DESIGN RECOMMENDATIONS FOR TEMPORARY PNEUMATIC STRUCTURES IN DISASTER AREAS

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in

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(Department of Architecture)

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By

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ABSTRACT

DESIGN RECOMMENDATIONS FOR

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IN DISASTER AREAS

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M.S. in Building Science
(Department of Architecture)
Supervisor : Assoc.Prof.Dr. Mustafa Pultar
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In this thesis, pneumatic structures are examined as an appropriate alternative technology for post disaster area housing problems and design recommmendations of the pneumatic structures in disaster area applications are identified. The disaster phenomènon and it's protection problems are analized in the second chapter, Pneumatics are investigated as an alternative for a protective shell in the chapter three. The behavior and the structural alternatives of the pneumatic structures are also analyzed in the chapters four and five, the production possibilities and a criticism of the situation in Turkey is presented in chapter six.

Finally, according to the information made available in the study, redefinitions, some practical values and general design recommendations for pneumatic structures in disaster areas are presented in chapter seven.

ÖZET

AFET BÖLGELERİNDE GEÇİCİ ŞİŞME YAPILAR İÇİN TASARIM KRİTERLERİ

Hakan, GÜRSU

Yapi Bilgisi Master Tezi
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Bu tezde ,şişme yapilar afet sonrasi dönemlerde ortaya çikan barinma sorunlarina olasi bir alternatif çözüm önerisi olarak incelenmekte ve temel tasarim ve uygulama kriterleri tanimlanmaktadir. Afet olgusu ve onun yarattiği barinma ve korunma sorunlari ikinci bölümde analiz edilmiş ve şişme yapilar bir koruyucu kabuk önerisi olarak üçüncü bölümde tanimlamakta ve alternativ olarak önerilmektedir. Şişme yapilarin davranişsal ve yapisal analizleri dördüncü ve beşinci bölümlerde ele alinmistir. Türkiyedeki olasi üretim olanaklari ve üretimin genel kritiği altinci bölümde incelenmiştir.

Son bölümde bu çalişmada elde edilen sonuçlara göre,yapisal önerilerin yeniden tanimlanmalari bazi pratik değerler ve şişme yapisal önerilerin uygulanmasinda yararli olabilecek genel tasarim ve uygulama kriterleri son bölümde sunulmuştur.

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The work of deciphering the manuscript and of typing, checking and re-checking the various drafts was performed by Mrs. Lale Gursu with a high level of secretarial skill: it has been a pleasure to work from typescirpts that are so intelligently set out and so free from error.

Lastly I would like to thank my family for encouragement and for putting up with the uncommunicativeness that writing entails.

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LIST OF SYMBOLS

P_i - Internal pressure acting on the membrane,

R - Radius of curvature of membrane,

T_{min} - Minimum Membrane Stress,

T_{max} - Maximum Membrane Stress,

P_x - Total pressure acting on the membrane due to external loads,

R - Breaking Lenght (km)

V - The Volume of rod, (cm^3)

F - The cross sectional service (mm^2)

σ - Ultimate stress of rapture of material, (kg / mm^2)

P_g - Self-weight Loadings,

P_L - Point Loadings,

P_s - Snow Loadings,

P_w - Wind Loadings,

C_w - Aerodynamic coefficient for wind loadings,

Q_w - Dynamic impact pressure of the wind,

p - Air Density,

v' - Air Velocity,

P_a - Average pressure differential across the whole of the membrane,

A - Plan area,

L_p - Unit Length,

$-E_c$ - Energy Losses by Conductivity,

$+E_r$ - Energy Gain by radiation,

k - Thermal Conductivity,

Q - Heat loss of surface,

r - Thermal Resistivity,

R_t - Thermal Resistance , ($m^2 h\ ^oC$ / KCal)

h_i - Internal surface conductance , (KCal / $m^2 h\ ^oC$)

r_a - Internal surface resistance , ($m^2 h\ ^oC$ / KCal)

h_o - External surface conductance,

r_o - External surface resistance,

U - Thermal Transmittance,

P_z - Permissible bearing capacity (kg)

V_s - Safety factor,

q_r - Specific frictional resistance (kg/ cm^2)

ℓ - Screw length (cm)

d_s - Screw diameter (cm).

1. INTRODUCTION

1.1. GENERAL

In the age of mass production where everything needs to be planned and designed ,design has become the most powerful tool with which man shapes his tools and environment. The belief that designers or architects shape people's future behavior by the environment they create is called environmemtal determinism .

Man, by nature, has the ability to adapt to the natural or artificial environment in which he lives with his capabilities, abilities and limitations. But, what determines the capabilities of the adaptation of man to his new environment when disasters arising from natural or human factors destroy the vulnerable settlement patterns ?

When a disaster strikes, it is assessed and reported in terms of number of the persons killed and in terms of the monetary value of material damage; the major disasters throughout history have earned their places in consciousness almost entirely due to their destructive impact up on human settlements. The cost or the extent of disfiguration and change in the natural environment are not really of lasting importance.

The constructive actions taken by humans in order to cope with the impact of disasters.(aside from threatening the injured and burying the dead).

are directed toward minimizing the impacts and reconstructing the damaged elements and components of the settlement, so that it can be operated as before. Disasters, especially natural events, may be classified in three groups according to their effects on the settlements ;

1. Events, whose formation and maturation can be foreseen by the people of the involved settlement, so that life and the property losses can be partly prevented, e.g., landslides and water rises.

2. Events, whose formation can be witnnessed by the resident but, which cause loss of life and property because of their instantaneous maturation, e.g., rockfalls and avalanches.

3. Events, whose formation and maturation can not be withnessed result in heavy life property losses, e.g., floods and earthquakes.

An analysis of the natural events which have occured in Turkey during the period 1958-1972 and their distribution is shown in Fig. 1 to 3. The average housing lost in Turkey due to disasters is 12617.667 house units per year.

Disaster activities can be operated in two ways; predisaster preparedness and post-disaster activities. The post-disaster relief operations are distinguished in three phases as an Emergency phase, a Rehabilitation phase and a Reconstruction phase. Post disaster problems and relief operations have to be handled differently depending on the periods following the disaster.

These three phases are important especially from the point of view of shelter problems and have relevance to the specific condition of Turkey. It is assumed that primary attention must be paid to the production of the

" Temporary Shelters" of emergency and rehabilitation phases. The selection of suitable construction technologies, materials, design, and services , etc. are the constraints imposed by factors which are raleted to the disaster pheomeneon.

Until now, whenever the problems of housing production in disaster areas have arisen, the problems of the construction phase have been considered primarily and the needs of transition phases to the reconstruction period have been generally fullfilled by the tents. Temporary shelters for the rehabilitation phases is a neglected subject, whereas it constitutes the most vital problems especially in Turkey. Also most of the time, the shelters of rehabilitation period built as temporary shelter later become permanent.

The history of architecture shows us that a proper design utilizing a new material comes always late.The characteristics of our period, as far as the new construction materials are concerned, are the advantages of the new synthetic materials and new agglomerates. New methods of construction are being investigated in order to use the new materials.When a new product made of non-traditional materials is proposed by someone,he runs against the mental cliches of the past and he is temped in an irresistible way to use, reproduce or adjust, existing manufacturing methods and patterns.

The building industry is familiar with conventional materials like timber,steel, cement and bricks and light-weight aggregates with respect to their use and performance.Plastics used as the building material have their advantages and limitations. Plastics have also provided new concepts in design and in architectural features of buildings and in solutions to emergency housing and shelters in the event of the natural disasters.

Plastic manufacturers and the designers around the world have come forward with new concepts and designers for low-cost housing or economicaly priced and socially acceptable systems of units or shelters. Invariably, in all such cases, the emphasis has been on the propogation of the composite materials or laminates in association with polymers and fibres, fillers and traditional materials.

Engineering structures will tend to become more like natural forms or biological ones in which fairly large usages are acceptable. Plastics have proved to be competitive with traditional materials in several building applications especially in engineering structures. Also plastics have resulted in a technical and structural dimension of the architectural concept which is simply called pneumatic structures. As a result , plastics help upgrade the utilities and services in the building industry and provide new concepts in designs and architectural forms in features such as the " Pneumatic architecture ".

Pneumatic architecture offers enourmous possibilities in shape, colour flexibilty, transportability, storage, easy demuntability, erection and the usage capacities, maintenance and repairment flexibilities, etc. all with new design potentiality.

The motives behind pneumatics were less of scientifically orientated interest than of plessure in the possibility of personally creating new "environments" with a minimum of material expenditure in a short period of time. Also they provide uniformly distributed membrane stresses and the largest possible volumes under the smallest possible surface areas. An additional feature is that the stability and the variability of the forms is directly related to the supply of energy. The pneumatic principles will

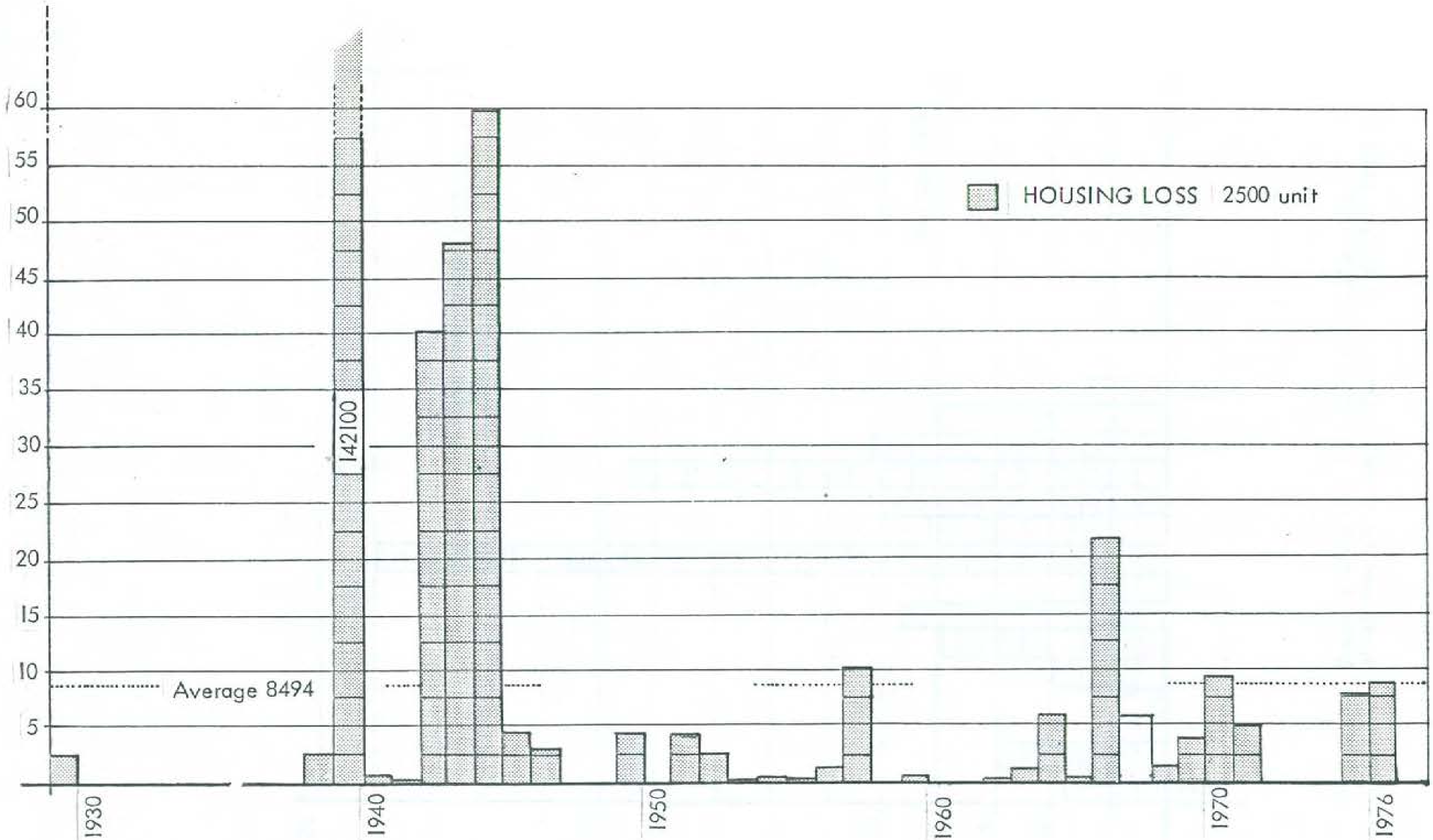

FIGURE.1 *Housing Loss due to Earthquakes in Turkey between (1929-1976) (1)*

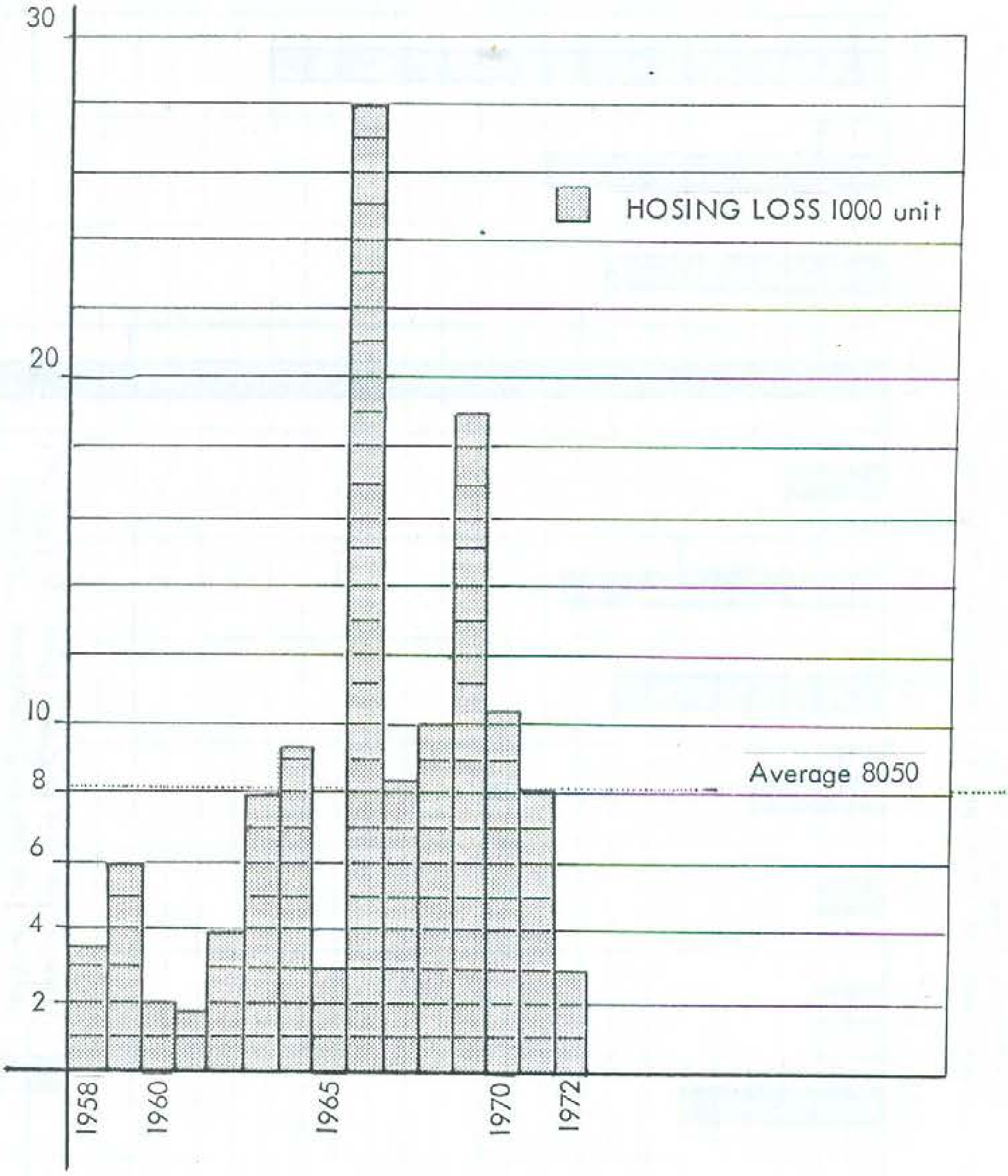

FIGURE. 2 Housing loss due to other kind of Natural disasters in Turkey between (1958-1972) (2)

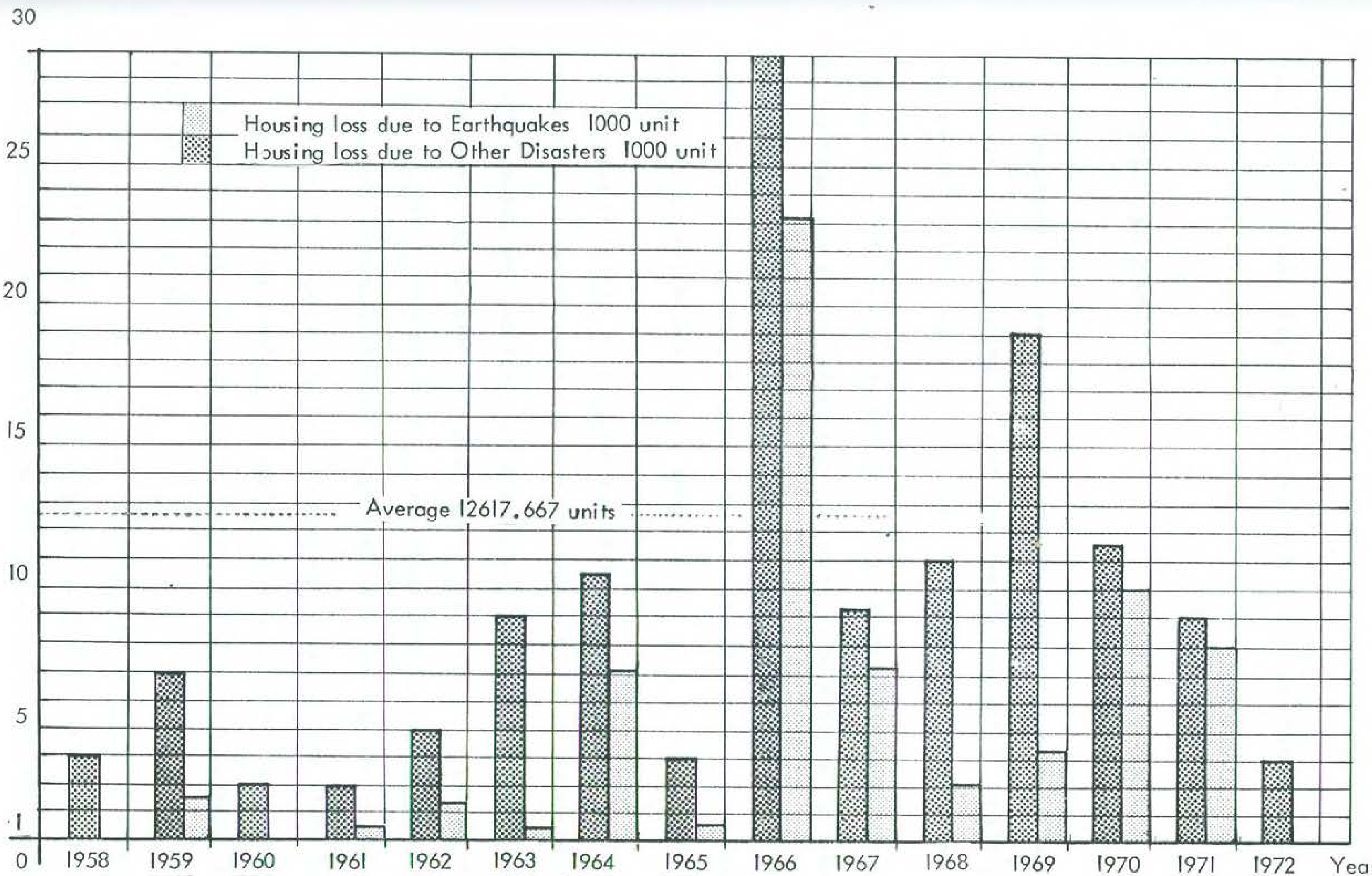

FIGURE. 3 *Total Housing loss due to disasters in Turkey between (1958-1972)* **(3)**

Av_E 4567.66 Units
Av_D 8050.007 Units

therefore doubtless play an important role in the realisation of the " Kinetic Architecture".

1.2. OBJECT AND SCOPE

The object of this thesis is to examine pneumatics as a technology appropriate to the problems of post disaster housing and to identify design recommendations for temporary pneumatic structures in diaster areas.

Disasters are frequently followed by the erection of temporary and most of the time, sub-standard dwellings, which by default become permanent especially in Turkey. Until now, temporary shelters of the post disaster phases have been fullfilled by tent-based technologies or with substandard houses which are completed 4 to 6 months.

Turkey is subject to frequent and hazardous earthquakes due its location which is in one of the main earthquake belts of the world.Also floods, landslides, rockfalls and avalanches, etc. are the impacts which often strike the inappropriate housing especially in the rural sections. 10.000 and more houses are lost due to disasters each year in Turkey. It is obvious that the emergency shelter problem of Turkey has not found a satisfactory solution until now. The problem has a constant clear demand but the quality and quantity of supply products do not satisfy the basic human needs.As long as these problem exist, there might be several possible alternative solutions.

The purpose of this thesis ,is to analyze the problems of emergency shelter and its requirements and to purpose pneumatic technology as an alternative solution to the problem. The general criticism and the analysis of the behaviour of the pneumatics are examined under the scope of the environmental conditions and the situation in Turkey is also criticised. The necessary recommendations and constraints of the pneumatic structure to be applied in disaster areas are presented at the final stage.

The concepts of disaster, elements, periods etc., are examined in Chapter 2. After the analysis of the problem, Chapter 3 tries to present the new technology of pneumatics and the material behaviour of the pneumatic membranes are examined in Chapter 4. The structural design alternatives of the pneumatic technologies and productions in Chapter 5, and situation in Turkey in Chapter 6. Finally, the necessary design recommendations of the pneumatic structure to be applied in disaster areas are offered in Chapter 7.

NOTES

(1) 50. Yilda Imar ve Yerlesme ,Imar Iskan Bakanligi ,Ankara 1978 pp.19

(2) Imar Iskan Bakanligi," Afet Isleri Genel Mudurlugu Calisma Raporu" Ankara,1984, pp.48

(3) Imar iskan Bakanligi , ibid., pp.58

2. DISASTER

2.1 THE MEANING OF DISASTER

A disaster is an expected event, with detrimental impacts upon content(s) within which occurs, the impacts are intense, widespread or both and are initially at least, essentially unalterable.

It is useful to stress that it is neither the intensity nor the extent the suddeness, the time or the location of the event, that make the event a disaster. It is only the impact upon the content within which the event occured, that make such an event a disaster.

It is a corollary of the above, however, that once the disaster occurs its intensity, the extent, the suddeness etc. (or the combination there of) are greatly dependent on the following factors ;

* Type of impact(s)
* Time Factors
* Type of Human settlements
* Environmental Conditions

Disaster occurs in many forms. Regardless of the type of catastrope in the environment, all disaster have common results, many people are killed, injured, left homeless or become sick due to the after effects of the events.

Several examples could be given of traumatic events of both ancient and more recent times. Accounts of disasters carried by the news media will always give statistics on the number killed, the physical damage to buildings, the infrastructures,etc. But often the pain and the suffering that plauques the homeless of effected area are soon forgotten.(1)

Events become disasters only when their impacts detrimentally affect human settlements of various components within them. Human settlements therefore serve as the contextual framework for disaster assesment.They provide the context within which the rising incidence of disasters, and particularly those caused by human errors and technological failures ought to be viewed so that systematic, trans-disciplinary efforts of the disaster prevention and the mitigation can be mounted at international, regional and the national levels.(2)

While in the past, because of their suddeness and unpredictability disasters used to be described as the " will of God ", today this form of over simplification persists in the common assumptions that most of the disasters are natural in origin and little can be done about them except cope through disaster aid and relief efforts.

