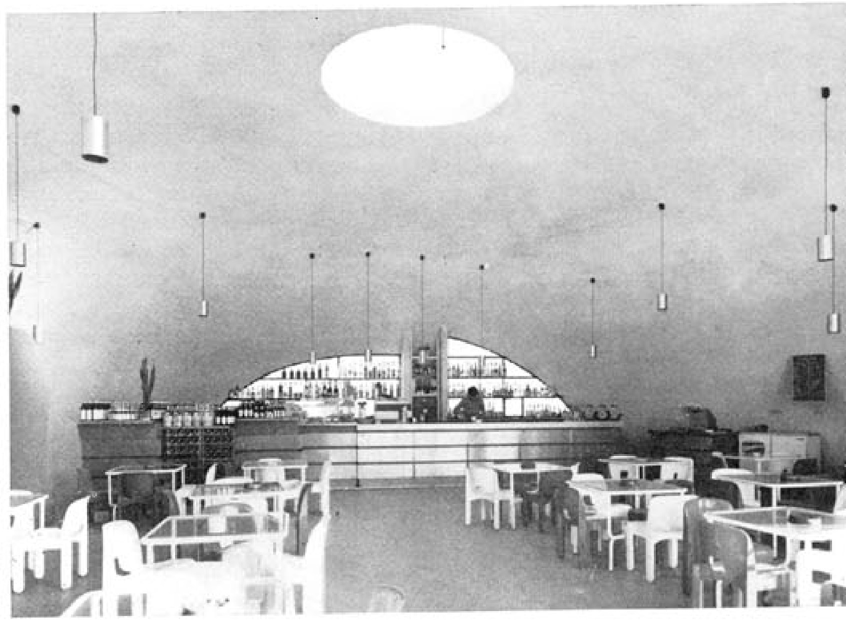
## 4 Standardizzazione del lavoro e libertà di progettazione

Questo sistema offre, da un lato le possibilità di standardizzazione e ripetizione del lavoro e dall'altro consente una libera progettazione.
Infatti il procedimento esecutivo è lo stesso qualunque siano le dimensioni della struttura.
I materiali d'altra parte, possono essere preordinati e standardizzati.
Naturalmente le caratteristiche della tecnologia portano i maggiori vantaggi in una produzione di massa ma sono anche molto evidenti nella realizzazione di strutture singole di grandi dimensioni.
Infatti una grande struttura viene realizzata sul posto con modeste incidenze di attrezzature e di trasporti e con una grandissima rapidità.
Con una stessa attrezzatura ci si può spostare nell'intero territorio Nazionale senza necessità di costosi investimenti e trasporti.
D'altra parte la possibilità di eseguire aperture nelle strutture, di effettuare i collegamenti e le intersezioni di più strutture, consente una grande libertà di progettazione e quindi la possibilità di risolvere molteplici problemi senza vincoli strutturali.
La possibilità, inoltre di utilizzare con la stessa tecnologia altri materiali, in sostituzione del calcestruzzo, apre nuovi orizzonti che si svilupperanno con il progredire della tecnologia dei materiali e con l'evolversi della regolamentazione nel settore delle costruzioni.
L'impiego, infatti di altri leganti, di calcestruzzi alleggeriti, di materie plastiche ecc., sarà agevolato da questa nuova tecnologia.
Per questi motivi riteniamo che la tecnologia Binishells sia un nuovo e sensibile passo avanti nella industrializzazione dell'edilizia.

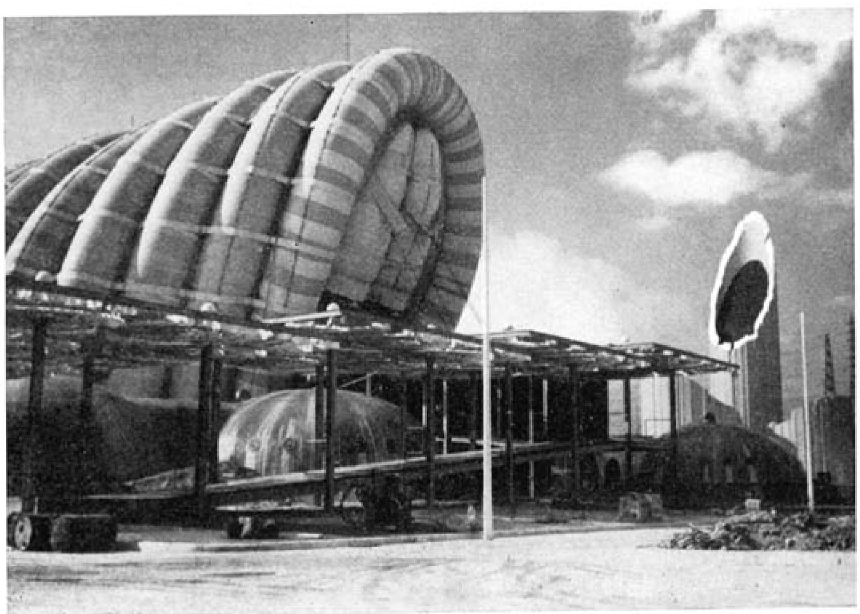
## ULTIME REALIZZAZIONI BINISHELLS



Centro ricreativo presso Arezzo costituito da n. 1 cupola da 20 m di diametro e da n. 1 cupola da 15 m di diametro con piscina all'aperto.



Centro ricreativo presso Arezzo: interno



Expo '70 ad Osaka (Giappone): Fuji Pavillion - n. 8 cupole da 12 m di diametro.


Atomic Energy Commission: realizzazione del Centro Dimostrativo Nucleare a San Paolo (Brasile) in n. 3 cupole da 25 m di diametro.
(tempo di realizzazione: 1 mese)

# Increasing Inflation Cuts Costs

*This paradox was made possible by a strikingly simple technique for building bubble-shaped reinforced concrete structures which employs a flexible, airtight membrane of rugged Du Pont neoprene synthetic rubber*

BY PETER HOWARD

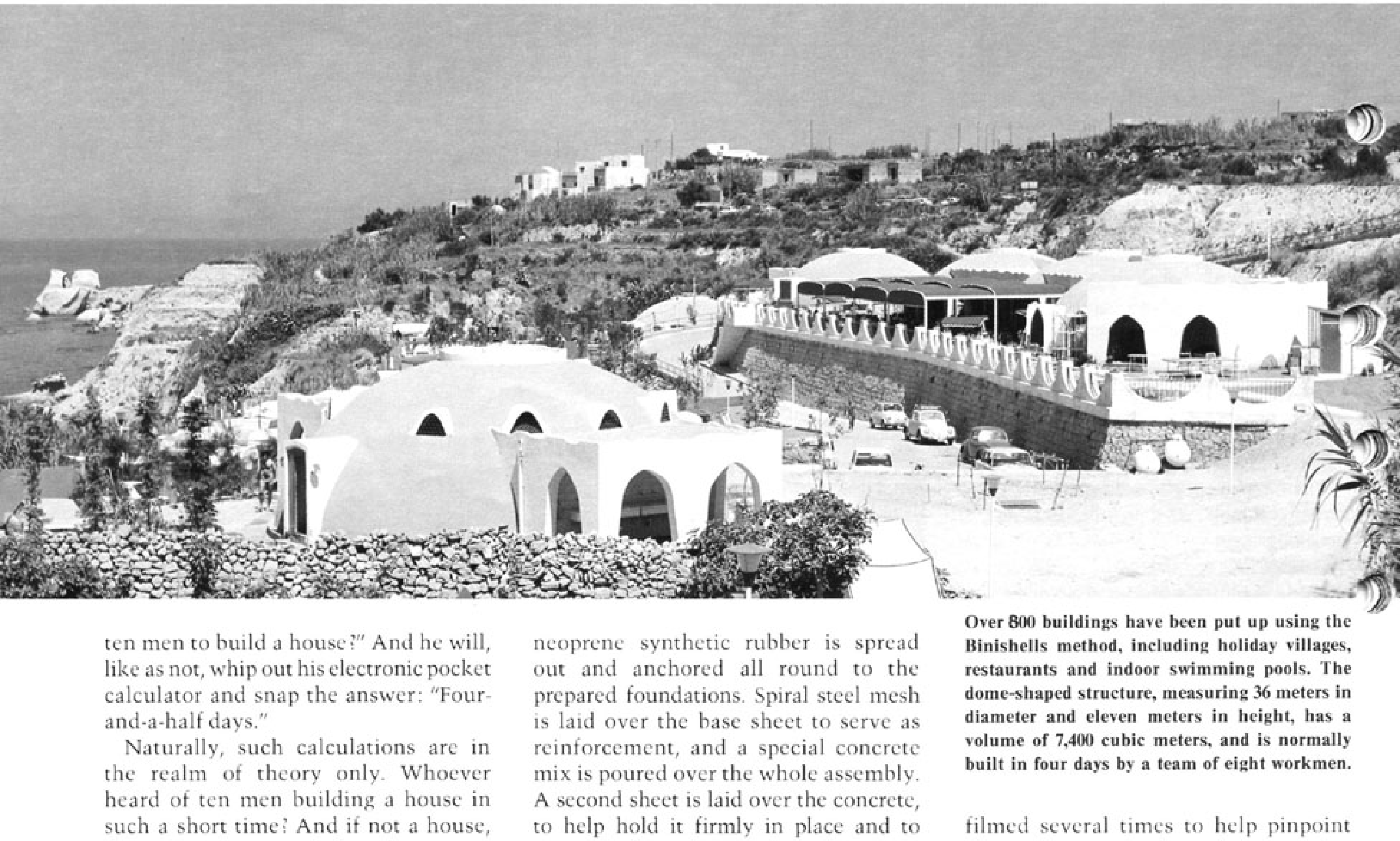
In this electronic gadget age, old brain teasers are out of fashion. Ask a typical ten-year-old this one: "If it takes a man-and-a-half a month-and-a-half to build a house-and-a-half, how long will it take ten men to build a house?" And he will, like as not, whip out his electronic pocket calculator and snap the answer: "Four-and-a-half days."

Naturally, such calculations are in the realm of theory only. Whoever heard of ten men building a house in such a short time? And if not a house, then even less a reinforced concrete dome eleven meters high and 36 meters in diameter?

Ask Alberto Michelagnoli how long it takes eight men to build such a dome, and he will reply with a smile that it can be done in four normal working days. And he can prove it. Michelagnoli is general manager of Binishells S.p.A., of Milan, Italy, a small but growing company which seems likely to set some time-honored building techniques on their heads.

To build a dome-shaped structure with his patented system, an air-tight sheet of nylon-reinforced Du Pont neoprene synthetic rubber is spread out and anchored all round to the prepared foundations. Spiral steel mesh is laid over the base sheet to serve as reinforcement, and a special concrete mix is poured over the whole assembly. A second sheet is laid over the concrete, to help hold it firmly in place and to protect it from the weather. Then air is pumped under the lower sheet which rises to form a bubble, lifting the concrete into the desired shape. 36 hours later when the concrete is dry and firm, the sheet is deflated and removed, leaving the self-supporting concrete shell-like dome ready for further work, such as cutting windows and doors.

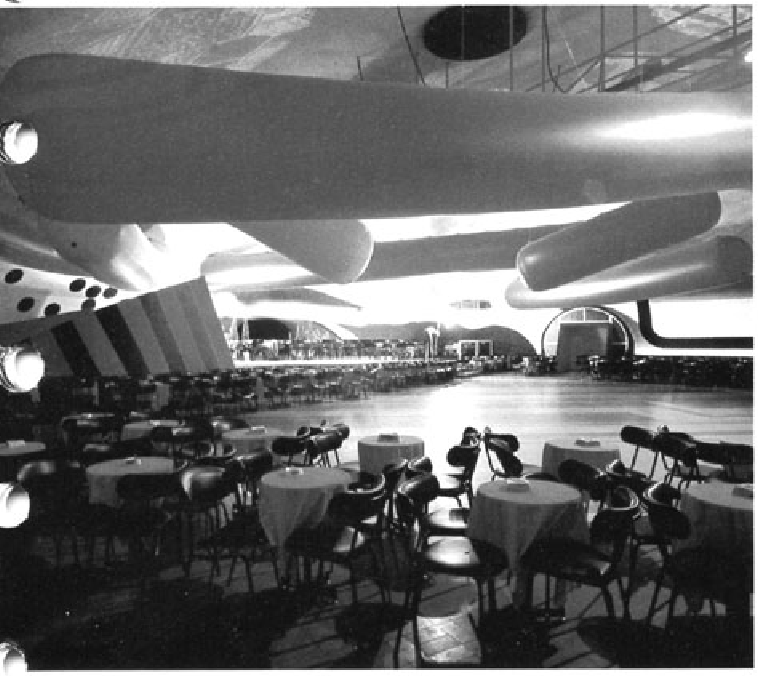
"This sounds simple," says Michelagnoli, "and in principle it is. But when we began our experiments in 1966, everything went wrong at first." For example, the lifting of the membrane was uneven, and this created slippage of the concrete. The whole process was

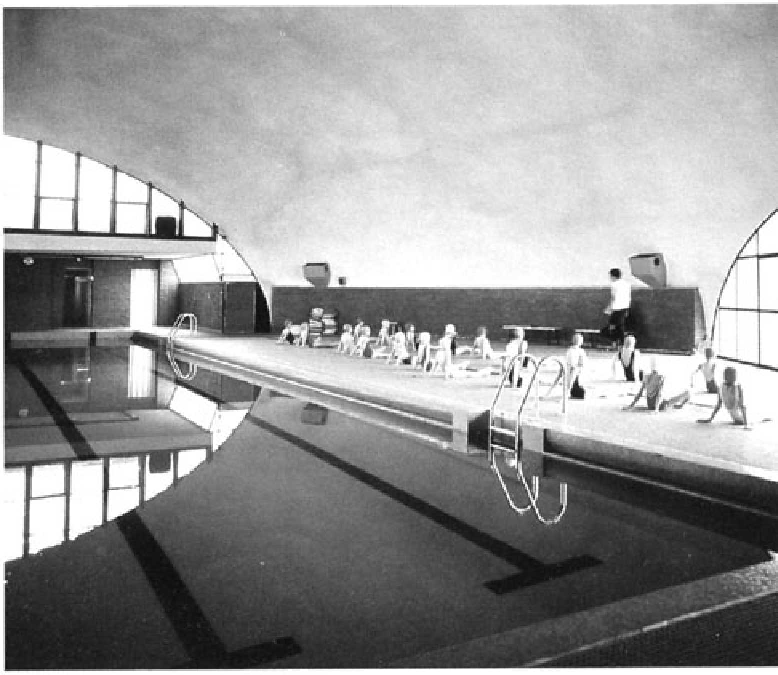


**Over 800 buildings have been put up using the Binishells method, including holiday villages, restaurants and indoor swimming pools. The dome-shaped structure, measuring 36 meters in diameter and eleven meters in height, has a volume of 7,400 cubic meters, and is normally built in four days by a team of eight workmen.**

filmed several times to help pinpoint the weaknesses in the technique. After a lot of trial and error the Binishells team developed a system of reinforcing the concrete with spiral steel mesh; special high-frequency vibrators were designed for compacting the setting concrete; and a computer was put to work to calculate how to position and control them. "It took three years to get all the bugs out of the technique," says Michelagnoli. "About the only part of the system which never gave any trouble was the neoprene sheeting." (The designation of the Binishells construction technique comes from Dr. Dante Bini, the Italian architect who had the first patentable idea for the system.)

This Du Pont synthetic rubber was selected for a number of reasons. "We needed a rugged material which would take the rough handling that any equipment gets on a building site," he explains. "It had to be abrasion-resistant for the workmen to walk over it while laying the steel spirals and spreading the concrete. It had to be resistant to the chemical liquidizing and retarding additives we use in our concrete, and





it had to have high strength to stand up to the stretching process when the membrane lifts the bubble off the ground."

For the builder, the advantages of the Binishells system are numerous. The equipment needed is simple and inexpensive, and the neoprene membrane can be re-used many times. The labor element is low; construction is astonishingly fast. A dome-shaped structure, 36 meters in diameter and eleven meters high, with a volume of 7,400 cubic meters, is normally built in four days by a team of eight workmen. The first two days are taken up with the laying of the first neoprene membrane and the steel reinforcement over it; the concrete is poured in about five hours on the third day; the structure is lifted – about another half day – and vibrated. The concrete sets in 36 hours, and the lower neoprene sheet can then be deflated and removed.

For the architect the system is attractive because openings for doors and windows can be cut with great freedom, using a circular saw. Several domes can be placed adjoining each other, in order to enclose bigger volumes or to achieve various floor plans. The simplicity of the method makes accurate cost estimates easy. Binishells structures are not limited to foundations at ground level: with the help of a temporary supporting floor, they can be built on columns or other supporting structures on which the dome is inflated.

An architect who has used the system is Piero Benenti, in charge of the design of municipal sports construction in the city of Turin, home of Italy's automobile industry. Under his direction workmen have just put the finishing touches to a multi-purpose double-dome sports hall which is suitable for a variety of indoor activities such as basketball, gymnastics, judo, boxing and table-tennis, to name just a few. Up to 2,000 people can watch the sporting activities in the hall. "The Binishells method is a real advance in building technology," he enthuses. "It is an intelligent way of enclosing large volumes such as sports halls and churches. The building is light and airy, needing no internal supports; it is incredibly fast to put up, and the costs are modest." As an afterthought he adds: "I don't need to stress the importance of this last point to any municipal architect."

The two domes of Benenti's construction, each 36 meters in diameter, are joined in the middle where they overlap. Maximum internal height from the floor to the top of each dome is 13 meters, "but two meters of this is excavation," Benenti explains. "The actual height of the dome built with the Binishells method is eleven meters." The erection of each dome took just four days, from spreading the base neoprene sheet to its final removal, leaving the concrete dome firmly standing.

Mario Panciroli of Milan, the largest city in industrial northern Italy, confirms Benenti's views. Panciroli designed a 25-meter-long swimming pool, which is housed in a single 36-meter-diameter Binishells dome. It was completed late in 1974.

"This was the first time I worked with the Binishells system – but certainly not the last," he says. "It has tremendous technical merit and is less expensive than any other system I know of for permanent buildings."

The thickness of the concrete in a dome of 36 meters diameter, such as the two described, varies from 12 centimeters at the base to about five centimeters near the top. Is such a thin shell perfectly safe? To this question Benenti anwers: "A municipal architect

*continued*

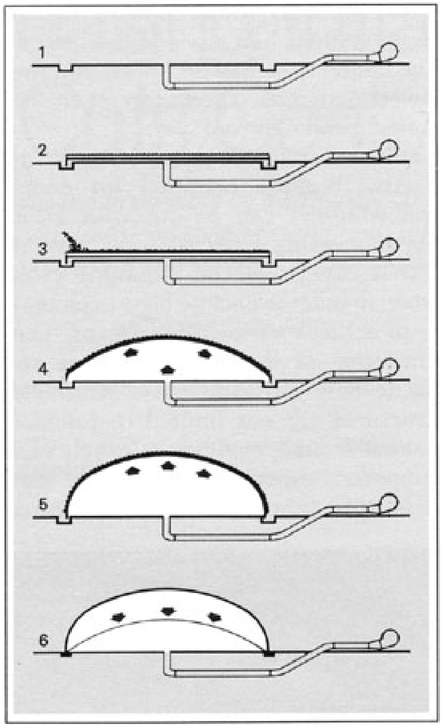
# Increasing Inflation Cuts Costs

cannot afford to take risks." Both architects agree that the system has only one drawback, and that is a minor one: it is relatively difficult to cut the openings for doors and windows with real precision.

When asked what types of building *can* be put up with this system, Michelagnoli says: "Your imagination is the only limit. More than 800 buildings have been put up using the Binishells method, including sports halls, indoor swimming pools and tennis courts, schools, social centers, filling stations, cinemas and holiday bungalows. And there are churches and private villas, restaurants, industrial buildings such as warehouses, electricity substations, and silos... the list of what *can* be built is virtually inexhaustible. The technique is suitable for any climate. It has been used in Italy, France and the United Kingdom, North and South America, Japan and in several Middle Eastern countries. Atmospheric conditions influence only the length of time th[e] concrete takes to set."

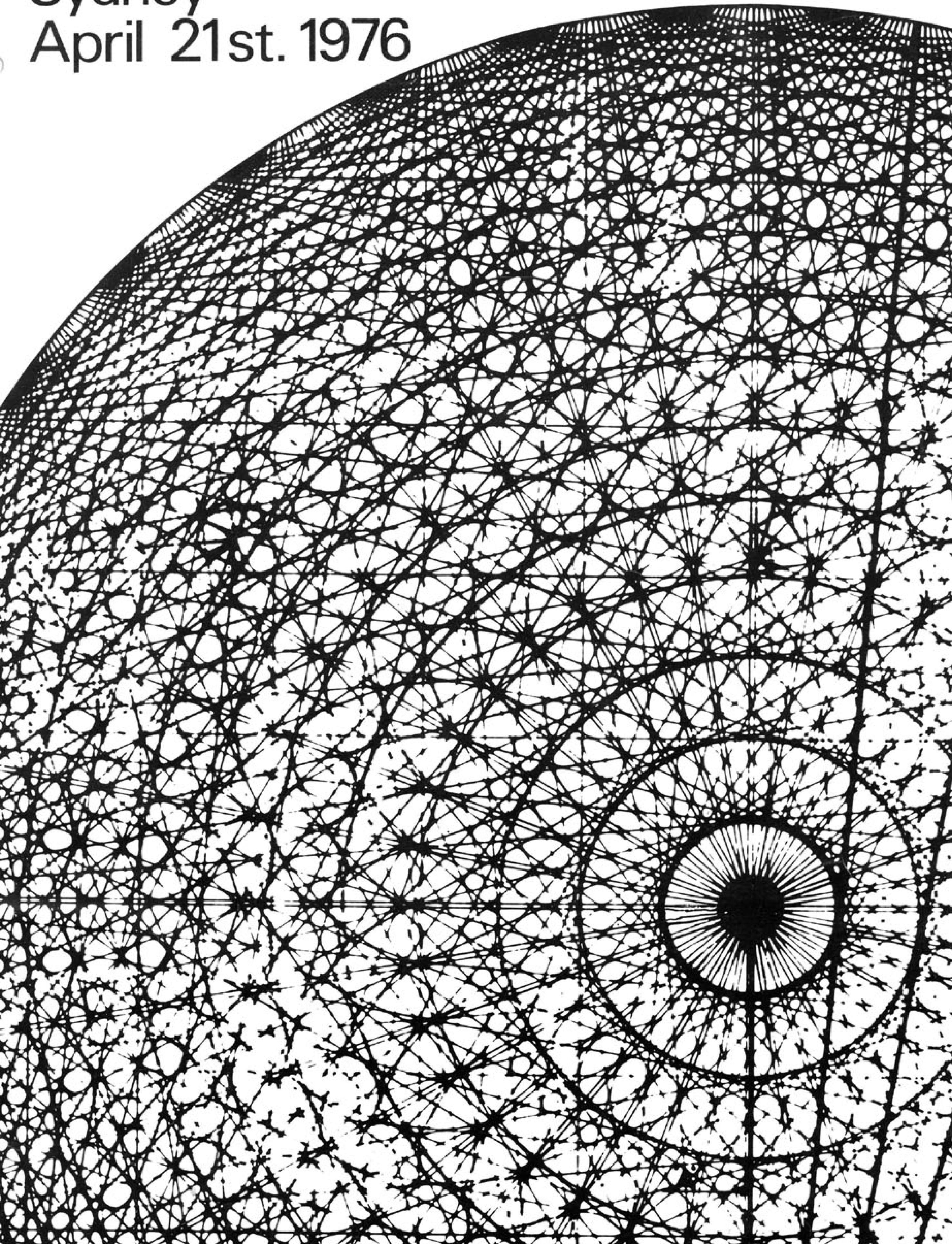
After the thin shell of reinforced concrete is ready, internal and external finishing can be carried out with materials used in traditional buildings. Various waterproofing exterior coatings are possible. The company recommends a bituminous layer reinforced with glass fiber, or a bituminized felt coating. Over this, acrylic resin paints can be applied, or a coat of "Hypalon" synthetic rubber, another Du Pont elastomer, noted for its resistance to weathering, discoloration and ultraviolet rays. Inside, a number of techniques can be used for acoustic damping and thermal insulation.