Planning for a disaster is a task that requires people of dedication since the event planned for may never occur. Obviously those who make these efforts, hope their plans will never be used and thus dedication to their task is a must. From the designer's point of view the task must be reduced to the after effects as much as possible by creating new proper design approaches utilising new materials and new methods of the construction.(3)

2.1.1. Type of Impacts

The type of impacts are generally classified into two main groups. Natural impacts and the impacts of the mankind.

Natural disasters are as follows ;

* Earthquake
* Floods
* Landslides
* Volcanic eruptions
* Ground subsidence
* Avalanches

Most of the time it is not possible to prevent these disasters. It is well known that such disasters cause harmful effects on the structures, establishments and generally to lives of people in the surrounding areas.

Natural disasters may occur alone or sometimes may follow each others. For example in earthquakes, the first shock is sometimes followed by fires, floods, seismic seawaves or landslides,etc. Similarly ground subsidence or landslide may cause of the other similar disasters.

Earthquakes can be accepted as the most important natural disaster. because it affects wider areas and more people than the others. New categories of hazard information from earthquake come from the majors faulting in suburban housing areas, the effects of severe, ground motion on modern reinforced concrete structures, highway overpasses and shaking of high rise buildings.

Floods can be classified as river floods or rises in ocean elevations, that cause or threaten damage and are produced in number of ways. The most common and the major one is the rainstorm riverfloods, the second types is the coastal flood.

Landslide is another inportant group of the natural disasters.Landslides ground settlement and avalanches interfere widely and persistantly with man's activities. Landslides occur on slopes in a variety of geological materials and develop through a variety of mechanisms and causes. They may bring about the major distruption of town and cities, communication systems and the large structures including dams and the bridges.

Also the fire, volcanic eruptions, tidalwaves, droughts, snowstorms, famine, etc.,are the natural impacts which cause the great disasters.

The made impacts can be classified into several groups ; Genetic, epidemics, power failures, gas explosions,water poisoning,water shortage strike, riots, anarchy, war, chemical contaminations,explosions ,nuclear radiation etc.

2.1.2. Human Settlements

Human settlements constitute the frame work for disasters. Today, human settlements are more numerous, much larger and have become immensely more complex through their interrelatedness and inter-dependencies than in the yesterdays. Human settlements have therefore become much more vulnerable to disaster than ever before.

Scientific and technological developments, coupled with population increases, movements of ideas, people and goods have made it so that today it has become nearly impossible to find a truly self-contained and independent city ; instead, settlements have become the very inter-related and inter-connected systems of the varying size, often spanning vast continental regions.

Within the stricken settlement, however, the disaster was normally felt much harder than now and for a considerably longer time. Due to the isolation of the stricken settlement, the inhabitants were left to the themselves to cope with fire, destruction and many other hardships ; tools and the equipment needed must have been available within the settlement. Similarly materials and resources needed to re-construct and re-arrange distrupted by the disaster, came from the settlement and its immediate surroundings.

The type of the human settlement and the general characteristic of it is important reducing the disaster damage and the futher losses. After the point of impact, the corrective actions undertaken by humans in order to cope with disaster impacts (aside from threating the injured and burying the dead) are directed toward minimizing the impact and reconstructing the damaged elements and components of the settlement, so that it can operate as before. In the past, such corrective action was relatively simple because the settlements were rather small and possible technology used to construct and therefore to reconstruction, was rather simple.

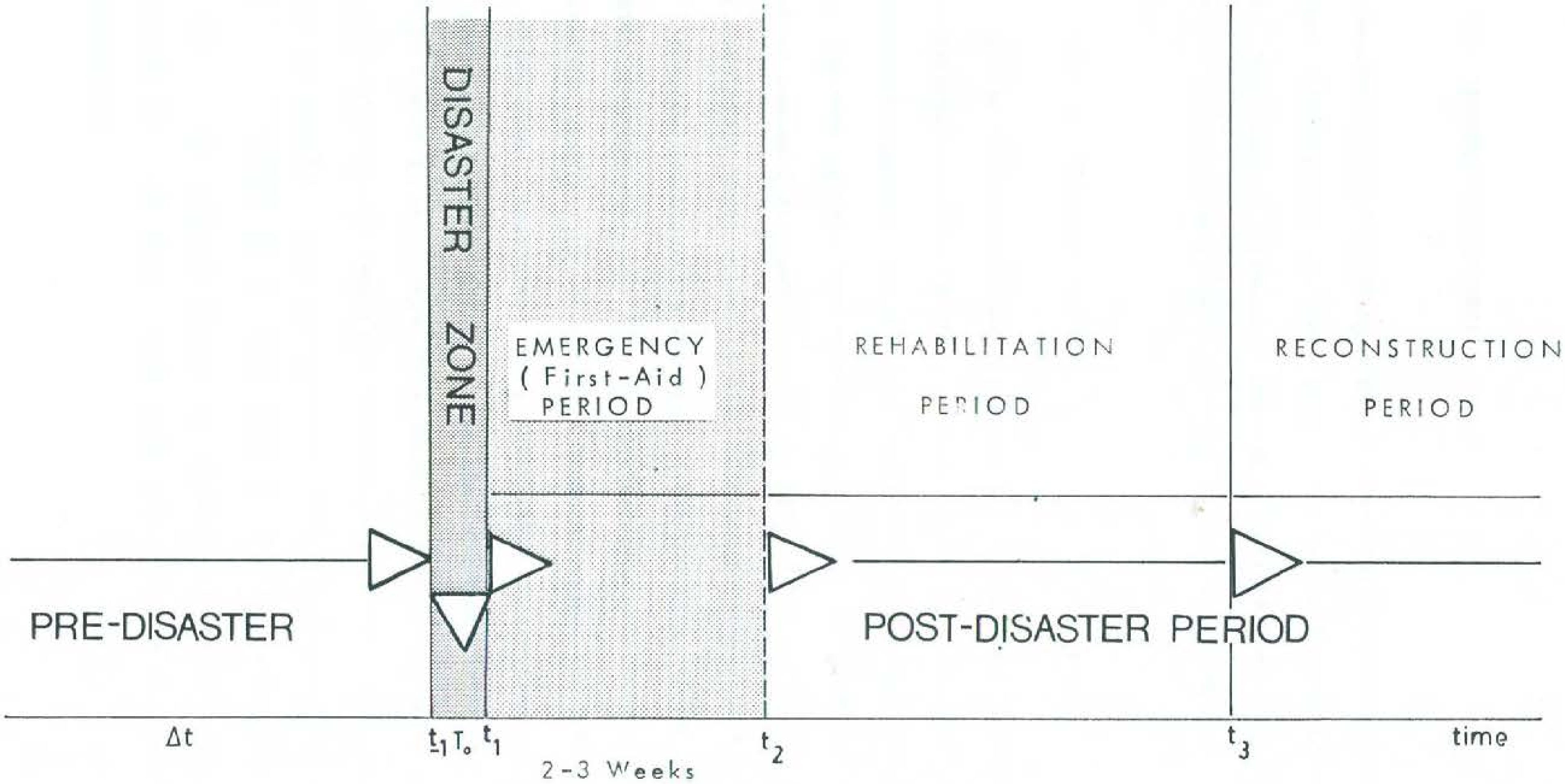

FIGURE. 4 Periods of a disaster

2.2. PERIODS OF A DISASTER

Recommendations regarding disaster areas can be considered at national international and local levels. Each levels has organizational social, technological, financial and the educational aspects. All of these are interrelated to each other. The periods of a disaster are as follows;

2.2.1. Pre-Disaster period

Planning before a disaster is important in reducing disaster damage and minimising its after effects. It must be understood that models and plans without adapting them to local conditions, which may vary even within the same country from district to district and from year to year. No matter how well they may apply in one part of the world, they may prove completely insufficient or even detrimental in anohter. (5)

There are two important concepts in the pre-disaster period : Pre-disaster planning and post disaster preparedness. Planning before a disaster is important in reducing the disaster damage and futher losses. Most of the time, these plans are greatly based on the time factor and the technological levels of the groups. The important subject is reducing the time losses in each stage. This means that after the point of impact the plan which has been adapted to the local conditions must be operated as soon as possible. These pre-disaster planning and operations will reduce futher losses and the after effects. The time losses can not be prevented if the plans are delayed by unexpected reasons or the impossibilities. The lack of time causes the existence of the new catastrophe. (6)

2.2.2. Emergency Period

Before the point of impact we have the predisaster phase. Following the disaster, we have the three generally accepted phases of post disaster activity. (Fig.4) The first of the emergency period may be also termed as the first-aid period. The primary concern of this period is savings of lives and support of immediate human needs. This phase is characterized by the input of medical aid and may be roughly assumed to have a duration a day to several weeks.

There is absolute need for emergency shelters for the inhabitants in this period. These shelters have to be completed or erected immediately after the occurance of a disaster, temporarily, in a large numbers,and in a shortest possible of time. They have been aimed only to serve as a basic shelter and temporarily satisfy the vital requirements of the inhabitants.

2.2.3. Rehabilitation Period

The second phase which may be termed the rehabilitation phase is generally characterised by the establishment of a temporary social infra structure. This means the provision of:

* Temporary housing
* Food supply
* Water & sanitary facilities
* Necessary activities.

These facilities are generally meant to serve until the period of permanent reconstruction.(7) This period may overlap of the first phase beginning one to two weeks after the point of impact and this phase may of course, extend for a considerable period of time, until permanent reconstruction is completed or at least well underway. In most of the disasters this phase has never been terminated.

2.2.4. Reconstruction Period

The third phase may be termed phase of permanent reconstruction. This phase is characterized by the construction of permanent houses, infra structures,well defined ownership structure and represents generally a return to normal.The ultimate goal of this phase is economic recovery self subsistence and hopefully a level self subsistence equal at least to that of the predisaster times.

2.3.SHELTER PROBLEM IN A DISASTER

Disaster area housing problem is a term that can be used either for :

a. Shelters that have to be built immediately after the occurance of a disaster, either temporarly or permanently, in a large numbers, in a shortest possible of time and within economic constraints or for,

b. Housing that is being built everyday in areas with in disaster zones aiming not only to serve as a basic shelter but to satisfy the user's needs permanently.

As a general tendency, the disaster area shelters or temporary housing construction follows three basic basic steps;

1. The planning

2. The design

3. The realization

and if it is analyzed on a strategical flow chart, the outcoming sub-steps can be shown as on Figure 5.

The planning is the decision process related with the qualitative and the quantitative values upon which the shelters or housing design has to be based. These may be summarised as follows;

* The definition of the expected impact(s) the frequency, the intensity, and extent of the disaster must be well defined.

* A clear outline of the local environment must be redefined such as type of earth surfaces, the macro-micro climate, the humidity, air velocity, temperature, etc.

* The present technological levels, the suitable materials and the alternatives must be examined carefully and outcoming solutions must be determined.

* The financial study of the project must be completed.

* Infra-structures have to be planned by taking into consideration all posssible impacts.

* All necessary services such as medical, social services during the post disaster phase have to be determined.

* The selection of the production centers and the storage centers of temporary housing units must be well defined.

The design process is the realization process of an appropriate alternative solution for the post diaster area shelter problems .

* The design proposals have to be prepared and choice of the optimum alternative solutions must be made.

* The selection of suitable materials, shape, form and the function of the design must completed in this stage carefully.

* The examination of the past and the present technologies,and the selection of the appropriate technology must be investigated as an alternative for a protective shell.

* The transportation problems of the units and storage problems are examined carefully and the outcoming criterion must be analysed.

* The alternative design solutions must be tested under the same environmental conditions during the specific periods.

The realization process can be divided in to two different main groups;The production process and the construction or erection process.

* The production process of the emergency units, temporary shelters must be completed in the predisaster periods.

* The allocation of storage center must be determined and the storages of the necessary components or units should be finished also in predisaster period.

The construction or the erection process has to start immediately after the point of impact.

* The transportation of the emergency units to the disaster area must be completed in the first aid period.

* Distribution of the components into the area and the erection or the construction of the units should be fulfilled in the first-aid period.

* The area selection for the transitional constructional production

from the temporary units to the permanent ones must be determined.

* The maintenance and the repair of the infra structures should be completed in the rehabilitation period.

* The production of permanent houses also must be completed in this period.

* The temporary units must be demounted and the repair and the maintenance services of each units should be fulfilled.

* The re-packing and re-transportation of the emergency units to the storage centers must be completed.

2.3.1. Temporary Shelters

Temporary shelter is to be built (erected) immediately after the occurance of the disaster. This type of housing is temporary, and has to be supplied and erected :

* In a large numbers,
* In the shortest possible of time,
* With in a economic constraints.

Temporary shelters is usually meant to act as a basic shelter after the occurance of the disaster and nothing much is expected from such shelters except that it should protect the inhabitants from the environmental effects such as; weather conditions, rain, snow, winds, radiation, etc. If such a shelter is intended to be used for a long period such as few months, it can be also serve some of the vital requirements of the inhabitants .

It is obvious that the properties of a temporary shelter must be different from that of a permanent houses . Taking into consideration

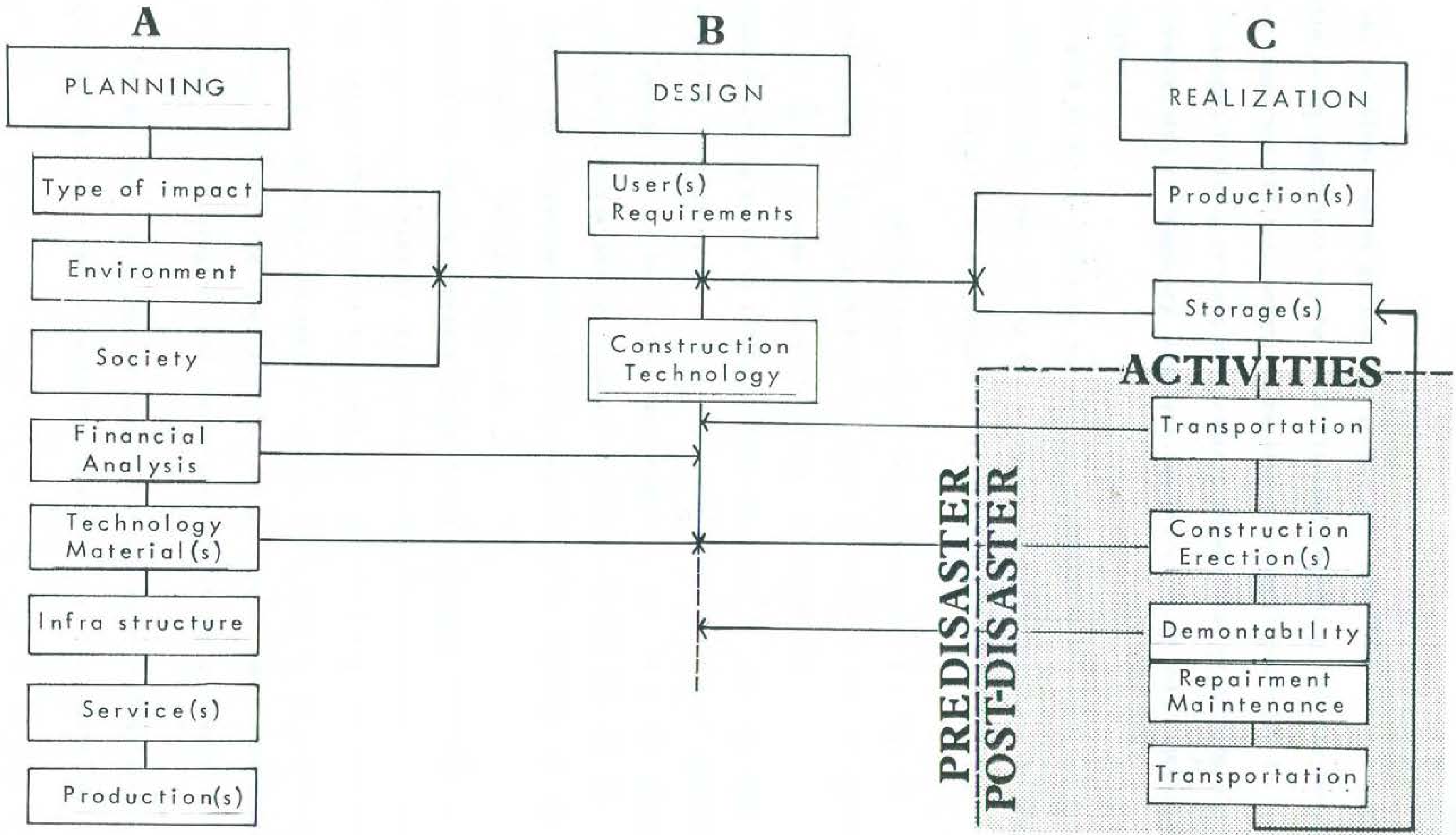

FIGURE. 5 A strategical analysis of temporary disaster area housing

the relatively short period that people will use these shelters, only the prime importance may be fullfilled. But, regarding that the occupation of temporary shelters sometimes reaches to several years due to prolonged building process of permanent houses, the production and construction of temporary shelters has proven to be very important for Turkey.

In fact it is not possible to make any suggestions for the limits of the rehabilitation phase during which the social-infra structure is prepared for the normal life and permanent settlements and houses. (8)

In Turkey, the duration of the use of temporary shelters are determined by the related Ministry. Usually, programs can not realized due to various causes brought forward by environmental systems and people have to go on to living in those shelters for periods longer than expected, even for years. It is seen that, even in the best conditions, this period can not be shorter than several months. When this period coincides with the severe climatic conditions in most part of the Turkey, this relatively short period creates great problems for the inhabitants of temporary shelters.

Considering that the people stricken by an earthquake in winter of 1977 have not been settled in their new houses before the autumn of the same year, it is not difficult to define this period of eight or more months as a long time. Under the weather conditions of East Anatolia with regard to these reasons, the temporary shelters gain great importance under the economical, technological and the natural conditions of Turkey. (9)

The main goal of temporary shelters or instantenous shelters is generally to serve the protection problems of the inhabitants until the period of reconstruction is completed. There is a clear urgent need for the closed surfaces in all diaster areas during the post-diaster phases. The construction period of the emergency housing series may begin in the first-aid period and continue on the rehabilitation period, they overlap the temporary infrastructure much of the time.

Site selection criteria for the storage and the erection, design and the dimensioning of the unit is done in accordance with govermental or district transportation regulations, If such is not outlined the temporary shelters,units,etc. should have designed in such a way that they are suitable to transport with all possible vehicles.Also the quick erection facilities, modulation, demountability, lightness, storage and packing are the vital subjects that they are very closed to the transportation problems. Referance could be made,in this respect to an almost European regulations in the "directive" prepared by the Union Europeenned'Agrement Technique de la Construction concerning lightweight housing it is required that elements should not be heavier than 150 kg per sq/m surface area. Also because the temporary units will be assembled or erected atsite using the prefabricated units shipped in, assembly should not require too many qualified labourers. Approximately, The units should be erected by 2 trained and 2 untrained labourers per unit should sufficient. The erection or the assembly period for per each unit should be limited to 12 hours.(10)

Post disaster temporary shelters or units production is not a desirable investment area for the private enterprises due to uncertainities in the size of the market demand potential, properties of time.

These units must be produced either by a rotating capital state organizations such as (General Directory of Natural Disasters, with in the frame work of Ministry of Reconstruction and the Settlement) or in the work places of state economic organizations produced multilateral productions (The Mechanical and the Chemical Industries Establishment of Turkey) or as an alternative factories could be established as attached to the non-profit making public organizations such as the (Red Crescent of Turkey). However private sector production could be utilized if a certain production system is selected as in the instance of large scale emergency demand following highly destructive disasters, providing that the avaible stocks are insufficient.(11)

2.3.2 Permanent Housing

A house that can be classified as permanent has to have comfort conditions and must endure the disasters that it might be subjected to during its life span. In other words,'it must satisfy the user-activity and the spatial requirements permanently. These disaster area housing units must be built in such a way that they protect the users from the disaster or minimize its effect as much as possible. They aim not only to serve as housing units or only basic protection but to satisfy all necessary requirements regularly. In any disaster zone; the most vital important user requirements are safety requirements, therefore measures for protection from disasters must be taken into consideration for every building constructed.

NOTES

(1) JOSEY,J.L., Mobilization to Expenditure Construction of Disaster Housing Doctoral Dissertation, Mississipi State University, September.1973

(2) ALEXANDER,R.B.," Human Settlements; The second Definition ", Ekistics Vol 41,Numb.247,June 1976

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3.PROPOSED ALTERNATIVE FOR A PROTECTIVE SHELL

3.1 THE BEGINNINGS IN NATURE AND THE BUBBLE FORM

The world of future may be expected to look more eternal more like fairyland then the world of present or of the past.(1)

In several design cases designers turn to mother nature and they search how the problems occur and natural solutions which exist in it. Most of the time these kind of works give realistic ideas, for the designers and architects for the beginning. "Forms which result from functional criteria are created by life, are therefore of an elementary and a natural kind. There has been a great change in a general attitude towards expression in the past decades. Under and during the reign of geometrical culture, formal expression was derived from laws which were contrary to life, to the creation of life,to movement and to nature laws recognized in purely geometrical forms".(2)

The next stage is apply the new technological developments and materials to new application areas. This kind of studies encourage the application of technologies, materials etc., which are being searched to the ideas which was originated from nature.

Any cell structure in nature tends to design for self protection of the users life. If the cell walls consist of solid materials then they are self-supporting ,e.g.compartments of shells.

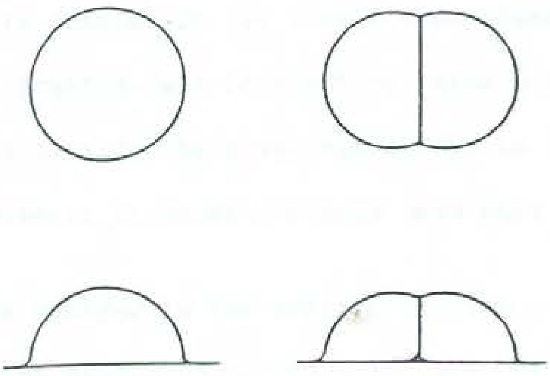


FIGURE. 6 Simple bubble combination

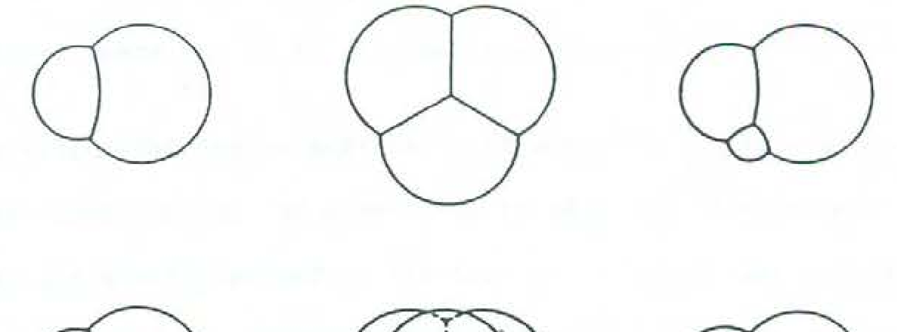


FIGURE. 7 Bubble agglomerations

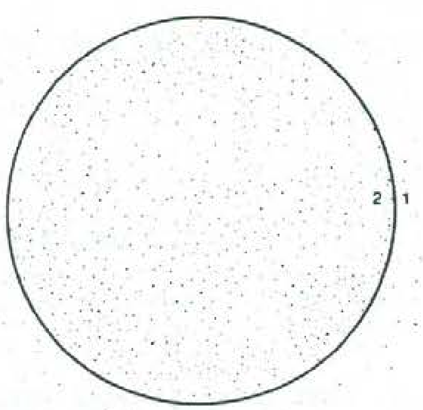


FIGURE. 8 The lamella form a spherical surface

If the cell walls consist of the flexible membranes, then they are stabilized in their position and form not by gases but by the fluids. Soap bubbles (Fig. 6-8) and bubble agglomerations in the sea foam are, however genuine pneumatic forms with closed membranes.