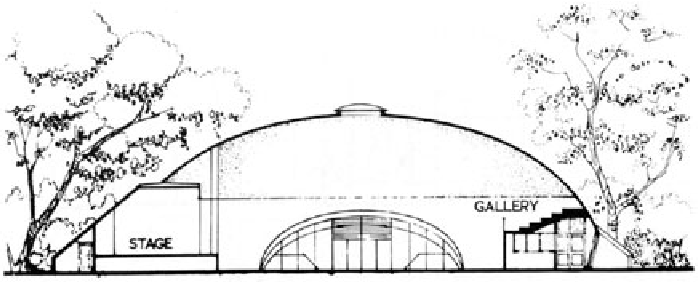
Looking back over the Binishell technique's initial setbacks and later successes, Michelagnoli concludes: "In the early days we had to think of new types of buildings which could be put up with our system and then persuade architects and builders that they were feasible. Now *they* come to *us* with ideas. I think that is proof that we have 'arrived'." ■



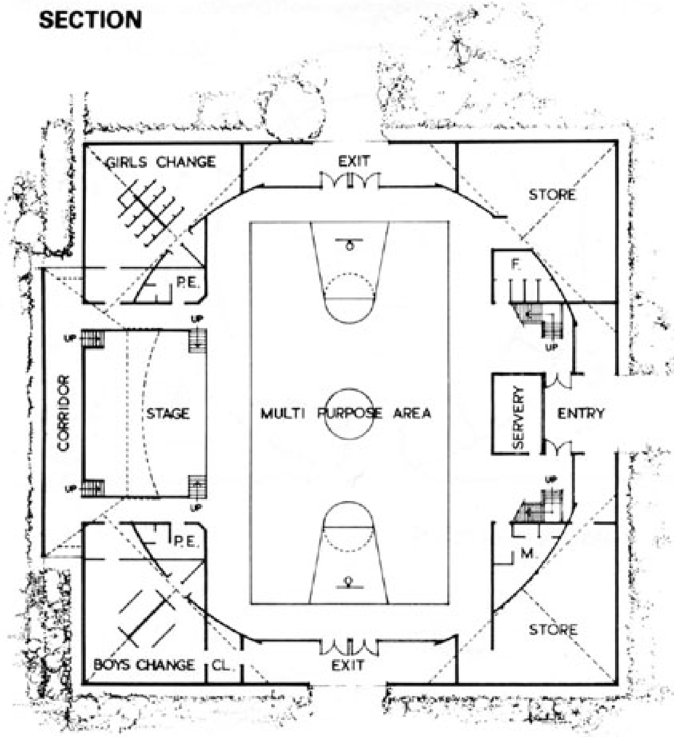

**In erecting a Binishells structure, foundations are prepared, peripheral anchorage for neoprene is laid, access for air provided (1). Membrane is spread out and fixed. Spiral steel mesh reinforcement put in place (2). Concrete is poured over reinforcement and membrane (3), which is inflated (4) to height and shape (5). When concrete has set, membrane is deflated and removed (6).**

# Bini-Shells Seminar
# Sydney
# April 21st. 1976





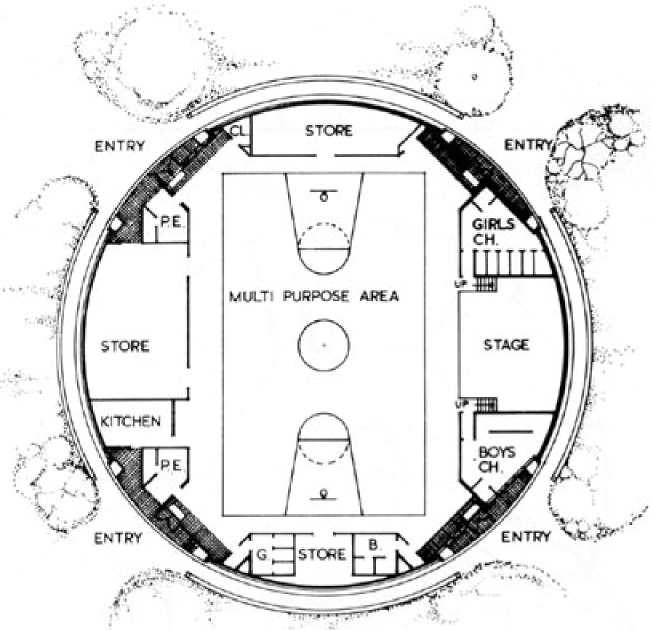

**SECTION**



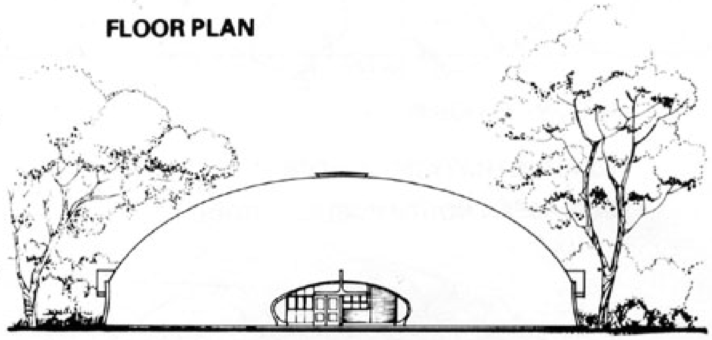

**FLOOR PLAN**

## MULTI PURPOSE CENTRE (Scheme 1)

**INGLEBURN HIGH SCHOOL**
**PEAKHURST HIGH SCHOOL**
**PITTWATER HIGH SCHOOL**
**RANDWICK HIGH SCHOOL**



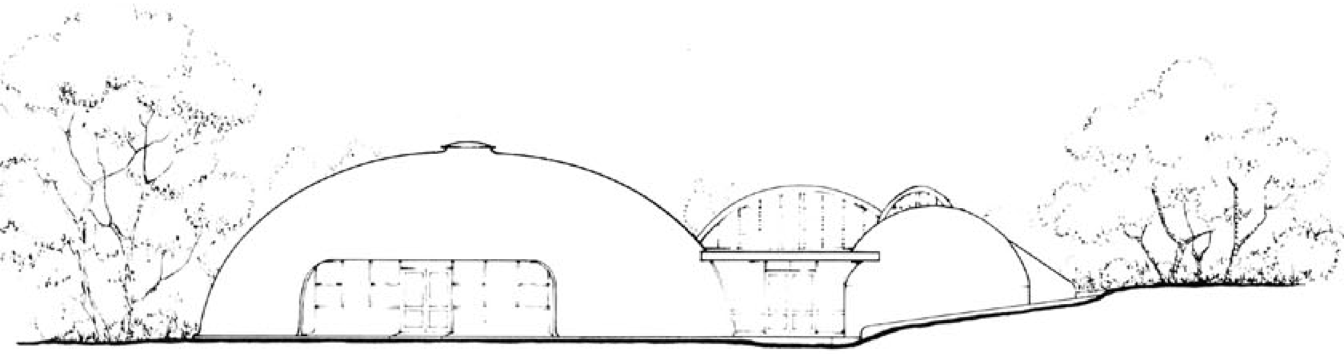

**FLOOR PLAN**



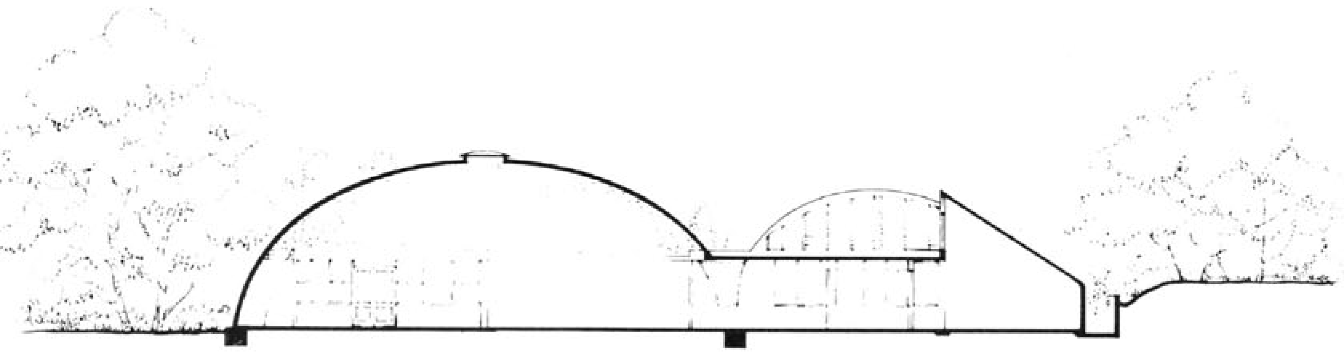
**ELEVATION**

## MULTI PURPOSE CENTRE (Scheme 2)

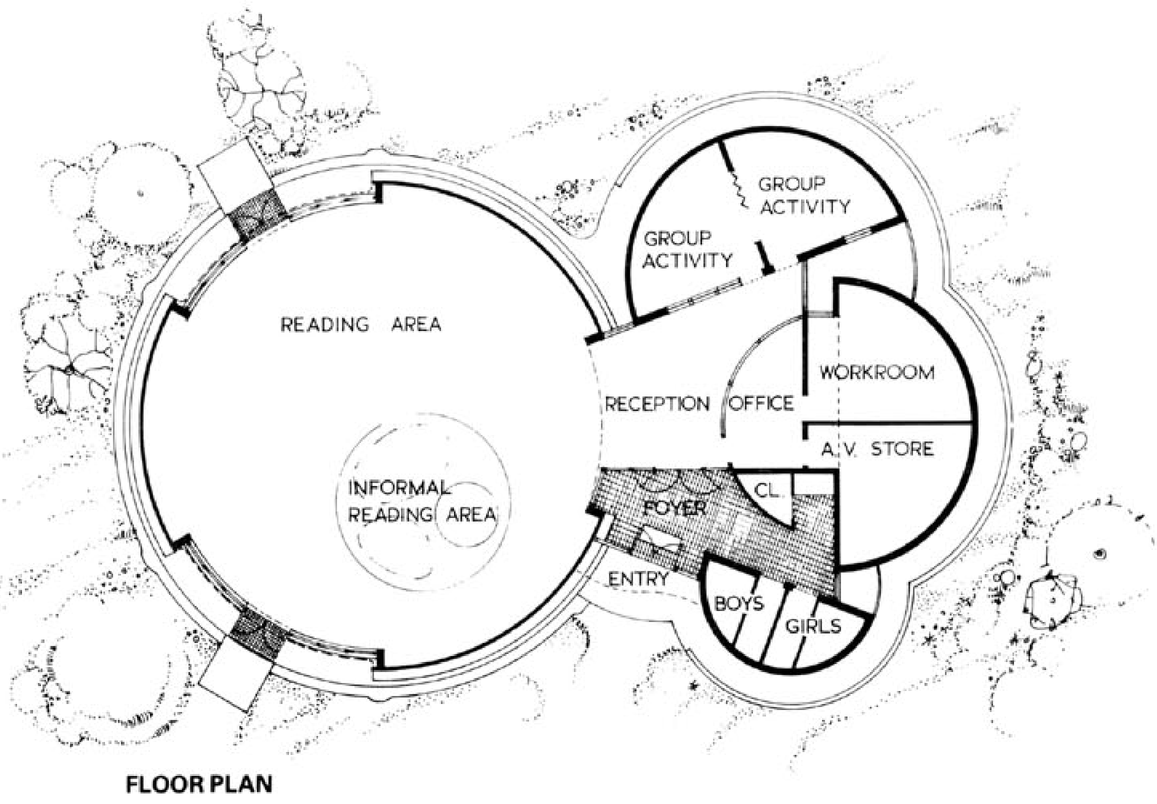
**KU-RING-GAI HIGH SCHOOL**
**FAIRVALE HIGH SCHOOL**



ELEVATION



SECTION

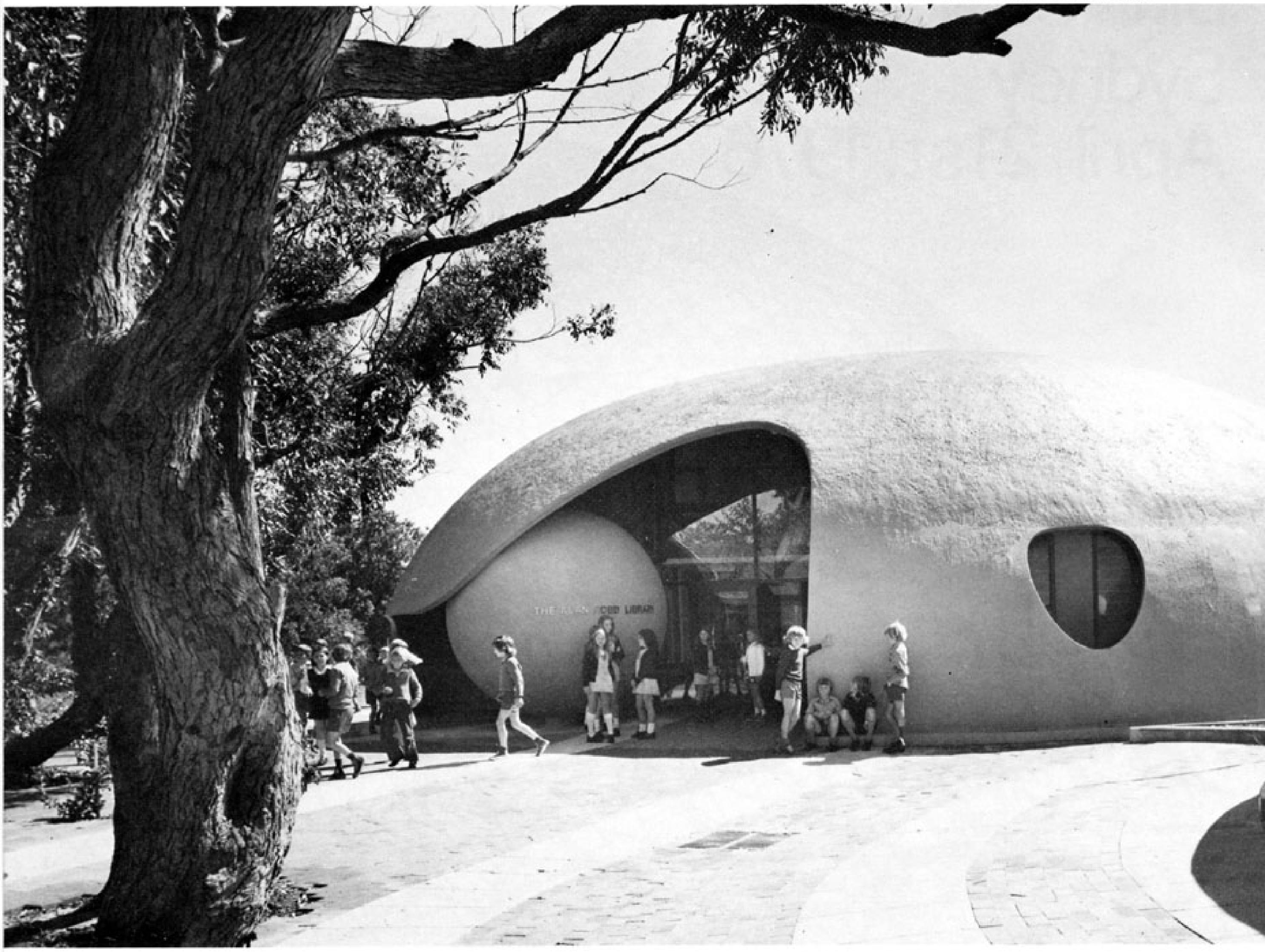



FLOOR PLAN

**LIBRARY**

**KILLARNEY HEIGHTS PUBLIC SCHOOL**

*Narrabeen North Public School Library.*

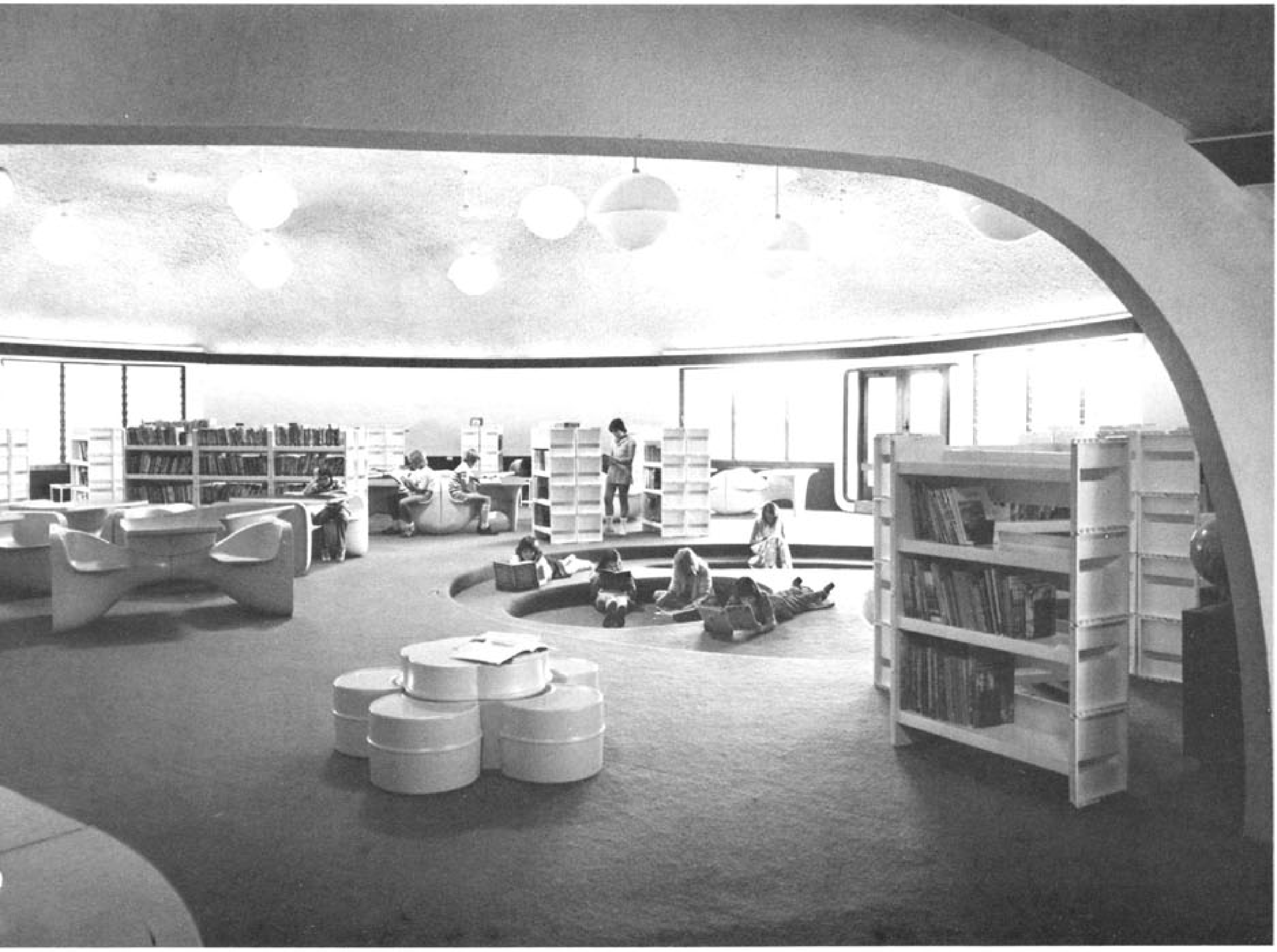



**Client** — N.S.W. Department of Education
**Architect** — Dr Dante Bini
**Consulting Engineer**
**Structural** — Taylor, Thomson, Whitting in association with Dr Dante Bini
**Mechanical and Electrical** — Public Works Department of N.S.W.
**Contractor for Shell** — B.C. & M. Construction and Maintenance Branch, Public Works Department.

The dome has long been one of the most efficient structures ever developed but also one of the most difficult and costly to build. The complex forming and construction procedures required for this type of structure have made the cost prohibitive on all but the most sophisticated of building projects.

However, a new construction technique, that of pneumatically inflating a layer of reinforced concrete immediately after it has been placed but before the initial set develops, has provided an economic method of producing domes and thus enclosing large volumes of unobstructed space.

*Narrabeen North Public School Library.*

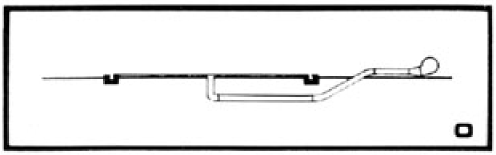


Inflated reinforced monolithic concrete domes have been constructed at a number of primary and secondary schools in the Sydney Metropolitan area.

Dr Dante Bini who devised this system of construction is retained by the N.S.W. Public Works Department as consultant for design, engineering, site supervision and training for construction of Bini shells.

Domes of up to thirty-six metres in diameter and one-third of the diameter in height, have been constructed more quickly and economically than conventional column-free structures of similar dimensions.

*Narrabeen North Public School Library.*



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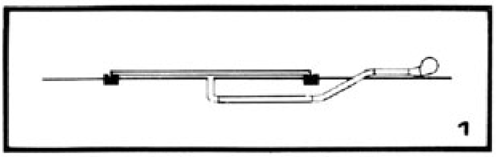
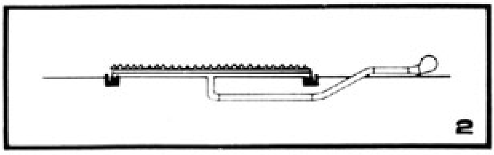
*A reinforced concrete anchorage beam circular in plan. It is constructed provided with a moulded recess in which is secured the anchorage device of the inflation membrane.*



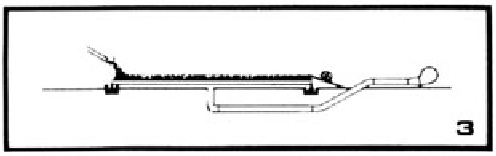
1

*A preshaped neoprene-coated nylon reinforcing membrane is securely anchored in a footing and placed over a floor slab or working platform.*



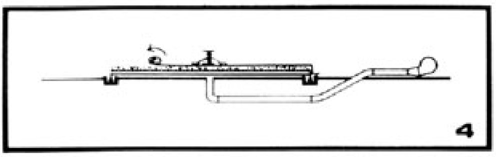
2

*Steel springs are stretched across this membrane in a particular layout. Reinforcing rods are then placed inside each spring.*



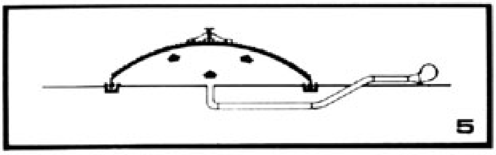
3

*A thin layer of concrete, containing retarder and plasticizer additives, is placed over the membrane covering the springs and reinforcing rods.*



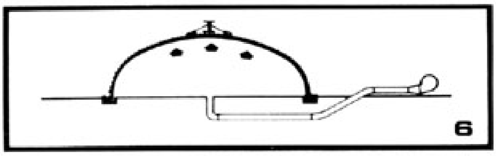
4

*The concrete is covered with a light P.V.C. sheeting and secured to the anchorage. The spool and roller vibrators are then placed at the centre.*



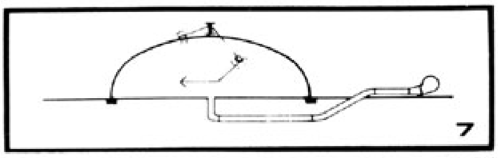
5

*Air is then introduced through ducts in the anchorage beam and under the membrane. The mass of concrete, springs and reinforcing steel then rises.*



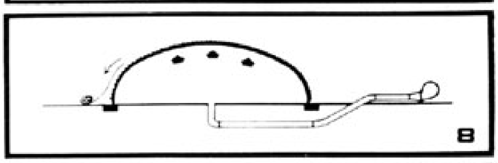
6

*Tension in the springs controls the lifting and the shape of the dome and the springs ensure the positioning of the reinforcing steel within the concrete as the dome is being inflated.*



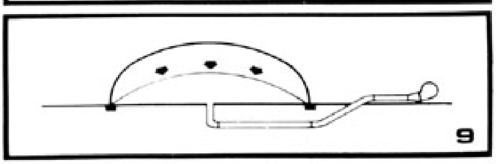
7

*When the dome has been inflated to the required height, specially constructed rolling vibrator machines are pulled over the exterior surface to reconsolidate the concrete.*



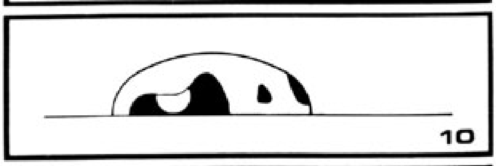
8

*Constant height and pressure control are maintained until the concrete achieves sufficient strength. The outer membrane is removed. Air support is maintained for one to three days, depending on dome size.*



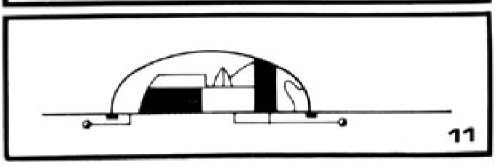
9

*The pneumoform is deflated and the pressure gradually lowered after 1 – 3 days when the concrete has obtained the right compressive strength.*



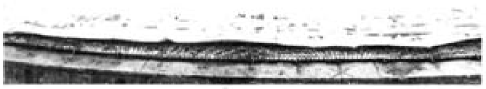
10

*Cutting openings of various shapes and sizes for doors and windows allows for different architectural designs.*



11

*Final Fitting out:*
*Depending on the design requirements of particular projects, provision for services and internal partitions are similar to traditional buildings.*

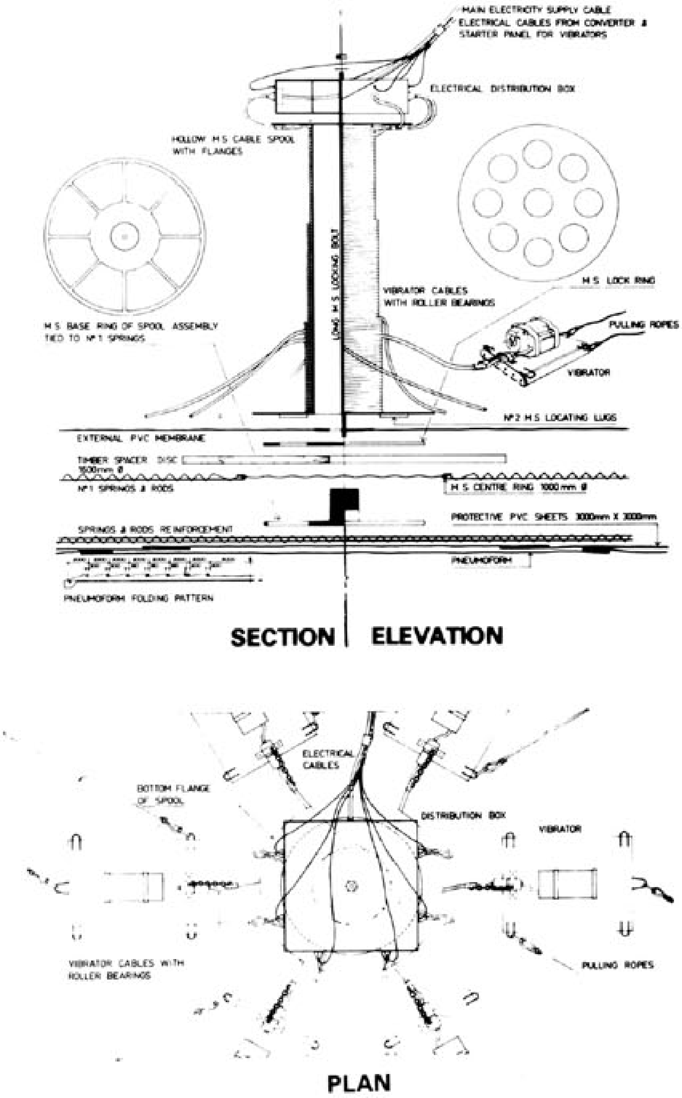


The construction is organised like a manufacturing process using equipment and two readily available materials, concrete and reinforcing steel. The only variables are openings and architectural finishing treatments to meet the client's individual requirements.

The first phase of the work consists of the installation of a concrete ring foundation into which a special anchorage assembly has been installed. A concrete slab is normally placed flush with the top of the foundation ring beam. A specially preshaped neoprene coated nylon reinforcing membrane is spread over the floor slab or working platform and securely anchored to the foundation ring. Steel springs are stretched across this membrane in a particular layout and anchored to the foundation ring. A smooth reinforcing bar is placed inside each spring and is also anchored to one side of the concrete foundation. Tension in the springs serves to control the lifting and the shape of the dome and also controls the positioning of the reinforcing steel within the concrete as the dome is being inflated.

For a dome of thirty-six metres in diameter a layer of concrete 130mm thick at the centre and 90mm thick at the circumference, (115$m^3$ of concrete), is placed on top of the membrane. This concrete is in turn covered with a light P.V.C. sheeting, also anchored to the foundation ring. Air is then introduced through ducts in the foundation wall and the entire mass of concrete, springs and reinforcing steel begins to rise. The whole procedure from the start of placing of concrete to the completion of inflation requires approximately four hours. After the dome has been inflated to the required height, rolling vibrator machines are passed over the exterior surface for up to one hour to reconsolidate the concrete and provide a smooth uniform finish to the concrete structure.

Constant height and pressure control are maintained for a period of thirty-six hours while the concrete sets, after which the membranes are removed and the structure is finished to the owner's specific requirements. By cutting openings of various shapes and sizes for doors and windows, many different architectural treatments of the inflated concrete dome are possible. Complete sections of the dome, (up to 50% of the diameter at the base), may be cut away to be used as glazed curtain walls, providing a large, bright column-free interior. One of the major advantages of the inflated concrete dome is the speed with which it can be constructed: from the start of foundation to completion of concrete structure requires approximately one to three weeks (depending on the diameter, weather conditions etc).




**ASSEMBLY OF VIBRATION EQUIPMENT AT CENTRE**

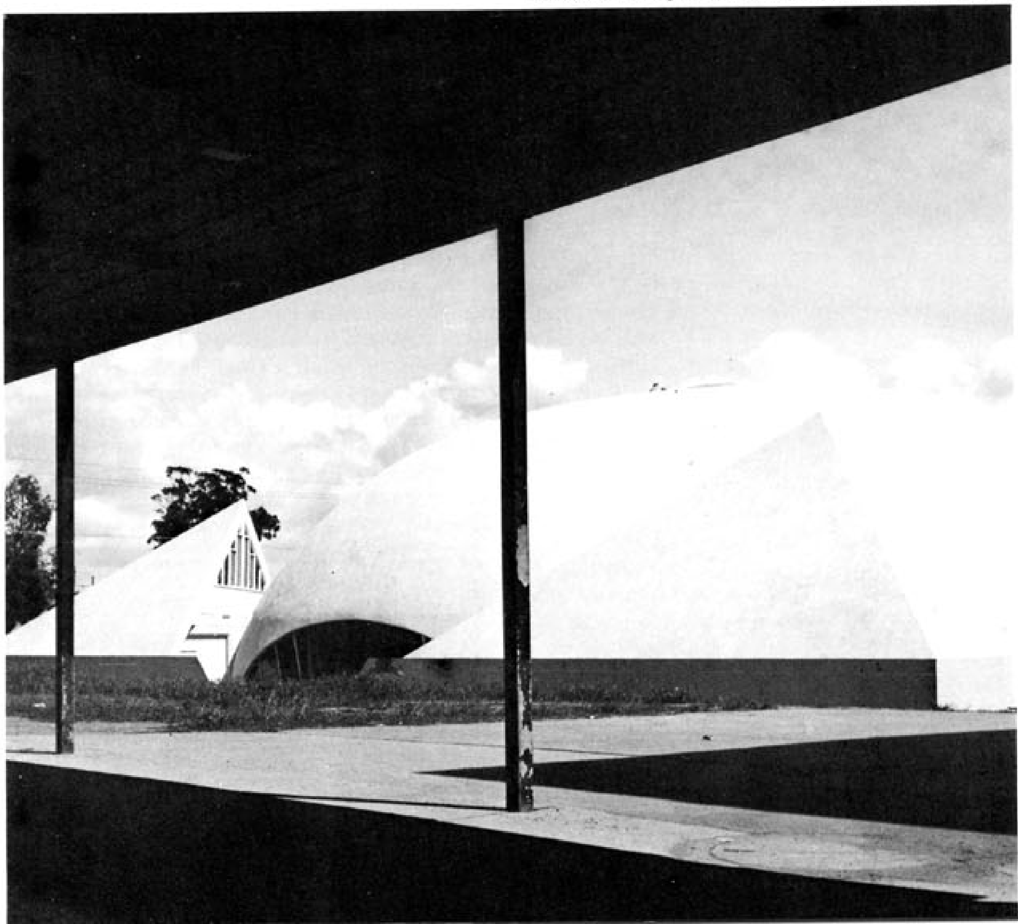
Over 400 shells have been constructed successfully in sixteen countries. A dome constructed at Fairvale High School, N.S.W. was subjected to severe and unusual weather conditions before insulation could be applied. After a very hot day (41°C) a storm caused the shell temperatures to change dramatically resulting in a temperature gradient approaching 30°C to develop through the shell thickness. This gradient is more than sufficient to cause moments to develop exceeding the bending moment capacity of the shell and the shell failed.

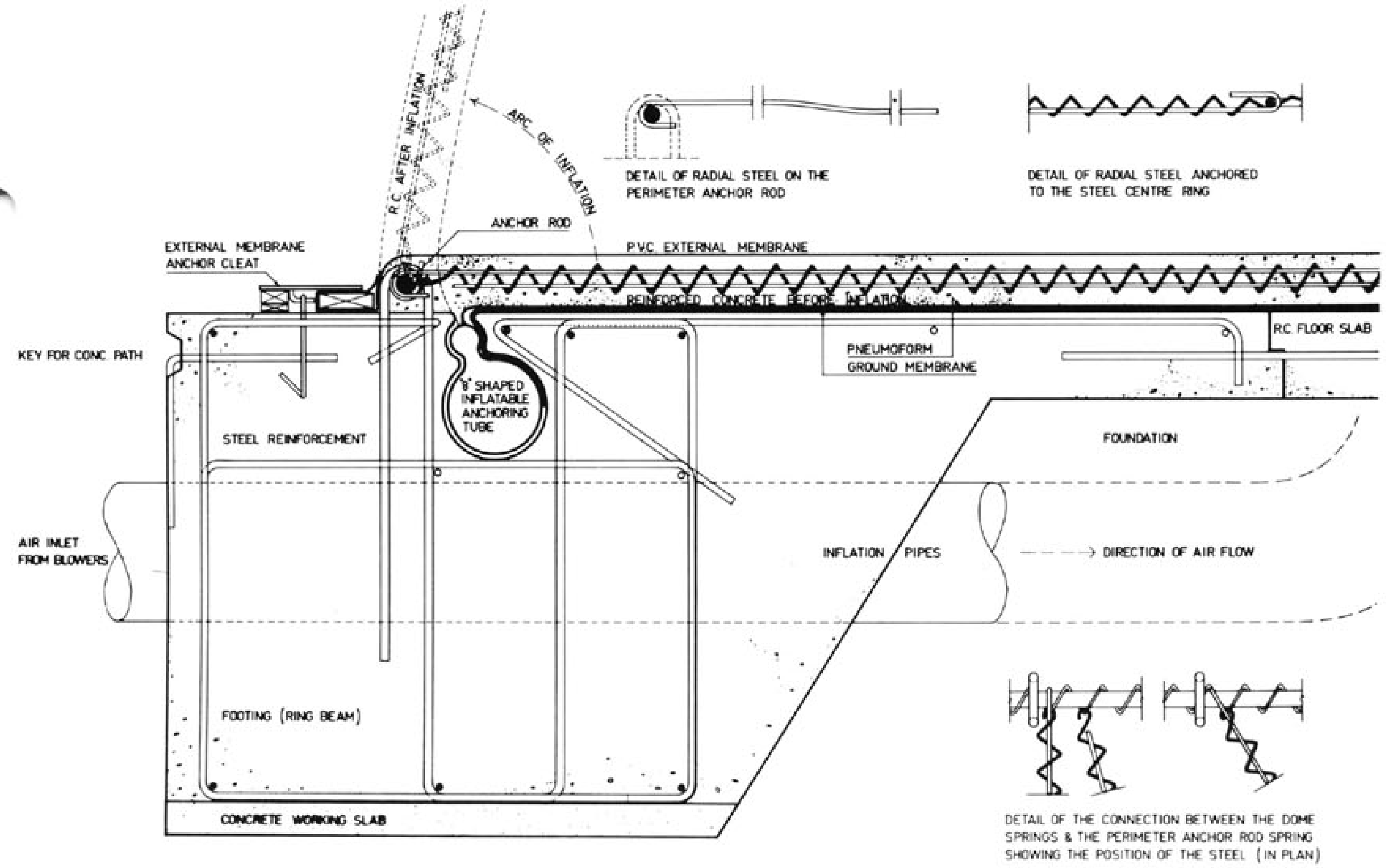
The knowledge gained from the subsequent research indicated the necessity for immediate provision of insulation to the external surfaces of the shell, which is now the practice, eliminating the possibility of this accident occurring again.

Domes of eighteen metre diameter and thirty-six metre diameter have been constructed in six metropolitan schools and serve a variety of uses. At Narrabeen North Public School two interconnected domes fulfil the school's library requirements and another houses administration. The library is carpeted in parrot green and furnished with imported plastic white shelving and yellow carrels. A library is being built at Killarney Heights and one is projected for Ashbury Public School.

At Peakhurst, Ingleburn, Pittwater, Ku-ring-gai, Fairvale and Randwick Girls High Schools, thirty-six metre domes are used to provide multi-purpose centres, for assembly, indoor recreation, basketball etc. and include change rooms, stage and chair storage facilities.

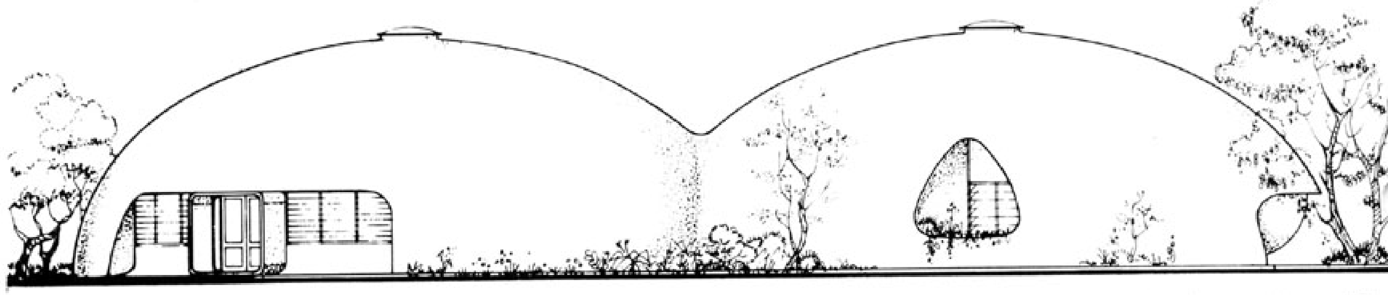
*Peakhurst High School Multi Purpose Centre.*



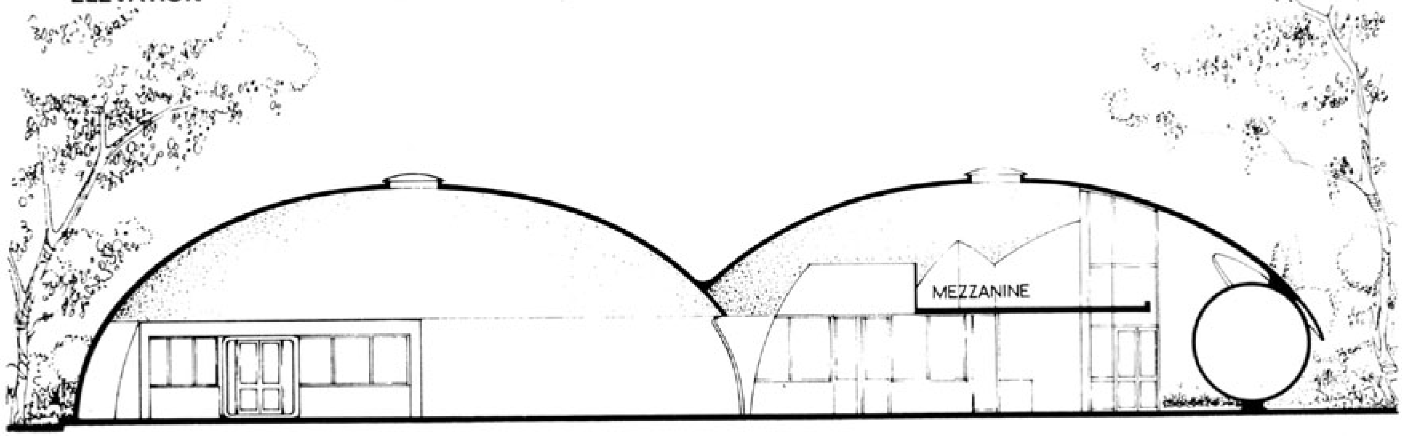



**TYPICAL DETAILS AT FOOTING**

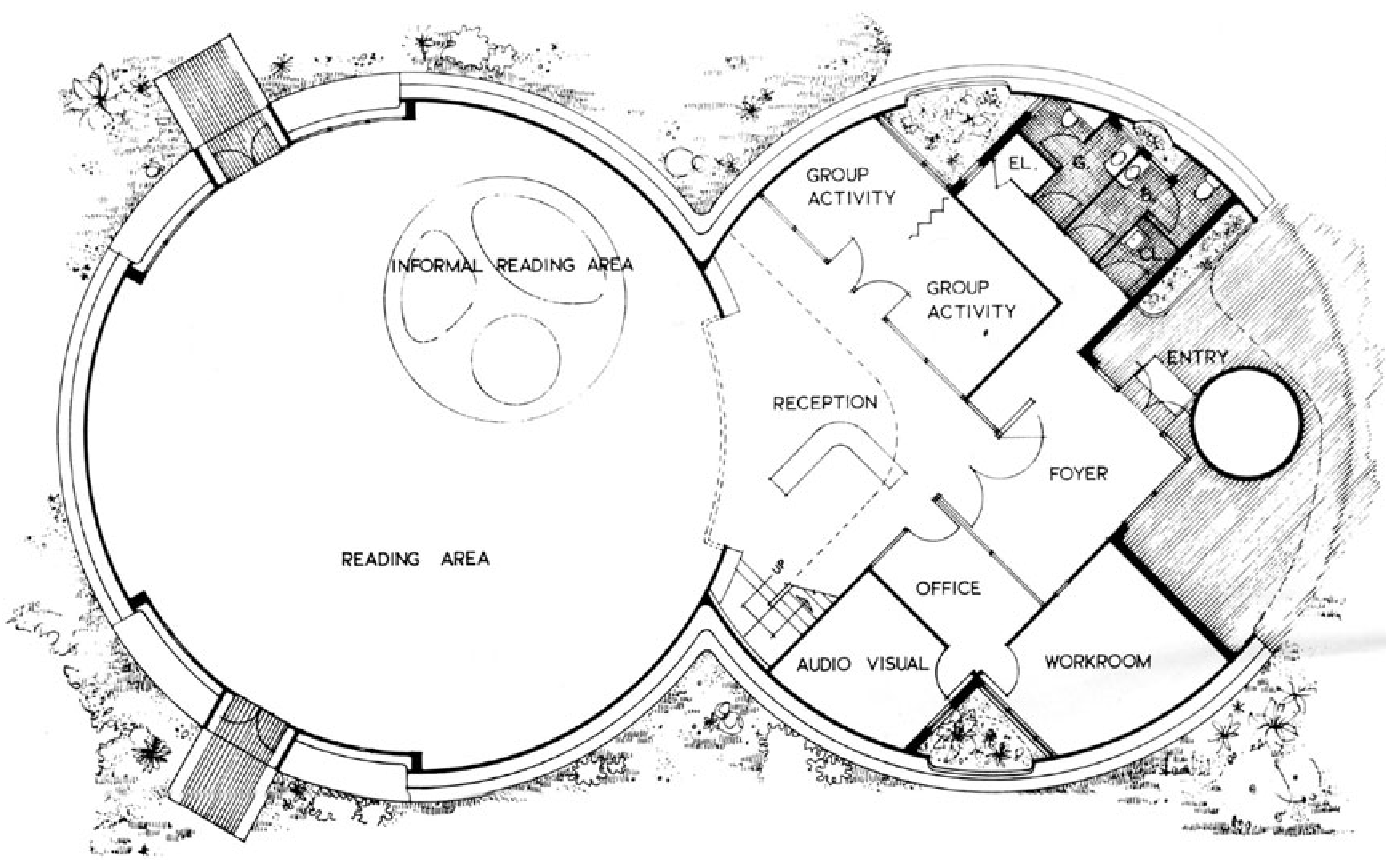
*Narrabeen North Public School Administration Centre.*



ELEVATION



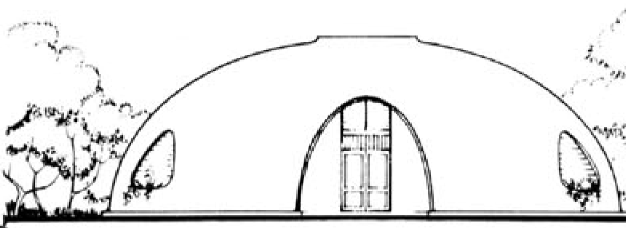

SECTION



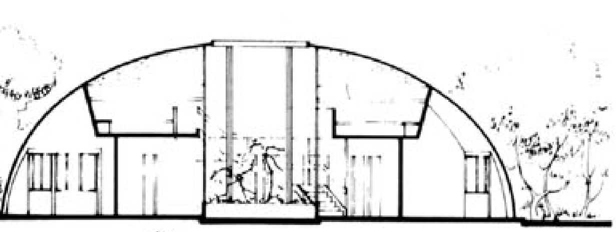

FLOOR PLAN

LIBRARY

NARRABEEN NORTH PUBLIC SCHOOL



ELEVATION



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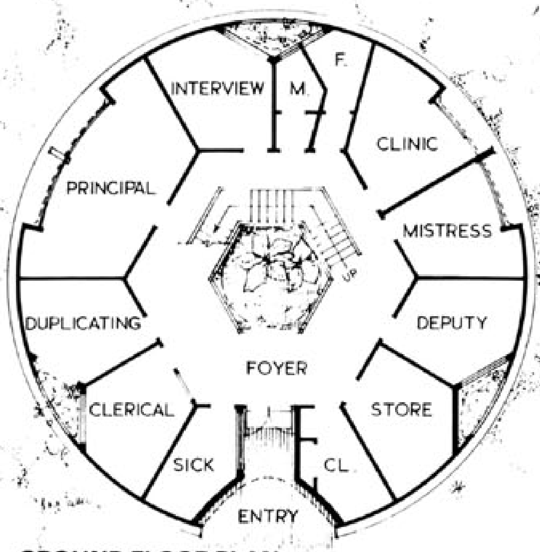
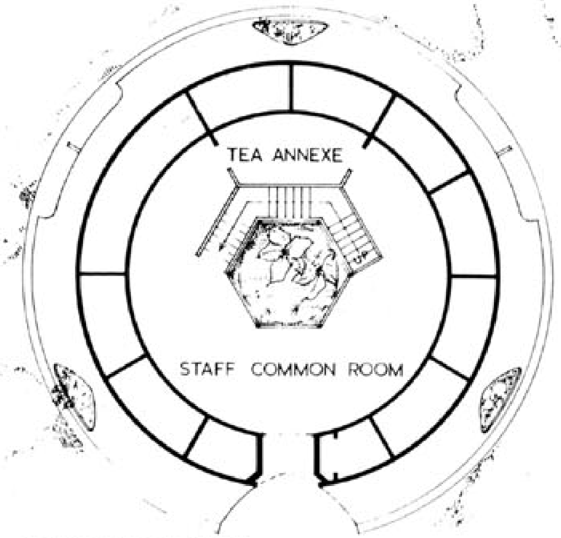


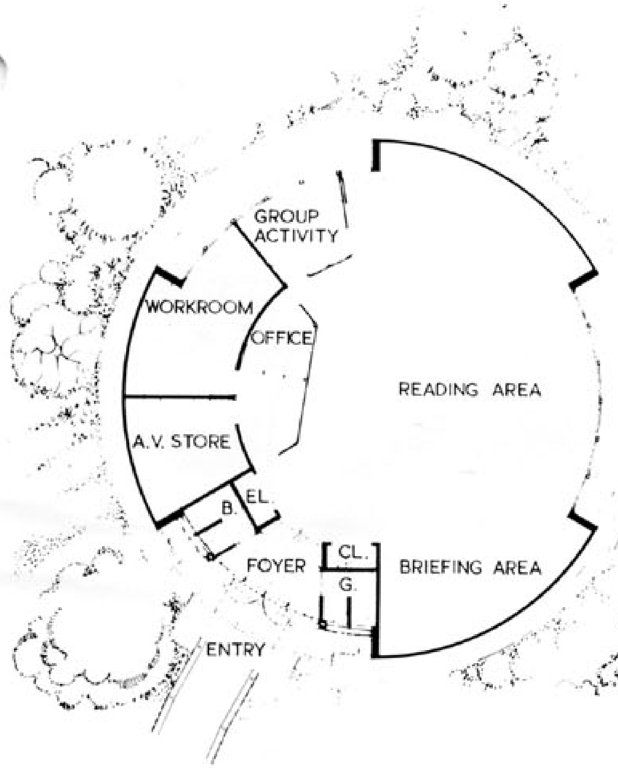

GROUND FLOOR PLAN



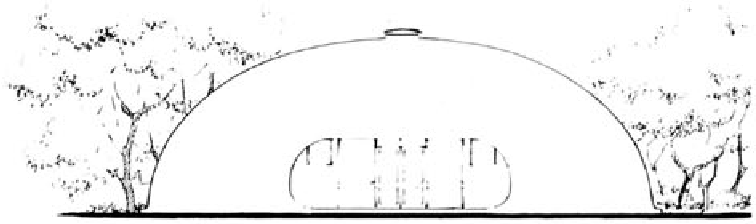

FIRST FLOOR PLAN

**ADMINISTRATION CENTRE**

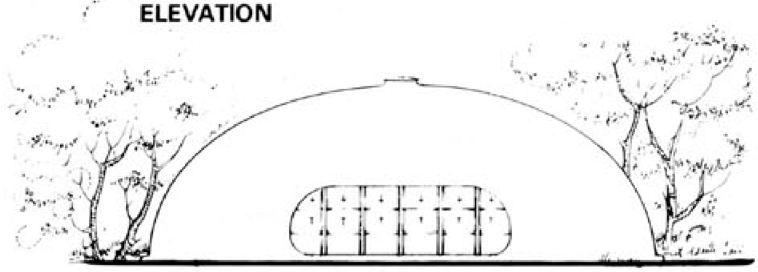
**NARRABEEN NORTH PUBLIC SCHOOL**



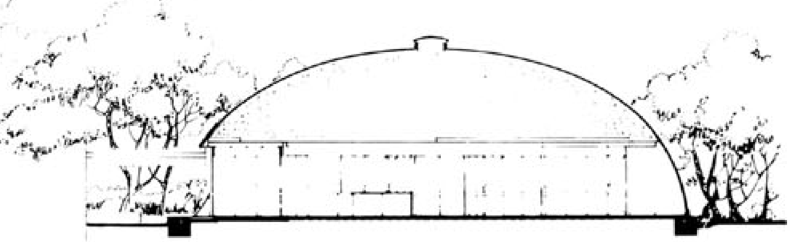

FLOOR PLAN



ELEVATION



ELEVATION



SECTION

**LIBRARY**

**ASHBURY PUBLIC SCHOOL**

# Malvern sports centre – an architect's adventure story

by Michael Godwin

**A standard concrete Parashell dome in the grounds of Malvern Girls' College has been designed and sculptured to form a unigue structure surrounded by water.**

*Photographs by Mervyn Mason RIBA*

Michael Godwin, MA (Cantab) RIBA, is a Partner of Godwin & Cowper, architects, Stourport-on-Severn, Worcestershire. He graduated from Cambridge University School of Architecture in 1950, followed by two years post-graduate studies in architecture at the Royal Academy, London.

FOUR years ago my Partner and I visited Milan to see what the Italians were achieving with Signor Dante Bini's invention of raising reinforced concrete structures by pneumatics, entirely without formwork.

From his earliest ideas in 1967, and lengthy experimental work, a highly sophisticated structural method has now been developed, which we believe begins a new era in the use of reinforced concrete.

### The standard shell

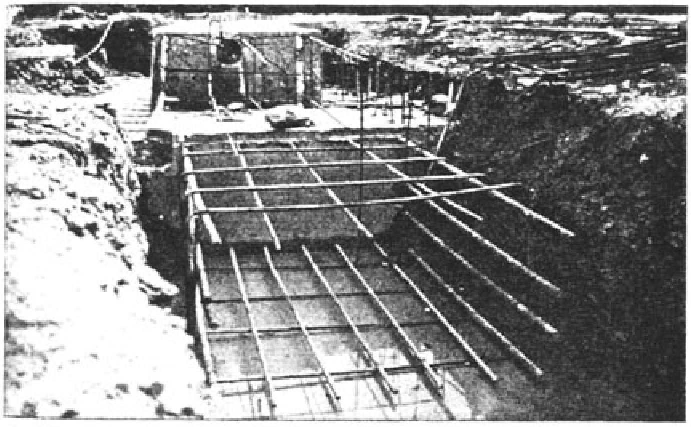
This structural concept is achieved by placing a circular reinforced concrete ring-beam deep into the ground, the surface of which is at ground level. In this top surface is a recessed channel with a raised steel bar running around the outside. Large pvc pipes are laid from outside the ring into the central area and connected to powerful air pumps. The inside ground surface of the ring-beam area is then carefully levelled and raked smooth and covered with a circular neoprene sheet to seal the ground against air leakage through which the pipes emerge.

A stout tailored neoprene membrane with an inflatable rim is then laid over the first neoprene sheet and the rim tucked into the channel in the foundation ring-beam and inflated to make an air seal. This "inner membrane" is test-inflated and then collapsed and folded rather like a parachute. The folds of the membrane are liberally dusted with talcum powder and the whole then covered with numerous single sheets of neoprene each about three metres square, to form overlapping fishscales.

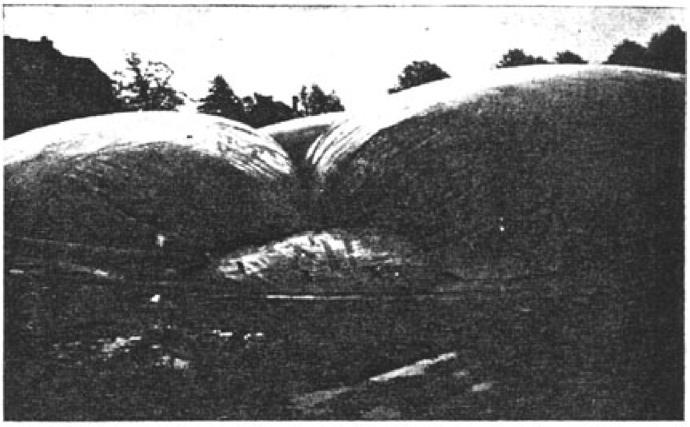
Over this fishscale surface is laid the complex helical reinforcement; sets of the helical reinforcing wires being hooked to and starring out from each of 48 equidistant points round the perimeter bar. When this main primary helical steel is in position, straight round bars are inserted up inside each one, first from the ring-beam end and then from the centre, being secured at each end only, so that free overlapping takes place at their meeting to allow for future massive expansion. As each helical is stretched to its station it opens and falls across, and into, those previously laid so that finally all units lock into one another and can therefore only move relatively to each other, like the springs of a mattress.

The completed reinforcement totals some thousands of bars. The base is then ready for concreting, is covered, and awaits favourable weather. It is essential that concreting begins in fine weather since rain will not only increase the surface water and the slump, but will very certainly add to its weight.

Immediately before concreting, the surface of the area is segmented with bright cord into equal areas which will



*Reinforcement to the concrete foundation ring-beam. The pear-shaped slot to anchor the inflation membrane can be seen in the top surface of the concrete at ground level.*



*The inflation membrane being test inflated prior to setting out the steel reinforcement. The rainwater held in the folds of the membrane was much more than realised, which eventually gave unsuspecting sitemen a heavy baptism.*

each contain one truck-mix load. Each truck-load is laid by pumping to an accurately gauged and raked depth. Working in a clockwise direction each truck-load must not only be tested on arrival at site for slump and temperature, but must also have a decreasing content of retarders due to the operation taking some six hours to complete.

The wet, ready finished surface cannot be walked upon, so the top and final neoprene sheet (the outer membrane), is unrolled by ropes, half-circle at a time. The perimeter is secured and a wound maypole of four vibrators is set at the centre and the work finally checked.

Air, at 1 lb above atmospheric, is then pumped between the first two neoprene sheets, the base one sealing the ground and the next (the inner membrane) lifting the whole prepared structure. The helical reinforcement begins to stretch and finally interlock. The fishscale sheets below the steel slide over each other to protect the membrane immediately below from being damaged by tearing.

After about one-and-a-half hours the final raised shell is complete, and the four electric vibrators at the top are then switched on and carefully unwound by hand until reaching the base. The air pressure, however, is maintained and carefully monitored for a further three days and nights, to allow the concrete to set and cure sufficiently for the outer membrane to be stripped and the structure entered. The completed shell is only 125 mm at the base and 75 mm at the crown.

This, then, is the basic technology which is the concept and achievement of Signor Dante Bini.

**First observations**

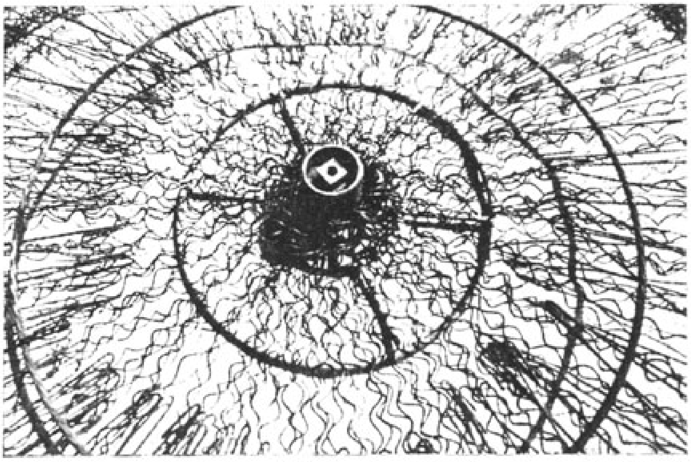
What, however, can be achieved with this deceptively simple dome-shaped shell structure is entirely open to the future designer, and I was fascinated to see what the Italians have already done, in all sizes, mostly in northern Italy.

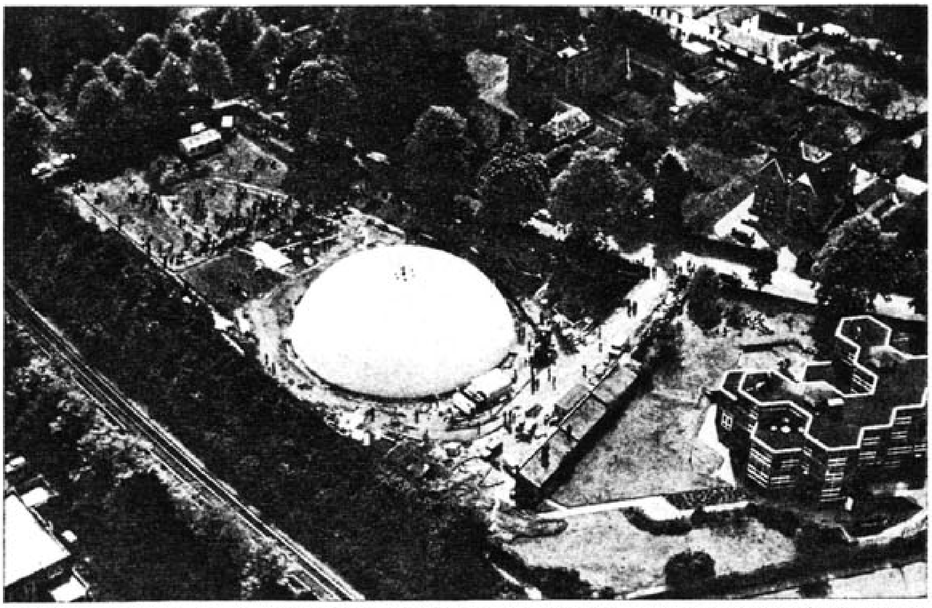
Travelling by mini-bus we visited many of the shells put to various uses, from school swimming pools to a prestige leisure centre for the Bank of Milan. What I found most interesting was that although the Italians have fenestrated the structure in a number of projects there was a strong tendency to use the completed dome as an untouched structure, except for the necessary entrance and exits, some projects even being totally without any natural daylight. This method allowed the maximum plan use of the floor area for ball games and high-stepped seating around, which would raise the eyebrows of our own fire officers!