A soap bubble is moulded by the surface tension forces acting in both sides of the soap film. Due to the uniformity of these forces, the main characteristic of the film is to form shapes of minimal surface area, in which the walls are stressed equally at every point and in all directions with no concetration of stress at any one point on the whole surface area. Stresses are equalised by liquid flow in the soap film, so that stress peaks can in no circumstance occur. (3)

Any shape that can be achieved with a soap film, is suitable for pneumatic construction. If a membrane is made out of extremely inelastic material and exactly shaped in the form of enlarged soap bubble, this membrane, provided its weight is negligible, will be uniformly stressed at every point and in all directions when inflated.

Soap bubbles are acted upon by internal pressure loads only and consequently, deviation from the soap bubble forms may be neccessary to obtain the most suitable form for the pneumatic structures which must also be capable of resisting external loading. The smallness and fragility of soap bubbles make it difficult to analyse their form experimentally and to subject them to external loading conditions.

Experimentation with soap films is most valuable in the early design stages since it can suggest to the designers, suitable pneumatic forms which may accomodate the design parameters within which they must work.

variety of pneumatic forms possible is clearly demonstrated by inflating soap films overvarious complex boundaries. Examples obtained thus have a clearly discredible tendency to generate spherical forms, doubly curved synclastic forms being usual, although singly curved and the anticlastic forms are by no means impossible. Besides this tendency towards minimal surface areas, soap films and conglomerate in a certain manner, always meet at an angle of 120 to one another relationship between the radius of curvature of the film and the pressure differential across it is always constant. Thus in floating twin bubbles of equal size, the dividing wall between them is planar since the pressure of each bubble is equal. (Fig.9-10)

In bubbles of different sizes, the internal pressures are different and these mould the common membrane wall into a curve form. (Fig.7) However, the tangential angles between the soap films remain at 120 . No matter how many bubbles are grouped together the soap films always meet at the same angle. Although a fixed number of bubbles can group together in a multitude of arrangements, there is an observed tendency for the bubbles to adopt circular plan forms, those with a minimal membrane surface area. These bubble conglomerations could perhaps be taken as the architectural protoypes for pneumatic buildings. The large bubble surrounded by numerous smaller bubbles suggest a pneumatic form of perhaps an assembly hall with ancillary accomodations. It must be underlined again that these studies can only serve as a guide to understanding of soap bubble forms of pneumatic phenomena, and for the designers functional and aesthetic design parameters. As a result with regard to their surface, all shapes produced with soap bubbles can be thought of as "ideal" pneumatic forms since, because of the fluidity of

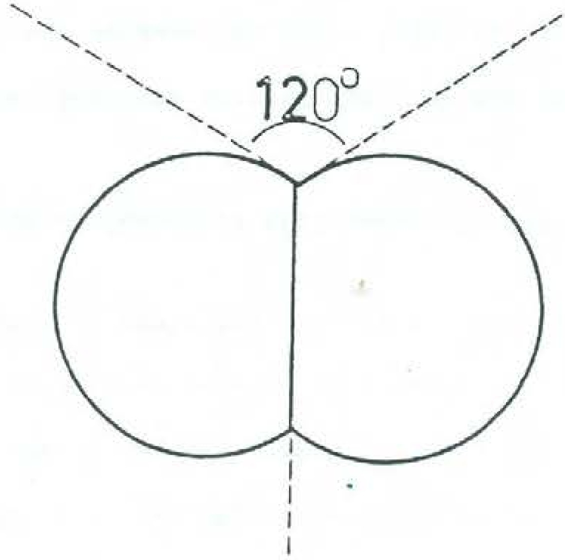


FIGURE. 9 Bubble combination

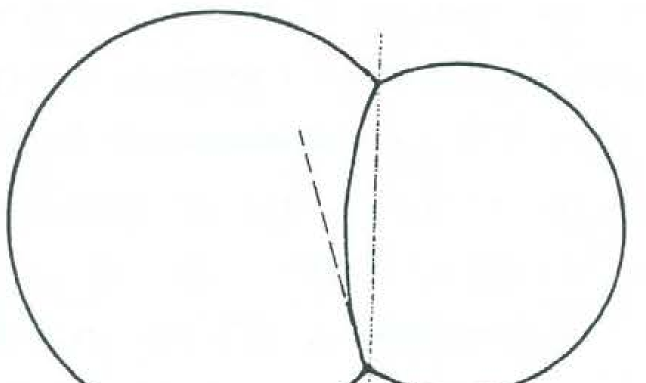


FIGURE. 10 Agglomeration

their film, forms always occur in which there are;

a. Equal membrane stresses at every point on the surface;

b. The largest possible volumes and smallest possible surface areas.

3.2. EVOLUTION OF COMPOSITE HEMISPHERE (Bubbles)

a. Take a point in space and call it A. Draw three lines, Ab, Ac, Ad with angles of 60 degrees between each other. (Fig. 12. A) (4)

b. Select a radius for the larger sphere I by locating point B, which is on Ab and A is the referance point on the circle. Select the radius distance of adjoining composite sphere K by locating point C which is on Ac and point A is the reference point on the circle too. (Fig. 12. B)

c. Point B is the centre of the sphere I, point C is the centre of composite sphere K and point D is the centre of the arc which forms the Interface between points A and E .

d. When designing the composite sphere K as a hemisphere I the distance AB must equal AD. AC will equal 1/2 AB or 1/2 AD. AE will have same curvature of sphere I but in reversed direction and have one-half the curvature of composite sphere K. (Fig. 12. C)

e. When designing sphere I equal to composite sphere K construct AB equal to AC, this time interface will be a straight line.

f. Note at every A and E, tangents of all three curves each form angles of 120 . (Fig. 12. B)

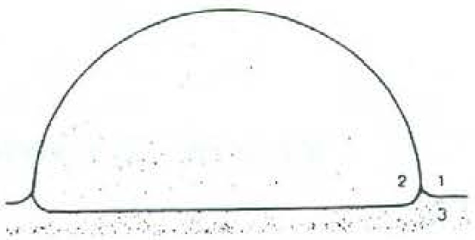


FIGURE. 11 Cross section of a single bubble

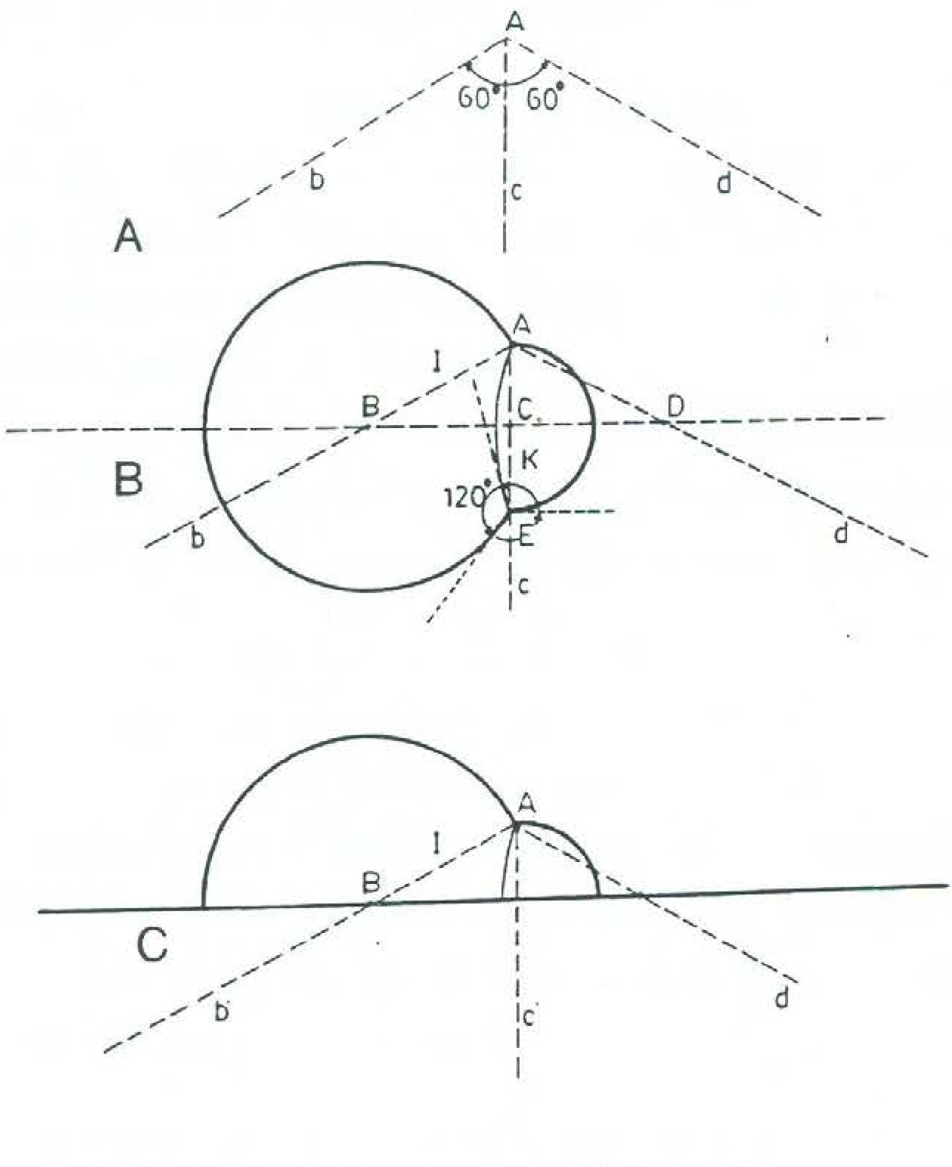


FIGURE. 12 Evolution of a composite hemisphere

3.3. THE PHENOMENON OF PNEUMATICS

Technological development nowadays is so rapid that soon the innovations of today will be obselete tommorow. This era of change is naturally reflected in social trends. People are no longer satisfied with the same enviroment day in day out. They demand change and variety this is manifest in two ways:

Firstly, the great turn over the material belongings,

Secondly, the increased movement, not only from one occupation to anohter but also between physical environments. (5)

Traditional architecture, evolving as it does from rigid structural forms which dictate the environmental conditions within them, could hardly be adapted to these requirements. Today a new understanding of architecture has been born, this new era is " pneumatics ", which is infinitely more flexible in its options. It can be erected or dismantled quickly, lightness, portability, easy maintenance and repairment, etc., are its desirable features. It therefore offers a possible solution to wide range of problems both of social and the commercial kind.

For instance, pneumatic construction can be used to evercome the temporary shortages of warehousing spaces. It can be used to provide a shelter for homeless in times of the natural or man-made disaster, and in these early days of space exploration, it have been suggested that for lunar shelters." The more important statement that these applications demonstrate, is the fact that pneumatic construction points the way to an architectural revolution". (6)

To correct the environmental deficiencies of rigid traditional structural envelopes, energy must be supplied to heat and ventilate them bringing them up to the comfort standarts that are determined by the building function, Most of this applied energy depends on the insulation characteristics of the structural envelope. Advances in technology have increased the effectiveness of these characterstics, but at the same time environmental engineering has become a much more sophisticated science. It is not possible to create fully conditioned environments without a structure of the kind usually associated with architecture. All that is required is a bag to contain this manufactured environment.

This is the complete reversal of architectural thinking. On one hand there is traditional or the conventional architectural thinking in which structure determines environment, and on the other hand there is pneumatic architecture in which the application of the energy produce structural stability.(7)

3.4. GENERAL CLASSIFICATION OF PNEUMATICS

As with many technologies in their infancy, the terminology of the pneumatics has not been clearly defined, although certain terms appear to have been accepted throughout the world.

The words "pneumatics", "blow-ups", "inflatables", "airdomes", and "airhouses", with many other are tossed around rather nonchalantly to describe in one case the whole field of this technology and in another just one particular aspect. To define it accurately, however, it should be known collectively as pressurised construction, which is a general term that implies the control and the stabilisation of all kind of structures by means of pressure differential achieved by the uniform loading action of air, gases, liquids or even granular solids. (Fig.13) Illustrates the relationship between the general category of pressurised construction and those sub-categories which under the general heading of pneumatic constructions refer to structures on acted by air, gases and related particullarly to architecture and the building. (8)

3.4.1. Constructional Classification

3.4.1.1. Air Controlled Construction

Any structure whose position or movement is controlled by air pressure differentials can be termed as "air controlled structure ". As yet these structures are not widely used and generally are not associated with architecture, although pneumatic tubes have long been used to transform messages and cash in big department stores. More familiar applications are pneumatic drills, air breaking systems and ground effects machines, such as howercraft and howerpads. These later ground effects and machines may be of particular significance in the architecture of the future and this possibility is examined more in today's applications.

3.4.1.2. Air Stabilised Construction

As yet only air stabilised structure has been adopted for building construction. The essence of the pneumatically stabilised construction, whether it be stabilised by air or gases, is a thin flexible membrane which is supported solely by pressure differentials.

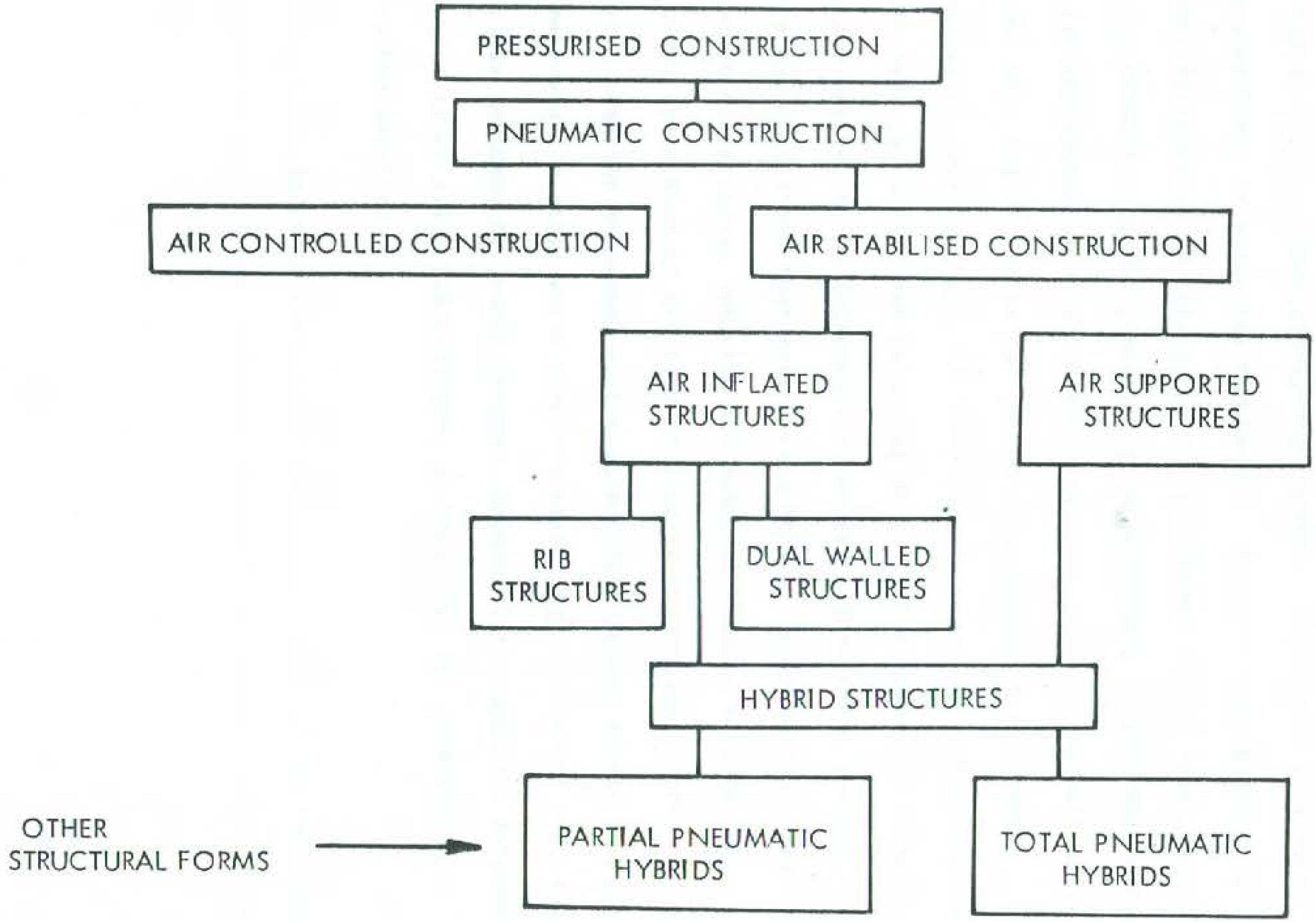


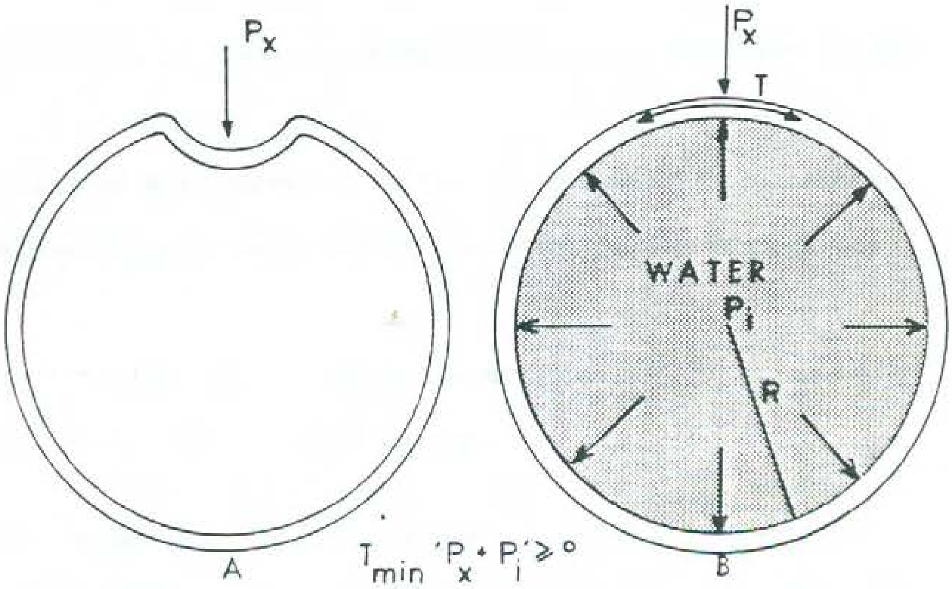
FIGURE. 13 General Classification of pressurised construction

These differentials in pressure induce tensile stresses into membrane and enable it to support gravitational and wind loads as a relaxation of these tensile forces. Consequently the pneumatic structures is a pure tensile structure, in which the membrane is utilised with great structural efficiency. An analogy of the phenomenon is the water hose-pipe which demonstrates the pneumatic principles very simply. When empty it is limp and posses very little stiffness, but once filled with water it becomes more rigid.(Fig.14-15) The water is causing a pressure differential accross the walls of hosepipe, which are so pretensioned as to resist bending. A full understanding of pneumatic behaviour is most complex and has yet to be achieved with accuracy. Basically, however, there are two conditions that govern this form of construction. Firstly, the pressure differential inducing the membrane tension must be high enough under the action of all kind of loading conditions to prevent compressive membrane stresses, such compressive stresses appear as folds in the membrane. In other words complete stability is achieved when all parts of the membrane are under tension. Secondly, the membrane stresses at any point under all situations must be less than the permissible stress of the material.

Arising from the principles of air stabilised construction,two types of structure emerge, the air inflated structure and the air supported structure.

3.4.1.2.1. Air inflated structures

In inflated construction, air is contained withih a membrane to from inflated structural elements, such as columns, beams, walls and arches which themselves resist the external loadings in much the same



$T_{min}\ 'P_x + P_i' \geqslant o$

$T_{max}\ 'P_x + P_i \leqslant T_p$

$T = P_i . R$

T - Memrane stress,

P_i- Internal pressure acting on memrane,

R- Radius of curvature of memrane

FIGURE. 14 Membrane stress

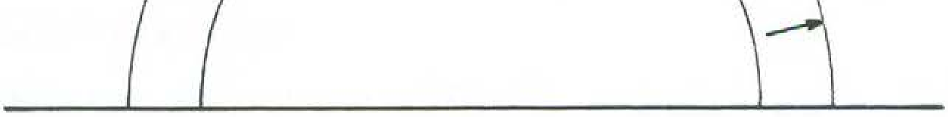


FIGURE. 15 Inflated dual-walled structure

way as the structural elements of more conventional structures. The structural capabilities of these inflated elements are dependent on four things:

1. The volume of air contained within the element by its membrane,

2. The excess pressure differentials exerted on the membrane by the air.

3. The characteristic of the membrane material,

4. The structural form of the elements.

With large volumes of high pressure great spans can be achieved, but these necessitiate the use of stronger membrane materials. The main characteristic affecting the structural performance of the element, besides tensile strength, is the modulus of elasticity of the materials The higher this is, the greater is the rigidy of the structural element. If the air could be sealed within the membrane, and no air leakages occured, then air replenishment would not be neccessary to maintain a constant pressure. However because of the slight air porosity of materials generally used in this type of construction, particularly at joints, air replenishment is generally essential.

There are two main types of air inflated structures;

1. Inflated rib structures

2. Inflated dual wall structures (Fig.15)

The former is made up of a framework pressurised tubes which support a weatherproof membrane tension. This membrane can add considerably to the stability of the structure. The small volumes of air contained within these tubes make the structure more suitable for small span construction

Inflated dual walled structures, as their names implies, consist of two membrane walls between which the air is contained. These walls are held together by drop threads and diagram configurations. The larger volumes of air associated with this form of construction give it a greater spanning potential that air inflated rib construction.

Erection times for air inflated structures vary considerably and are dependent on the volumes of air contained within the membrane, the pressure of this air and the capacity of the inflation equipment. Small structures like air inflatable tents can be inflated with in a couple of minutes, an instant structure in fact whereas the larger structures can take thirty minutes or even longer.

3.4.1.2.2. Air supported structures

Air inflated structures , apart from the fact that they depend on air pressure differentials for the stability,can not readily claim to be far removed from conventional structural systems. Air supported constructionon the other hand, is certainly a complete new structural form which, in same cases,has already shown signs of producing a complete contradiction of traditinonal architecture.

The air supported structure consists of a single structural membrane which is supported by a small air pressure differential. This means that the internal building volume is at a pressure slightly above atmospheric usually between 15 and 25 mm of water pressure and consequently access in and out of building is accomplished of air from the buliding interior which must be replenished by an uniterupted air supply so that pressure differential is maintained at all times.(Fig.16)

Unlike convential structures which exert a positive loading on the ground the pressure differential across the membrane of an air supported structure causes up lift forces, and this must be resisted by firmly anchoring the air supported structure to the ground. (fig. 17)

In general, there are three unique structural design problems presented by the air supported structure. (10)

a. The need to maintain the pressure differential across the membrane with a constant air supply,

b. The need to minimize air leakages,

c. The need to conteract the up-lift forces by some means of the anchorage.