During our visit to the new international arena for the City of Turin, which had been inflated two weeks previously, I observed that the Italian contractors had entered the structure, not by piercing a hole in the shell, but by excavating beneath the concrete ring-beam. This opening was deep and wide enough to admit three-ton vehicles by way of a dipping track, leaving some ten metres of hanging shell with attached ring-beam soaring unsupported in mid-air! This sight was somewhat of a shock, but after my own later experience I have come to understand their confidence in such a thin but immensely strong structure.

Although it was a bright sunny day it had rained the previous evening and the entrance trackway into the dome was covered with water. Standing high upon the internal staging I saw that the dome was lit by the fascinating interplay of reflected moving sunlight over its surface. This was the most lasting and significant impression of the visit.

The return flight gave me time to apply my own thoughts as an architect, not only to the worrying acoustic problems the Italians were then having, with their use of hard surfaces, particularly on the floor, but also to their use of the structural concept as engineers.





*Inflation complete—as seen from the air. The air pumping station can be seen against the perimeter, and the crane is to hold the electric cable to the vibrators off the surface of the dome, until the vibrators are dispensed with.*

**Later thoughts**

When we were commissioned to design the new sports centre for the Malvern Girls' College nearly two years later a number of points in favour of this structure made me consider it in greater depth, and I finally decided to recommend it to the clients.

Firstly, sports centres really require far more height at the centre above the play area than the Sports Council's minimum eight metres, and much less at the ends of courts, since the path of a ball in flight is parabolic. The dome shape exactly satisfies this requirement. The basic cost of the initial dome structure is about half that of any other known building system, to which must, of course, be added the further cost of completion and fitting out.

I should perhaps mention here that my practice does not accept a prior written brief from the client for any project, as we consider it beyond the capabilities of most clients, except those of considerable experience, to see the cumulative effects of their decisions. We ask, therefore, that they themselves form a small select committee with ourselves, consisting not only of those who will pay for the building, but also those who will use and run it.

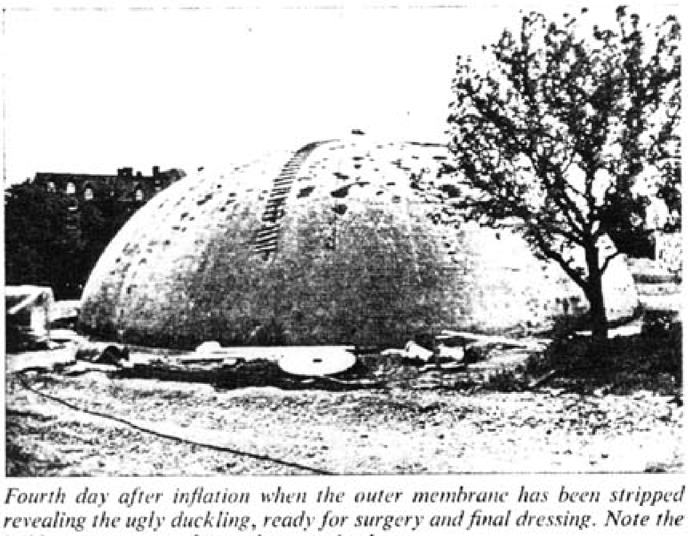
Informality in these discussions allows all members of the committee to speak freely of their ideas and anxieties, and what it is hoped to achieve. Gradually the minuted meetings formulate the brief, so that we as architects can begin to carry out the work of design for what is needed, rather than what the committee members initially imagine they want.

Usually some half dozen meetings are required before sketch designs can be prepared. Meetings are maintained, as and when necessary, right up to the day of completion of the project, so that the client js always fully informed, and therefore much more inclined to be sympathetic to time and costs; but far more important, the client knows how to get the best from the completed building.

The "Plan of Work" meetings with the Malvern Girls' College produced some surprises and unexpected requirements. First, it was made clear that the new building should be lit by natural daylight, unassisted by artificial lighting, during daytime use. The Headmistress and staff considered an environment totally illuminated by artificial lighting to be most undesirable for teaching staff, who might only see the sunlight hours during breaks for meals.

Secondly, the building was to be used for leisure in the evening, when the girls could meet socially, without duty staff discipline, for tennis or badminton on the arena, or to play chess, sit out, watch, or gossip. The building was also to have a sense of joy, as well as practicality and cost effectiveness.

Meetings were often long, but always intensely interesting and full of humour. The final design concept used the Bini structure in architectural rather than purely engineering terms, thus the shell although raised in its entirety was to be cut into sculptural form and placed in a pool, so that all parts of the exterior and interior were reflected in the water, and the sunlight reflected over the inside of the dome, as in Turin. Inside, the arena and all accommodation (including two squash courts), would be contained within a disc beneath the dome, being set clear of the legs, which would stand in the water. Base shoes supporting the structure were to be in a contrasting material of crushed mica-granite to emphasise the simplicity of the shell structure. Setting the dome on shoes in the pool also had the practical aspect of collecting and shedding rainwater from the shell without need for a damp-proof course, a problem which has given the Italians much trouble.



*Fourth day after inflation when the outer membrane has been stripped revealing the ugly duckling, ready for surgery and final dressing. Note the ladder arrangement for working on the dome.*

*The interior showing work advanced on the upper ring-beam highlighted by a shaft of sunlight through the top domelight aperture. It was possible inside to tell the time of day by the position of the beam.*

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# THE CHARTERED BUILDER

THE OFFICIAL JOURNAL OF THE AUSTRALIAN INSTITUTE OF BUILDING

# BINISHELLS

*contributed by Jennings Industries*

### Introduction to Binishells

For thousands of years the dome has been recognised as one of the most efficient structures ever developed while at the same time known to be one of the most difficult and costly to build.

The complex forming and construction procedures required for this type of structure have made the cost prohibitive on all but the most elaborate of buildings.

Now with the BINISHELLS process of pneumatically inflating concrete, commercialised in Australia by Jennings Industries Limited, the construction of concrete domes is possible with a speed and economy that surpasses other conventional structures of equivalent size.

During the past 12 years, more than 500 "Binishells" have been built around the world to serve as shopping centres, sports facilities, schools, industrial complexes and a multitude of other uses.

Peter Rogers, Manager of the Jennings "Binishell" division, describes the process:

"The construction of inflated monolithic concrete domes up to 36 metres in diameter and approximate height 1/3 of the diameter is organised like a manufacturing process using plant and equipment with two simple readily available materials: concrete and steel. The only variables are openings and architectural finishing treatments to meet the client's individual requirements.

"The first phase of the work consists of the installation of a concrete ring foundation into which a special anchorage assembly has been installed. A preshaped neoprene coated nylon reinforced membrane is securely anchored to the foundation ring beam, then spread over the ground membrane. Steel springs are stretched across this preshaped membrane in a particular layout and are also anchored to the placed inside each spring and is anchored to one side of the concrete foundation. Tension in the spings serves to control the lifting and the shape of the dome and also controls the positioning of the reinforcing steel within the concrete as the dome is being inflated.

"For a dome of 36 metres in diameter a layer of concrete 130mm thick at the centre and 90 mm thick at the circumference, is placed on top of the membrane. This concrete is in turn covered with a strong P.V.C. sheeting, also anchored to the foundation ring beam. Air is then introduced through ducts in the foundation wall and the entire mass of concrete, springs and reinforcing steel begins to rise. The whole procedure from the start of placing of concrete to the completion of inflation requires approximately 4 hours. After the dome has been inflated to the required height, specially constructed rolling vibrator machines are passed over the exterior surface for up to one hour to reconsolidate the concrete and provide a smooth uniform finish to the concrete structure. The actual inflation of the structure itself is about one hour.

"Constant height and pressure control are maintained for a period of 48 hours while the concrete sets, after which the membranes are removed and the structure is finished to the client's specifiic requirements. By cutting openings of various shapes and sizes for doors and windows, many different architectural treatments of the inflated concrete dome are possible. Complete sections of the dome (up to 50% of the diameter at the base) may be cut away to be used as glazed curtain walls, providing a large, bright, column free interior. One of the major advantages of the inflated concrete dome is the speed with which it can be constructed; from the start of foundation to completion of concrete structure requires approximately one to three weeks (depending on the diameter).

"Binishells are available in diameters that include 10, 12, 18 and 36 metres.

### Binishells History

The Binishell System was invented by the Italian architect, Dante Bini whose interest in thin-shell structures goes back to the days of his architectural studies and he chose this subject for his final doctorate thesis at the Florence University.

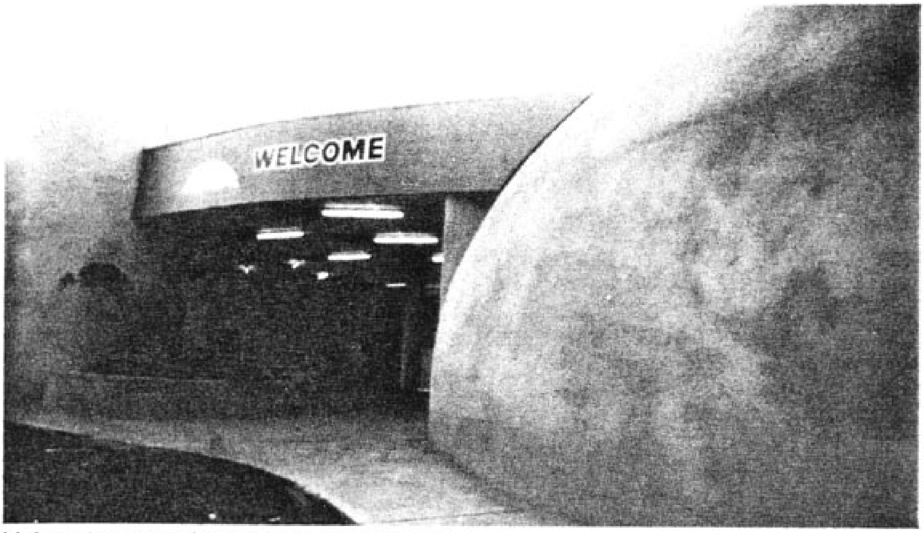
The *Daily News* in Perth, W.A. on July 29, 1977 described Bini's inspiration for the dome structures in the following terms:

"Like Archimedes, Dr Bini's idea came to him in a flash of inspiration. But instead of being in the bath he was on the tennis court.

a big balloon held up by air pressure", he says.

"Suddenly I looked up at the dome and stopped playing. I realised that the dome was being held up by the air but I couldn't feel any pressure while I was standing inside it".

Aerial view of the Kallangur development built by Jennings Industries.



Main entrance to the Kallangur development.

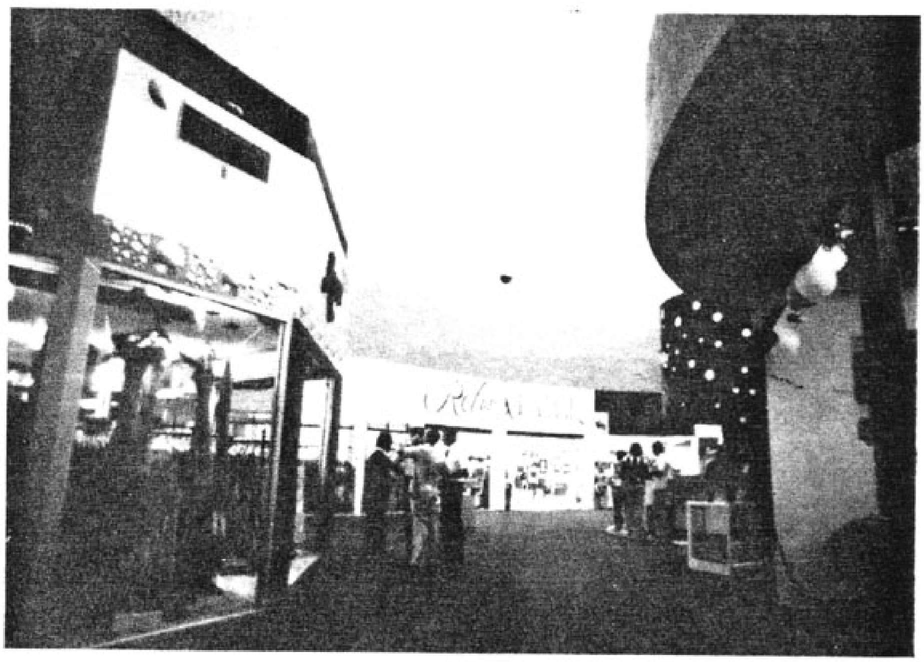
Bini is grateful to the New South Wales Public Works Department, which originally contacted him in Italy to introduce the Binishell System to Australia in 1974.

The system of constructing domes by lifting the materials into place using low compressed air as energy, is as revolutionary and new as his patents and has been acclaimed by academics as one of the truly great innovations of this century.

Against traditional methods providing comparable clear floor space, Binishells use:

- Less material
- Less time
- Less energy
- Less manpower

Shopping mall at Kallangur.



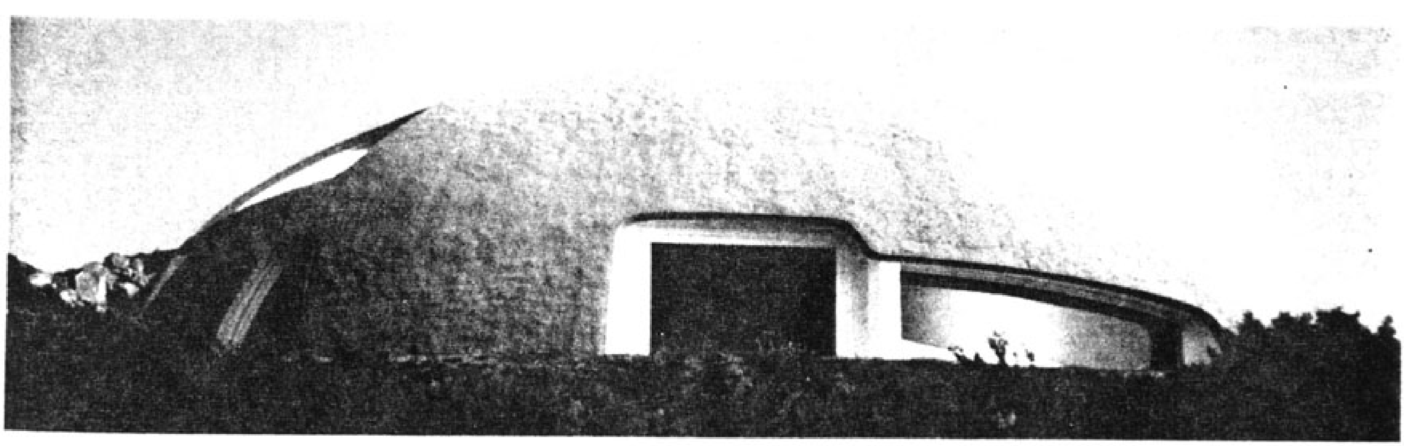
"He abandoned the game instantly and to the amazement of his companions rushed home to re-read a thesis he had written on thin-shell structures.

"From that moment I thought of nothing else", he says. "I realised that a huge weight of reinforced concrete could be lifted and shaped with no more air pressure than you can make with your mouth".

Initially he suffered the fate of most original thinkers. All the experts in his own country — engineers, architects and professors told him that he was mad.

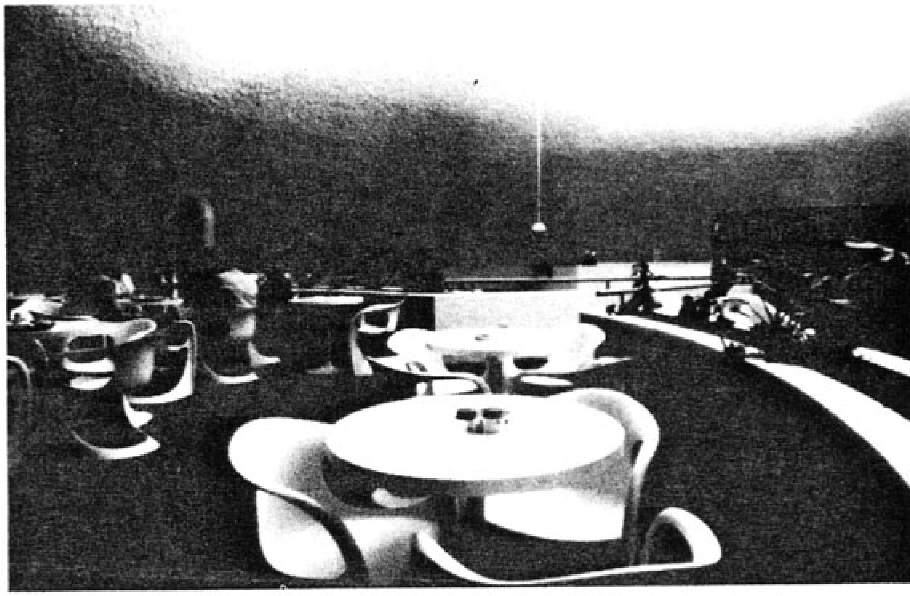
Finally, Dr Mario G. Salvadori, a Professor of Columbia University, New York, heard about his work and asked for a demonstration. There were 7,000 architects, engineers and students watching, at "The Architectural Happening" held at Columbia University.

From then on Dr Bini and his Binishells have never looked back.


*Michelangelo Antonioni House in Sardinia*

And there's more to come. Such as:

- The Minishell. A small thin-shell concrete dome, technically a sprig from the Binishell patent, which is suitable for 2-3 bedroom housing, envisaged for mining towns, tourist villages, disaster area rebuilding and weekenders.
- The Binisix. A hexagonally-based dome using a new patented construction method — capable of up to 100 metres, suitable for huge exhibition halls, sports stadiums, churches, shopping centres, factories etc.



Pleasing internal effects of one of the domes at Kallangur.

**Space City Shopping Centre, Brisbane**

The recently completed $3 million seven domed shopping complex at the Brisbane Northern suburb of Kallangur is an excellent example of the speed, economy and limitless flexibility of the Binishell system.

Jennings were appointed to design and construct the project for the Client, Kallangur Supermarkets Pty Ltd, and after feasibility studies of both the Binishell and conventional methods the Client elected the Binishell scheme.

Construction on site commenced on June 1978 and the centre opened on schedule for trading on December 1, 1978, only six months after commencement on site. The first shell was inflated just three weeks from the start and all the seven domes were completed after only eleven weeks on site, reflecting considerable time savings and providing protection against the climatic elements and reducing pilferage.

When the first dome for the centre was inflated a crowd of about 5,000 stood and watched Dr Bini and the Jennings Binishell team perform the magic inflation process.

As a result fitting out was able to begin in the very early stages of construction, adding to the insurance of completion to time and budget.

The centre consists of 4 x 36 metre and 3 x 18 metre diameter Binishell domes, three of the larger domes being interlocked and all connected with a common mall roof.

Great freedom of architectural planning is created with the large areas of column free floor space and interesting shop layouts were developed giving a feeling of free flowing mall areas.

Facilities provided in this fully air-conditioned and carpeted centre are 35 specialty shops, together with a supermarket and junior department store. The centre covers over 6,000 square metres of floor space.

The shopping centre is just one example of the flexibility and use for which this exciting system can be applied and its uses are only restrained by one's imagination.

**1. Technical Data**

To give more detailed information about the process and equipment, various stages of the technique are analysed:

a. Internal pneumatic form (pneumoform)

The pneumatic form consists of a membrane in nylon reinforced neoprene, with a peripheral anchorage. It is anchored to the base by means of a patented system which allows both air tightness and mechanical resistance (Fig. 1)

b. Pumping Station (Fig. 2)

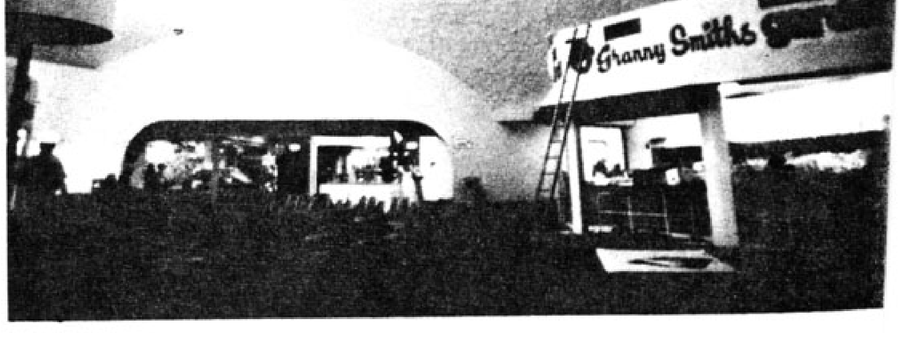
The pumping station consists of low pressure electric blowers, which absorb moderate powers of 10-15 kw, switchboard and a converter.

The internal pressure needed to lift the membrane and construction materials, is only several hundredths of atmosphere (and usually varies from 300 to 500 mm of $H_2O$). Air is passed through P.V.C. pipes (or other materials), which are under the floor and through the ring beam.

When the structure is completed these tubes can be used for provision of services.

Air pressure to the dome during inflation is controlled by inlet and outlet butterfly valves.

Auditorium at Kallangur



The shape of the structure is stabilized by creating air circulation; that is by inflating air into the pneumatic form, and similarly letting out a small quantity to avoid movement of the structure.

c. Steel reinforcement (Figs. 3, 10, 11)

Reinforcing steel consists of a mesh pattern and additional reinforcing elements. The pattern is made by springs hooked to a peripheral ring anchored to the foundations (Fig. 3).

The springs are manufactured at close pitch; taking up little space and can be easily packed and transported to the site.

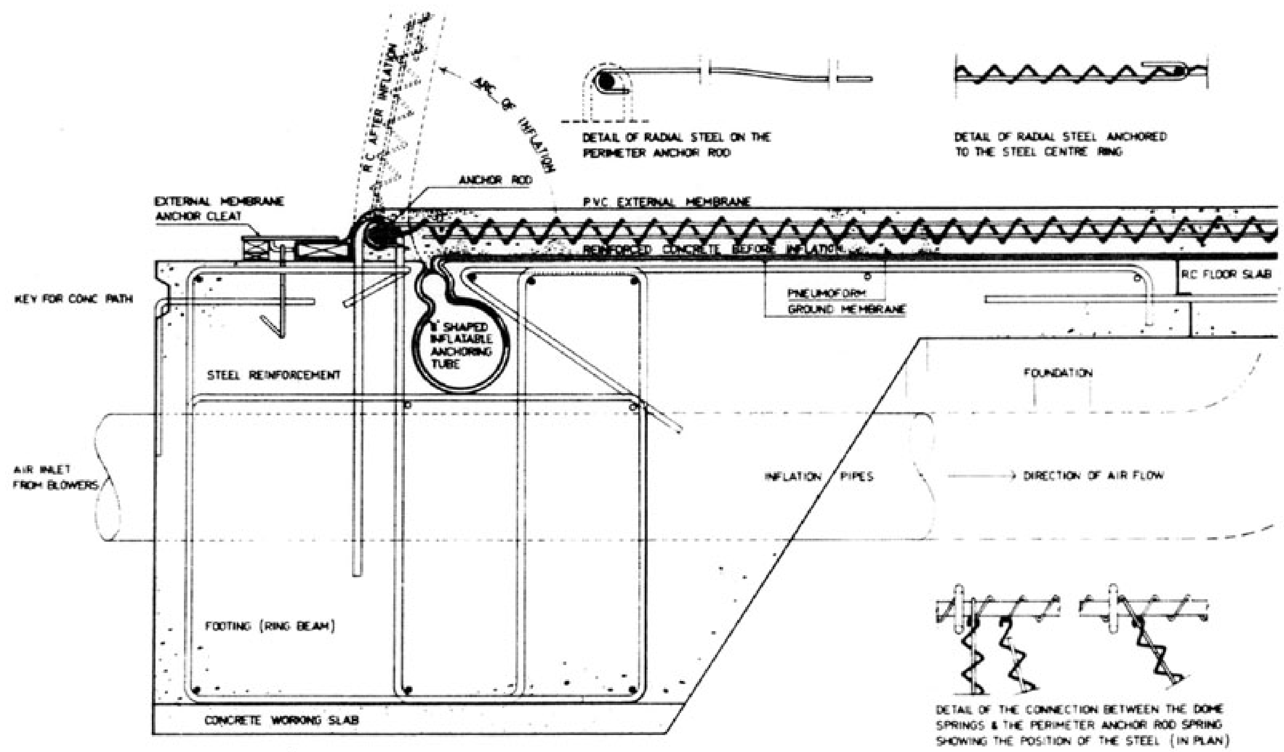
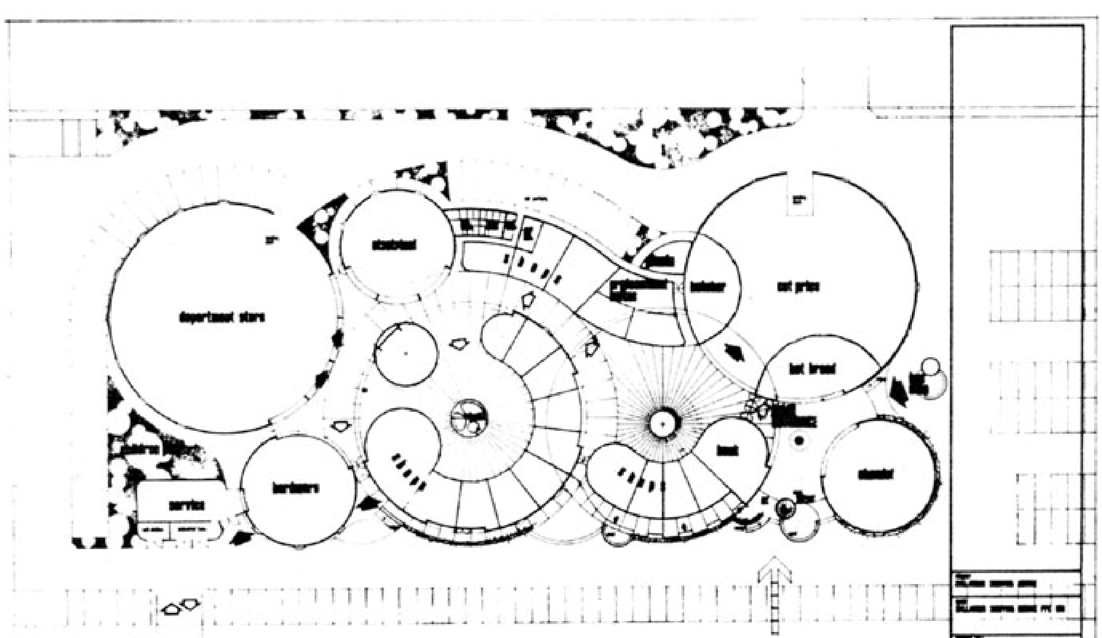



Fig. 1 TYPICAL SECTION



Jennings Industries Limited is the licensed constructor in Australia of the unique, pneumatically formed Binishell concrete dome system under a national agreement with Dr. Dante Bini, inventor of the system.

Uses include centres for recreation, assembly, swimming pools, gymnasiums, schools, libraries, motels, restaurants, commercial, industrial and agricultural purposes.

Binishell domes are constructed by pneumatically raising from ground level a layer of reinforced concrete which has not yet begun its initial set.

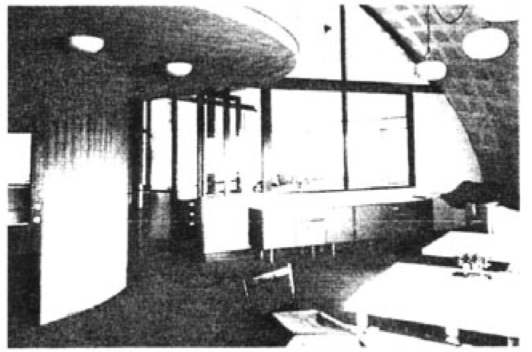
Jennings is able to build Binishells economically and quickly for a wide range of purposes in any location in Australia.

The process uses a nylon reinforced neoprene membrane which is anchored to a circular concrete foundation. Steel reinforcement and springs are placed across the uninflated membrane. Concrete containing set retarding chemicals is placed over.

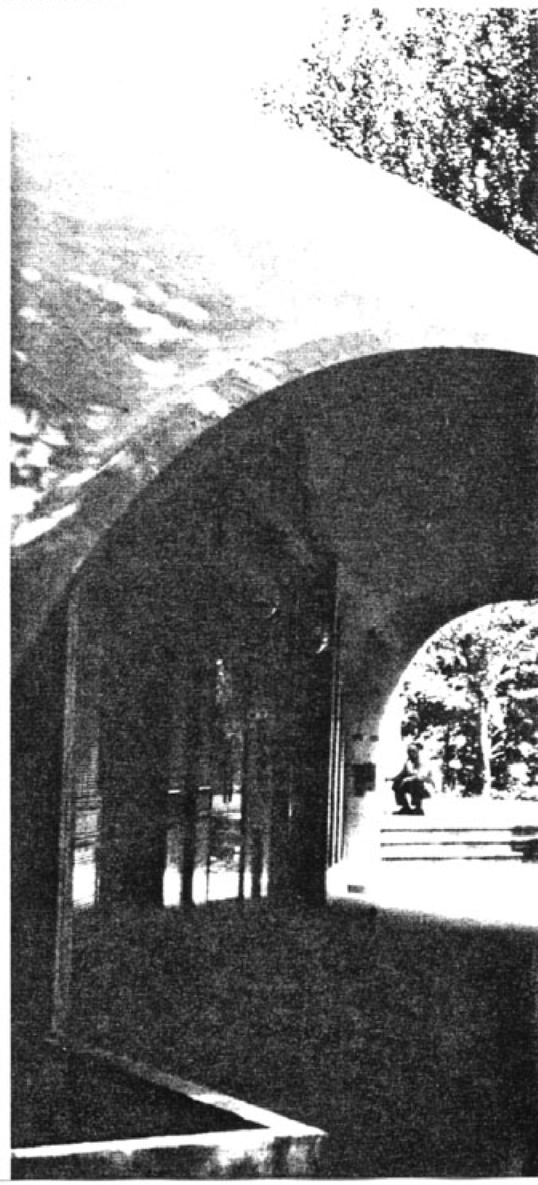
Low air pressure is forced between the floor and the membrane, lifting all the building materials up to the required shape. A vibrator process consolidates the concrete into a homogeneous dome. The air pressure supports the structure in position until the concrete sets. Openings to any desired shape may be then made.

SHOPPING CENTRE

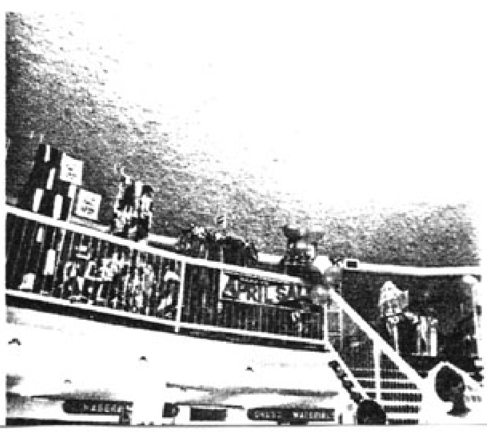

COMMERCIAL



ENTRANCE



SHOPPING MALL

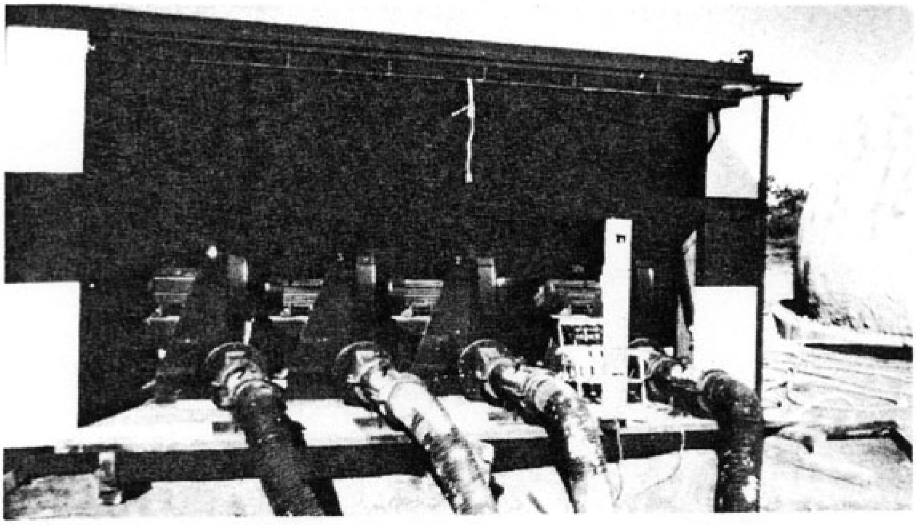


Fig.2 Pumping Station

Each structure requires 10 to 20 types of spring lengths. Placing is easily carried out directly on the ground, following the sequence shown on the drawings. Any type of Binishell structure follows the same operation. (Figs. 10, 11).

Reinforcing elements consist of straight steel bars, varying from 4 to 12 mm in diameter, which are positioned inside the springs and left free to slide.

During inflation the springs stretch and the bars settle and slide, keeping, however, in the required position and maintaining the necessary overlap needed to assure the continuity of the reinforcement.

The springs have many functions, the most important of which are:

— to prevent the concrete from sliding during the uplifting
— to guarantee concrete thickness
— to position and settle the reinforcing rods
— to control the uplifting and shape

The shape of the structure is defined by the pneumatic form as well as by the type and elongation of the springs.

d. Concrete characteristics

Concrete consists of a mix which has a high workability and contains a plasticiser and retarder. The characteristics of the mix are usually the following:

| | |
|---|---|
| Sand | 60% |
| Gravel (max 12-15) | 40% |
| Cement | 400kg/cm |
| Water/cement ratio | 0.50 |
| Slump | 18-20cm |

In order to protect the concrete and allow sound vibration a partially shaped P.V.C. sheet is placed on top as described hereunder:

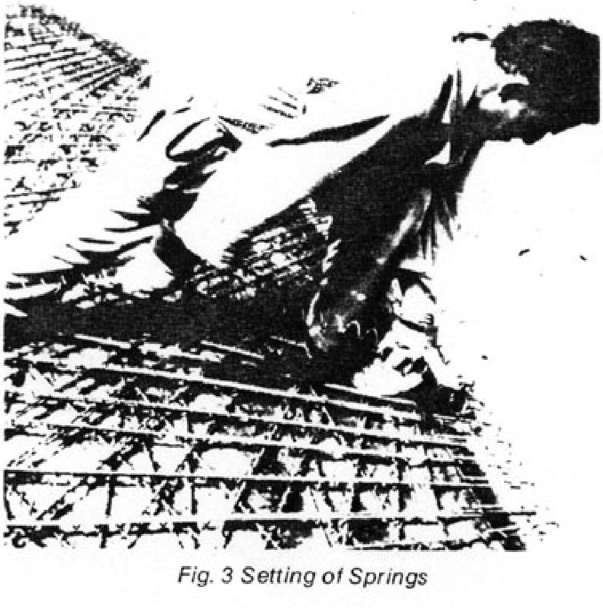


Fig. 3 Setting of Springs

e. External membrane

On top of the concrete and prior to inflation, the P.V.C. sheet is positioned (Fig. 5). This sheet is also anchored to the foundations in a simple and quick manner.

During inflation the P.V.C. sheet is put under stress, pressing against the concrete.

Its functions are:

— to protect the concrete both from the rain and strong evaporation due to sun irradiation.
— to help hold the concrete
— to allow vibration as explained hereunder:

f. Vibration

Before inflation, vibration equipment is placed on top of the P.V.C. membrane in the middle of the structure and it is lifted with the concrete (Figs. 6, 7, 8 & 9).

Fig. 4 Pouring and laying the concrete at ground level on the pneumatic from still deflated.

Fig. 5 Laying of the external membrane.

Vibration is carried out when inflation is completed by means of high frquency vibrators (6000-8000Hz) fixed on rolling carts.

These rolling carts, anchored to a cylinder placed at the top of the structure, are drawn across the surface of the dome. Each vibrator makes a path partially overlapping the one in front, so obtaining a total vibration of the surface (Fig. 9).

g. Setting of the structure and deflation of the membrane

The concrete of the structure, after stabilization and vibration, sets and hardens between the two waterproof membranes, with a gradual evaporation of water, and protected against atmospheric agents.

Usually, the membrane is deflated after 1 to 3 days, depending on the size and atmospheric conditions.

Soon after, an opening cut is made in the structure in order to remove the membrane for its re-use.

h. Openings in the structure

Cuts are made with a small Kango hammer.

This work is usually carried out as soon as is practical after the internal membrane has been removed.

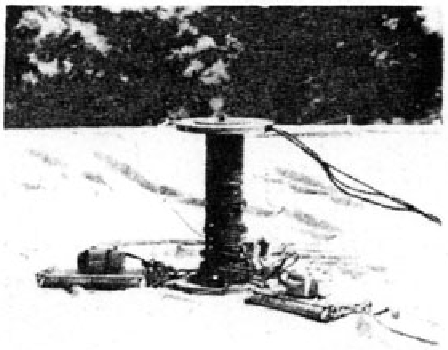


*Fig. 6 Vibration equipment installed before air inflation.*

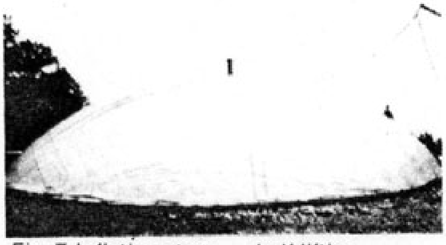


*Fig. 7 Inflation stage — half lifting.*

## 2. Shapes and Uses

The technology allows the realisation of double curvature thin shells resulting from demoration of elastic systems or having shapes geometrically well defined.

The structures can be built directly on foundations and floors at ground level, or on a traditional structure previously built.

In this event, the system consisting of membrane and steel mesh, instead of being anchored peripherally to the foundation is anchored to a bearing beam of the structure.

The uses of the system are many as listed hereunder:

- sports facilities, gymnasiums, swimming pools, multi purpose centres
- Social buildings, schools
- kindergartens, recreation centres
- commercial buildings, restaurants, supermarkets
- residential, tourist purposes
- industrial and agricultural buildings
- silos
- treatment plants, reservoirs
- electrical sub-stations
- exposition pavilions
- aero-clubs, hangars.

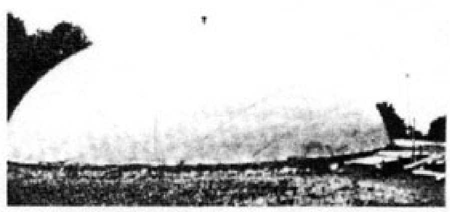
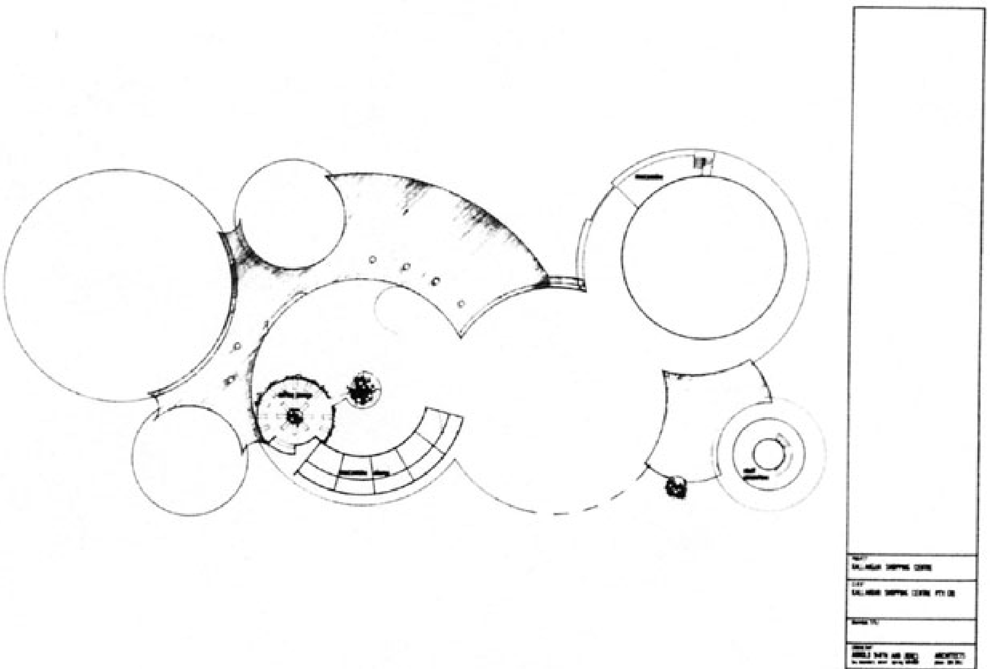


*Fig. 8 Completed lifting of a structure.*

*Fig. 9 Vibration stage after completed lifting.*



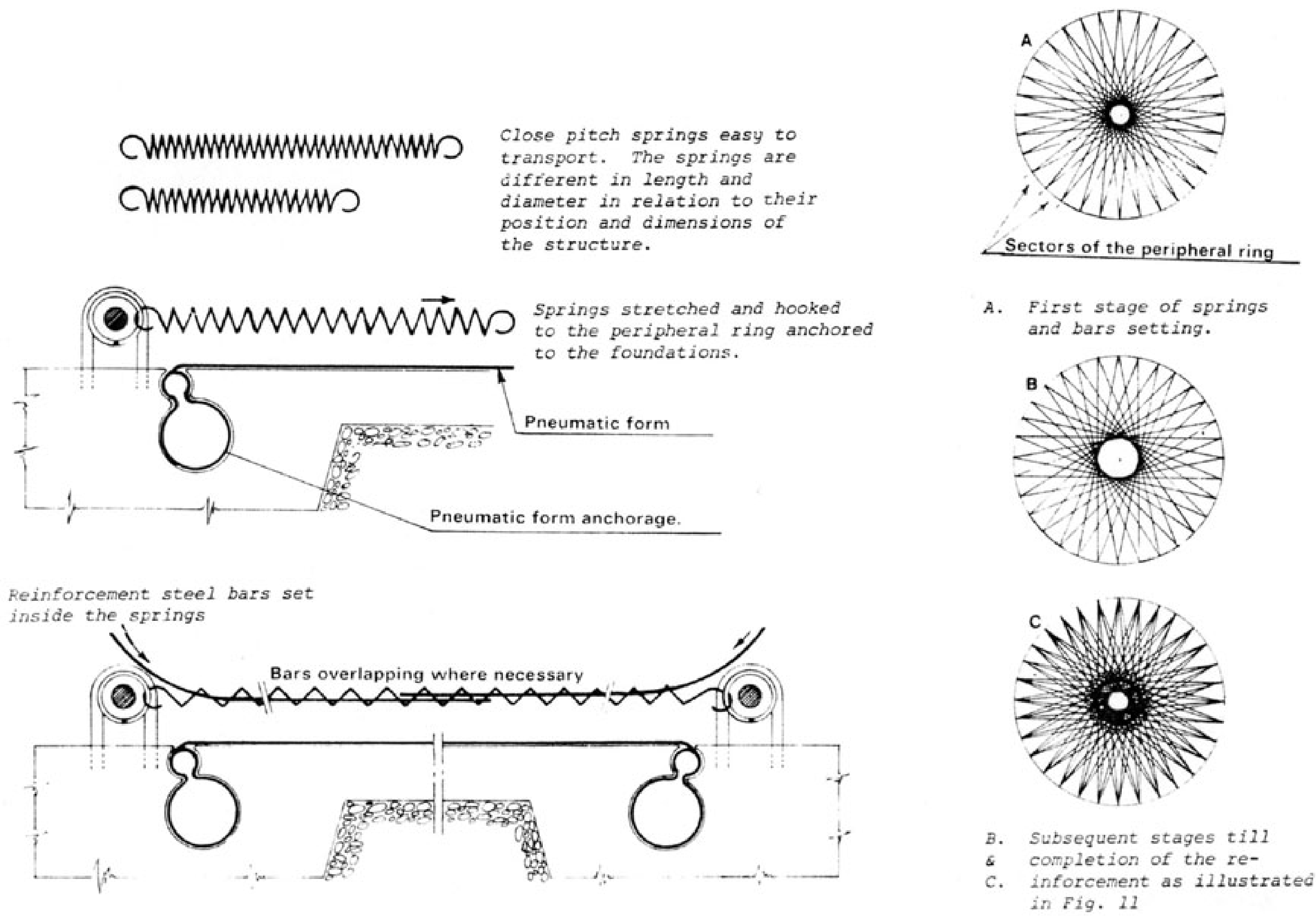
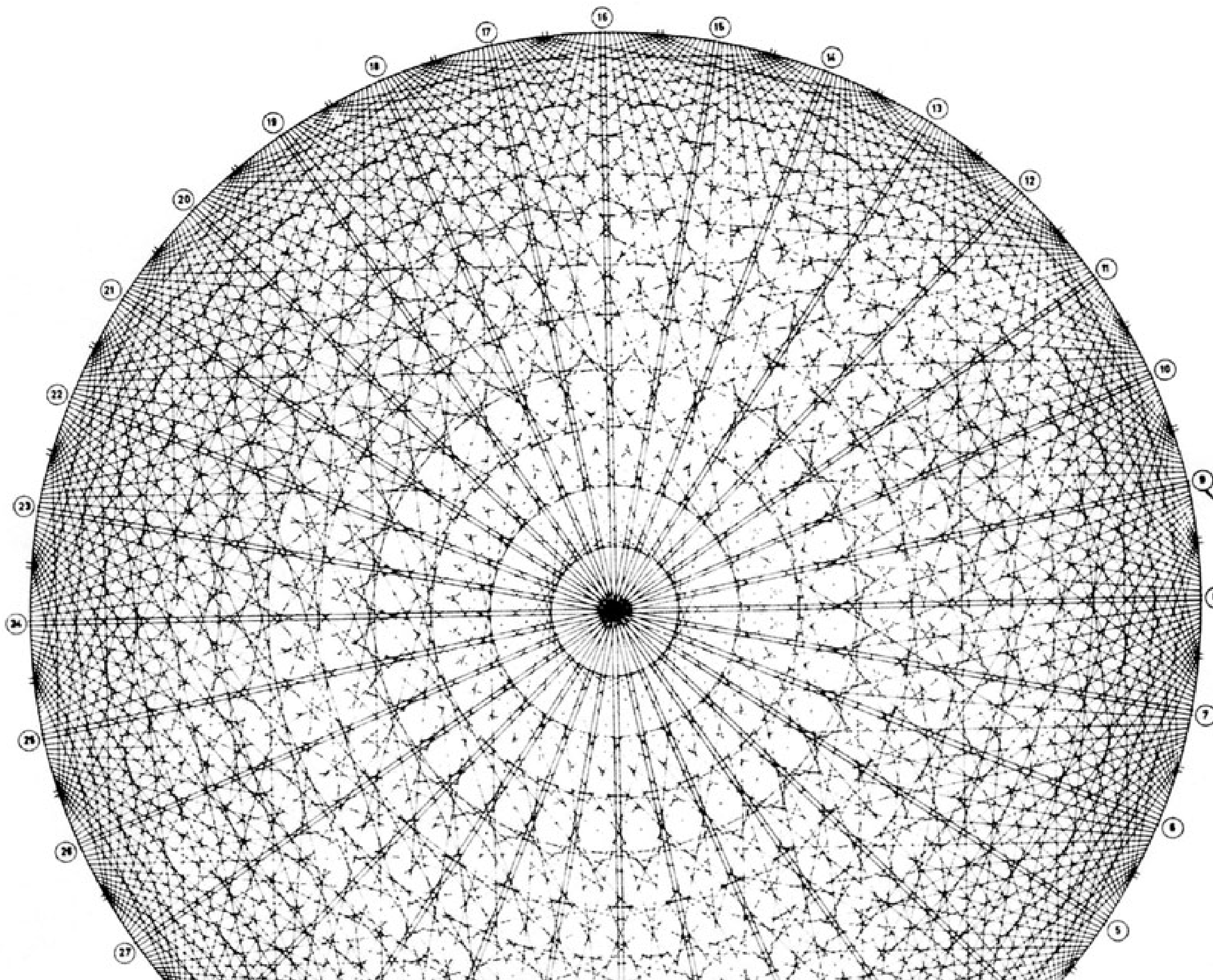
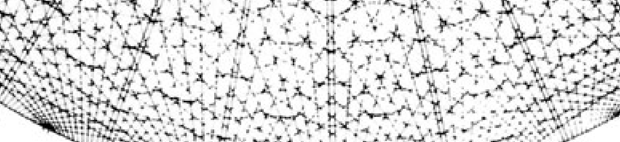



Fig. 10

## STANDARD DOME DIMENSIONS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Base diam. (m) | 10 | 12 | 15 | 18 | 20 | 32 | 36 |
| Max. Height (m) | 3.2 | 4 | 5 | 6.3 | 6.5 | 10.2 | 11 |
| Covered Floor Area ($m^2$) | 75 | 119 | 177 | 254 | 314 | 804 | 1018 |
| Vol. of Air Space ($m^3$) | 168 | 302 | 588 | 1070 | 1360 | 5460 | 7450 |





*Detail of a bar inside a spring*

*Fig. 11 A complete steel reinforcement. Notethethickeningofthereinforcement alongthemeridian andparallel lines.*

## 3. Insulation and Finishings

Finishings of Binishell structures can be carried out with materials normally used in traditional buildings.

a. Waterproofing finishings and insulation

As Binishell structures are 'monolithic concrete', the waterproofing and finishings can be carried out with traditional materials available on the market with the advantage that the monolithic nature of the structure eliminates the discontinuity of the waterproofing coat and moreover its shape facilitates the drainage of water. A spoon drain around the perimeter collects all surface water from the dome.

b. Acoustic Treatment

The problems are essentially the same as those of large empty areas with strong reflecting flat walls, obtained with traditional structures.

The most evident phenomenon, is the focusing of sounds typical in structures (not only Binishells) with large surfaces and particular shapes, on the other hand the acoustical correction problem does not exist if one divides the internal spaces with walls or furnishing.

Generally acoustic correction of large empty areas is resolved in two ways, by:

i. reducing wall reflection with the application of sound absorbent materials;
ii. installing sound absorbent ceiling panels which break the reflection and the sound focusing.

For small Binishell structures with one or more internal partition walls it is not necessary for extensive acoustic treatment; for the large structures a sound absorbent acoustic spray-on material to the internal face of the dome is applied. Only in particular cases, e.g. cinemas, theatres, auditoriums, discotheques etc, it may be necessary to adopt variously placed panels in addition to the sound absorbent spray.

Generally these panels are combined with the internal furnishing, lighting system, heating and ventilation ducts. It must be pointed out that acoustic treatment *can* be resolved with adequate internal finishing materials and furniture.

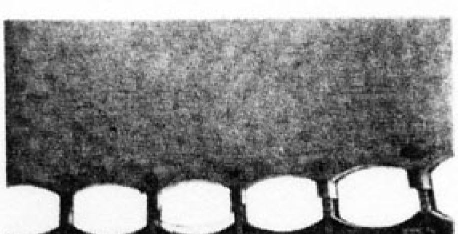


*Fig. 12 Dome built on a traditional structure.*

GEOMETRICAL CHARACTERISTICS

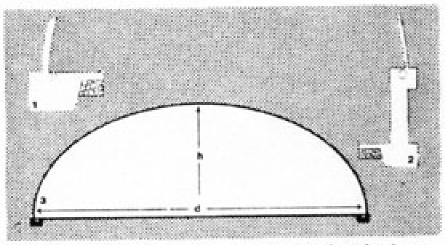



Fig. 13 1. dome on ground level foundations
2. dome on traditional structure
3. standard semiellipsoidal section

c. Thermal insulation

The thermal insulation of Binishell structures, as for any other structure, must be determined on the basis of costs and desired results and essentially in relation to the climate, air conditioning plant and the use of the dome. For the solution of this a wide range of materials exist, varying in price and characteristics, which are well established; provided that the technical specifications are followed and suitable products used the insulation of Binishells can be carried out on the external face.

Binishell structures are 'continuous and monolithic' and thus present no joint problems.

The external insulation of the structure increases the thermal stability, and provides a sound insulation barrier.

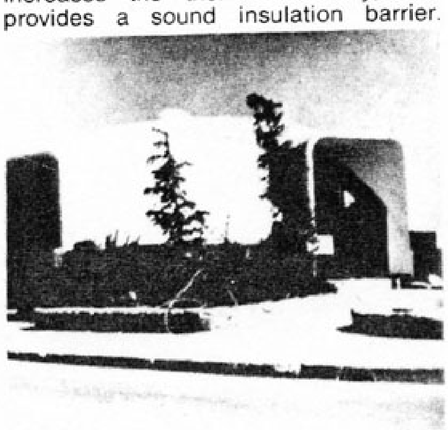


*Fig. 14 A dome in Mexico City.*

Polyurethane foam to the desired density and thickness is applied to satisfy these criteria.

The natural shape of Binishell structures facilitates internal ventilation.

The structure is waterproofed with a spray-on elastic membrane coloured or covered with granules (colour selection available). Thus ensuring a totally waterproof structure and providing protection against ultra-violet rays, etc.

## 4. Structural Data

The Binishell technology represents a novel building technique, i.e. the use of pneumatic forms uplifting both the construction material and the steel reinforcement permitting the realization of a reinforced, cast in situ concrete shell structure. The quality of the materials used (concrete and reinforcing bars) are normal and conform with the standard specification for normal concrete work.

The analysis and design is based on the criteria inspired by the construction science for 'double curvature thin shells in membrane systems'.

It is worthy of note that these structures for their 'closed and continuous' shape, their reinforcement, their uninterrupted foundation ring and their rigidity, are antisismical.

If the floor or part of it is structurally joined to the dome, one has a system 'floor and dome' highly resistant to every type of sismical stress and differential or dynamic loads.

a. Stresses in membrane system

The stresses, in thin shell structures are exclusively tensile and compressive, (due to the shape and structure thickness) and lie on the plane tangent to the shell. Therefore in the membrane system there does not exist bending, torsion or shear stresses.

First the stresses in the membrane system. For dead and live loads one takes the values fixed by the norms and regulations of the various areas and categories taking into account that the structures are merely covering.

For prudential reasons, the vertical loads are considered weighing on the whole structure. In effect this unfavourable load situation will not occur because the lower part of the structure,

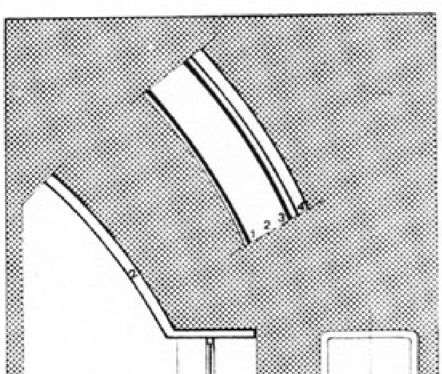
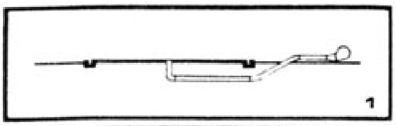



Fig. 15 Opening and insulation detail

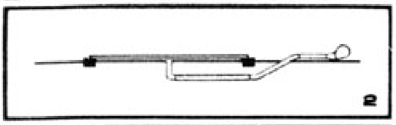
a) Window fixed to the structure as in traditional buildings;
b) Spaces for technological installations or fixtures;
1) Internal sound-absorbent sprayed plaster;
2) Concrete structure;
3) Rigid foam polyurethane insulation applied by spray with transmission coefficient less than 0,8;
4) Water-proofing with other eventual protections and external finishings

**Operation sequence:**

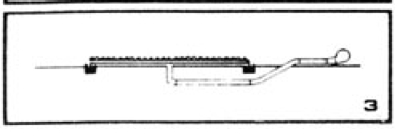
The following is a pictorial description of construction of a Binishell:



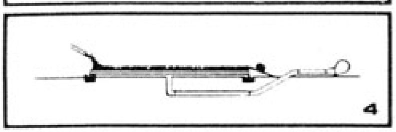

A reinforced concrete ring beam is poured with a moulded recess.