As with air inflated structures, the strength of the air supported structures is dependent on the contained air volume, the internal air pressure, the structural form and the membrane material characteristics the former two being the most influential. The greater these two variable are, the more rigid structure is . Thus the larger volume enclosed by the membrane of air supported structure, requires only very small pressure differentials, 15 to 25 mm of water pressure, for stability. With air inflated structures smaller volumes are contained by the membrane material, so higher pressure differentials are required. From this it can be seen that air supported structures possess the greater spanning potential. However, against this greater advantage must be set the three critical design problems of air supported construction, which have already been mentioned.

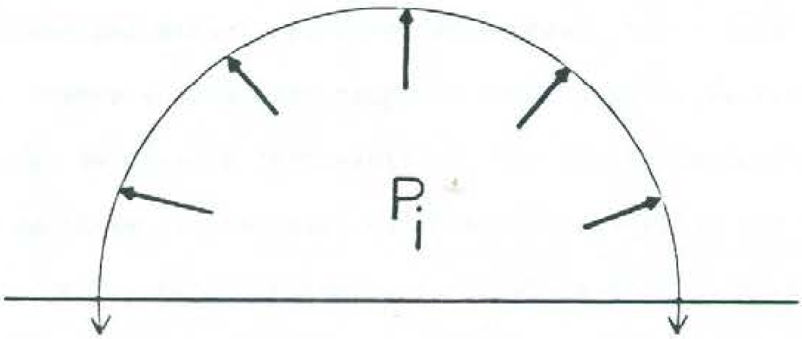


FIGURE. 16 Air supported structure

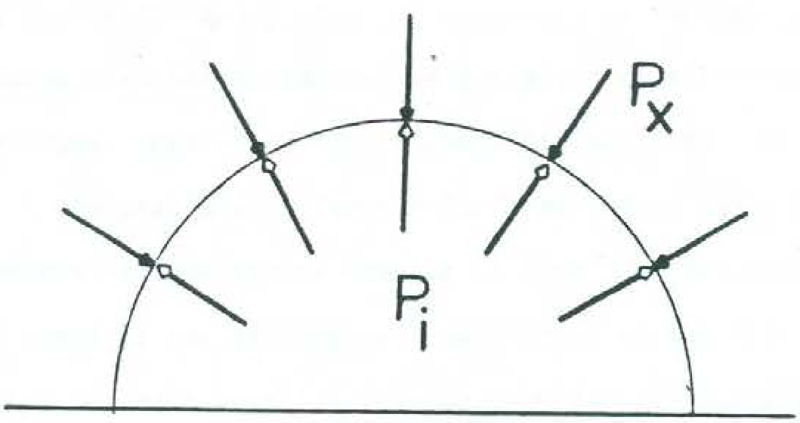


FIGURE. 17 Behaviour of air supported structure

P_x Total pressure acting on the membrane due to external loads only,

P_i Internal pressure acting on the membrane.

3.4.1.3. Hybrid Construction

Because of the limitations of both air supported and air inflated construction,another structural form has emerged, the hybrid structures. The hybrid covers a very wide range of structural types,although two basic forms can be clearly distinguished. The first has logically developed from these limitations, but has capitalised on the benefits of each the two constructional forms by integrating them both into one structural system. The spanning potential of air supported construction is achieved, but with the added insulation of dual wall construction. Since structural stability is achieved by two different methods, safety against collapse is increased.
As yet there are few of these sophisticated structures, but amongst them is one of the most notable examples of the pneumatic architecture. The first group of the hybrid structures might be termed as' total pneumatic hybrids ', the second group would be described as partial pneumatic hybrids. These structures combine the pneumatic construction with other more conventional form of constructionand obviously the variation and the range of combinations is immense.The semi- rigid airship of the early twentieth century is one example of this of hybrid construction. The global shape of the airships was maintained by the internal pressurisaton whilst a very light frame provided overall rigidty of the structure,although similar construction has been used with air supported structure with a light metal structure to ever come some of the problems posed by air supported design.

Almost certainly, it is through hybrid construction that the truly sophisticated pneumatic architecture will appear.(11)

3.4.2. The Morphological Classification of Pneumatic Structures

To classify the understanding of complex phenomena,analogies are often used to pneumatics.Designers need not search very far for an appropriate anology, for a soap bubble and films are the purest forms of the present pneumatic structures.(12)

In the classification in the (Table.1), pneumatic structures are described and compared by means of formal characteristic properties. Phenomenological variables other than those used are certainly possible. In (Table.1), it is stated that pneumatic structures can be open or closed .

Differentiation should therefore be made between structures with ;

* Two dimensions of similar size and on large dimension,
  Examples; " Tubes ", " Masts ", " Columns ", " Towers ",
* Two dimensions of similar size and one smaller dimension,
  Examples; " Cushions ", " Lens ", " Discuses ", " Mattresses ",
* Three dimensions of similar size.
  Examples; " Balloons ", " Balls ", " Bubbles ", " Spheres ".

Especially there are borderline cases between these alternatives. In assessment, therefore the main directions of extension are compared in their relationship one to another, if a structure is twice as long as it is wide but its height only amounts to a third of its widtsth and height is the decisive factor in its classification. The absolute dimensions play no role in the differentiation factors.(13)

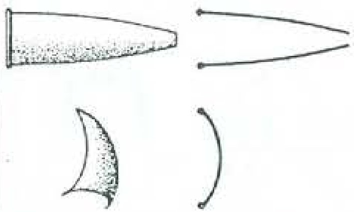
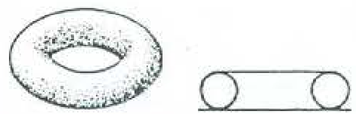
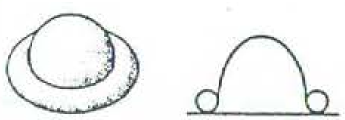
feature	alternatives		
type of membrane type of structure 6 alternatives	membrane open structure open 	membrane closed structure closed 	membrane open structure closed 
possible mixtures of forms			
membrane open and membrane closed, structure closed 	membrane open, structure open and structure closed 	membrane open and membrane closed, structure open and structure closed 	

TABLE 1A. *Morphological classification of the pneumatic objects.*

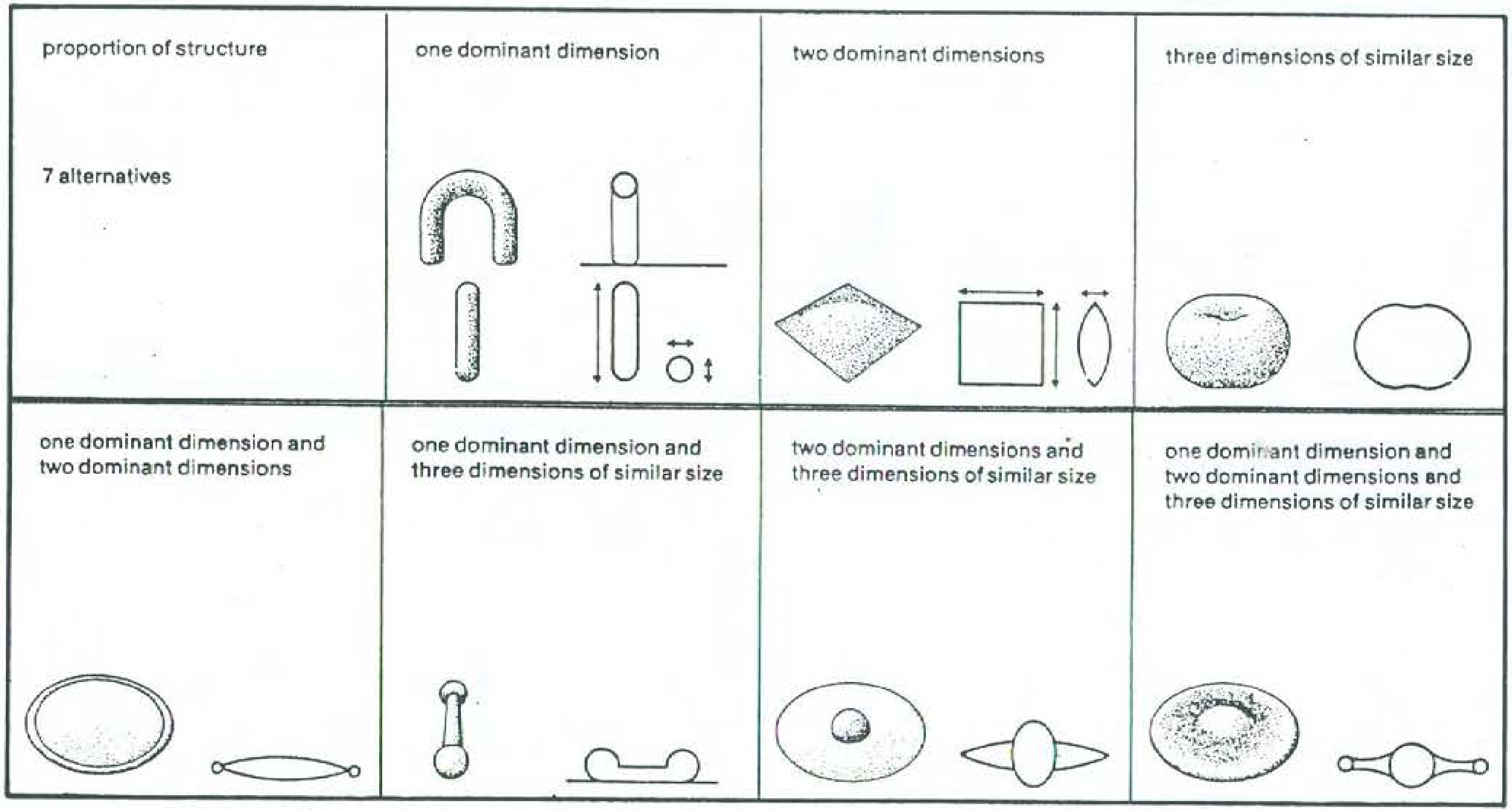


TABLE 1B. *Morphological calssification of the pneumatic objects.*

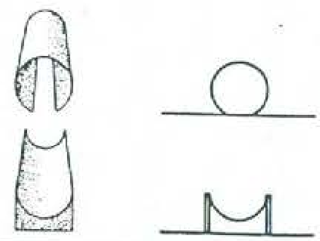
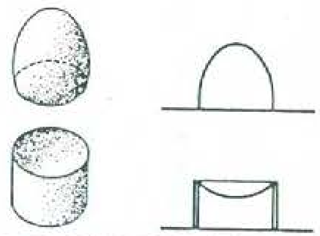
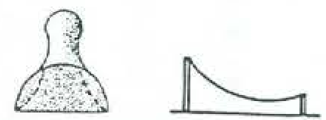
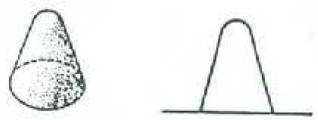
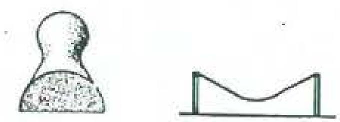
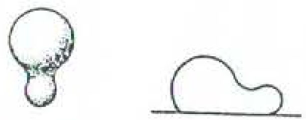
type of curvature 7 alternatives	singly curved 	doubly curved in the same direction 	double curved in opposite directions 
singly curved and doubly curved in the same direction 	singly curved and doubly curved in opposite directions 	doubly curved in the same direction and doubly curved in opposite directions 	singly curved and doubly curved in the same direction and doubly curved in opposite directions 

TABLE 1C. Morphological classification of the pneumatic objects.

The form can be futher classified according to the types of curvature of the outer surface.

* Singly curved
* Doubly curved in the same direction or synclestic

Plane membrane sections can also occur in the pneumatic structures when there are interior skins whose edge is attached to outher membrane (similar to inner lamella in the case of equal sized soap bubbles). However, these skins are not stabilised in the plane, because there is no difference in pressure. They obtain their tension throughout the tensile force acting at the edge.

A futher aspect of classification is the establishment or whether an object represents an individual pneumatic structure or comprises several pneumatic structures and whether these structures are the same as each other or different.If the structures are bound together so that they are not seperable from each other then its in a combination. This is the case where the adjacent elements possess common membranes so that one elements must be destroyed in order to seperate the next but one element from first.

The question of the kind connection between individual structures is important when considering ;

* Production,
* Erection,
* Dismantling,
* Transportation,
* Volume,

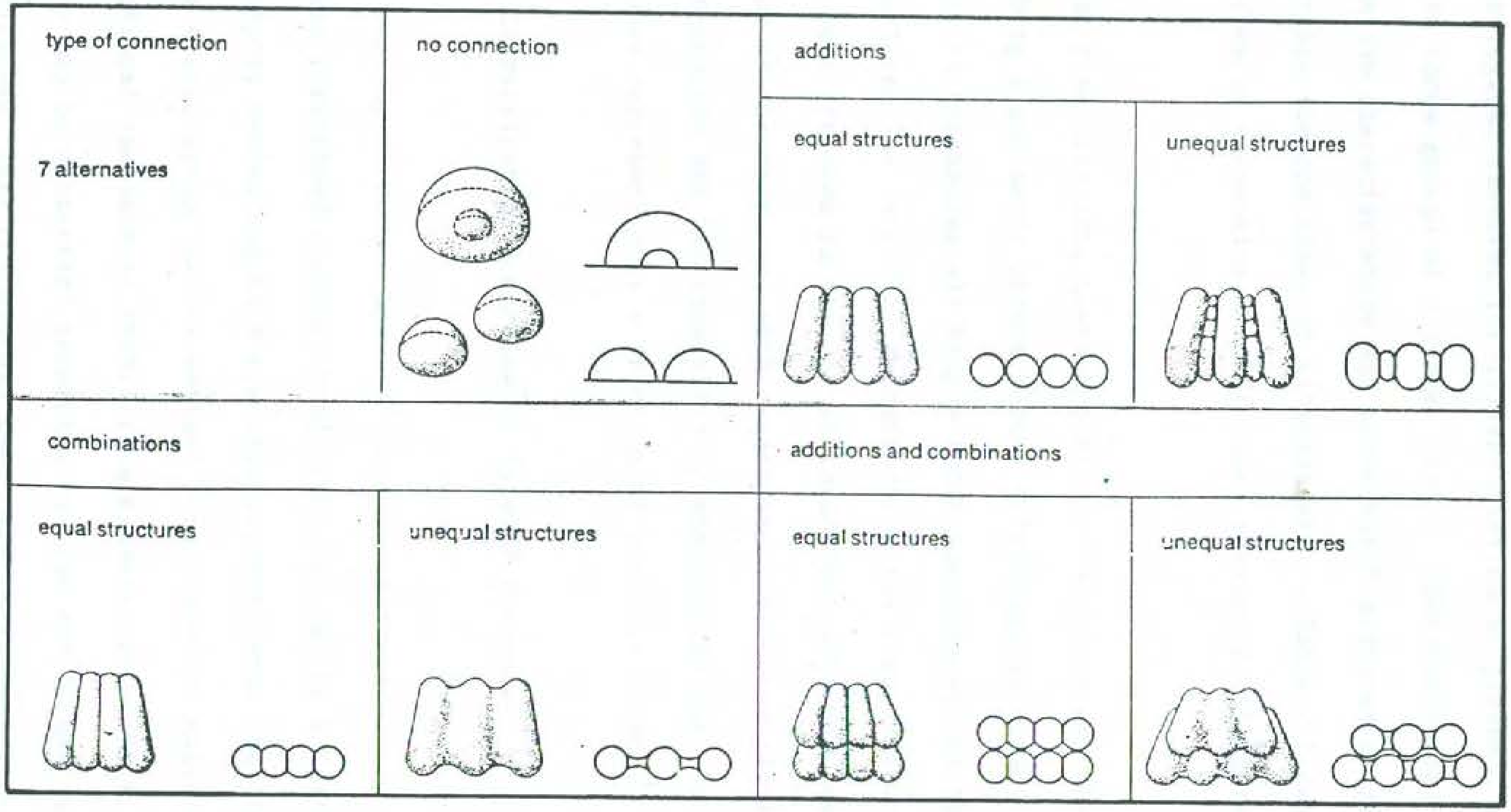


TABLE 2. *The possible types of connection of individual pneumatic structures to an object.*

* Development of structural details,

* Type of anchorage.

The morphological features for differentiation of pneumatic structures are shown in three groups of (Table. 1A-C), each horizontal line gives the alternative characteristics and shows which mixtures of forms are possible within the one lines of alternatives. (Table.2) describes the possible types of connection of individual pneumatic structures to an object.

Within the classifcation, there are about 2000 different possibilities for describing a pneumatic object from a morphological view point. It is not possible to schematise all single forms possible within the rules of the structures.The fact that geometrically the simple structures have previously been prefered in the use is consistent with the favourable exploitation of membrane webs with regard to models, the simplified and calculation process and the possibilty of standardization. However, the standard types represent only a fraction of possible forms.

3.4.3. Classification According to Type of Pressure

A load bearing structure has the function of transferring certain forces within prescribed boundary conditions. It can be allotted to a specific support system and to a specific support form. The structural system is a static sytem that is neither formalized nor materialized.(14

If additional (secondary) stabilizing elements occur in a load bearing they may be classified according to type and formation of the secondary elements, into sub-systems which are called"structural types".

One should refer to a structural formb when the longitudional and the cross sectional properties are known . Thus a structural form is a building which is certainly formalized but not materialized. If the consideration of pneumatic structures is restricted to their function as a load bearing structure, pneumatic structures are the load bearing structures stabilized by the differential pressure. Differential pressure is necessary for the load bearing function and consequently the stabilizing medium is apart of the structure. Soils, hot air ballons and parachutes are not generally pneumatically stabilized but pneumatically stressed structures. If one relates the term "pneumatic" to direct stabilization, then one can only refer to load-bearing structures made of curved, stiff surface elements as shells even if they are pneumatically stressed (High pressure containers) or in addition are pneumatically stabilized. Then the specialized term pneumatically stabilized membrane structure is used instead of the general term" pneumatic structure".

Pneumatically stabilized membrane structures can be subdivided by a series of different features.(Table.5 A-B)

i) Type of differential pressure
   a. Positive pressure systems
   b. Negative pressure systems
ii) Degree of differential pressure
iii) Type of support medium (Table.3)
iv) Formation of membrane
v) Number of membranes

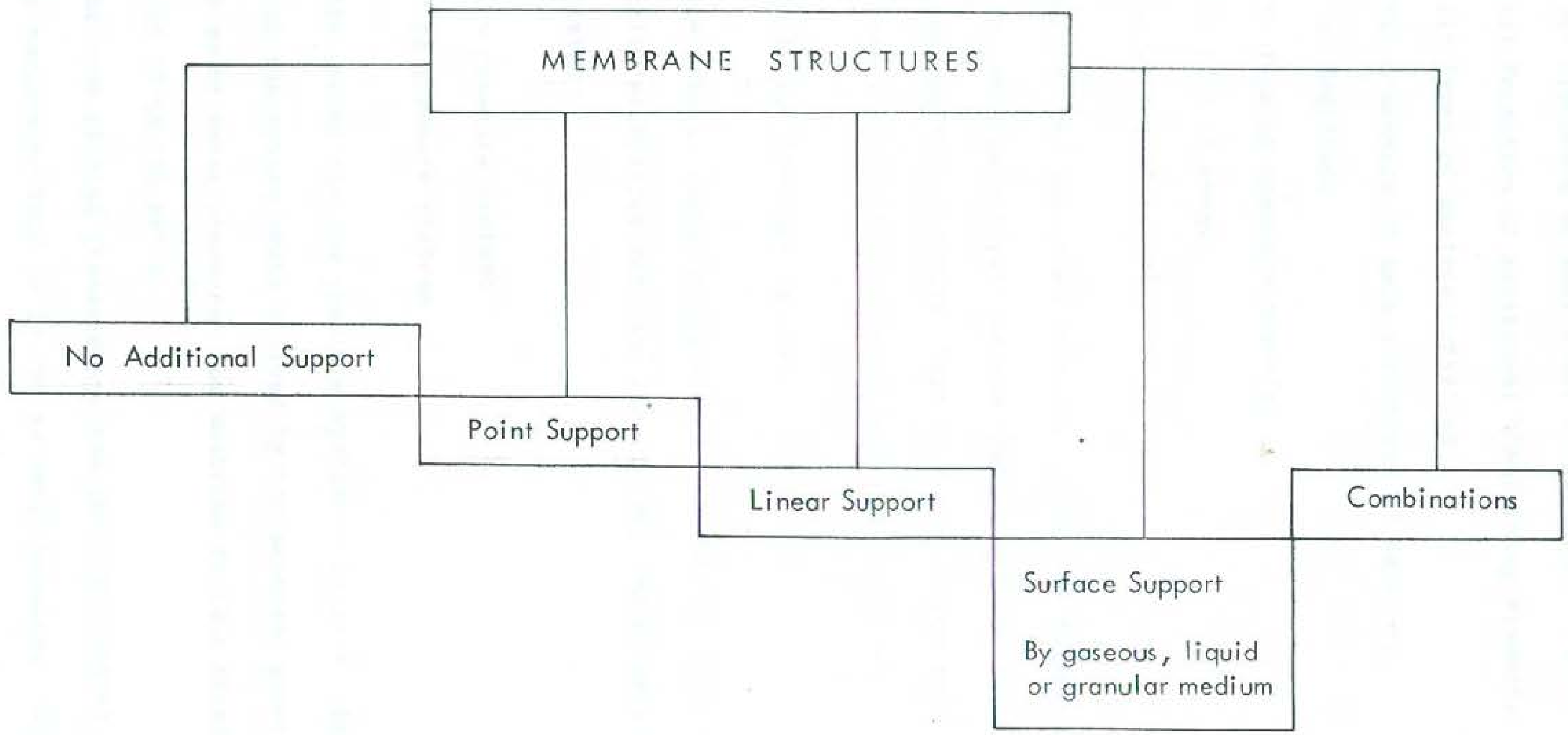


TABLE 3. Classification of membrane structures.

vi) Dimension of additional stabilizing elements

vii) Formation of additional stabilizing elements

viii) Types of surface curvature

ix) Dimension of main directions of expansion

x) Magnitude

xi) Type of membrane material

xii) Type of usage

xiii) Degree of variability

For each of the mentioned features, there are different characteristics for example, two characteristics are used to distinguish the type of the negative and positive pressure. That is a distiction made between the positive pressure systems and negative pressure systems.

3.4.3.1. Low Pressure Systems

In the general characteristic of the survey of different systems of pneumatically stabilized membrane strüctures, two primary systems can be differentiated :

a. Low pressure systems

b. High pressure systems

In the cse of the low pressure systems.(Table.4) the differential pressure of the system media divided by the membrane generally amount to 10 to 100 mm of water pressure. The membrane is thus stressed by a normal pressure of 10 to 100 kg/m^2.