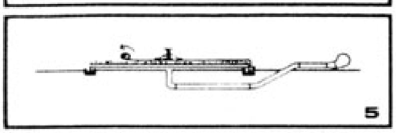

A pre-shaped neoprene membrane is anchored in the recess in the ring beam.



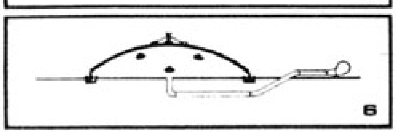

Steel springs and reinforcing rods are stretched across the membrane in a pre-designed layout.



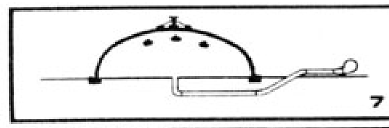

A layer of specially formulated concrete is spread over the membrane covering the reinforcement.



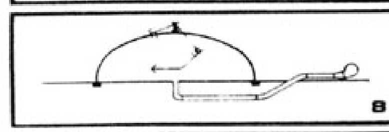

The concrete is covered with light PVC sheeting which is secured to the ring beam. Rolling vibrators are positioned in the centre.



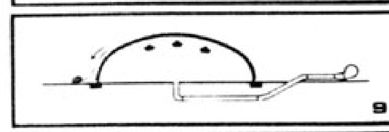

Air is introduced through ducts under the membrane, lifting the structure.



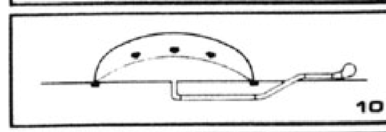

Tension in the springs controls the lifting and the shape of the dome.



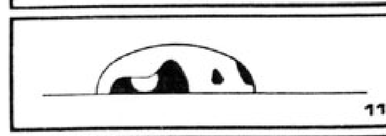

The exterior surface is vibrated when the dome is inflated to the required height.



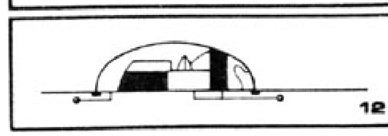

Constant height and pressure control are maintained until the concrete has set.




Air support is maintained for one to three days after which the membrane is deflated.

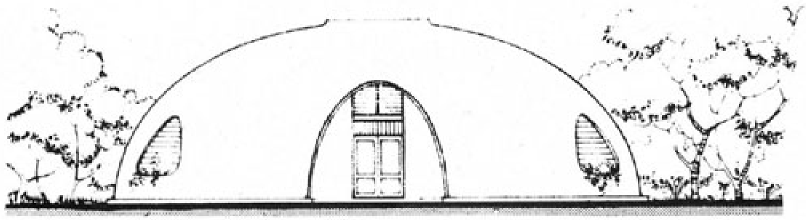



Openings of various designs are made as doors and windows.




Final fitting out is undertaken as determined by the design requirements of the particular project.

# Inflatable Concrete Technique Speeds Construction of Domes.



A new and revolutionary building system has been recently introduced in the United States. Called the Binishell, after its inventor Dr. Dante Bini, the unique construction system provides a quick and comparatively inexpensive method of building a domed structure.

Bini is very proud of his design. In explaining its advantages he points out that, "For many years, the dome has been one of the most efficient structures ever developed. However, in practice, it has proven to be one of the most difficult and costly to build. The complex forming and construction procedures required for this type of structure have made the dome impractical on all but the most elaborate of buildings. Now, with the Binishell process, the construction of concrete domes is possible with a speed and economy that is competitive with conventional structures of equivalent size."

Simply stated, Dr. Bini's process is a method of pneumatically inflating a concrete shell. Currently, the domes can be up to 120 feet in diameter and have a height equal to one-third of their diameter. They can be erected individually or joined together to make a much larger building.

According to its designer, the construction of the dome is simple and quick.

Prior to inflation of the dome, steel reinforcement and concrete is placed on top of a neoprene membrane, and then covered with a P.V.C. membrane. For a large dome, the pouring of the concrete takes about three hours while the inflation of the structure occupies another hour. The only materials required are steel and concrete – both of which are readily available.

The dome structures are formed by slightly compressed air supplied by electrically-driven centrifugal fans through ducts under a concrete ring foundation.

After the dome is inflated to the required height, specially constructed vibrating machines pass over the exterior surface to provide a smooth, uniform finish. Constant height and pressure control is maintained for 36 hours afterwards, while the concrete cures.

The membranes are then removed and the exterior of the dome completed by the cutting of doors and windows through the shell, in line with the design requirements of the particular dome concerned.

While it shares the general advantages associated with dome-shaped structures, including high stability, the Binishell has its own particular advantages.

Speed of construction is a key factor. The entire Binishell, from the time of constructing the initial foundations to the removal of the interior membrane, takes about two to three weeks. The actual time taken is dependent upon the size of the dome and the prevailing atmospheric conditions.

Another major advantage is that the exterior walls and roof are erected in one complete operation, and once the exterior structure is erected, the finishing of the interior can be completed without interruption from inclement weather.

For over ten years now, the Binishell system has been in use throughout the world. Projects have been completed in Italy, Australia, France, Japan and Peru, to name a few. Currently, in Pakistan, approximately 250 Binishell structures are being erected for grain storage. The project, for the Pakistani government, is averaging a 100-ft. diameter concrete dome every two days. If all goes as planned, Binishells will soon start appearing in the United States.

With the forming of Binishells International in San Francisco, a consulting organization will be available to promote and give advice on Binishell technology for the U.S. market. Their office is located at 300 Market Street, Suite 531, San Francisco, CA 94104.

# П Р О Г Р А М М А

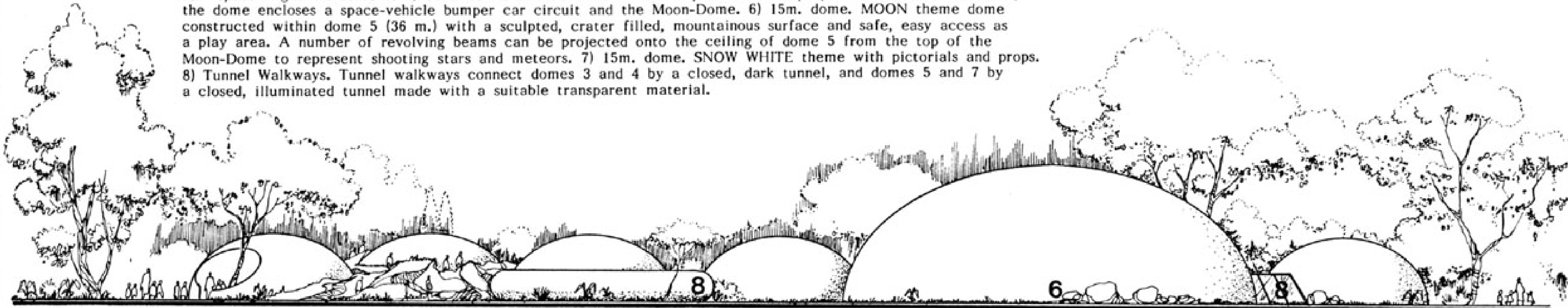
семинара фирмы "БИНИШЕЛ " , США для советских специалистов
/ Павильон № 1, Красная Пресня, Пресс-клуб, 3 этаж, подьезд А /1/

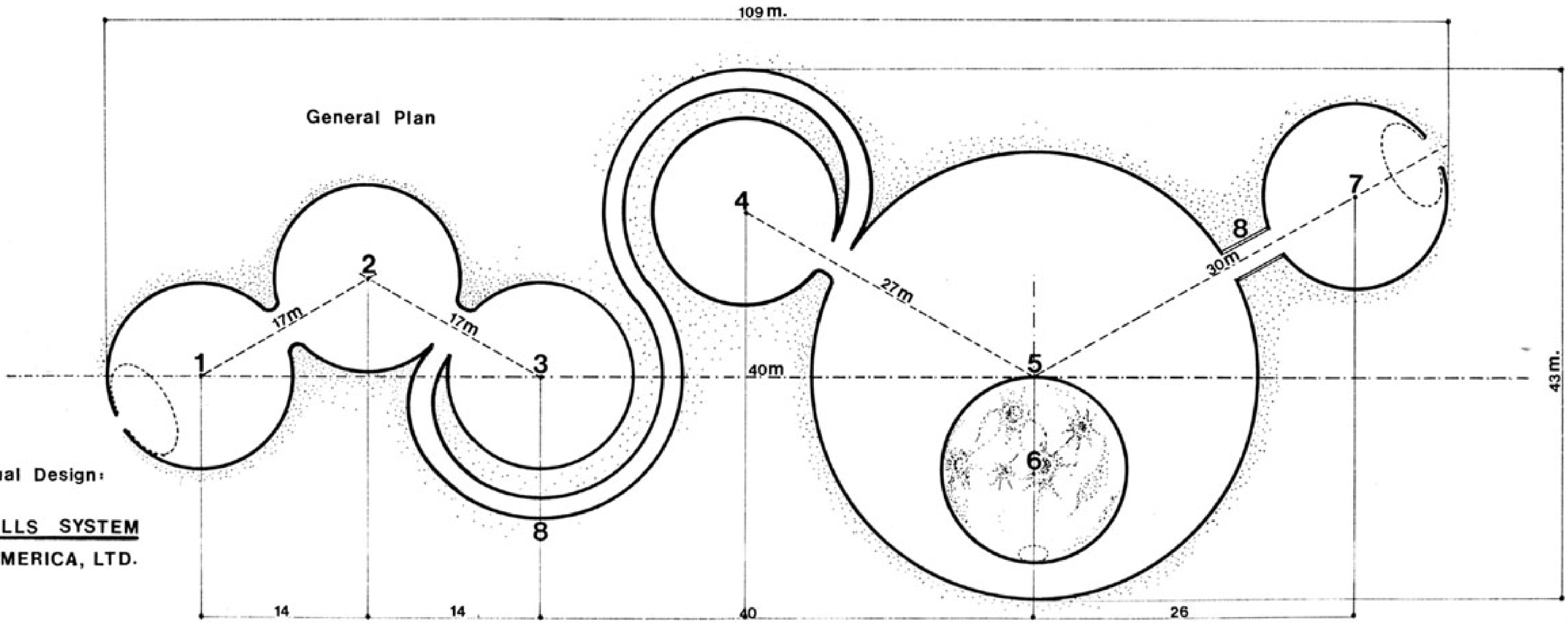
| | | |
|---|---|---|
| <u>9 июня 1986 г</u> | - 10.00 | - Открытие семинара. |
| | 10.15 | - Доклад об общих принципах скоростного метода возведения купольных железобетонных зданий. |
| | | - Демонстрация видеофильмов, кинофильмов и слайдов. |
| | 13.00 | - Перерыв |
| | 15.00 | - Вопросы советских специалистов и ответы американских специалистов. |
| <u>10 июня 1986 г</u> | - 10.00 | - Доклад об организации строительства, его этапах, технических характеристиках применяемых материалов, оборудования и квалификационных требованиях с специалистам, привлекаемых к строительству. Вопросы и ответы. |

<u>Примечание:</u> По всем дополнительным вопросам, просим обращаться в Представительство фирмы "АРМКО ИНК" :

Москва
гостиница "Берлин" , комната 230
Тел: 225-60-38, 923-62-34

CHILDREN'S RECREATIONAL AREA. EXPOCENTR 1987. KEY: 1) 15m. dome. WALT DISNEY theme pictorials and props. 2) 15m. dome. RUSSIAN FAIRY TALE theme pictorials and props. 3) 15m. dome. MYTHOLOGICAL theme pictorials and props with internal labyrinth. 4) 15m. dome. SPACE theme pictorials and props in preparation for "space flight" in dome 5. 5) 36m. dome. SPACE FLIGHT theme pictorials and props. Under a star filled ski, the dome encloses a space-vehicle bumper car circuit and the Moon-Dome. 6) 15m. dome. MOON theme dome constructed within dome 5 (36 m.) with a sculpted, crater filled, mountainous surface and safe, easy access as a play area. A number of revolving beams can be projected onto the ceiling of dome 5 from the top of the Moon-Dome to represent shooting stars and meteors. 7) 15m. dome. SNOW WHITE theme with pictorials and props. 8) Tunnel Walkways. Tunnel walkways connect domes 3 and 4 by a closed, dark tunnel, and domes 5 and 7 by a closed, illuminated tunnel made with a suitable transparent material.




Conceptual Design:
D. Bini

BINISHELLS SYSTEM

BSNA AMERICA, LTD.

## PRESENTATION OF BINISTAR, BINISHELLS AND OTHER BINI SYSTEMS TO MOSCOW CHAMBER OF COMMERCE MOSCOW, U.S.S.R. June 9, 1986

### INTRODUCTION

The basic principle of the patented Bini Systems is the use of low air pressure to lift and shape all materials needed to build column-free structures, thus maximizing speed of construction and minimizing skilled labor, construction costs, time and energy. All systems are or will, within the prescribed filing times, be protected by U.S.S.R. and other patents.

Bini Systems produce a series of structures representing the evolution and the development of the concept. These systems provide column-free, permanent and/or semipermanent structures for a multitude of applications in various dimensions ranging from 80 to over 10.000 square metres of covered area.

The Bini Systems include the following:

1. **MINISHELL** (10x10 or 12x12 metres)
   A small square based monolithic reinforced concrete structure with a domed shell roof, usable for small dwellings, such as individual or multiple living units.

2. **BINISHELL** (up to 1.200 square metres of covered and enclosed area)
   A circular based monolithic, reinforced concrete dome structure constructible in sizes from 12, to 40 metres in diameters.

3. **BINISIX** (up to 3.000 square metres of covered area)
   An hexagonal based monolithic reinforced concrete framed or ribbed dome structure constructible in "diameters" from 40, to 64 metres.

4. **BINISTAR** (up to 10.000 square metres of covered area)
   An hexagonal based metal and plastic structure constructible in dimensions from 40, to 120 (and over) metres in "diameters". Unlike the other Bini Systems, the Binistar uses no concrete and construction time is reduced from days to a matter of hours. This system provides almost instant shelter, particularly useful for emergencies and/or temporary uses.

5. **PAK-HOME** (80 square metres of covered/enclosed area)
   A low cost kit for pre-fabricated modular, affordable, emergency, single family housing, which is "self-shaping" on inflatable elements which can serve as a temporary supporting foundation for the building.

The Bini Systems are in various states of design, development and application, ranging from the Binishell, with over 1,500 structures having been erected around the world, to the new PAK-HOME kit for which final engineering is being completed with the erection of a prototype to follow.

## THE BINISHELL AND MINISHELL SYSTEMS

Binishells have been built in approximately 20 countries throughout the world.

Binishells are in use as Gymnasiums, Swimming Pools, Silos, Warehouses, Schools, Libraries, Civic-Centers, Shopping-Centers, Motels and Tourist Settlements.

The two most recent projects are:

(a) 150 domes at Pipri (Karachi), 137 domes at Vehari, Arifwalla, Bahawalpur (Punjab), 150 domes at Bolari and Jhang.

(b) 7 domes at Salman Pak, 21 domes at Khan Bani Saab, (Bagdad), 14 domes at Najaf.

In comparison with other conventional building systems able to produce structures of similar characteristics and volume, construction of Binishells has been shown to save time, material, labor and energy.

A separate set of special Binishell equipment is required for each of the Binishell sizes, which go from 12 to 40 metres in diameter.

The Binishells Companies and associated organizations have been using the Binishell system for the last 15 years and are available to provide their expertise together with specific Binishell equipment.

A further development of the Binishell, is the Minishell, a square base building structure which has been divised for housing. A Minishell cluster has been built near Cairns (QL) Australia, as a tourist resort.

## BINISIX SYSTEM

The BINISIX is a monolithic, reinforced concrete hexagonal base framed or ribbed structure. This technology has been developed to increase the column-free covered area with the use of a reduced amount of reinforced concrete per each square metre of projected surface.

The first Binisix prototype was built for the Government of New South Wales, in Australia. It was a 16 metre diameter structure equivalent to the top segment of a 64 metres domed structure.

The equipment cost for the Binisix systems is less than that needed for the Binishells. The maximum diameter of the Binisix is approximately 64 metres, yielding over 2.600 $m^2$ of covered area. This system has been designed to meet international reinforced concrete codes in order to make it easier to obtain local governmental approvals.

## BINISTAR SYSTEM

The BINISTAR System produces a metal hexagonal frame inflatable structure utilizing a flexible fabric membrane which is an integral and permanent part of the system. This technology has been developed to further increase the column-free covered area available up to approximately 10.000 $m^2$ of enclosed area produced in a single one-day operation.

An initial model was built in Australia for the development of a feasible geometry for a base computer program. The second model was built in the United States to further understand the structural an architectural practicability of the new geodesic-like structure. The first full-scale 40 m. "external diameter" prototype was successfully built in Italy and tested in 1986.

The Binistar equipment is limited to low-pressure, high volume blowers provided with simple control devices which can be re-used for many inflations. The Binistar technology was developed to eliminate the very large amount of closely controlled concrete required for the construction of 36 m. Binishells and 64 m. Binisix structures, thereby eliminating the need for close proximity to a large concrete batching plant. The Binistar technology has also been developed to provide a self-supporting complete structure usable the same day of its construction and easily dismantled the day after, if needed.

In addition to the footing system, the Binistar building basically consists of two materials/components:

1. Simple metal telescopic pipings with spherical metal nodes.

2. Special, air-tight, long lasting pre-shaped fabric membrane.

The Binistar package may be used as a kit which can be taken anywhere in a typical semi-truck trailer, and can be assembled and erected with a small, minimally skilled crew. The first Binistar 40 m. prototype was built in Bari, Italy, on a prefabricated footing/floor system in less than two weeks.

## PAK-HOME SYSTEM

The PAK-Home low cost housing package relates to a building construction concept utilizing modular components which can be readily shipped in disassembled form and which can be readily assembled to provide a rapidly erectable, enclosed shelter by means of inflatable elements.

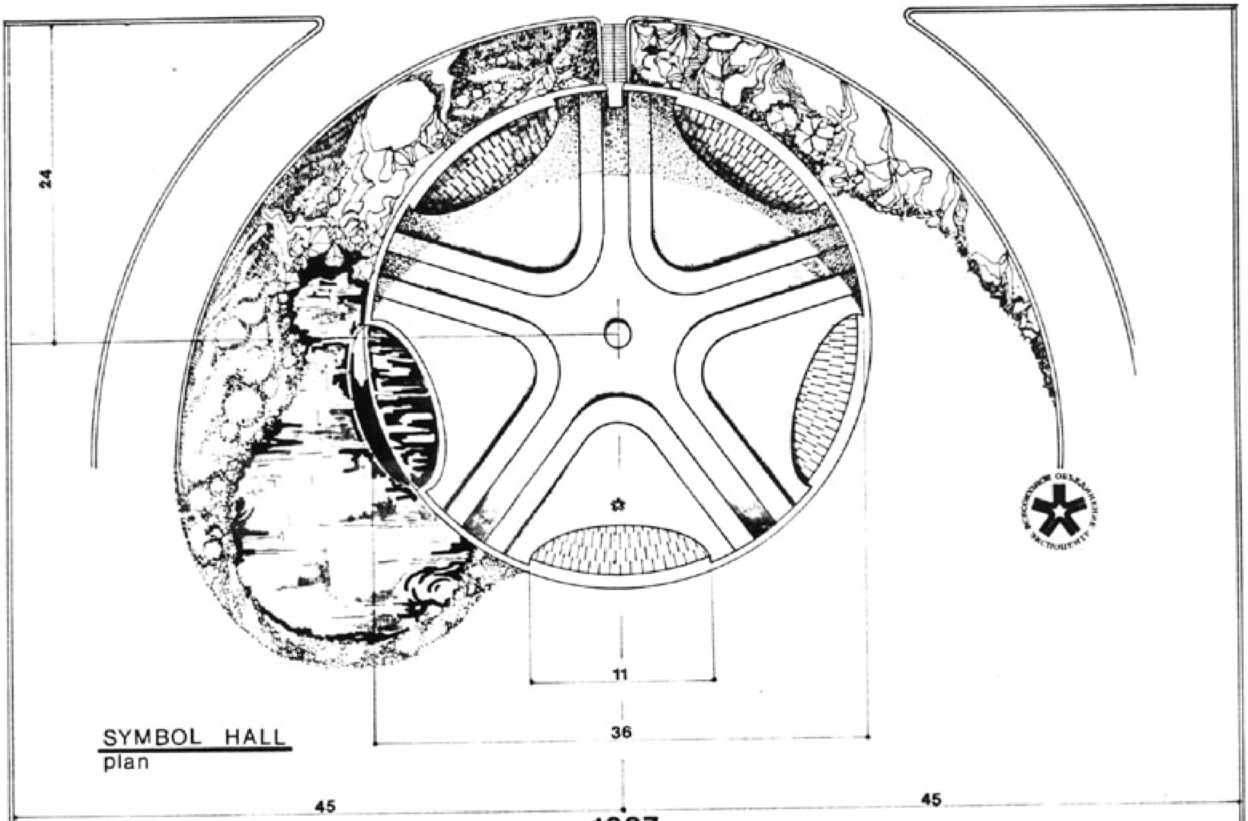
The PAK-HOME package is made up of 16 basic modular components that combine to make an 80 $m^2$ family dwelling. This shelter is of sufficient size to enclose at least two large bedrooms, two bathrooms, ample closet space, laundry and pleasant kitchen, living and dining environments.

The package is easily deliverable and can be erected in one day on a reasonably flat surface by unskilled workers directed by a supervisor. The low-cost design features (a) plug-in connections for local water, electric and drain-sewage, or (b) external existing utility networks. All internal partitioning is available with a number of different floor plans to suit every need and price range. These internal systems are designed for end user installation.

The PAK-HOME can be totally disassembled in one day and each component packaged for either storage or transport for further use.

## INFORMATION

Further information regarding any or all of the Bini Systems can be obtained by writing to: Binistar Inc., 215 Maple Street, San Francisco, CA, U.S.A. 94118.

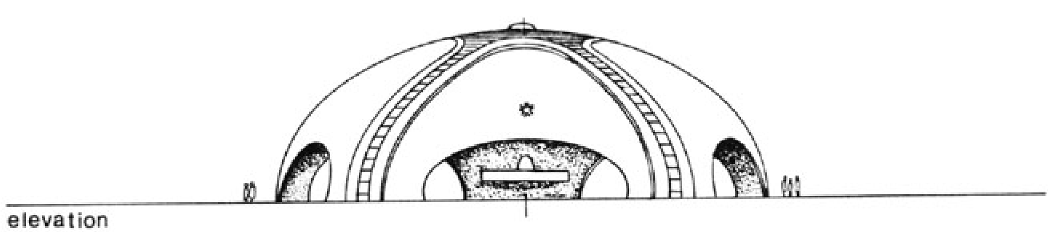



SYMBOL HALL
plan

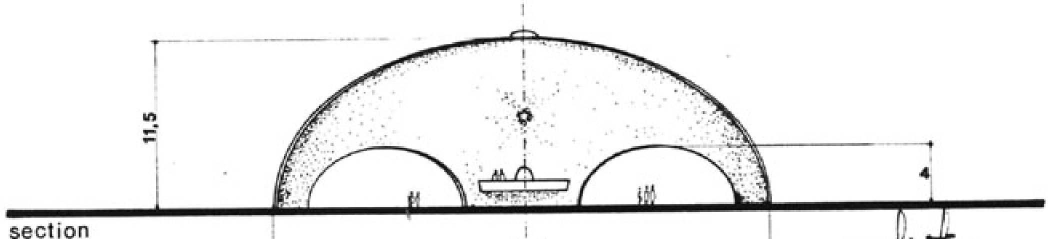
## 1987

# INTERNATIONAL EXHIBITIONS IN THE USSR

# EXPOCENTR



elevation




section

Conceptual Design: D.Bini —— Binishells System —— BSNA America LTD.

The McGraw-Hill Construction Weekly

ENR

# Inflatable domes of steel

Inflatable buildings that pop up with a push of a button may evoke cartoon images, but one inventor has been erecting concrete structures like that for 20 years. He is now using the same method to put up permanent, steel-framed structures in about an hour.

Italian designer Dante Bini inflated his first concrete dome building 20 years ago. Since then, thousands of Binishells have been built around the world. But the technology did not catch on in the U.S. Building codes require a thicker concrete cover over the steel rebar than the process allows. Shotcreting on another layer would solve that problem, Bini says, but adds to the total cost of the building. Another obstacle was personal resistance to thin-shelled construction. It proved to be a problem Bini could not overcome.

"It was a tad," says William C. Panarese, manager for construction information services for the Portland Cement Association, Skokie, Ill. People are reluctant to try a new shape and a new method, he adds.

Bini is hoping people will not have the same reservations about his latest construction technique. Instead of concrete, an interlocking metal frame is lifted with an air pump to form a building that can be used for anything from an airplane hangar to a tennis court cover.

To erect the self-shaping dome, a roof membrane made of PVC-coated polyester is laid out on the ground and the interlocking metal roof frame made of steel pipes is assembled over it. Air pumped under the membrane raises it. The metal pipes have telescoping sleeves that expand and lock into place. When the air is turned off, the building remains standing.

**Interlocking pipes** covering a polyester membrane are raised with air in an hour.

Clear spans of 120 ft to 300 ft are obtainable, and one study shows that 850-ft-dia domes are possible. Using the polyester membrane, Bini estimates installation costs at $15 per sq ft. Other fiberglass membranes, coated with Teflon or silicon, are also available.

The structure can be moved easily, Bini says. A 120-ft-dia building can be deflated and packed into a standard inter-modal shipping container.

Two Binistar structures, as the steel-frame units are called, exist now in Italy—a demonstration hexagonal structure 120-ft across and a 130 x 130-ft tennis court cover. A third tennis court cover measuring 200 x 130 ft is planned.

CBI Na-Con Inc., Chicago, will distribute Binistar systems in the U.S. The air-raising technique will be valuable in regions where construction is difficult, says Gary R. Marine, CBI business development manager. ■

CENTER FOR CONSTRUCTION RESEARCH AND EDUCATION
DEPARTMENT OF CIVIL ENGINEERING
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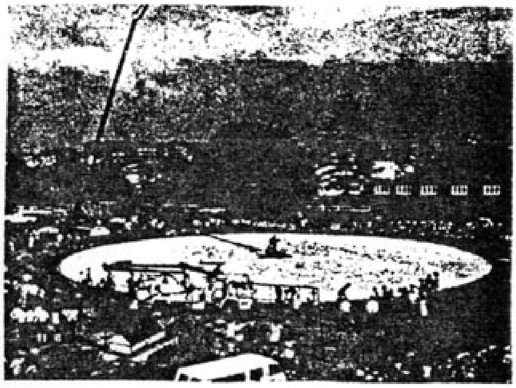
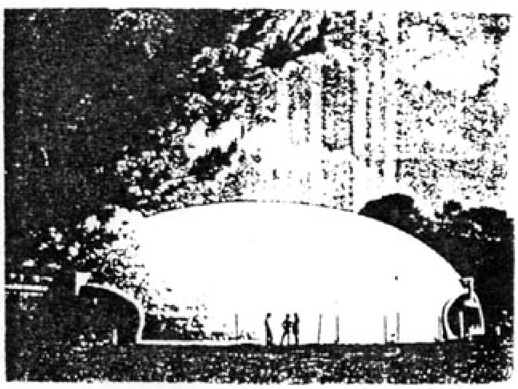
Binishells®





# DR. DANTE BINI

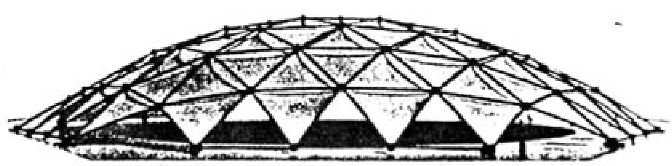
the originator of BINISHELLS and BINISTAR will present his unique building technology at MIT on

Thursday January 22, 1987
Time: 11:30-1:00
Location: Room 1-350

This creative method is based on pneumatic formation of reinforced concrete or steel structures, assembled and cast at ground level, and raised to their final configuration by air-inflated P.V.C. forms.