In the case of high pressure systems the differential pressure are generally amounts to 2000 to 10.000 mm water pressure. This means that the membrane is exposed to high differential pressure 2000 to 10.000 kg/m^2

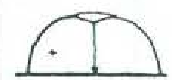
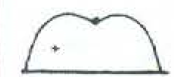
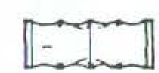
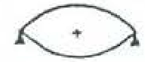
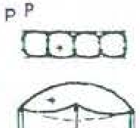
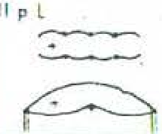
low pressure systems				
I single membrane structures				
	0 no additional support	P additional point support	L additional linear support	P+L additional point and linear support
I n negative pressure	I n 0 	I n P 	I n L 	I n P+L 
I p positive pressure	I p 0 	I p P 	I p L 	I p P+L 
II double membrane structures (inflated)				
	0 no additional support	P additional point support	L additional linear support	P+L additional point and linear support
II n negative pressure	II n 0 	II n P 	II n L 	II n P+L 
II p positive pressure	II p 0 	II p P 	II p L 	II p P+L 

TABLE 4. Classification of low-pressure systems

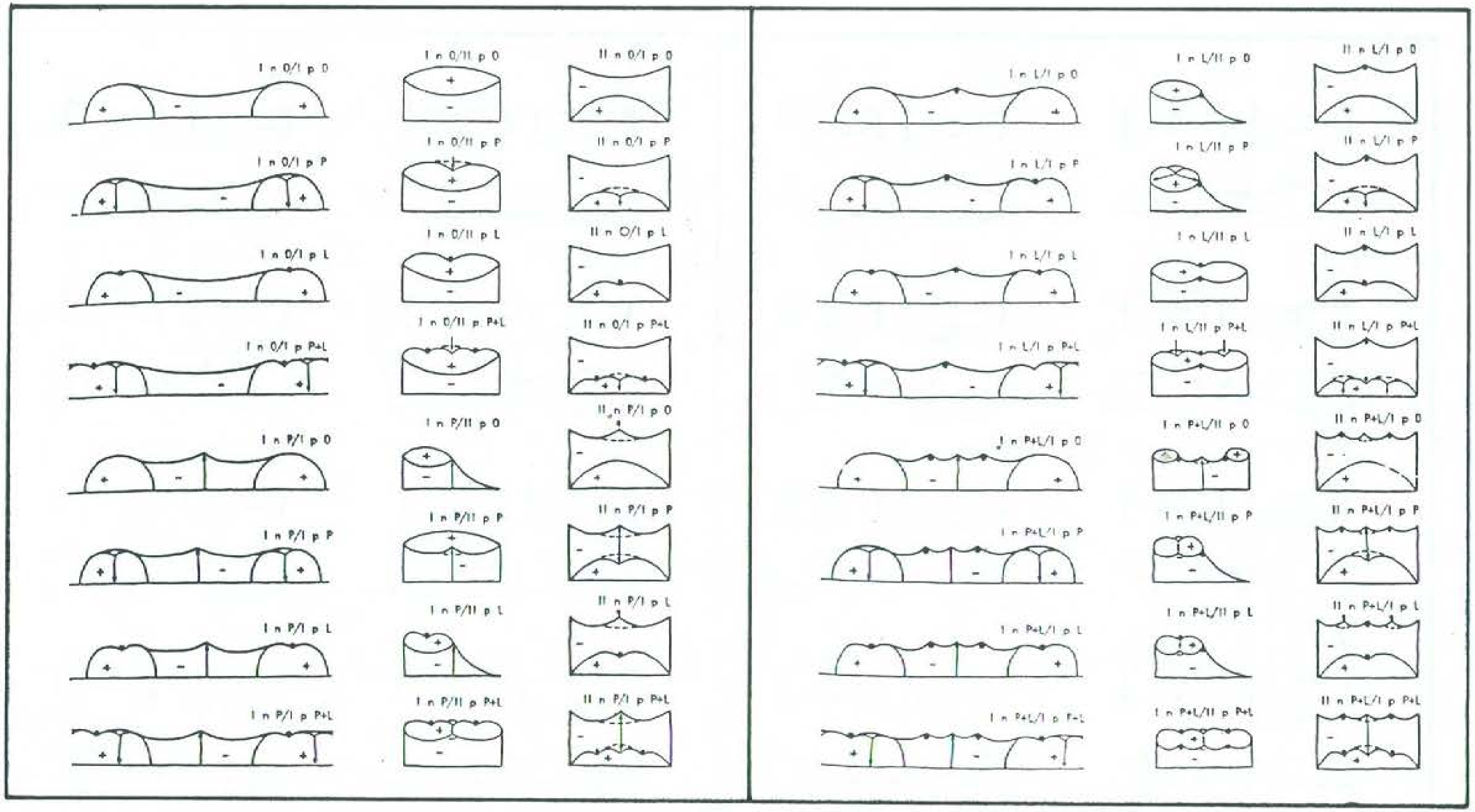


TABLE 5A. *Combination of negative and positive pressure systems.*

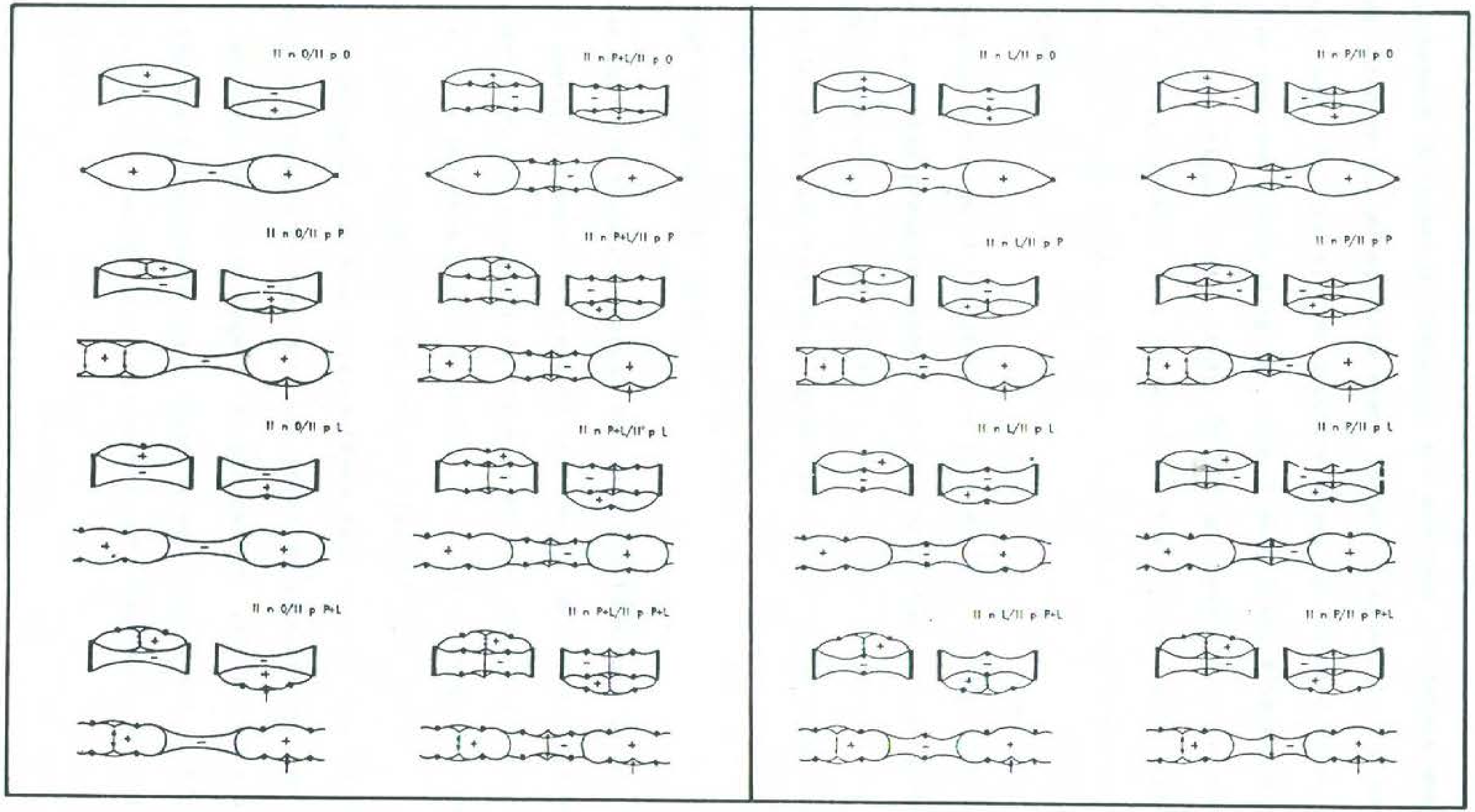


TABLE 5B. Combination of negative and positive pressure systems.

In a single membrane structures an accessible space under positive and negative pressure is formed or closed by one membrane. In double membrane structures, however the accesssible space formed or closed by the membrane structure is not under positive or negative pressure. In this case the parts of the membrane surrounding the support medium are always curved in the opposite directions to each other. Double membrane structures can by reason of their appearance, also be called as the "cushion structures". Other structural forms which are called tubular structures are also high pressure systems.

The second division of low pressure systems into negative pressure systems and positive pressure systems, according to the kind of internal pressure may seem insignificant at first, as in stabilization of structures only the differential has however, a great influence on the structural form of the boundary formation, on the static and dynamic loadings of the membrane and as the spatial form.

In the positive pressure systems the membrane is always curved outward (convexly) whereas in negative pressure systems the membrane is always curved inward (concavely) except in the area of the secondary support.(15) As a result, in a negative pressure systems snow and water pockets can very easily occur in the roof as well as instabilities of form due to aerodynamic loading in the wind-disadvantages that are not usually present in the positive pressure systems.Moreover,negative pressure systems usually requires high supports at the edge or in the center. This means relatively expensive secondary structures.These disadvantages have meant that negative pressure systems have meant that negative pressure systems have so far been hardly used.

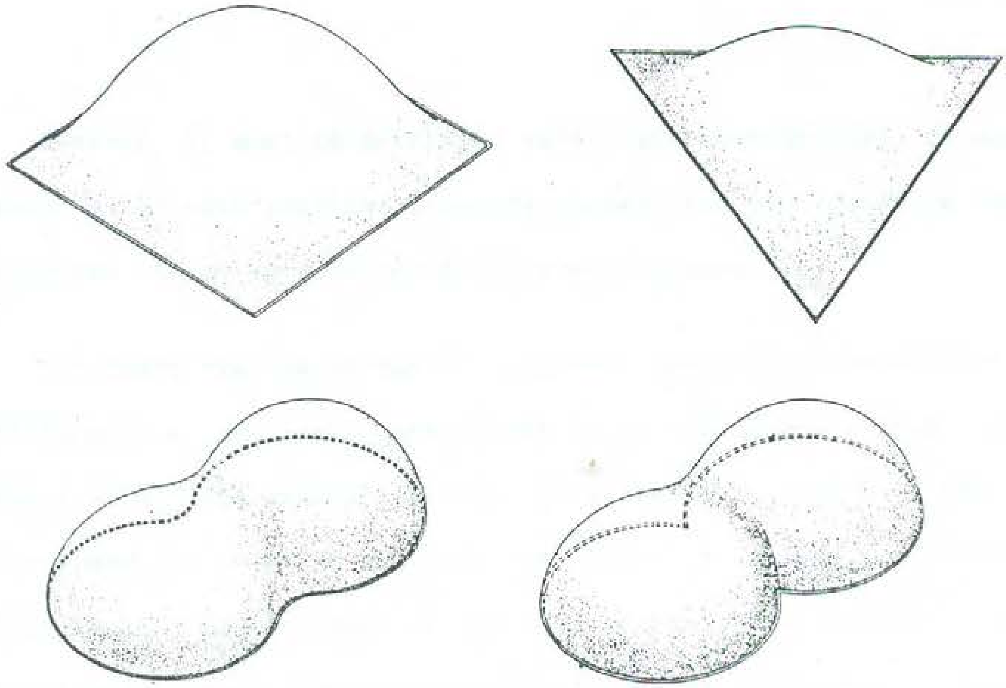


FIGURE. 18 Point supports

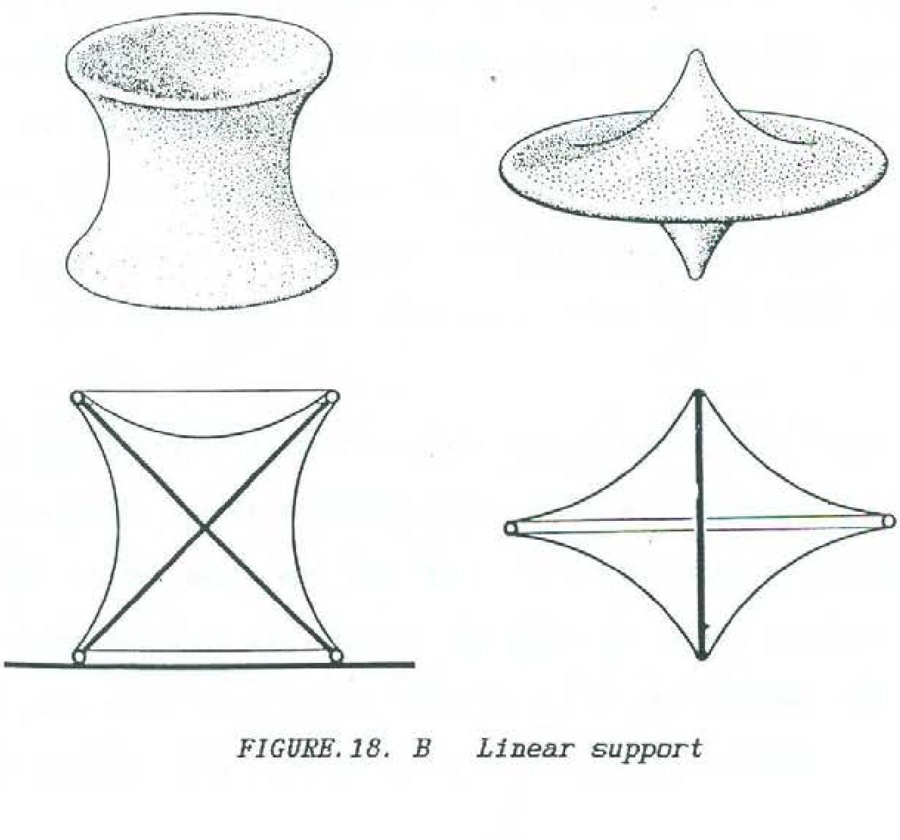


FIGURE. 18. B Linear support

However, it must be mentioned here that these systems, in combination (Table. 5A-B) with positive pressure systems and high pressure tubular structures can be very suitable for some purposes.(16)

The third feature of the low pressure systems is the kind of the additional i.e. secondary, stabilization of the membrane used. Additional support within the membrane surface is generally suitable in the case of large spans, in order to decrease the radius of curvature and thereby reduce tension in the membrane. By this means it is possible to use the conventional flexible membrane materials, which are simple to manufacture and to work on ,even in the largest spans.

Additional point supports(Table.6) and (Fig.18A) are usually suitable for average and larger spans, but the development of support points is generally complicated and expensive in terms of materials, so that it is normally more economic to make use of the principle of the additional linear supports. With certain boundary formation and with some fields of use it can be practical to combine the principle of point and linear support, if it is thereby possible to produce sufficient curvature in all areas of the membrane or if, for example, Tunnel-shaped areas of larger diameter are required in the membrane surface for the drainage rainwater or snow.

If one attempts to increase the curvature of the surface in a baloon made of elastic rubber membrane by pressing with a pencil point on the membrane, it becomes clear that at a "support point" very high tensions occur in relation to the rest of the membrane, which can very easily lead to the skin splitting. On the other hand, if one expands the individual support points, to a circular band or a rounded of bulged surface, then it

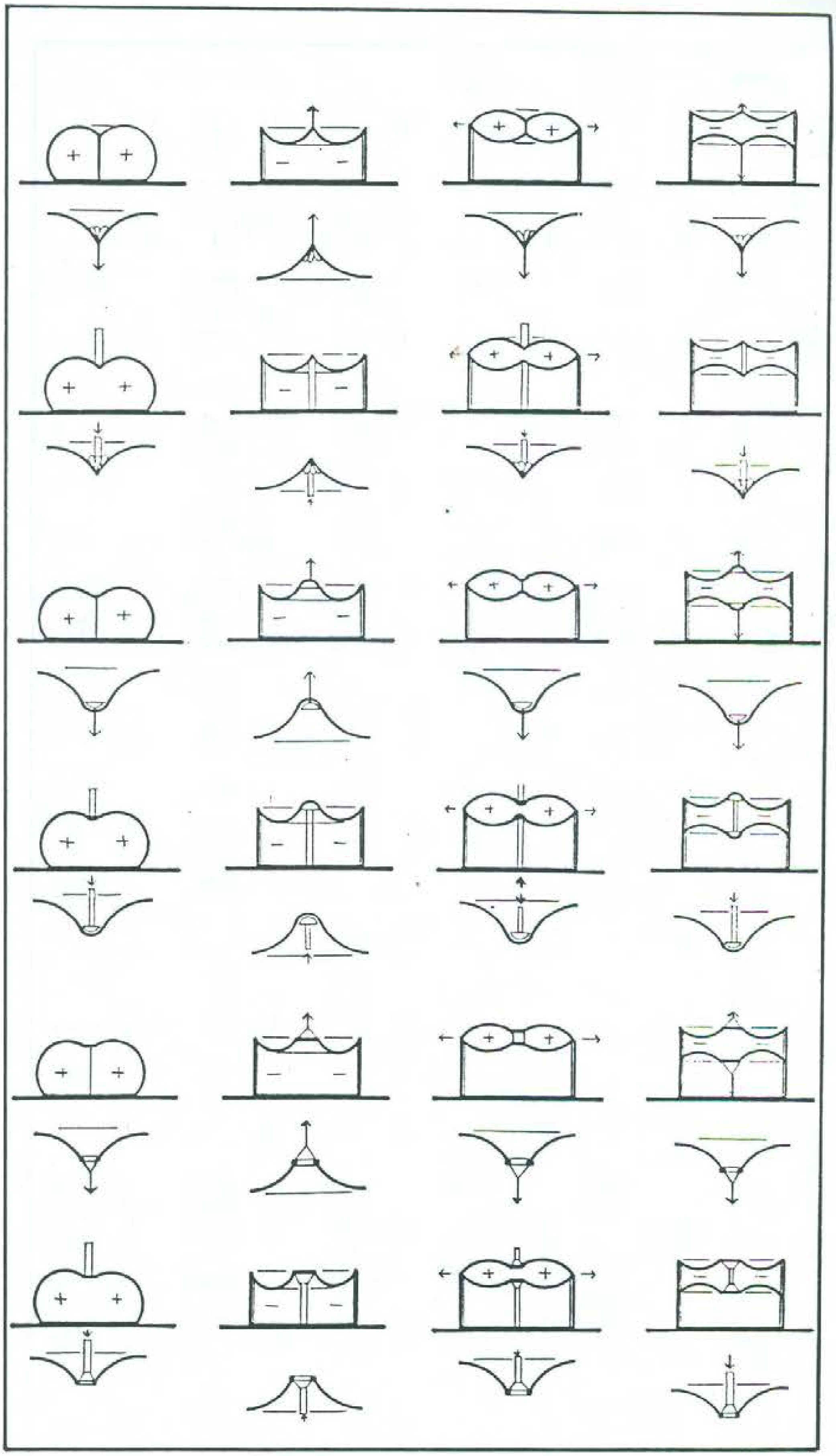


TABLE 6. Basic types of pneumaticaly stabilised membrane structures with additional point support.

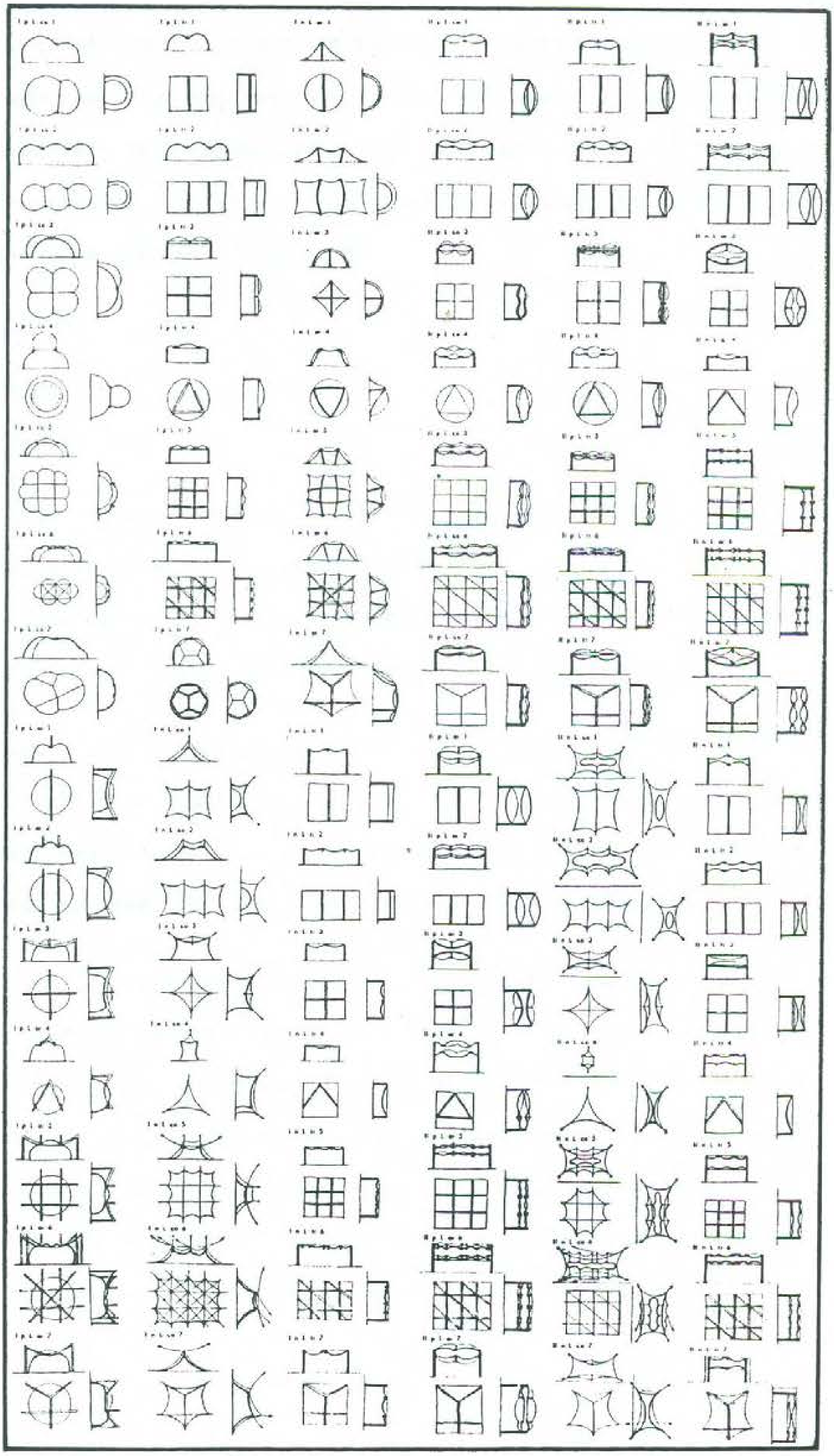


TABLE 7. 84 possible types of single-double membrane structures with aditional linear support.

is possible if this expanded support surface is large enough in relation to the whole membrane, for the membrane to show the same tension distribution at every point and thus the danger of the membrane breaking at the support points is no greater than at any point. With point supports three different formations can be defined : (Table.8)

* Rosette
* Ring
* Bulged Surface

The term " Rosette " is used only when the tensioned element is concerned in which the forces from the membrane are collected into the edge cables and from there into tertiary support elements. It is also possible to use only a single cable, which is then referred to as a "loop".

The term " Ring " is used for a circular element under bending stress as well as tensile or compressive stress. The bending stress, which usually predominates, results from the angle between the angle between membrane plane as well as from the support of the ring tertiary elements.

The termed " Bulged surface " is used when there is a spherical rounded off support surface which is mainly under compressive stress. The bulged surface can be baloon, which adapts to increasing curvature and directs forces away from membrane.It can however, beformed the flexible star shaped lamella or clover leaf shaped disc under bending tension or, in special cases, be resolved in individual disc like surfaces formations which are already well know from test construction.(Fig.18 B)(17)

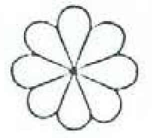
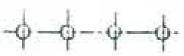
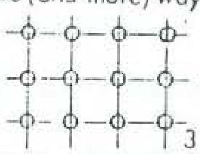
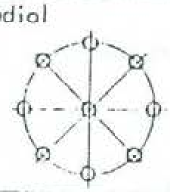
formation / arrangement	rosette/loop  ro	ring  ri	bulged surface  bu
single  1	I p P ro 1 I n P ro 1 II p P ro 1 II n P ro 1	I p P ri 1 I n P ri 1 II p P ri 1 II n P ri 1	I p P bu 1 I n P bu 1 II p P bu 1 II n P bu 1
row  2	I p P ro 2 I n P ro 2 II p P ro 2 II n P ro 2	I p P ri 2 I n P ri 2 II p P ri 2 II n P ri 2	I p P bu 2 I n P bu 2 II p P bu 2 II n P bu 2
two (and more) way  3	I p P ro 3 I n P ro 3 II p P ro 3 II n P ro 3	I p P ri 3 I n P ri 3 II p P ri 3 II n P ri 3	I p P bu 3 I n P bu 3 II p P bu 3 II n P bu 3
radial  4	I p P ro 4 I n P ro 4 II p P ro 4 II n P ro 4	I p P ri 4 I n P ri 4 II p P ri 4 II n P ri 4	I p P bu 4 I n P bu 4 II p P bu 4 II n P bu 4
irregular  5	I p P ro 5 I n P ro 5 II p P ro 5 II n P ro 5	I p P ri 5 I n P ri 5 II p P ri 5 II n P ri 5	I p P bu 5 I n P bu 5 II p P bu 5 II n P bu 5

TABLE 8. *Kind of formation and arragement of additional point support.*

3.4.3.2. High Pressure Systems

Under high pressure systems the pneumatically stabilised membrane structure consist of tube-like elements and therefore is termed a tube structure.The "Tube elements" show a very strong curvature in one direction and are able to transfer the transverse forces in the direction of the low curvature.(Table.9)(18)

In high pressure systems, the differential pressure required for this generally lies between 2000 and 70.000 mm of water pressure and this is 100 to 1000 times as large as that of the low pressure systems. Thus the high pressure systems differ from low pressure systems in the differential pressure, the structural function and the type of the support action. The high pressure systems, in a comparison with other structures transfering transverse forces, have a relatively low structural efficiency and are thus only used when requirements such as easy erection and dismantling,low-weight and low transport volume are the decisive factors for the choice of the structural system.A significant property of tube structures is that their form within the certain limits can adopt the stresses through the external forces. Thus they are particularly suitable as support elements for cable net and membrane structures which are subject to strong changes in form and tension, If the tensile stressed skin increases then the support surface increases.

As high pressure systems have different structural functions and characteristics from low pressure systems, the differentiating faetures for low pressure systems are not applicable here. In order to distinguish between high pressure systems the following features should be taken into account :

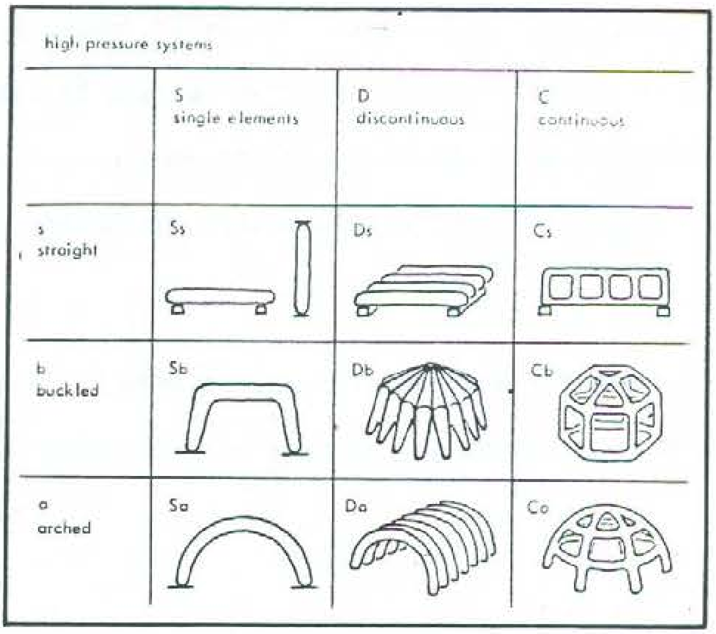


TABLE 9. High pressure systems

* The pattern of the element,

* The kind of connection of the elements to each other.

In the case of the first feature the three characteristics, straight buckled and arched should be considered. With the second feature the three characteristics are "single elements", discontinuous and continuous. The nine systems thereby defined are put together in the form of matrix in form (Table.9). They are provided with memo-technically derived code and presented as a system diagram.(19)

The term " straight","Buckled","Arched",etc. relate to the axis of the element. Inthe case of system "Ss" with the loadbearing effect of a beam, for example a small curvature can occur in the longitutional direction for structural or manufacturing reasons or the beam can be put together from two cones.

Through addition and combination, the surface structure, which represent a discontinuous or contiuous for transfering forces, can be developed from individual elements.

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4. MATERIAL BEHAVIOR OF THE PNEUMATIC STRUCTURE

4.1. SURVEY ON MATERIALS

The selection and the use of fewer materials and those having an initial basic liquid form has outstanding advantages.
Requirements for tensile strength, flexibility and the durability heavily restrict the range of the suitable materials.

The choice of the membrane material is generally dependent on a great number of design criteria, which must vary considerably with the function and design life of the structure. (1) The following criteria are suggested;

a) Strength Properties

i) Tensile strenght (Pa)

ii) Tear resistance (Kg)

iii) Modulus of elasticity (MPa / mm^2)

iv) Strength to weight ratio (k)

b) Air permeability

c) Weather resistance properties

i) Precipitation

ii) Vapour permeability

iii) Radiation

iv) Wind

d) Chemical resistance properties

e) Insulation properties

i) Thermal transmitance (Kcal/m^2 hC^o)

ii) Sound

iii) Light

f) Flexibility;

g) Incombustibilty:

h) Variation properties (+-C^o)

j) Type of jointing methods

After the selection of given criteria, the materials are divided into two main groups of which are called " Isotropic " and " Anisotropic " materials.

4.1.1. Isotropic Materials

Isotropic materials show the same strenght and strength properties in all directions,anisotrophic materials have direction orientated properties. Isotropic materials mainly consist of :

a) Plastic films,

b) Fabrics,

c) Rubbers,

d) Metal foils.

Plastic films are primarly produced from PVC, Polyethelene, Polyester Polyamide, Polypropylene, Polyvinylfouride, Polterephtahalate or Syntetic rubber (Polisobuthylene, Chloroprene, Polytetrafluorethylene, etc.)
Many designers are obsessed with transparency, which enables appreciation of man's total environment, without the accompanying inflictions of natural climatic conditions and human manufacture pollution. This era is the

attraction of transparent plastic films. (2) The films available did not have sufficient strength or satisfactory weathering properties until recently. Transparent films are very susceptible to ultra violet deterioration, but these harmful rays can be filtered out by the addition of suitable chemicals, such as the derivatives of benzophenon and benztriazol. A high performance plastic film is polytetrafluorethylene, which is light strong and durable, etc. It is very suitable for pneumatic applications.

Only one method of jointing is suitable for plastic films and that is welding. Both sewing and cementing reduce the strength of the film considerably with welding 90 percentage of the materials strenght can generally be developed, and in some cases; joints as strong as the material it self can be produced.

Fabrics are made of glass fibres or synthetic fibres and they are coated in PVC, polyester or polyurethane film.

Rubber membranes are very flexible. They are particularly useful as test specimens, as a wide range of forms can be constructed with them without a complicated cutting pattern. They are not suitable for permanent pneumatic membranes of larger dimensions because of their low modulus of elasticity and their low weatherability. They are used particularly in a special pneumatic concrete and synthetic forming processes which make use of their great abilty to deform. (3)

Metal foils possess a very high gas diffusion resistance and their tensile strength range up 90 kg/mm^2. However they have low breaking loads and can only be used for pneumatic structures when they are fairly ductile Aliminium foils are mainly used in outher space because of their high reflective properties.

4.1.2. Anisotropic Materials

Anisotropic materials consist mainly of;

a) Woven fabrics,

b) Gridded fabrics,

c) Synnthetic films,

d) Coated woven fabrics.

Woven fabrics have two main directions of weave initially at right angles but some angular displacement between threads is possible. They can be made of;

* ORGANIC FIBRES	; Wool, Cotton, Silk,
* MINERAL FIBRES	; Fiberglass,
* METAL FIBRES	; Thin steel fibres,
* SYNTHETIC FIBRES	; Polyamides (Perlon, Nylon, Dederon)
	Polyesters (Dacron, Diolen, Grisuten, Terylene
	Polyarcylnitrilen (Dralon, Dolan ,Orlon,Redan
	Polyvinyl (Rhovyl)

Organic fibres are seldom used today for pneumatic structures. Deterioration processes can be largely prevented by additive materials, however they have considerably lower durability or less favorable elasticity after the outside exposure than mineral or synthetic fibres. The lowest elasticity under loading is shown at the moment by fibre-glass (breaking strains of 3 to % 4 .(4) However,because of the low elasticity their spatial deformability is relatively low despite the angular displecement of the fabric threads and thus their abilty to adopt to forms of syclastic or anticlastic surfaces is also low, so that a very accurate cutting pattern is necessary.

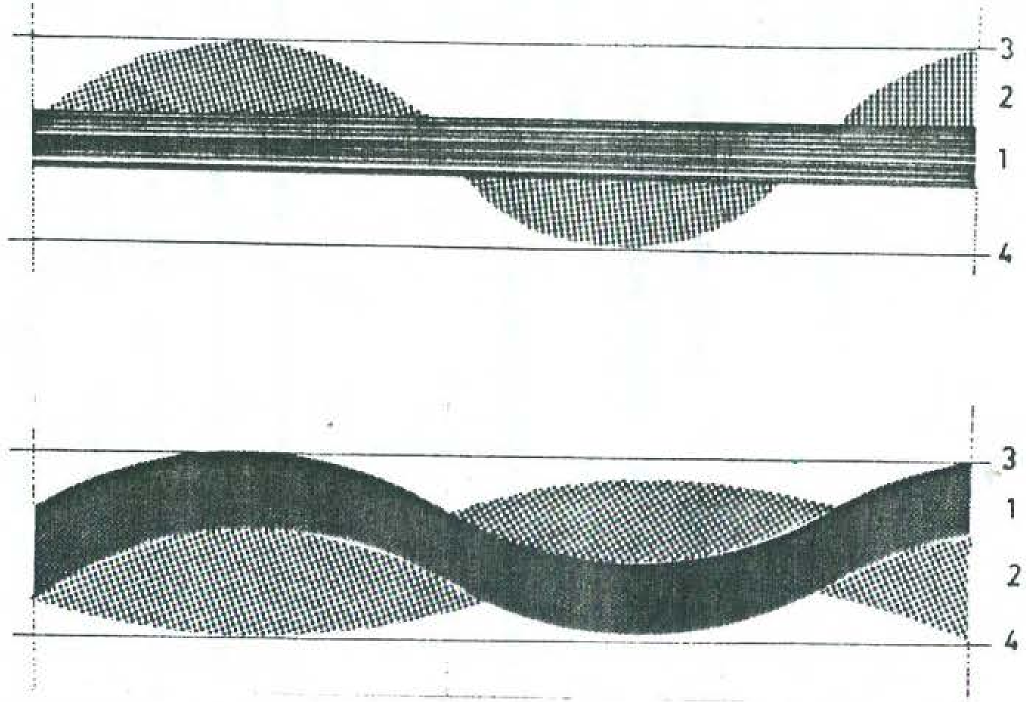


FIGURE. 19 Diagramatic cross section through a coated fabric in the warp-weft direction

1. Warp 2. Weft 3. Topside 4. Bottomside.

A great variety of materials is used for coating these fabrics. In particular it is to use.(Table.10)(Fig.25)(5)

* Rubber
* Bitemun
* Parafin
* Polyster
* Acrylester
* Polyacrylicacid (Flexigum)
* Plasticised PVC
* Polychloropor (Neoprene, Perbunan)
* Chlorysulfonated Polyethelene (Hypalon)
* Alkathelene
* Althylene / Propylene-Terpolymerisat (Holstapren)
* Butyl
* Polyurethane

Gridded fabrics are coarse weaves made of the organic, mineral or synthetic fibres or metallic networks with mesh sizes of 3 to 20 mm.They are often embedded in several layers of synthetic films by means of casting or rolling processes. Gridded fabrics are particularly recommended when maximum light transmission plus high strength is required.(6)

Synthetic films are especially suited for use in pneumatic structures because of their high gas diffusion resistance and their great flexibilty. They also offer advantages in their easy workabilty (Welding and cementing) and their high transmission properties. Like all synthetic materials however, under constant load they show an increased tendency to stretch so that they only maintain their form over a period time if relatively low

COUNTRY	MATERIAL Name	WEIGHT gr/m^2	THICKNESS (mm)	TEARING RESISTANCE (kp/5 cm)	
				Warp	Weft
FRG	Hostavan	53	0,04	45	36
USA	Mylar	16	0,0015	8.2	5.5
USA	Polyterhalic Acid-Ester Aluminium	110	0,127	15	11
USA	Polyvinyl Chloride	285	0,25	36	32
USSR	Polyethylene	53	0,0065	4.5	4.5

TABLE 10. Technical data for different foils

loads of less than % 10 of the short term tear resistance are applied. Futhermore, limits are placed on the use of films on the basis of the relatively low tensile strength of 3 to 20 kg/mm^2 and with their low tear-propagation resistance plus their low weather resistance. The strength of thin films is affected primarly by ultra-violet rays in conjuction with the water and can be greatly reduced within the first few months after an object is erected. The durability can be considerably increased by the use absorbent carbon coatings or vaporisation or lamination of metals. (7) For protection against the ultra-violet rays although at expense of transparency, which is in any case greatly reduced by dirt in the coarse of time, if high light penetration is required it is often most economical to use the cheapest possible materials and not to clean this when it gets dirty but simply to change it. (8)

Coated woven fabrics as already stated woven fabrics are anisotropic surface forms with two right angled preferential directions whose angle can be displaced. In the weaving process the threads are streched more strongly in the warp direction thus this has lower elasticity in comparison with the weft direction. (9) Other properties of the uncoated fabric, such as tear prongation resistance and flexibilty are also affected by the coating. For example, if the coating has a very high adhesive strength, then the long term tearing resistance is reduced. Basically the uncoated fabric is primarly responsible for strength and the elasticity. Further important requirements, such as high gas diffusion resistance, flame resistance, resistance to ultra-violet rays, insensitivity to mechanical influences and chemicals must be provided by the coating. (10)

Tension length is specific to each material and expressed in terms of breaking strength and the specific weight . It signifies the capacity of a material in terms of possible spans the structure.

A thread or rod breaks when its weight corresponds to the breaking load. This is equal to the maximum weight (GMax) as;

$$R = \frac{V\ Max}{F} \qquad (1)$$

$$F = \frac{G\ Max}{\gamma} \qquad (2)$$

$$\gamma = \frac{G\ Max}{V\ Max} \qquad (3)$$

(2)(3) $$R = \frac{\sigma}{\gamma}$$

where;

R; The breaking lenght (km),

V; The volume of rod (cm^3)

γ; The specific weight (g/cm^3)

F; The cross-sectional surface (mm^2)

σ; Ultimate stress of rapture of material (kg/mm^2)

(Table.11) shows tension lenght of freely suspended profiles with the prismatic cross sections.(11)

MATERIAL	kg/mm	g/cm	R km
Lead	1.7	11.4	0.15
Aluminium wire	17	2.7	6.5
Structural steel St52	52	7.8	6.7
Duraluminium	50	2.8	18
Pine wood	10	0.5	18
Steel wire	220	7.8	28
silk	-	-	45
Cotton	-	-	26-40
Perlon wire	57	1.14	50
Aluminium Oxide whisker *	2000	3.3	606
Graphite Whisker *	2100	1.4	1500

* whisker; monocristal-fibres

Table.11

Tension lenghts of different materials

From this it can be seen that disregarding the duration of load application temperature and other limiting factors, the best value is achieved by those materials which have low volumetric weight and are able to make up high tensions. Under short term loading natural and synthetic fibres have a tension lenght than light strenght steel wires (St 200/220) as they have a considerable lower specific weight. Today tension lenghts of over 80 km. can be achieved with high strenght synthetic fibres as well as with glass fibres, even higher values can be attained by monocrystal fibres(Silicon-Carbide) , called "Whiskers" which have tensile strenghts of 2200 kg/mm and more.(12)

In theory considerably larger span can be achieved with perlon wires than metal wires. Because of the relatively low modulus elasticity,the flow behaviour under permanent load, the comparatively low fatique strenght and considerably higher safety factors which are therefore required, Perlon is still inferior to steel in terms of maximum spans which actually be achieved. Using the safety factor coefficient of 5 on a typical fabrics as today and the maximum span of a flat dome without additional stabilization is about 40 m.

4.1.3. The Different Coatings

PVC coatings have good wheather stability, favourable price, easy workability and above all variation in respect of colour and transparency account for the fact that in over % 90 of all cases in Europe synthetic fabrics are coated.(13) Usually it is stipulated that a PVC coating should have thickness of at least 0.2 mm over the crossing points of the threads. For reasons of pice and weight it is not in any case economical to greatly exceed this figure.The support fabric hardly ages when the coating is strongly pigmented.(eq. with carbon)(14) If transparency or translucence is desired, it is usual to try to make good the lack of coloring by adding the ultra-violet absorbents.(e.q.Tinuvin or Uvinul) Rotting due to mould or bacteria can not occur in synthetic coatings or in synthetic woven fabrics. A reddish colouring which was observed in the membrane was found after the investigation to metabolic products of a fungus type whose 'nutritive substratum 'was probably fine dust. Even this could be prevented by special additives in the PVC.(15) Atmospheric elements such water, oxygen,ozone,as sulphur and the industrial gases have hardly any effect on the PVC coatings

Country	Material	Weight g/m²	Thick-ness mm	Tearing resistance kp/5 cm		Tear propagation resistance kp		Breaking elongation %	
				warp	weft	warp	weft	warp	weft
FRG	PVC coated high-strength Trevira fabric, dtex 1100 f 200, 9.5/9.5 threads/cm, linen weave 1/1	850	0.75	330	310	35	35	14	20
FRG	PVC coated high-strength Trevira fabric, dtex 1100 f 200, 11/12 threads/cm, mat weave 2/2	1,000	0.9	400	400	70	70	15	21
FRG	PVC coated high-strength Trevira fabric, dtex 1100 f 200, 14/15 threads/cm, mat weave 2/2	1,100	1.0	500	500	70	70	15	23
FRG	high-strength Trevira lattice fabric, foil coated on both sides, translucent, dtex 1100, 5/5 threads/cm, linen weave 1/1	420		200	190	56	55	16	16
FRG	PVC coated super-strength Diolen fabric, 12/11.6 threads/cm, mat weave	873		451	362	43	56.3	17.3	21.5
FRG	PVC coated super-strength Diolen lattice fabric, dtex 1100, 17/18 threads/cm	1,250	1.02	550	625	70	62	20	26
CSSR	PVC coated Atmotol 600/TE 516, 7/7 threads/cm	691		225	234			20	28
CSSR	polyurethane coated Chemlon TE 514-TH 370, translucent, 14/13 threads/cm	532		562	479.6			43.2	31
CSSR	butyl rubber coated Chemlon TE 522, 11/10 threads/cm	770		406	326			25.4	39.2
GDR	PVC coated polyamide fabric	760	0.76	375	370				
UK	PVC coated polyester fabric	540	0.51	180	115			52	
France	PVC coated polyester fabric	650		230	200				
France	PVC coated polyester fabric	730		300	270				
France	PVC coated polyester fabric	850		400	360				
Japan	Hypalon coated PVA fabric	980	0.92	770	720	48			
Japan	PVC coated "Vinylon KV 71,000" PVA fabric	1,000	0.95	600	575	45	60	24	24
Japan	PVC coated "Vinylon KV 70,600" PVA fabric	600	0.6	325	300	12	14	25	20
Japan	PVC coated "Tetoron TT 51,000" polyester fabric	600	0.45	375	850	50	50	25	30
Japan	"Vinylon KV 40,629" PVA fabric, Hypalon coated on the outside and PVC coated on the inside, double ply	3,200	3.5	c. 2,000	c. 2,000			37	33
Japan	PVC coated "Cordoglass X-340/864" fibre glass fabric	1,000	1.2	550	500	30	26	4	15
Japan	PVC coated "Tetoron TT 4,000" polyester fabric, double ply	3,700	3.2	c. 630	c. 920	300	350	25	30
Japan	PVC coated "Tetoron TT 55,000" polyester fabric	1,100	0.7	c. 750	c. 750	60	60	25	30
Sweden	type 199 PVC coated nylon fabric	950	0.6	490	410	60	60	16	28
Sweden	type 196 PVC coated nylon fabric	708	0.6	300	260	35	30		
Sweden	PVC coated nylon fabric, dtex 840, 5/5 threads/cm	750	0.8	201	170	56	74	25	30
USA	Hypalon coated dacron fabric, double ply below 45°	2,380	1.78	910	910	180			
USA	silicone rubber coated dacron fabric	540	0.51	270	270	41			
USA	PVC coated nylon fabric	610	0.66	360	305	50			
USSR	rubber coated polyamide fabric No 24	1,200		270	216			32.9	39.6
USSR	rubber coated polyamide fabric No. 806	1,200		180	130			28	28

TABLE 12. Tecnical data for different coated fabrics.

The coating can if necessary be additionally provided with very thin rolled metal foil or even be damped with aliminium. A final coat of varnish which for ultra violet protection can be strengthened with the finest aliminum lamellae mica or quartz granules, prevent plasticizer dispersion and thereby sticking and smearing on the surface and, in the case of coloured coatings, diffusion of coloured pigments. As these varnishes are very smooth, they also reduce the effects of the pollution and allow water to drain away more quickly.(16)

The case of rubberising is a contrast to PVC coatings; the durability of synthetic rubbers is considerably affected by industrial gases. Transluence can also be achieved in the rubberised coatings,as in the use of chlorosulfonic polyethlene (Hypalon) and ethylenepropylene rubber. Polychloroprene (Neoprene, Perbunan) is only suitable for dark coatings, because of its tendency to yellowing.(17)

Rubber coating are practical especially when a greater mechanical tensioning has to be taken into account for emergency usage.