About 1500 structures of these kind in 500 projects have been successfully built all around the world.

For more information, or arrangement of appointments with Dr. Bini during his stay in Boston between Jan. 21, 1987 and Jan. 23, 1987, please contact Professor Yechiel Rosenfeld Telephone: 253-7201



BINISTAR®
PATENTED CONSTRUCTION SYSTEM

# The World According to Dante Bini

**Dante Bini** designs buildings that bury themselves like beetles in the surface of the moon and cities that soar a mile high. This visionary's innovative technique is construction automation, which uses air pressure to erect domes—creating a new way of thinking about architecture.

In 1967, Bini was invited to Columbia University to erect a 50-foot dome (an event that landed him in the *New Yorker*, which likened him to a young Valentino). His inspiration? While playing tennis on a balloon-roofed court, he was startled to see several feet of snow had fallen during the game—yet he didn't feel a trace of pressure. "I realized I was facing an enormous potential for energy if I was able to use air pressure to lift and shape buildings," says the 66-year-old Stanford lecturer, who divides his time between Arezzo, Italy, and St. Helena. Working in the dome style of his idol Heinz Isler, Bini replaced wooden formwork with balloons—inflated using about the pressure it takes to puff on a cigarette—to define and elevate his Binishells.

Thirty years later, there are more than 1,500 around the world. And the man some consider "one of the greatest creative minds of the century" is looking to the moon, consulting for Japan's Shimizu Corporation on building space structures, including an orbiting hotel. Bini would willingly be the first guest. "I could have the same perception as [astronaut] Buzz Aldrin," he says dreamily. —*Susan McCarthy*

L.W. SCHERMI

251 MAGGIO 1999

DANTE BINI • LATERIZIO • PORTE DI SICUREZZA

modulo

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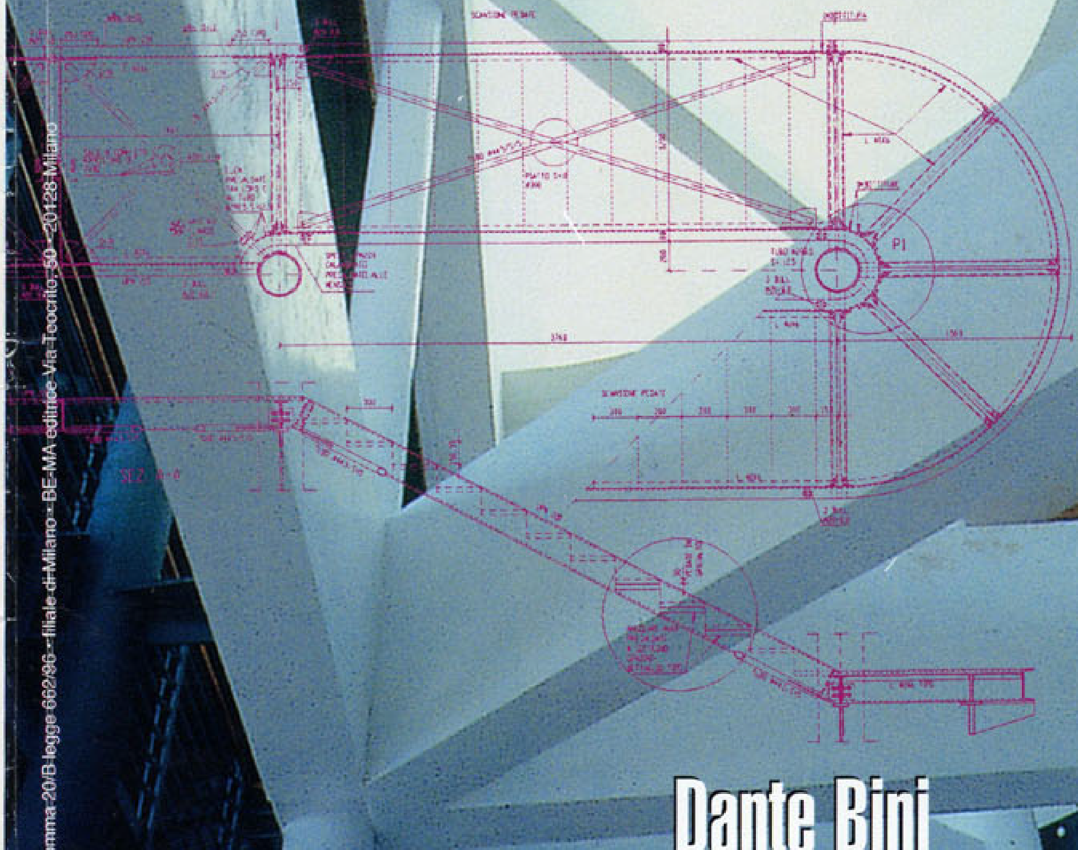
# modulo

Mensile di Tecnologia e Progetto per la Qualità Edilizia



## Dante Bini
## Laterizio • Porte di sicurezza

251 MAGGIO 99

# Architetto e inventore

Architetto, imprenditore, inventore, "utopista tecnologico", raggiunse una certa notorietà negli anni '80 con le "Binishell". Figura anomala nel panorama italiano. Tanto da doversi trasferire in USA.

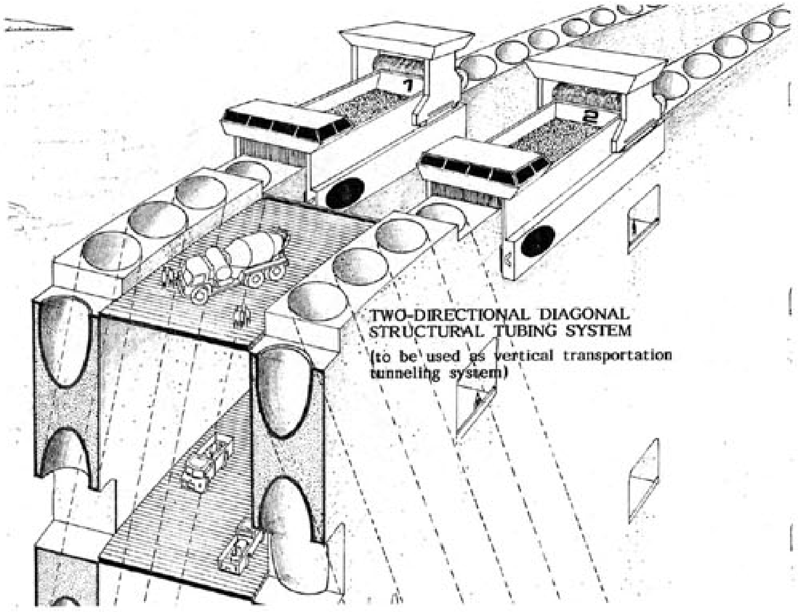
Alessandra Scalici

L'influenza del momento storico in cui si vive è sempre molto forte e soggettiva. Alcuni ne subiscono aspetti esteriori, effimeri, altri ne riportano un imprinting così profondo e solido, sono talmente pervasi dallo spirito della propria epoca, che finiscono per rappresentarla in toto, nel bene e nel male.

Dante Bini potrebbe essere vissuto solo in questo secolo o nel primo rinascimento. Potrebbe essersi formato - come è successo - soltanto all'alba degli anni Sessanta, quando si respirava aria di grandi scoperte scientifiche, di novità tecnologiche, di forti speranze, quando il mondo usciva dal suo secondo medioevo, fatto di guerra, oppure alla scuola di Filippo Brunelleschi, quando si riscopriva un'architettura, governata da nuove regole scientifiche. Forse tutti coloro che vivono grandi utopie e grandi slanci nel futuro hanno una cupola in testa. Forse subiscono più di altri il fascino di questa bolla che, senza soluzione di continuità si spinge verso l'alto con un'unica grandiosa curva. Ma dove portano le utopie? Qui da noi, in questi anni, portano poco in là.

Per questo Dante Bini si è trasferito all'estero, a lavorare tra altri spazi, dove non è vissuto solo di grandi idee incomprese: sono pochi gli architetti, anche quelli di cui si parla molto, che possono vantare di aver realizzato oltre 1.500 strutture in giro per il mondo. E all'estero, prima in Australia, poi negli Usa, Bini ha proseguito nella ricerca della chimerica sintesi tra prodotto finale, materia prima e macchina. L'affinamento di questo irraggiungibile state of the art lo ha portato a introdurre una nuova valenza: l'automatismo, da cui è nata la mecatronica edile, applicabile sia alle alte tecnologie terrestri che a quelle extraterrestri nelle quali Bini si è cimentato con progetti per realizzazioni di basi lunari, come il Lunab commissionato dalla Space Systems Division della Shimizu Corporation.

Iniziando da una cupola, il concetto tradizionale di industrializzazione edilizia si è per lui spostato a monte, slegandosi da quello di prefabbricazione. L'innovazione associata alle sue tecnologie sta piuttosto nel fatto che le stesse




*In basso a sinistra, vista della Tower City (Binistar).*
*In alto, esempio schematico della struttura della Tower City: il trasporto è automatizzato attraverso un sistema di tunnel.*

producono in loco strutture portanti autoformanti. Ad esempio, nel caso dei sistemi Binishells, Minishells e Binix (mediante i quali si possono raggiungere luci nette che superano i cento metri) la prefabbricazione è limitata a componenti metallici facilmente trasportabili, mentre il calcestruzzo è gettato in opera. Nel caso poi, del più sofisticato sistema Binistar, la struttura dell'edificio e le attrezzature per la sua edificazione, addirittura si identificano.

Infine, se all'automatismo si aggiunge la robotica ci si avventura nel campo della mecatronica edile, che offrirà ai progettisti di domani seri motivi di riflessione. In buona sostanza, Bini ha saputo creare le proprie opere inventando sistemi costruttivi per realizzarle riuscendo a non cadere mai nel campo del restauro o dell'interior designer, professioni molto nobili ma di altro genere. Per questo, dice di sentirsi un architetto nel senso più classico - e brunelleschiano - del termine.

## Un cittadino del mondo

Dante Bini nasce a Bologna nel 1932, si laurea in architettura all'università di Firenze nel 1962. Docente della facoltà di ingegneria della Stantfor University, ha insegnato presso la Uc di Berkley, la Ucla e il Mit di Boston. È stato consulente speciale della divisione tecnologica delle strutture spaziali ed extrerrestri della Shimizu Corporation di Tokio, membro del Royal Australian institute of architets e Special consultants to the Minister of Pubblic Works, membro dell'American military engineer, membro della Repubblican Presidential Task Force, Special consultants in Low cos housing systems presso le Nazioni Unite. È stato insignito del Save (Society of American Value Engineering) Award, dell' Award for Excellence in Engineering design, di quattro Oscar of packaging design dall'Istituto Italiano di imballaggio e dell'Urostar for packaging design, dall'European Institute for Packaging. Ha progettato e diretto la costruzione di numerose ville private, tra cui vale la pena di ricordare quelle di Monica Vitti e Michelangelo Antonioni; ha realizzato diversi complessi turistici in Italia (villaggi di Monopoli in Puglia, l'Isola dei Cappuccini in Sardegna, Trinity Village in Australia. Oltre 1.500 costruzioni sono da lui state realizzate in Australia, Austria, Angola, Arabia Saudita, Brasile, Canada, Canrie, Cuba, Francia, Germania, Ungheria, Israele, Italia, Costa d'Avorio, Liechtenstein, Jamaica, Giappone, Messico, Pakistan, Perù, Tunisia, U.S.A. e Regno Unito. Dal 1963 a oggi ha ottenuto 127 brevetti di invenzione industriale, depositati in 18 Paesi del mondo. Attualmente vive e lavora A Saint Helena, nei pressi di San Francisco in California.

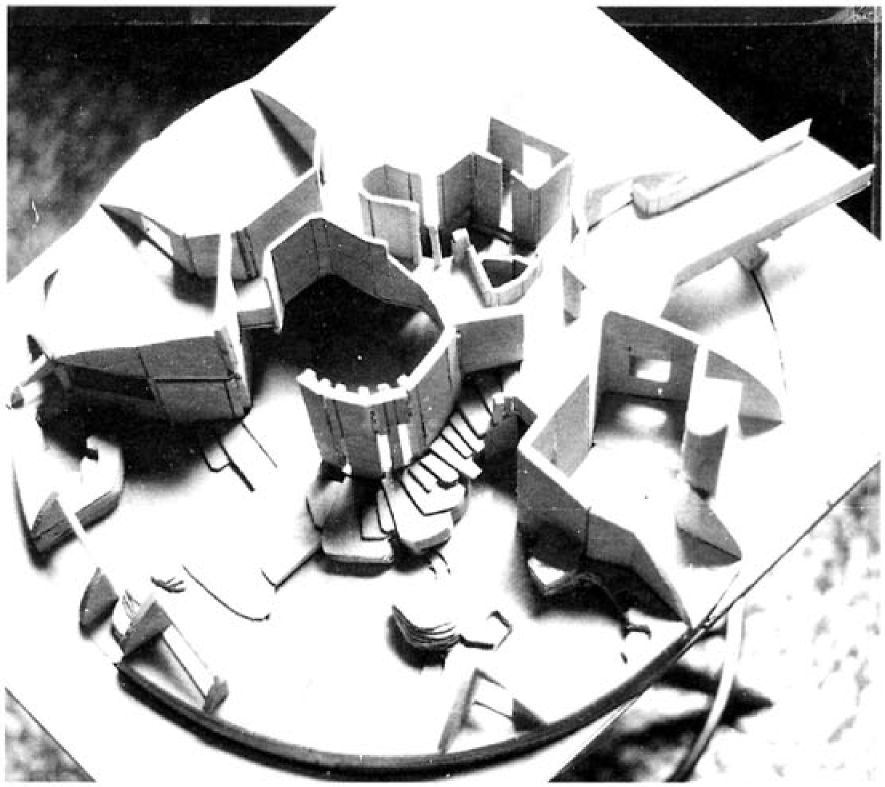
# Intervista con Dante Bini

*Modulo: L'inizio di tutto fu una cupola ipertecnologica. Come le venne questa originale idea?*
Bini: Se devo essere sincero tutto nacque da una sorta di complesso d'inferiorità che mi ero creato ai tempi dell'università.
*In che senso?*
Bini: Nel senso che ero circondato da bravissimi colleghi, davvero eccezionali, con una mano felicissima nel disegno e da altrettanto bravi insegnanti. Mi dicevo che sarebbe stato molto difficile per me competere con loro nel campo dell'architettura tradizionale, e allora mi sono buttato sulle nuove tecnologie e materiali.

*Modulo: E le cupole come sono arrivate?*
Bini: Vede, ho iniziato a interessarmi di cupole perché si riteneva che questa struttura fosse l'anello di congiunzione tra tecnologia ingegneristica e architettura. Così, con quel poco di conoscenza che avevo sulle volte sottili me ne sono andato in giro per l'Europa a vedere le nuove realizzazioni, a informarmi sui metodi costruttivi, sui costi, a visitare i grandi architetti di quei tempi e così via.

*Modulo: Ma di qui all'idea di gonfiare le cupole con l'aria ce ne passa.*
Bini: Certo, però mi ero creato un'attitudine, avevo le antenne protese. Filtravo ciò che vedevo e lo finalizzavo a queste strutture.

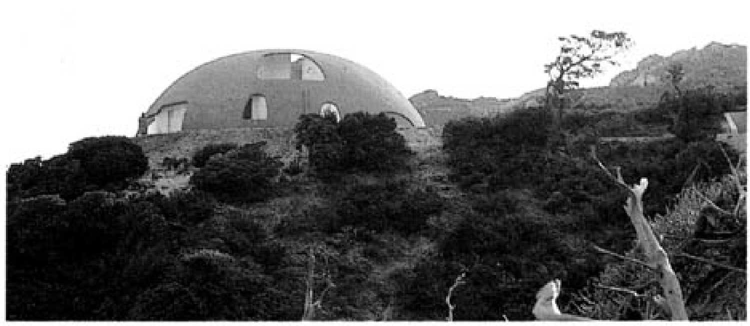
*Modulo: E allora quando è nata l'idea dell'aria?*



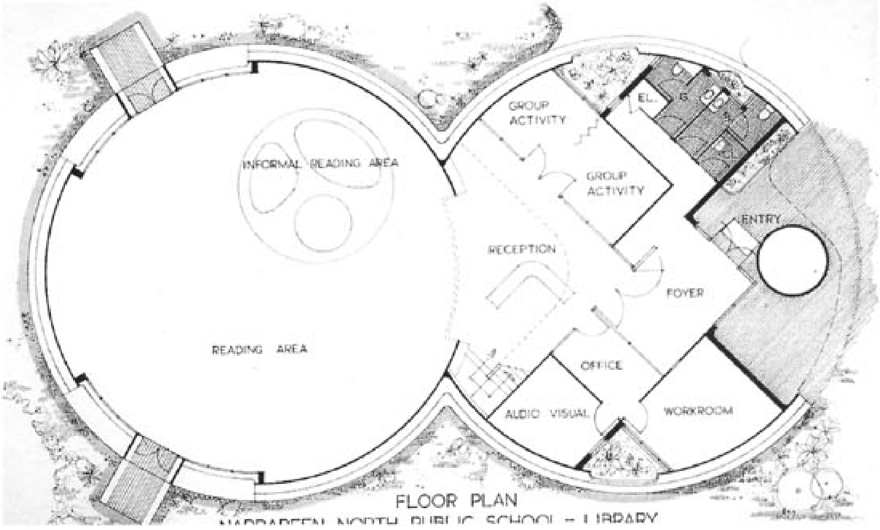
Bini: In modo quasi banale: giocavo a tennis con alcuni amici, in un campo coperto da un pallone, a Bologna. Dopo una partita di oltre due ore, uscendo, scoprii che era scesa una fortissima nevicata. I palloni erano coperti da almeno dieci centimetri di neve. Fu in questo modo che mi resi conto di come una pressione irrisoria potesse sostenere una massa enorme. Ecco tutto nacque così. Il passo successivo, fu quello di combinare questa forza apparentemente debole, ma estremamente efficace, al concetto di automatismo, quindi non spruzzare cemento sul pallone già gonfiato, come molti mi suggerivano, ma innalzare e modellare tutto con l'aiuto dell'aria compressa.

*Modulo: Quello dell'aria compressa è un po' il filo conduttore che denota tutte le sue opere.*
Bini: Certamente da quel primo brevetto sono nate molte altre idee: i sistemi Binix, Binistar, i moduli lunari, lo stesso Alu system, ma preferisco pensare che

*Due esempi di Binishell, in alto, plastico della distribuzione interna della Villa di M. Vitti e M. Antonioni. In basso a destra veduta esterna.*



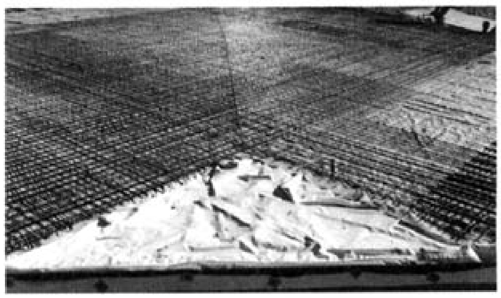
*A fianco, pianta della Biblioteca della scuola elementare a Narrabeen North.*
*Sotto, prime cupole sperimentali, in particolare una sequenza di costruzione di una Minishell (Trinity Beach).*

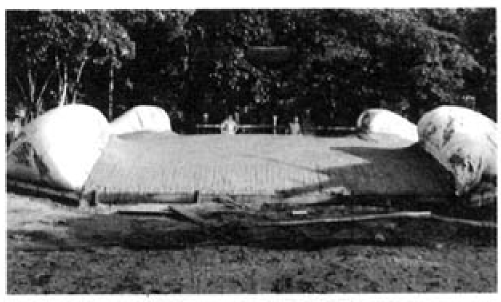



il minimo comune denominatore di tutto ciò che ho fatto sia l'automazione, il costruire, anche grandi opere, senza sforzo, con costi eccezionalmente bassi. Insomma, l'uomo riesce ormai in quasi tutte le sue attività a realizzare cose grandiose. Prendiamo i trasporti: fino a cent'anni fa per coprire 200 chilometri di distanza occorrevano giorni. Oggi, possiamo andare da Roma a New York in una manciata di ore. E questo grazie all'aiuto della tecnologia. Quello che non mi spiego è perché in edilizia, a parte qualche rara eccezione, una casa viene costruita ancora come mille anni fa, quando la tecnologia ha aperto ben altre prospettive.

*Modulo: Dunque, gli anni Sessanta, ricchi di grande creatività e attività tecnologico-strutturale hanno lasciato pochi risultati permanenti. Cosa rimane, in generale di quel periodo?*

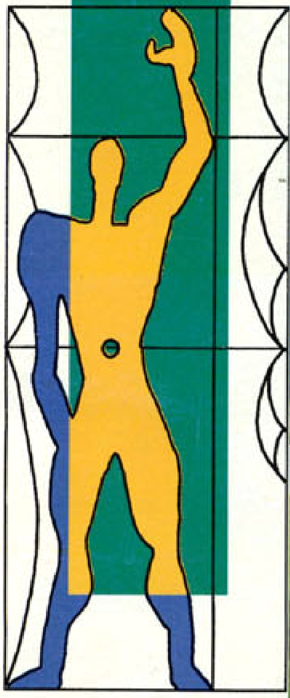
Bini: Guardi, io non sono molto d'accordo con questa affermazione. Voglio ricordare soltanto quattro grandi amici e pionieri di quegli anni: Buckminster Fuller che ha legato il suo nome alle strutture di tipo geodetico, di cui esistono migliaia di esempi in tutto il mondo e da cui sono derivate una miriade di strutture spaziali reticolari mono o pluristrato. Felix Candela, che conobbi attraverso il grande matematico Mario Salvadori. Candela, dicevo, raccogliendo l'eredità della scuola spagnola di Torrohja ha prodotto fantastiche forme architettoniche principalmente in Messico; Hein Isler che ha lasciato in Svizzera una enorme mole di fantastiche nuove forme statiche; Frei Otto, le cui opere hanno influenzato le mie Binistars, e che ha intuito i primi metodi per il calcolo delle moderne tensostrutture a materiale singolo o composito. Di lui voglio ricordare solo un paio di opere che hanno sbalordito il mondo: il padiglione di Montreal e l'incredibile copertura dello Stadio di Monaco. Ma è stato lo stesso Frei Otto che ha stimolato l'inventiva di altri amici architetti, come Horst Gaiger e David Berger i quali, aiutati dai primi computer, crearono innumerevoli strutture per lo sport in tutto il mondo. Mi sono limitato a questi grandi quattro pionieri, ma personal-

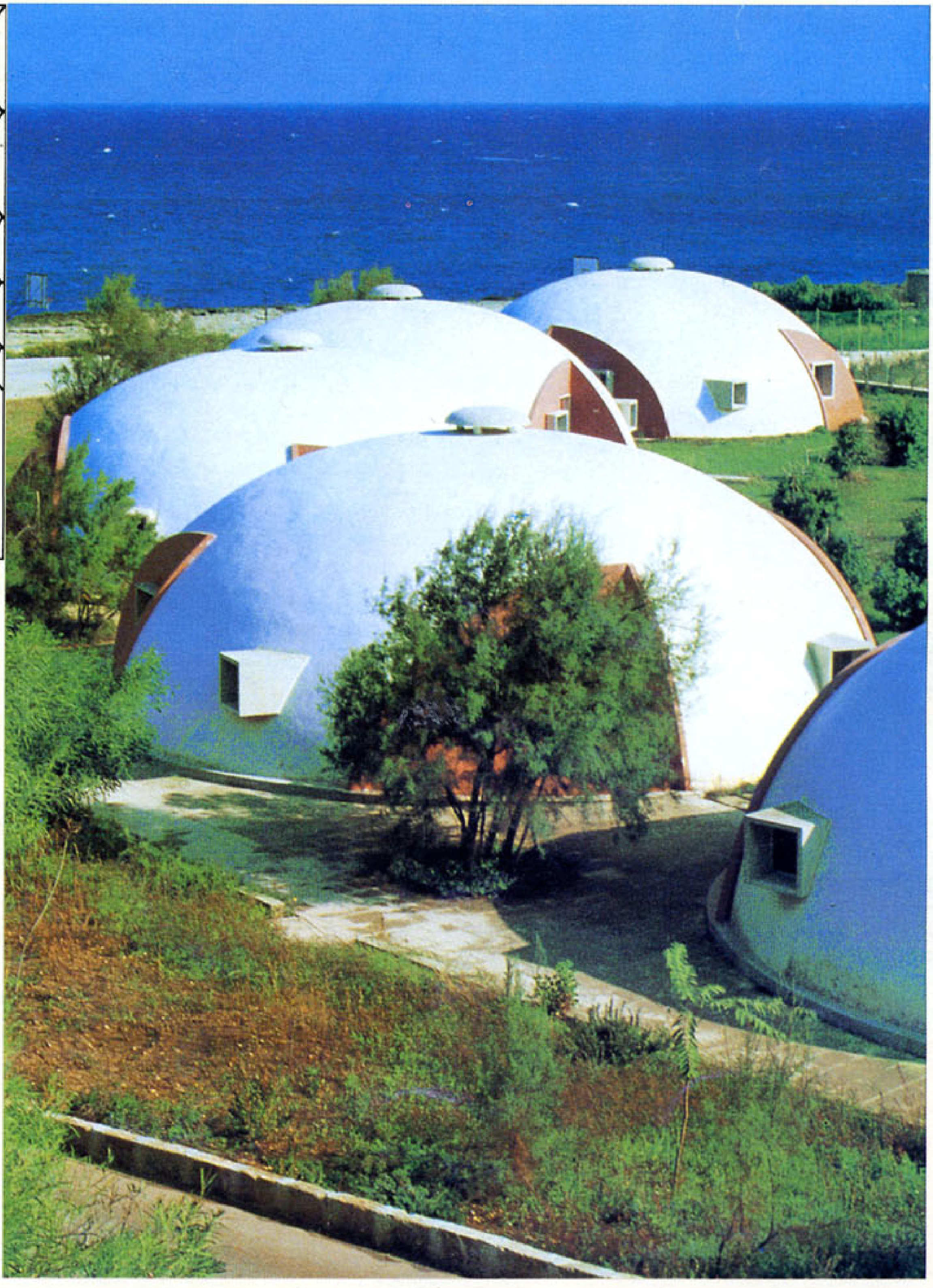




# modulor

RIVISTA DI INFORMAZIONE E TECNICA EDILIZIA





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DEL
GYPSUM
*Club*

1

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EDITRICE LAFARGE GESSI

# Ritorno al futuro

La figura professionale di Dante Bini, si distacca in modo deciso dalla classica iconografia dell'architetto, per raggiungere forse una delle punte più avanzate e moderne del mestiere di costruire. Il suo curriculum ne è una testimonianza fedele: docente alla facoltà di ingegneria della Stantford University, consulente speciale presso la divisione tecnologica delle strutture spaziali ed extraterrestri della Shimizu corporation di Tokio, membro del Royal Australian institute of architects e Special consultants to the Minister of Public Works, membro dell'American military engineers, membro del Republican Presidential task force (USA). Dal 1960 al 1990, Dante Bini ha ottenuto 127 brevetti di invenzione industriale depositati in 18 Paesi del mondo e, per 4 anni consecutivi, ha vinto l'oscar dell'Industrial design nel campo dell'imballaggio. Ecco cosa ha risposto ad alcune domande formulate da Modulor.