Other coatings use only the very specific requirements are necessary, such as high flexibility, abrasion resistance and the resistance to cold. Polyurethane coatings have not been used much due to their high price and the long run they are being attacked by hydrolitic decomposition.(18)

The greatest weather resistance coating at the present time can be achieved with polytetraflourethlene (Hostavan, Mylar). However, due to its high price and difficult workability it is only used in special cases (Table.10) and (Table.12) are showed the most important technical values of the commonly used membrane materials.(19)

4.2.PHYSICAL FACTORS AND THERMAL ENVIRONMENT

In the introduction, air supported architecture was described as a complete reversal of traditional architectural thinking,in that application of environmental energy structurally stabilises the air supported building. However the true significance of this statement is as yet only realised in a very few pneumatic buildings.(20)

With single membrane structures, the membrane is extremely thin and provides very little insulation. Because of this close temperature control is very difficult. Besides the largest heat losses that occur, these structures are vulnerable to the 'green house effect' and these solar gains are known to produce temperature rises as high as 10 Deg C.(21) To avoid large variations in the internal environment either additional insulation is needed or sophisticated air conditioning equipment must be installed. For most applications in which pneumatics are at present used, the latter method is economically prohibitive initial costs of equipment being as much or more than the cost of the structure itself and the operational costs are correspondingly high.

4.2.1. Thermal Control

It is clear that such thin and the light materials as foils and woven fabrics can only offer exteremly low thermal insulation and heat storage. PVC coated polyster a conductance of 4.0 to 4.5 $KCal/h.m^2.{}^oC$ more or less the same conductance as a normal window panel.

Considerably lower cofficients of heat transmission can be achieved by laminating the membrane with insulating material. Flexible foams made of rubber, PVC and polyurethane are most frequently used and these are either stuck in sheets or sprayed on direct as a foam. The pasting on off stiff and relatively thick foam sheet results in a shell like stiffening. in stiffened halls a very high internal pressure is necessary in order to prevent the changes in the form due to aerodynamic loading. If air supported halls frequently have to be erected and dismantled, this method can not be used for sheets can only be pasted on when the structure is already erected and the insulating layer must be removed again before the structure is dismantled.

Anohter solution is offered by membrane sandwich construction as in;

* Hypalon (1)
* Ply (2)
* Air Sealed Layer (3)
* Nylon Threads (4)

These multi layered membrane has a conductance value of ;
2.6 KCal/ h.m^2.^oC. (Fig.20)

A further possibilty of achieving a higher thermal insulation is the use of multilayer membranes which are enclosed air cushions. However it should be remembered that a membrane distance over 5 cm an increase heat transfer can take place by means of convection in the vertical direction within the individual chambers. In contrast to conventional buildings whose great thermal inertia demands constant heating, in pneumatic structures only need to be heated while in use, so that short term heating systems, such as hot air or radiation systems, are the most suitable.

The heating of the inside air supported halls in strong sunlight is only a problem when hall is low in height. (Fig.22) Large halls with a height of 10 m to 20 m even in strong sunlight have temperature in the main hall only a little above the outside, although the membrane temperature at the top of the hall could be + 40 deg C and more. This is because thermal convection causes the temperature to reduce from top to bottom at the rate of 1 Deg C per metre.(22) The higher temperature in the upper area is any way convenient in so far as it helps in melting snow and ice in the winter. It is sufficient in the case of ,- 10 C and a 10 m height hall for the volume at 1 m height to be heated up slightly 0 C. It is recommended that the proportion of fresh air be kept constant or as low as possible and that the fans run with more recirculated air in order to save thermal energy.(23

The colouring and the surface threatment of the hall membrane have a decisive influence on the heating of the hall interior by means of sun radiation. White and silver coatings show the highest reflection values and therefore result in the least heating. For this reason PVC coatings are frquently provided with an additional aliminium varnish. In the case of dark membrane surfaces the internal temperatures are 3 C to 5 C higher than with light membrane surfaces.

In the 1967 a very interesting research was mentioned in the U.S.A by N.Laing. This research worked on the problem of the hot house effects in the hall interior in sunshine and variable transmission wall constructions of thin and very light membrane material were developed, The walls were connected with radiation control systems and use the sun for heating up and extra terrestrial space for cooling down. With minimal energy contributions for the servo system these wall elements can give frost temperature in the sahara and sub-tropical conditions in the newfoundland (Alaska). Some of 20 different wall systems have been developed by which the internal climate of forms can be widely controlled in respect of all classic climate factors r= Thermal resistivity

2 $$r = \frac{1}{k} \ (mhC°/Kcal)$$

R= Thermal Resistance

3 $$R = \frac{l}{k} \ (m^2hC°/Kcal)$$

1′ $$Q = A \frac{1}{R} (t_1 - t_2)$$

4 $$Q_{15} = Q_{12} = Q_{23} = Q_{34} = Q_{45}$$

$$R' = R_1 + R_2 + R_3 + R_4 + R_5$$

$$R' = \frac{l_1}{k_1} + \frac{l_2}{k_2} + \cdots + \frac{l_n}{k_n}$$

5 $$R = \frac{1}{h_i} + \frac{l_1}{k_1} + \frac{l_2}{k_2} \cdots + \frac{1}{h_o} + \frac{l_n}{k_n}$$

h_i = Internal surface conductance ($Kcal/m^2hC°$)

r_i = " " resistance ($m^2hC°/Kcal$) ($r_i = \frac{1}{h_i}$)

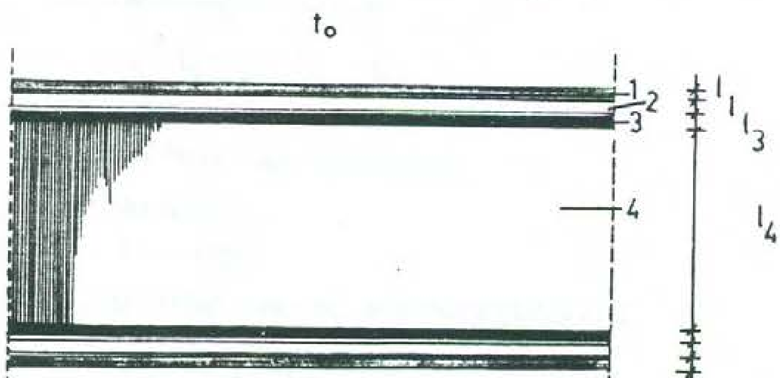
h_o = External surface conductance

r_o = " " resistance ($r_o = \frac{1}{h_o}$)

1″ $$Q = A.U\,(t_i - t_o)$$

6 U= Thermal transmittance ($Kcal/m^2hC°$) ($U = \frac{1}{R}$)

FIGURE. 20 Pneumatic sandwich plates



Pneumatic sandwich plates, M L Aviation co ltd. 1-HYPALON, 2-PLY, 3- AIR SEALED LAYER, 4-NYLON THREADS

U= 2,6 ($Kcal/m^2hC°$)

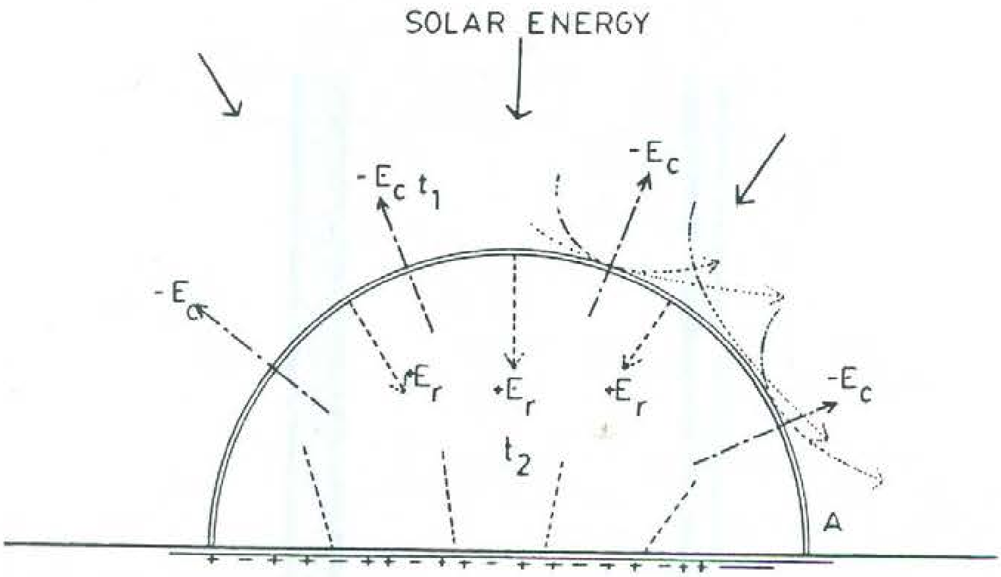
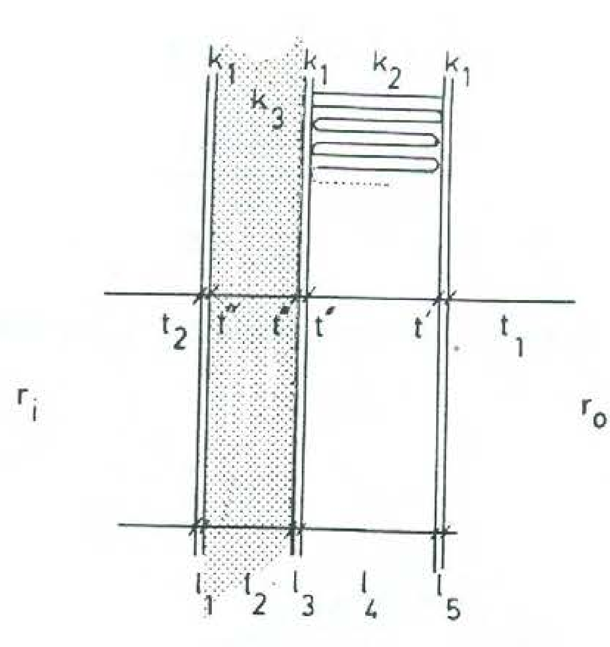


FIGURE. 21. A Thermal conductivity



k = Thermal Conductivity

A = Area

l = Length

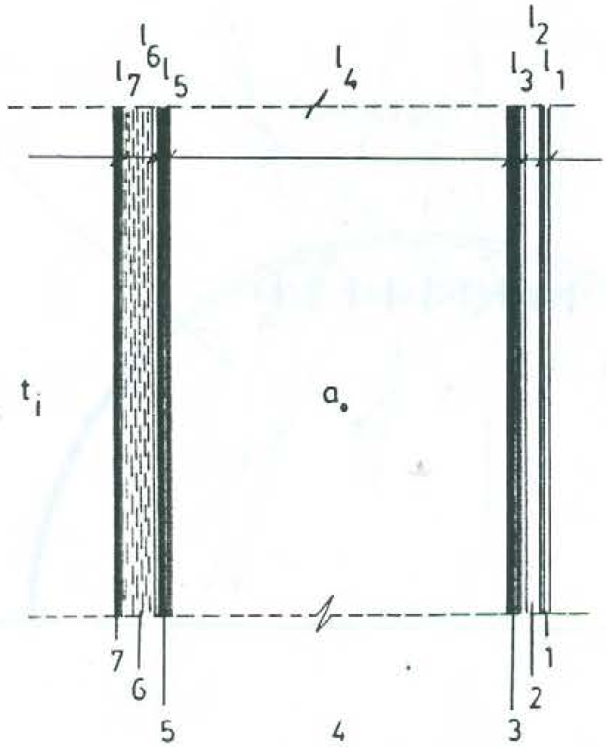
Q = Heat loss of surface (kcal/h)

1 — $Q = A \frac{k}{l} (t_1 - t_2)$

$(t_1 - t_2) = (t_1 - t') + (t' - t'') + (t'' - t''') + (t''' - t'''') + (t'''' - t_2)$

$l = l_1 + l_2 + l_3 + l_4 + l_5$

FIGURE. 21. B Heat loss of the surface



$$R = \frac{1}{U} = \frac{1}{h_o} + \frac{l}{k_1} + \frac{l}{k_2} + \frac{l}{k_3} + \frac{l}{k_5} + \frac{l}{k_6} + \frac{l}{k_7} + \frac{1}{h_i} + r_a$$

l (mm)	r_a
10-20	0,16
20	0,20

FIGURE. 21. C Thermal insulation with multi-layered membranes

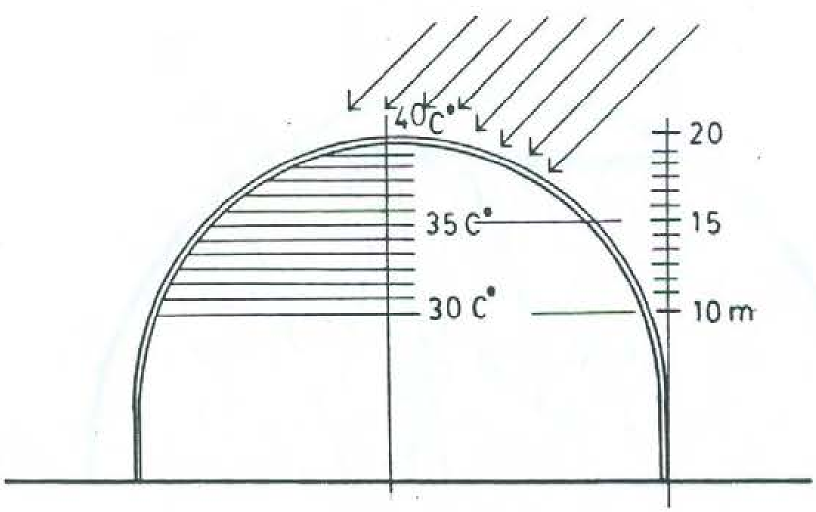


FIGURE. 22 Temperature distribution

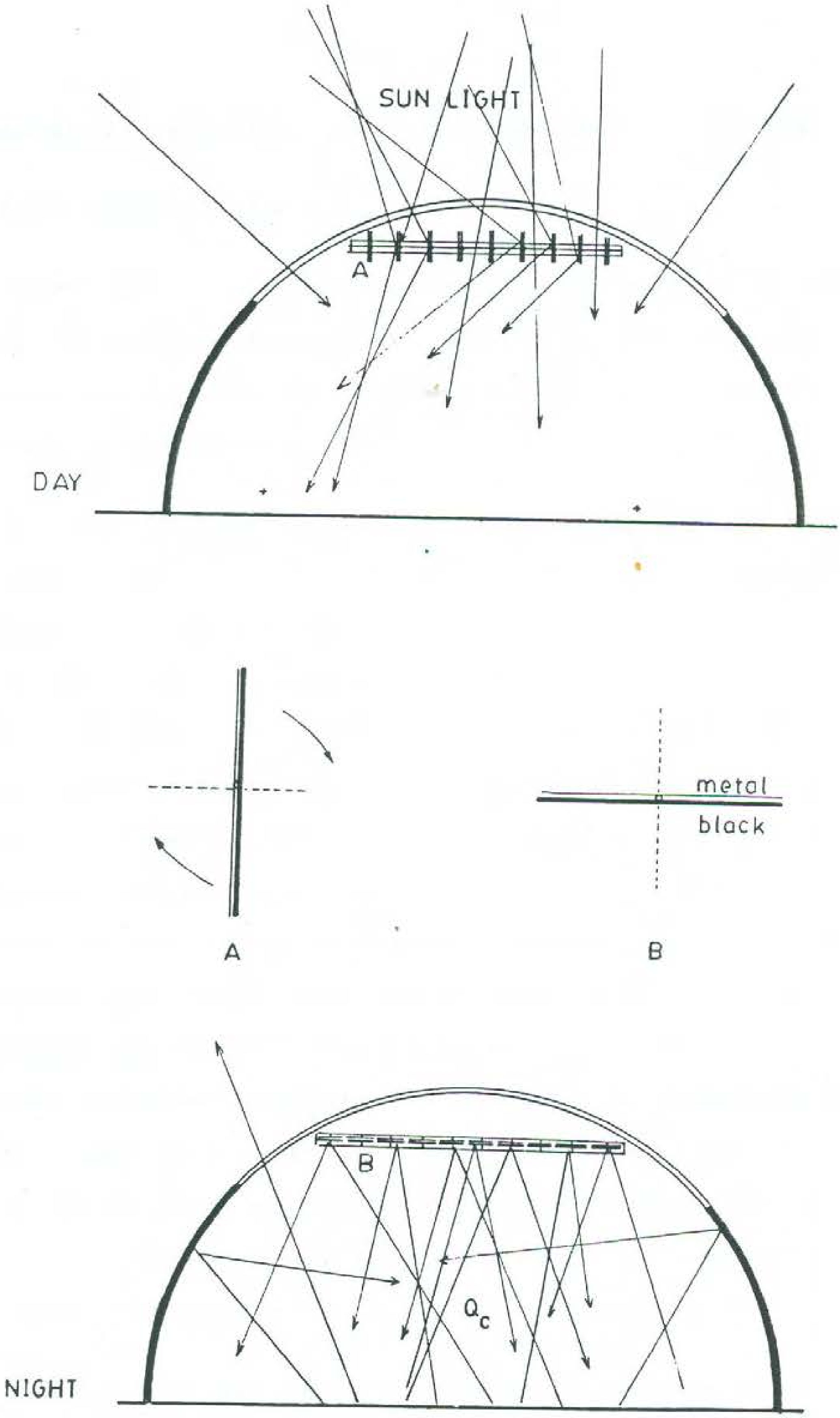


FIGURE. 23 Green house effects and radiation control

air temperature, air humidity, precipitation and the air current. (24)

4.2.2. Humidity Control

Almost completely air tight and watertight membranes are logically only used for high pressure structures, while in buildings whose positive or negative pressure zones are occupied by men a certain air moisture penetration is even desirable.

If highly impervious synthetic foils are used in the single membrane structures, the ventilation flaps are indispensable as an aid for greater circulation of air. By using coated fabrics such flaps can usually be dispensed with if there at least 4 to 5 changes of air per hour can be possible in the structures. If the fresh air in the inblown air volume is so proportioned that absence of condensation is assured , a temperature difference of at most 30 C between the inside and outside ,can be bridged with the usual fans so that with an internal temperature of 26 C the hall membrane can be kept dry down to an external temperature of 4 C . If is proportion of fresh air is reduced and the proportion of recirculated air is correspondingly increased, then a temperature difference 40 C is attainable, so that an internal temperature of 26 C can be maintained down to external temperature of -14 C. With the reduction of the proportion of the fresh air the drying effect e.g. the absorbation capacity for humidity is reduced; however, the film of condensation on the membrane is usually insignificant. (25)

The heat storage capacity of the water is considerably greater than of the air. It is thus more practical to make allowance for a slight cooling of the water during the night than to continually drawn off warm air to the outside. Even with night temperature outside of 0^{o}C to 5^{o}C and corresponding air temperatures in the hall of 15^{o}C to 18^{o}C, considerable amounts of the condensation occur on the inside of the membrane.

4.2.3. Acoustics

No completely satisfactory solutions for pneumatic structures have yet been found as regard acoustics. In the case of single shell structures a high weight per unit area and great rigidity are decisive for good sound attenuation so that sound transmission is hardly affected in single membrane structures with their very light envelope systems in comparison with other materials.

In order to protect exhibition areas in pneumatic structres against noise, attempts were made to provide curtains made of leaded vinyl which, however, at the same time caused a great increase in the reflection of sound waves.(26)

There are also suggestions for sheilding pneumatic structures from the outside noise by connecting a second sound absorbing skin to the envelope system or incorporating a sound absorbent material.

It is interesting that the sound insulation values of the pneumatic structures did not prove to be as bad as had been expected. Detailed investigations into the influence of internal pressure in double and multi membrane structures as well as investigations into the influence of tension conditions in the membrane have still to be drawn. In this connection it is also worth mentioning the phenomenon that the intensity of sound waves from the noise of speaking is hardly reduced at all by a single pneumatically stressed membrane, but the sound waves are transposed so that on the other side no speech but only noise can be heard.

Improvements in accoustics can be achieved by means of sound dispersing hanging surface elements, mobile sound absorbing curtains, roofs and the pasting of absorbent, soft porous materials.(27)

NOTES

(1) DENT, ROGER,N., op.cit., pp.93

(2) DENT, ROGER,N., op.cit., pp.94

(3) FREI, OTTO, Tensile Structures .Vol.1 , Frankfurt/ Main Berlin 1969 pp.168

(4) WALTER,D., Construction in Glass Fibre , London, Isopon Interchemical 1974, pp.76

(5) Guide to Plastics, Newyork, Mc Graw Hill, 1985

(6) ISONO YOSHITO, op.cit., pp.91

(7) FREI OTTO, op.cit., pp.172

(8) HERZOG THOMAS, op.cit., pp.139

(9) HERZOG THOMAS, op.cit., pp.138

(10) GUIDE TO PLASTICS, op.cit., pp.235

(11) FREI OTTO., Frei Otto Structures, Cambridge,Mass and london 1972

(12) HERZOG THOMAS, ob.cit., pp.140

(13)GUIDE TO PLASTICS, op.cit., pp.274

(14) FREI OTTO, op.cit., pp.87

(15) GUIDE TO PLASTICS, op.cit., pp.279

(16) GUIDE TO PLASTICS, op.cit., pp.284

(17) HERZOG THOMAS, op.cit., pp.139

(18) ISONO YOSHITO, op.cit., pp.82

(19) DENT ROGER,N., op.cit., pp.58

(20) DENT ROGER,N., op.cit., pp.124

(21) DENT ROGER,N., op.cit., pp.124

(22) GERNOT MINKE, op.cit., pp.161

(23) GERNOT MINKE, op.cit., pp.161

(24) FREI OTTO, op.cit., pp.168

(25) GERNOT MINKE, op.cit.,pp.160

(26) HERZOG THOMAS, op.cit., pp.129

(27) HERZOG THOMAS, op.cit., pp.163

5.STRUCTURAL DESIGN OF PNEUMATICS

5.1 DEVELOPMENT OF THE MEMBRANE ENVELOPE

5.1.1. Structural Design of the Envelope

Single layer membranes are used in places where concentration of forces occurs (anchorages,connection to other stfuctural parts or triangulations) with reinforcement provided by super imposed flanges, so that the forces are conducted away from the membrane surface.(Fig.24)(1)

Double membranes are structurally necessary over the whole surface when because of an above avarage internal pressure(high pressure structures) of a lower the an average membrane curvature, the forces in the envelope become so large that they can no longer be taken up by a single layer of the membrane material available.

A multi-layered membrane is generally produced by spraying insulating synthetic foam or by sticking soft lamellae on the membrane. Such measures bring about an additional stiffening. If the coating is so stiff that the pneumatically stressed membrane is structurally superfluous, then this can subsequently be removed. Then the building can naturally no longer be referred to as pneumatic design.