*Quando e come inizia la sua passione per le alte tecnologie nel campo delle costruzioni.*

Ancora prima della laurea in architettura fui fortemente affascinato da tutte le innovazioni che gli anni Sessanta offrivano nel campo della scienza applicata all'industria in genere. Si apriva allora un mondo nuovo, che rappresentava per me un incentivo alla crescita e una sfida. Inizialmente l'Industrial Design associato al packaging mi ha consentito di approfondire l'indissolubilità tra disegno, sostanza e produzione, cioè tra prodotto, materiale e macchina. Ho proseguito nella ricerca continua di un affinamento ideale di tale rapporto tripolare al fine di perseguire un irraggiungibile *state of the art* in continua e sempre più rapida evoluzione. Successivamente, come professionista, ho applicato la stessa filosofia alle tecnologie edili aggiungendo una valenza: l'automatismo. È nato così in Italia, a metà degli anni Sessanta, il sistema di costruzione conosciuto in 28 paesi del mondo con il nome Binishells. Questa tecnologia, successivamente sviluppata con i marchi Binix e Minishell, ha rappresentato il primo esempio pratico di autocostruzione strutturale. Invece, capostipite della meccanica automatica applicata all'edilizia di cantiere può essere considerato il sistema Binistar sviluppato in Australia negli anni Settanta e messo a punto negli anni Ottanta in Italia dalla società F.lli Dioguardi.

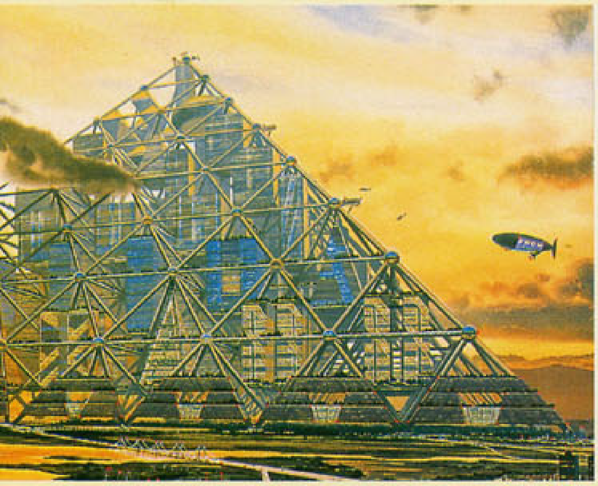
Il passo dalla meccanica automatica di cantiere alla mecatronica edile, applicabile sia alle alte tecnologie terrestri che a quelle extraterrestri è stato, per me, assolutamente imprevedibile ed è dipeso dalla fiducia accordatami da una delle imprese di costruzioni più importanti del mondo: la Shimizu Corporation di Tokyo.

*Il filo dell'industrializzazione edilizia lega un po' tutte le sue realizzazioni. Vede nel futuro un mondo del progetto slegato dalla figura dell'architetto classico?*

Il concetto tradizionale di industrializzazione edilizia è per molti legato alla prefabbricazione della forma dei componenti strutturali, al loro trasporto e al loro assemblaggio o montaggio in situ. In questo senso la prefabbricazione ha dimostrato molti limiti. L'innovazione associata alle mie tecnologie sta invece nel fatto che le stesse producono in loco strutture portanti au-

***A fianco, uno dei centri stampa realizzati in occasione dei mondiali di calcio '90 con il sistema Binistar.***
***Al centro, Try 2004, un esempio di come, con il sistema Binistar, sia possibile progettare intere città autoedificanti.***
***In basso, l'architetto Dante Bini.***

to-formanti Ad esempio, nel caso dei sistemi Binishells, Minishells e Binix (mediante il quale si possono raggiungere luci nette che superano i cento metri) la prefabbricazione è limitata a componenti metallici facilmente trasportabili mentre il calcestruzzo è gettato in opera. Questo limita la problematica relativa alla produzione industriale, riduce la dimensione dei mezzi di trasporto ed annulla tutte le ingombranti e costose attrezzature di sollevamento di cantiere, limitandole ad un paio di ventilatori a bassa pressione. Nel caso del più sofisticato sistema Binistar, la struttura dell'edificio e le attrezzature per la sua edificazione, addirittura si identificano. Se poi all'automatismo si aggiun-



ge la robotica ci si avventura nel campo della mecatronica edile che offrirà ai progettisti di domani seri motivi di riflessione. Relativamente alla seconda parte della domanda, devo dire che il simbolico ispiratore delle mie teorie è sempre stato ser Filippo Brunelleschi. Lo considero il vero architetto, colui che ha saputo creare le proprie opere inventando sistemi costruttivi per realizzarle. Per questo, non vedo nel futuro un mondo del progetto slegato dalla figura dell'architetto classico; vedo piuttosto la necessità di dissociare sempre più questa professione da quella del restauratore o dell'*interior designer*, entrambe molto nobili ma che, a mio avviso, devono rimanere distinte. Mi avventuro a dichiarare che l'architetto di domani deve ritornare ad essere un architetto classico, nel senso brunelleschiano. L'architetto di oggi dovrebbe informarsi di più e imparare a progettare per il futuro con tutti i mezzi che la tecnologia di oggi mette a disposizione.

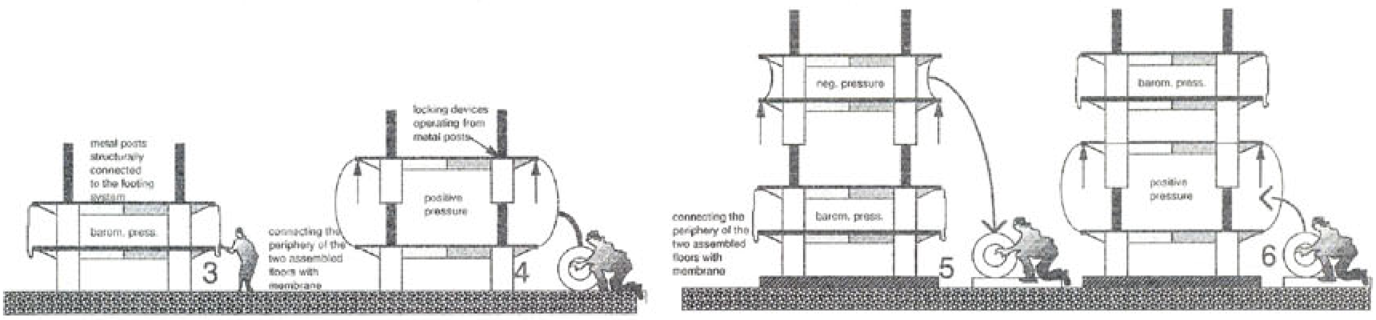
*Il suo ultimo progetto ad alto contenuto tecnologico. Può descriverlo brevemente?*

Posso segnalare un progetto per una base lunare da me originariamente ideato e battezzato Lunab per conto della Space Systems Division della Shimizu Corporation, presentato come Joint Research al 42° Congresso Spaziale di Washington, promosso dalla Federazione Internazionale di Astronautica attualmente detentrice del copyright; oppure "The Tower City", una infrastruttura cittadina ideata per 600 mila persone, che si autocostruisce dal fondo del mare innalzandosi un miglio dal livello dell'acqua. Un altro sistema costruttivo da me sviluppato in collaborazione con la Technology Division della Shimizu Corporation di Tokyo e di contenuto tecnologico meglio adattabile all'attuale realtà italiana (alla cui legislazione deve comunque essere ancora adeguato) è forse rappresentato dall'A.L.U. system, già presentato al Simposio internazionale dei metodi costruttivi applicabili negli anni Duemila, svoltosi ad Helsinki in Finlandia. Tale sistema può essere vantaggiosamente utilizzato per edifici di 3-6 piani e si basa sull'impiego di casseri a perdere che vengono assemblati in cantiere prima di procedere al loro autoposizionamento pneumatico. Il processo costruttivo si ottiene per successive fasi di pressioni e depressioni la cui energia positiva e negativa è contenuta da membrane vincolate alla periferia dei solai.



***Nell'altra pagina, tre fasi dell'innalzamento di una cupola Binishell. Nel fondo, un particolare dell'armatura metallica.***

***Per chi volesse saperne di più, molti progetti e sistemi dell'architetto Dante Bini sono illustrati con disegni e fotografie a colori in Internet alla pagina: http://www.webville.com/oak/bini. Per qualsiasi delucidazione, è disponibile il numero E-Mail: bini@a.crl.com***




mente devo riconoscere la determinante influenza, il fascino e lo stimolo all'innovazione che in quei tempi hanno esercitato nella fantasia dei giovani ingegneri e architetti italiani, personaggi già affermati, del calibro di Pierluigi Nervi, che rappresenta tuttora uno dei simboli del genio dell'innovazione nel campo della scienza della costruzione italiana. Purtroppo da allora, la ricerca e lo sviluppo hanno subito un brusco rallentamento.

*Modulo: Quindi, alla luce delle sue esperienze all'estero, è difficile fare sperimentazione in Italia?*
Bini: Voglio essere sincero, a costo di apparire impopolare: ho potuto fare un timido e modesto tentativo di sperimentazione in Italia solo all'inizio della mia carriera, perchè ho avuto la fortuna di essere stato appoggiato dalla mia famiglia che, nei primi passi, mi ha sostenuto, anche finanziariamente. Le mie solide esperienze di sperimentazione si sono potute sviluppare solo all'estero, principalmente in Australia e Giappone. Queste esperienze, tuttora in corso, mi hanno permesso di entrare in contatto con ottime organizzazioni di ricerca e istituti accademici in Usa, Inghilterra, Francia e Germania.

*Modulo: Un giudizio poco lusinghiero per il nostro Paese.*
Bini: Tutt'altro, penso che l'Italia abbia tuttora il miglior substrato ricettivo all'innovazione e che qui, molto meglio che altrove, possa essere coltivata la passione per l'inventiva. Per quanto mi riguarda ho provato spesso a fare qualcosa, offrendo anche co-finanziamenti esteri. Ho tentato in molte occasioni di coinvolgere ministri della ricerca scientifica che, dimostrando incredibile arroganza, non si sono nemmeno degnati di rispondermi. Ho contattato imprenditori, che ritenendo di poter fare tutto da soli hanno rivelato soltanto una profonda presunzione. Ho interpellato istituti universitari, immobilizzati dalla loro feudale baronia e decrepiti, patetici organismi parastatali di ricerca disposti soltanto a rifinanziare la scoperta della ruota, ma non ho avuto alcun successo.
Ma per rispondere direttamente alla domanda: no, non sarebbe affatto difficile fare sperimentazione in Italia; anzi risulterebbe molto più facile che all'estero, grazie alle particolari attitudini degli italiani. Però sarebbe necessario istituire finalmente una seria e moderna organizzazione che sappia gestire con competenza un settore di capitale importanza per il futuro dell'Italia e agevolare fiscalmente le spese sostenute per una seria ricerca privata.

*Modulo: Per concludere, su quali progetti sta lavorando attualmente?*
Bini: Ho terminato lo scorso anno un progetto, per un concorso a inviti promosso dalla municipalità di Kyoto "Future Vision of Kyoto for the 21st Century", una rivisitazione urbanistica di tutta la città che ho interpretato a mio modo e che mi ha impegnato moltissimo. Attualmente sto invece lavorando a un altro concorso a inviti per il museo De Young di San Francisco. Poi sto progettando una villa a Napa Valley; infine, un complesso teatrale con una cupola di 70 m. di diametro dove spero di utilizzare una nuova tecnologia derivata dal sistema Binistar, ma con l'uso di profilati metallici allungabili anziché di tubi telescopici.

*In alto, schema di assemblamento di una Binistar, dove le colonne sono l'elemento strutturale di connessione con il suolo.*
*A sinistra, Binistar: il montaggio di una struttura.*
*In basso a sinistra, classico stadio di calcio per i campionati del 2002, in basso a destra Try 2004: la città in una piramide.*

«chiave» del congresso che purtroppo ha deluso. Non il «designer-visagiste» ma il «designer dentro la fabbrica», è tornata a dire l'industria, con più o meno sottili sfumature. E i designers Dieter Rams e Kenji Ekuan, peraltro già dentro la fabbrica, hanno risposto il primo «Per me esiste una sola strada: la disciplina. Il miglior design è il ... minor design possibile»; il secondo con la necessità di un «turning point» del design: «la gente non chiede più solo automobili, ma conoscenza e stimoli sulla forma dell'informazione».

Tra le frasi sentite, lo slogan magico «progettazione, ingegnerizzazione, produzione» (Luigi Rossello della Castelli) e «fare oggi del design è un'avventura ben diversa da quella di un tempo» (Ennio Brion). Avventura che oggi forse preoccupa più il designer dell'industria.

**Design e tecnologia: l'edilizia, 24 ottobre**

pubblico: ••

critica: **

Grande cast per un soggetto in crisi, due amanti che vorrebbero ma non riescono a incontrarsi. Toni tra il nostalgico («che bello che era il sogno della componibilità della composizione e dell'abbattimento dei costi», ha ricordato Pierluigi Spadolini) e il critico-storico di Lodovico Belgiojoso quando ha imputato il «matrimonio mal riuscito» a una normativa insufficiente; «occasione perduta», ha aggiunto Luigi Astori, perché la vita è breve ma le case sono più lunghe. Poi, nell'atmosfera che stava precipitando nella più cupa disperazione, il raggio di luce «ambasziano»: il problema dell'edilizia industrializzata è «artificiale». Quindi abile gioco da illusionista di Angelo Mangiarotti che ha rovesciato le carte invertendo il titolo, e sfolgoranti sono apparse le «cupole» di Dante Bini.

**L'automobile, 24 ottobre**

pubblico: ••

critica: *

Una volta tanto che si poteva parlare di forma e funzione senza cadere nell'ovvio, si è parlato solo di forma e in maniera abbastanza ortodossa. A confronto i designers e i rappresentanti delle maggiori case automobilistiche mondiali: l'italiana, la statunitense, la giapponese, la tedesca, l'inglese. Chissà perché, mancava la Francia.

«Auto a misura d'uomo», dunque vetture «dagli interni confortevoli dal punto di vista fisiologico ma anche da quello psicologico», ha detto Rodolfo Bonetto; poi: «creatività più ingegnerizzazione più avanzata»

The McGraw-Hill Construction Weekly

ENR

# Inflatable domes of steel

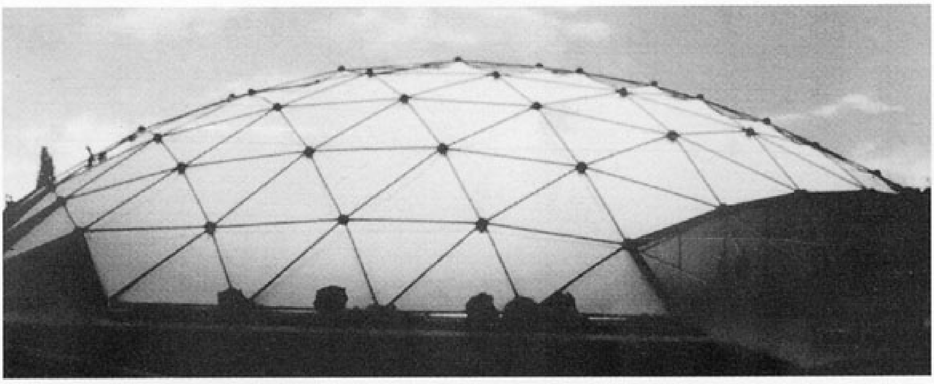
Inflatable buildings that pop up with a push of a button may evoke cartoon images, but one inventor has been erecting concrete structures like that for 20 years. He is now using the same method to put up permanent, steel-framed structures in about an hour.

Italian designer Dante Bini inflated his first concrete dome building 20 years ago. Since then, thousands of Binishells have been built around the world. But the technology did not catch on in the U.S. Building codes require a thicker concrete cover over the steel rebar than the process allows. Shotcreting on another layer would solve that problem, Bini says, but adds to the total cost of the building. Another obstacle was personal resistance to thin-shelled construction. It proved to be a problem Bini could not overcome.

"It was a fad," says William C. Panarese, manager for construction information services for the Portland Cement Association, Skokie, Ill. People are reluctant to try a new shape and a new method, he adds.

Bini is hoping people will not have the same reservations about his latest construction technique. Instead of concrete, an interlocking metal frame is lifted with an air pump to form a building that can be used for anything from an airplane hangar to a tennis court cover.

To erect the self-shaping dome, a roof membrane made of PVC-coated polyester is laid out on the ground and the interlocking metal roof frame made of steel pipes is assembled over it. Air pumped under the membrane raises it. The metal pipes have telescoping sleeves that expand and lock into place. When the air is turned off, the building remains standing.



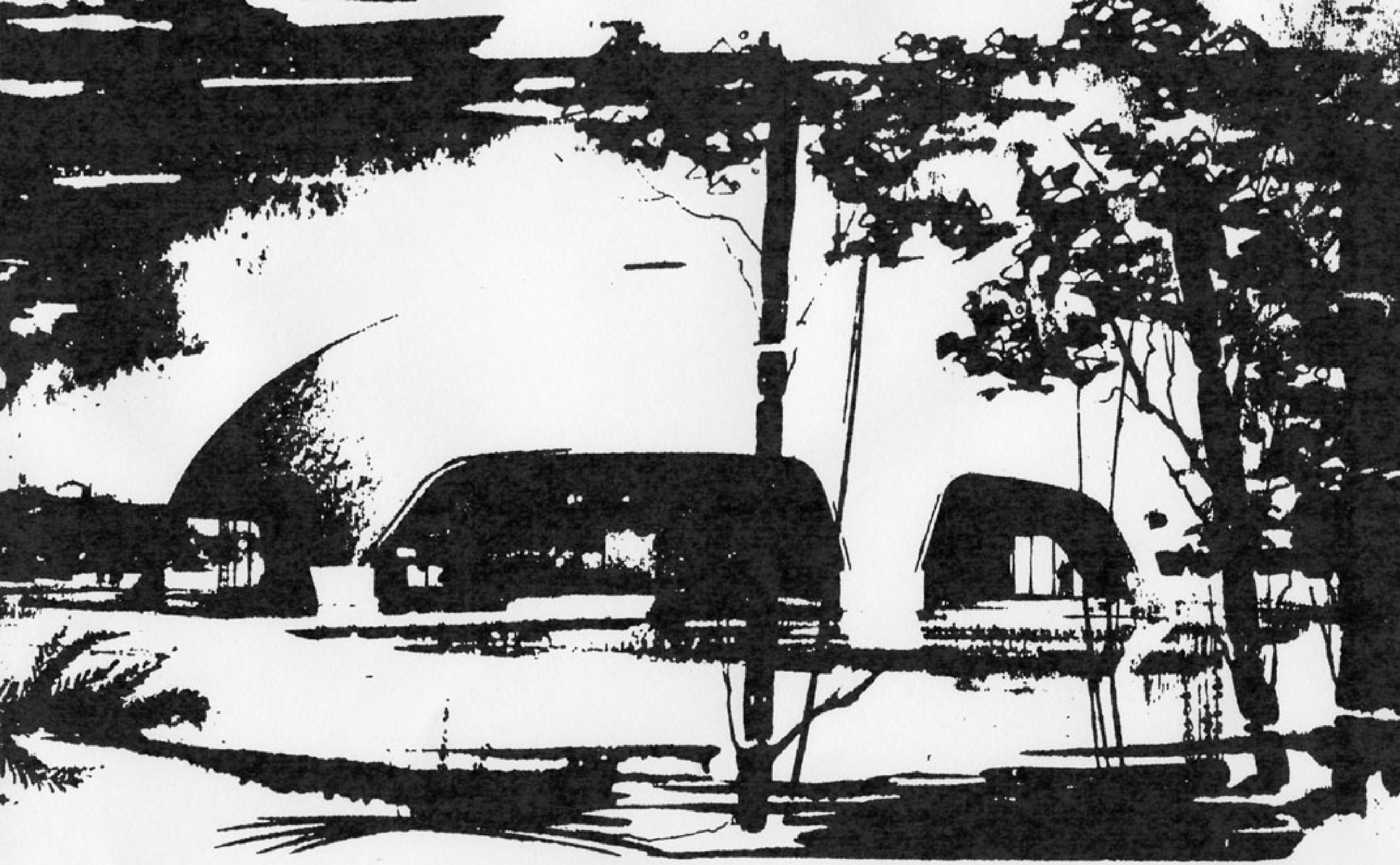
**Interlocking pipes** covering a polyester membrane are raised with air in an hour.

Clear spans of 120 ft to 300 ft are obtainable, and one study shows that 850-ft-dia domes are possible. Using the polyester membrane, Bini estimates installation costs at $15 per sq ft. Other fiberglass membranes, coated with Teflon or silicon, are also available.

The structure can be moved easily, Bini says. A 120-ft-dia building can be deflated and packed into a standard inter-modal shipping container.

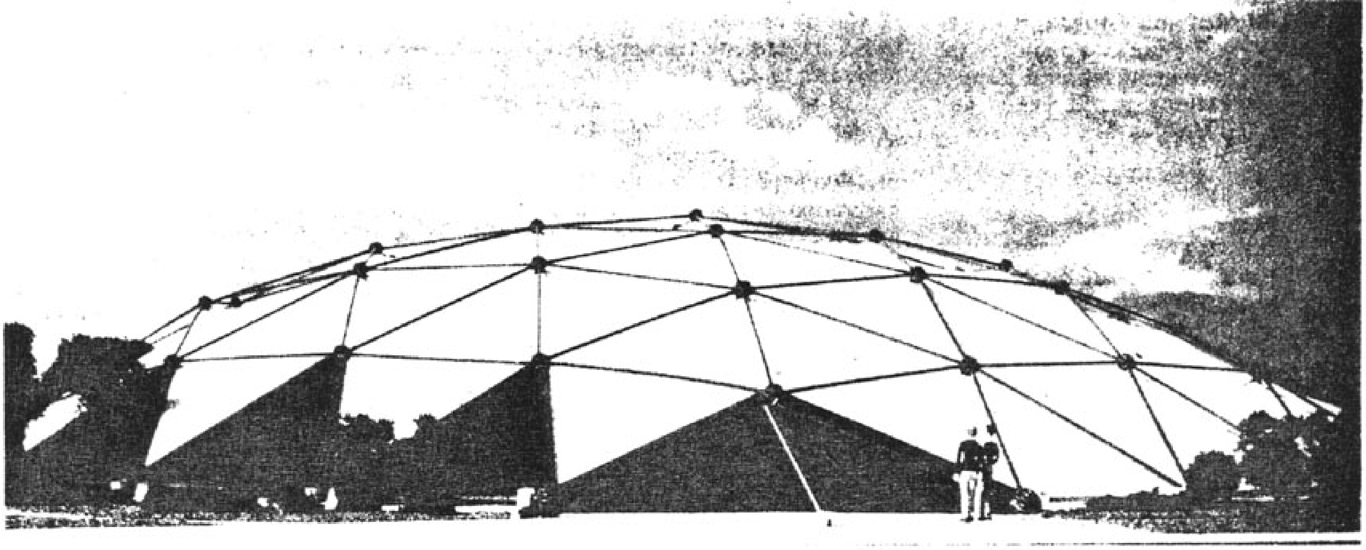
Two Binistar structures, as the steel-frame units are called, exist now in Italy—a demonstration hexagonal structure 120-ft across and a 130 x 130-ft tennis court cover. A third tennis court cover measuring 200 x 130 ft is planned.

CBI Na-Con Inc., Chicago, will distribute Binistar systems in the U.S. The air-raising technique will be valuable in regions where construction is difficult, says Gary R. Marine, CBI business development manager. ■



This booklet is produced to commemorate the opening of the Edinburgh Dome by His Royal Highness Prince Philip Duke of Edinburgh on 4th May 1978.

PRINTED BY CHESHIRES, KIDDERMINSTER.



Bini explains how his domes are constructed

ARCHITECTURE

# Bini's stately measured domes come to life

By CAROL HENTY

IT TOOK Brunelleschi nearly 14 years to finish his famous Il Duomo of Maria del Fiore, in Florence, by 1435. Today it takes Italian architect Dr Dante Bini a few hours to construct a similar-sized dome.

This is the estimate for his latest invention, the Binistar, constructed, as are his other dome structures, using pneumatic inflation to blow the building into position.

Unlike his other inventions, the Binishell, the Minibini and the Binisix, the Binistar uses no concrete and construction time is reduced from three days to a matter of hours.

It is completely prefabricated – using plastic/fibreglass for the shell, and aluminium rods to form a superstructure to strengthen and give support to the shell.

The Binistar can, says Bini, provide almost instant large-scale shelter and is particularly useful for emergency shelters, for military depots and for agricultural storage. It can span diameters from 40 to 100 metres. It will pack down to a neat kit and make a neat helicopter load. Once landed on site, a trench will need to be dug for the foundations. The membranes will be anchored into the trench.

It will then need the efforts of only two men to make final adjustments to the assembled superstructure "stars" and to turn on the low pressure blower to inflate the building. A vacuum cleaner will almost do, and it will take about 60 minutes. Doors and windows can then be made, where needed, by cutting holes in the membranes.

It is estimated that the membranes will last 15 years without weatherproofing, but can be proofed every 10 years.

An Italian company has decided to build the first prototype by the end of the year.

At present the Binistar is in model form in San Francisco where Bini and his family have been living for two years after six years in Sydney with the NSW Public Works department.

Invented 14 years ago, Binishells are now seen around the world and are being built at the rate of one every two weeks. They have a span from 12 metres to 34 metres and are used as schools, libraries, community halls, discos, swimming pools, gymnasia, and for agricultural storage. At Karachi a cluster of 350, for grain storage, has been built at the rate of one every two days for the past two years. The government of Iraq has ordered $60,000,000 worth of them to use as silos. Architects often incorporate them into conventional buildings.

They are made by using twin plastic membranes, shaped in the form of a dome, to sandwich wet concrete and steel springs. Then the pre-anchored membranes are blown to a height one third the diameter of the building using hot air from low pressure blowers placed beneath ducts in the ground.

The Binishell takes about one hour to inflate, but the concrete takes three days to cure and set before the apertures for doors and windows can be cut and the building finished for use. Once the concrete is set, the membranes are removed.

It's a building method which takes, says Dr Bini, less energy, less time, less money, less manpower than conventional methods of construction yielding the same volume of space.

The Minibini, which uses the same building technique, is built on a square base, has a span of 10 metres and is used for two to three bedroom housing.

It has moved more slowly than the Binishell. A cluster of them has been built near Cairns as a motel.

The Binisix is soon to go into production with the Italian Binishell Company. It has a larger span than the Binishell and differs in that, although it uses concrete, it is formed from sections or "pans" which fit together and can be made from fibreglass, wood or steel to form the structure of the dome.

The new Binistar grew, says Bini, from the limitations of the previous domes. As it doesn't need to be built near a concrete batching plant, it has greater freedom of site. Unlike the other inventions, it can be constructed in virtually all weathers. Even in the rain. "I like to keep one step ahead of my previous models," says Dante Bini.

When he's not doing that, he is promoting and constructing Binishells in the US, Mexico and Canada, is a consultant to the Italian company for the production of the Binisix and lectures on his inventions at Berkeley and Stanford Universities. □

## THE BINISHELL

DANTE N. BINI

**Asking an architect to design a building that** could be raised within an hour would likely elicit a blank stare. But not from Dante N. Bini. For the last 40 years, the Italy-born and educated pioneer of "automated building construction sequences" has sought to defy our conceptions of the building process.

The Binishell, and its diminutive offspring, the Minishell, are Bini's most popular designs (more than 1,600 have been built) and are used for a variety of functions, including shopping centers and gymnasiums.

While these sturdy structures may look like they require a serious amount of time and effort to construct, amazingly, most are raised in under an hour, with, as Bini proudly states, "less air pressure than it takes to puff a cigarette." Here's how:

A pre-shaped "Pneumoform" (basically a sophisticated balloon) is rolled out and affixed to an anchoring system on a flat, octagonal base. PVC sheeting protects the surface of the Pneumoform so it can be reused. The most time-consuming part of the operation follows—laying out an intricate, crosshatched system of stretched, steel-reinforced springs. Concrete is then poured, covered with an external membrane, and with a flip of a switch, inflation of the Pneumoform begins. In under an hour the Binishell (or Minishell) has taken its final shape. Air pressure and springs with steel reinforcement keep the concrete from sliding down the sides of the dome. For two days the concrete sets and dries, then the Pneumoform is deflated, and fixtures are added to the openings.

Bini has since turned his attention to other projects, such as the Binishelter—low-cost, self-erecting housing for disaster relief. Reflecting on people's resistance to residential domes, and the dominance of right angles in home architecture, Bini says, "Only a few special people may choose a dome structure for living in." —SAM GRAWE