There are two main possible designs for pneumatic envelopes made of two membrane layers separated from one another by a support medium:

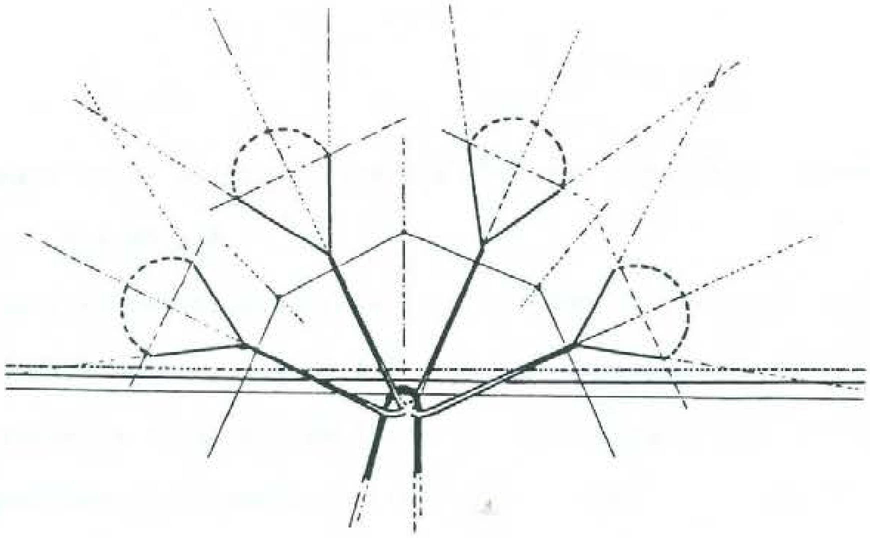


FIGURE.24 Membrane surface Stress

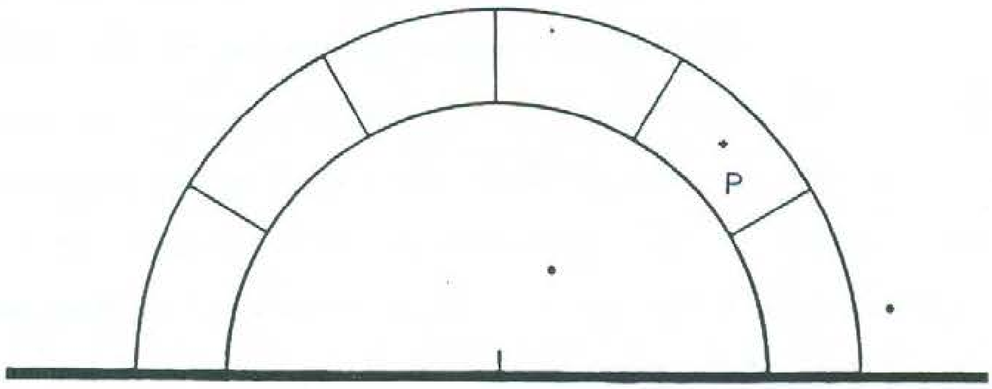


FIGURE.25 B

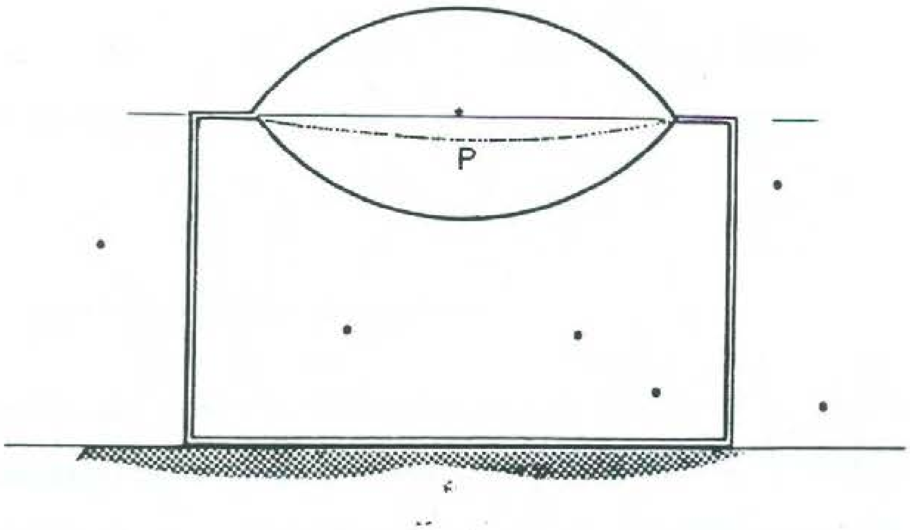


FIGURE.25 A Double Membrane Structures with same pressures in the space to be utilised and outside

i) The space to be utilized receives the same atmospheric pressure as the exterior. (Fig.25.A-B)

ii) The space to be utilized receives a higher or the lower atmospheric than the exterior space. (Fig.26.A-B) In the cases illustrated here the support pressure is reduced from layer to layer towards the outside so that the inner membrane is stressed by the support pressure of the utilized space.

Lens-like cross sections are formed if the membrane surface is damaged The support air escapes and the membrane becomes slack, although the structural part will not collapse. Only in the case of severe applied force need subsequent damage be expected. Lower heights with a smaller radii of curvature in the membrane are achieved with positive pressure or with the negative pressure by means of support. (Fig.27-28) A large number of the proposals which have not yet been executed can be found in the case of large spans it is recommended that the space between the membranes be divided into individual compartments so that if the skin is damaged only single parts of it fail. (Fig.29 A-C)

The main advantage of the structures in Fig 26 A-B are that in the event of external damage there is still a reserve membrane available. (Fig.30.A-B)

5.1.2. Cutting Pattern of Envelope

The commercial semi-finished material for membranes in the case of foils and coated fabrics is lenghts which in Europe are usually supplied in widths of 150 cm, 120, 140, 160 or 200 cm. At the sides overlaps of 2 to 4 cm are required. (2)

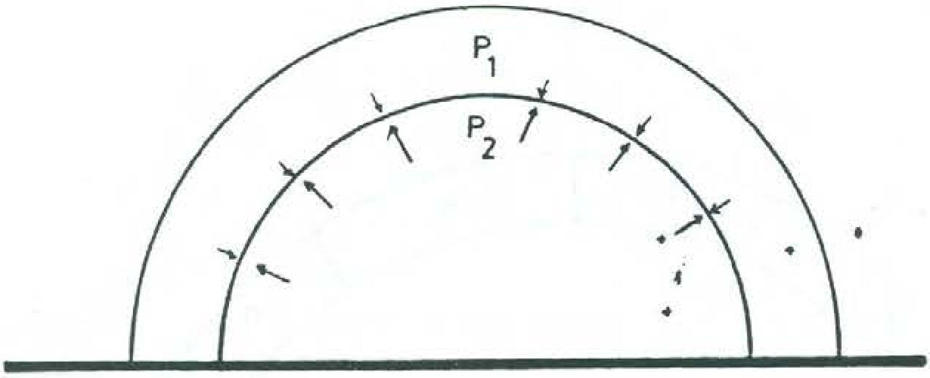


FIGURE.26 A

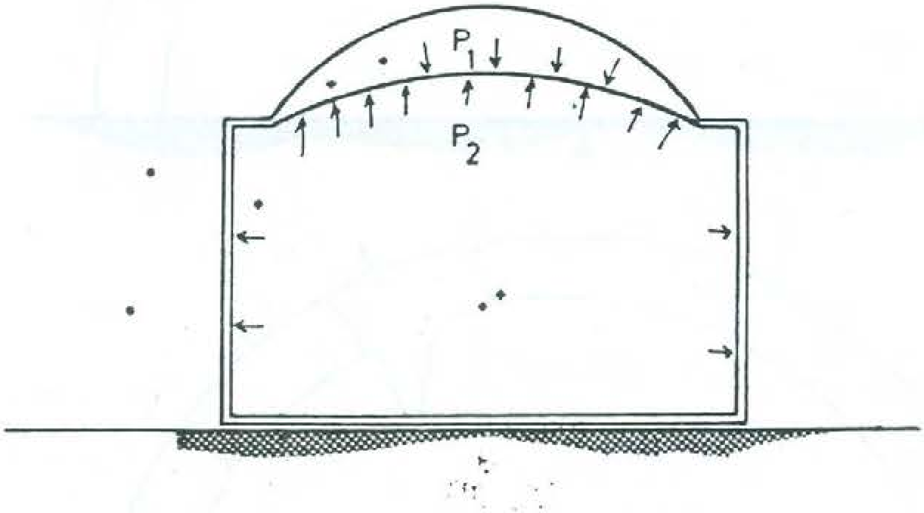


FIGURE.26 B Double Membrane Structures with different pressure

A - $P_1 \geq P_2$
B - $P_1 \leq P_2$

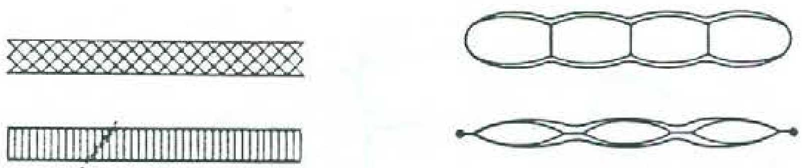


FIGURE.27 Sandwich Type Positive Pressure Structures

FIGURE.28 Sandwich Type Negative Pressure Structures

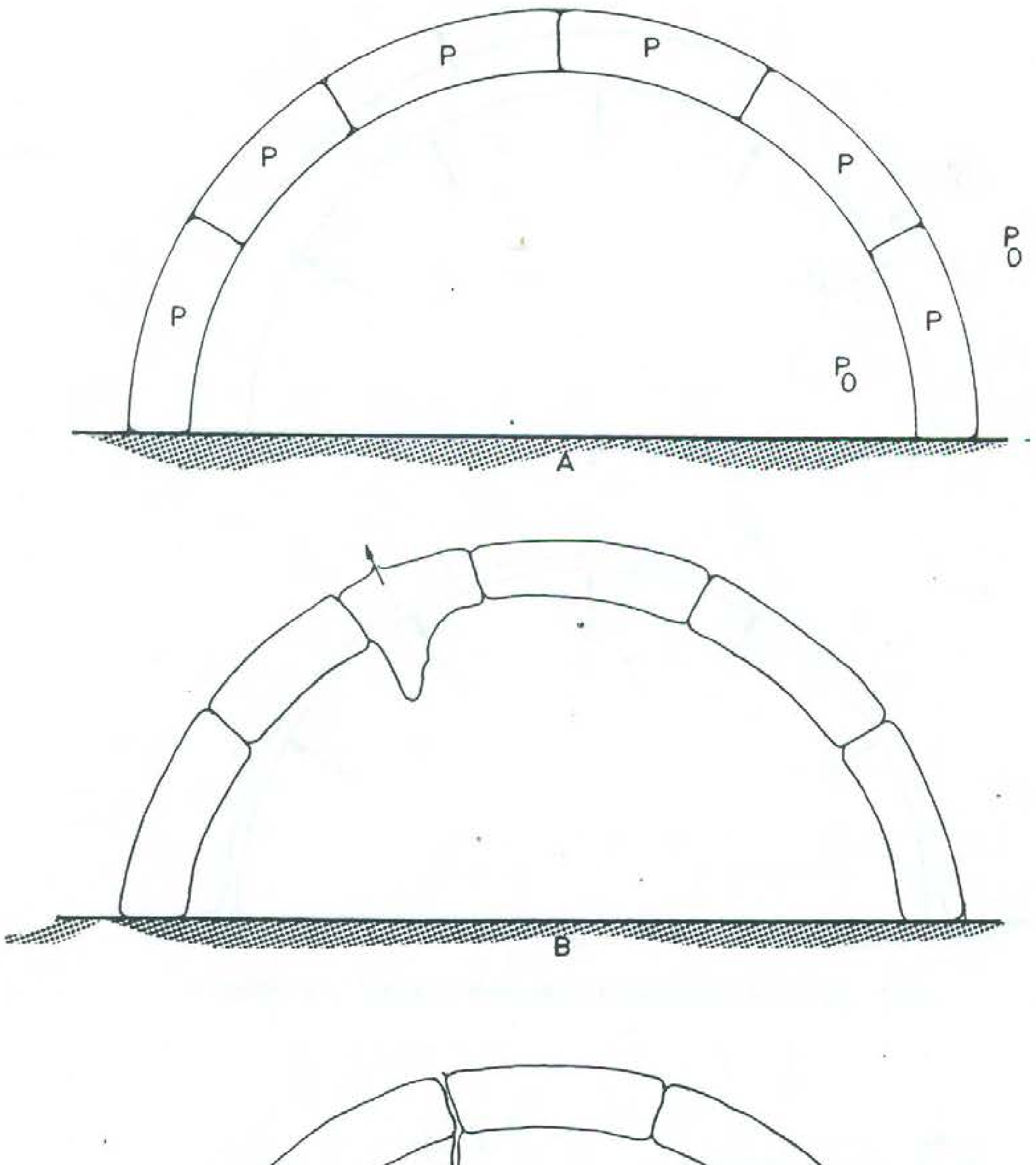


FIGURE. 29 Double Membrane structures with air loss

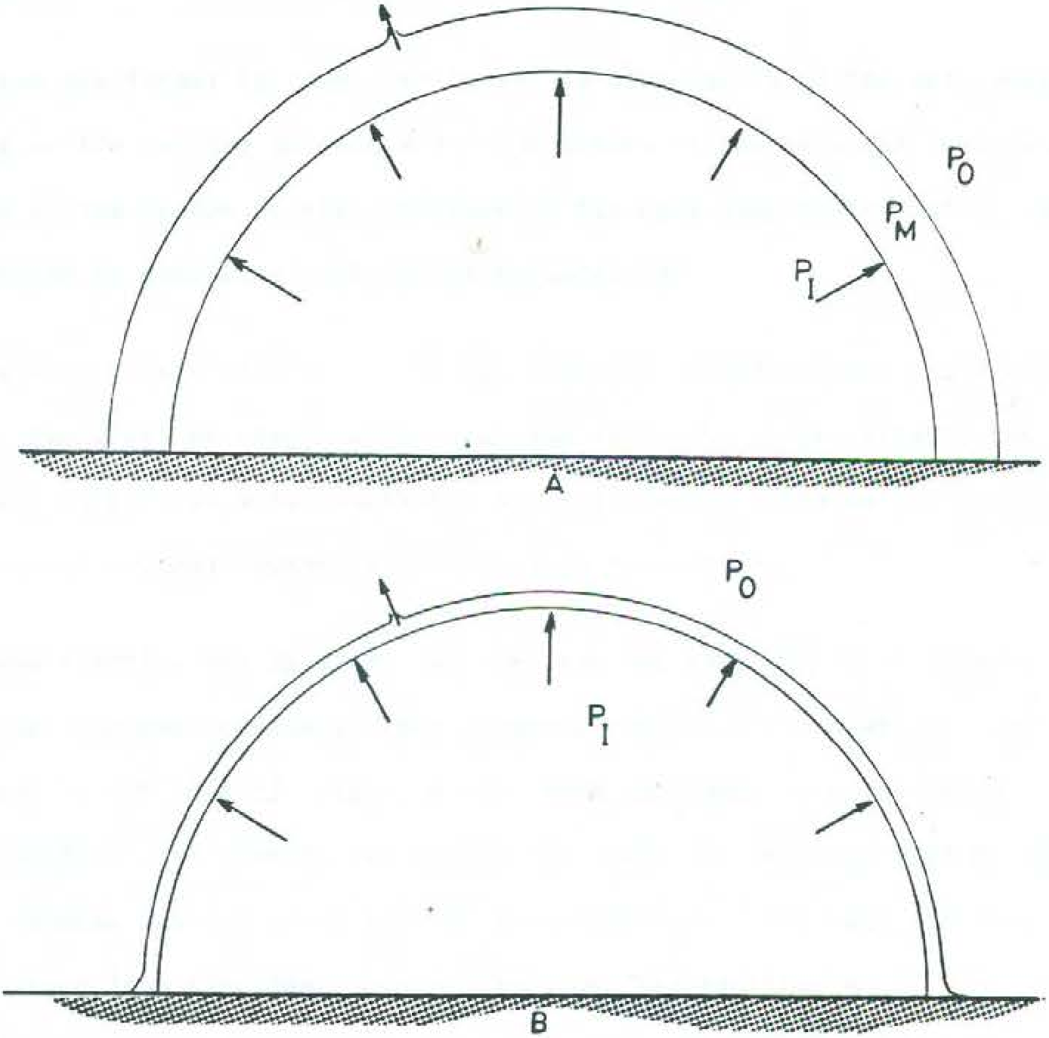


FIGURE.30 Single Membrane structures with air loss

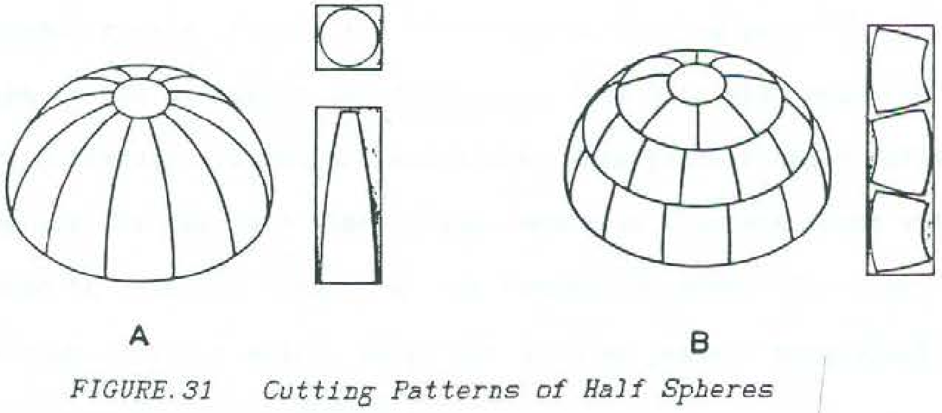


FIGURE.31 Cutting Patterns of Half Spheres

An untreated width of 150 cm for simply curved surfaces gives finished widhts 146 to 148 cm according to the type of bonding used.

Overlaps are formed by localized linear reinforcements of the skin, which depending on the cutting pattern and construction of the seam can lead to a reduction in the radius of the curvature of the skin-similar to that in the use of cables as additional structural elements. (3)

With a double skin, the joints of the membrane lenghts in the individual membrane layers can be staggered so that the stability is practically the same in all directions. With synclastic and anticlastic surfaces the lenghts must be cut in rounded countours according to their form.

The less flexible the material and the less the possibility of generous deformation, the smaller the surface elements must be which comprise the total form. In the case of Fig.31 A the seam increases in relation to the same surface unit-towards the top of the dome. The reinforcement of the membrane towards the top ledas to unequal elongation of the skin and thus to a deviation from the ideal form of the spherical section. (4)

Fig.31 B shows anohter cutting pattern in which the seams are fairly equally distributed over the whole surface. However, manufacturing costs are higher in this case . Furthermore there is a greater danger of failure under aerodynamic stress. Fig.32 A-E show typical cutting patterns for standard halls by the different manufacturers. Type D is also produced in Turkey and 24 different volumes are available. When geometrically different partial forms are put together than various membrane tensions occur which can easily lead to wrinkles forming at the transition areas. In order predetermine such tensions and to adopt the cutting pattern accordingly, exact dimensioning models are necessary.

Cutting pattern drawings of standard halls are being prepared today by programme controlled plotters. Further simplification will be brought by automatic pattern cutters, which are directly linked with computers to avoid intermediate step of " drawing ".

5.1.3. Jointing Tecchniques of Envelope

5.1.3.1. Inseperable joints

The production methods used in envelope manufacture depend primary on the basic material and sometimes on its coating. The requirements made of joints are the following ;

i) A strength equal to that of the main material,

ii) As great a flexibilty as possible, so that no kinks or break points occur in inflating and deflating envelope,

iii) A density which will prevent the escape of air penetration of the surface water.

iv) A low relief so that there is little suspectibilty to meteorological factors.

For the production of inseparable joints, the possibilities are as follows:

* Sewing,
* Cementing,
* Vulcanising,
* Welding,
* Riveting,
* Clamping,

In sewing, suitable forms of seam are the double and multiple sewn in simple and double overlaps. There are various special forms (Fig.33 A,B,C) (5)

In the case of natural fibre fabrics the seams seal themselves through swelling of damp fibres, in the case of synthetic materials methods of seam sealing must dependent on the actual material used.

In the case of coated fabrics wrinkles occasionally occur in the seams; the use of saddle making machines with combined lower, upper and the needle carriage as well as thread with contrarotation and chromium plated round pointed needles are therefore recommended. (6)

The strength of sewing threads is decreased by ultra violet rays. It is therefore best if the point with the highest loading, the overlap between the upper and lower thread, can lie deep in the material. Effective protection of the seam can be achieved by coating the seam area with a pigmented protective varnish or a pigmented foil. (7) The strength of a seam depends largely on the strength of the seam thread and the number of stitches. With too many stitches tears occur in the perforated skin, with too few stitches and weak sewing thread tears occur in the seam.

Cementing usually produces very high strengths. In peeling tests the cemented area is often stronger than the bond between fabric and coating. In the course of time the adhensive strength of soft PVC cementings fall considerably when affected by higher temperatures probably due to the plasticing diffusion in the cement. Cementing is fairly complicated and comparatively expensive. Therefore it is only worthwhile for very high grade materials such as butyl rubber, neoprene or hypolon for repairs in rather inaccessible places and in the production of complicated forms. (Fig.34 A-C)

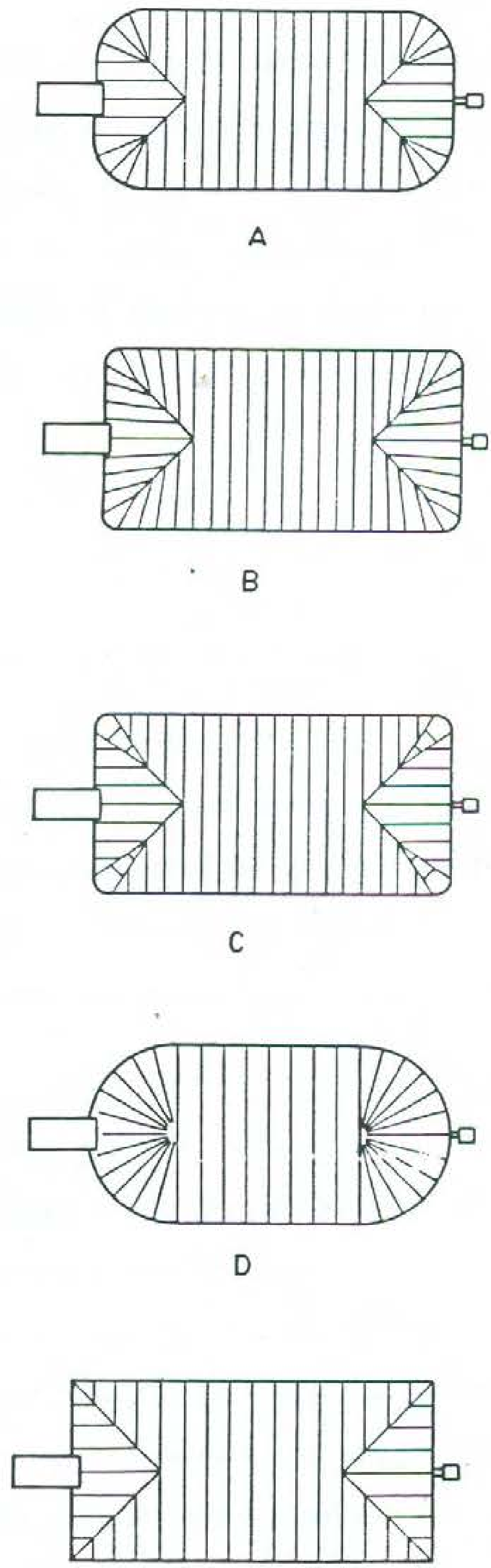


FIGURE. 32 Cutting Patterns of Standard Halls

Vulcanisation can be used for joining together rubber skins or rubberised

Welding which can be carried out on all thermo plastic synthetics, is one of the best bonding techniques. In the case of PVC coated fabrics with adequate adhensive strength the bondings are stronger than the basic material. The main requirement is that not more than % 60 of the coating should be on one side of the basic fabrics. (8) There are three different processes;

a. Hot key welding,

b. Hot air welding,

c. High frequency welding.

In the hot key process the materials to be bounded are fused to the seams by means of heated key on the surface and bounded under pressure by means of two pressure rollers. Portable hot key welding machines exit which under favourable conditions can reach a working speed of 5 m/min. Welded seams 30 mm wide are now possible; usually however a seam width of 20 mm is adequate. (9)

In the hot air process the membrane material is fused by means of jets of hot air. Here also bounding occurs through pressure of rollers. In the high frequency welding process a high frequency field is set up between the electrodes which are usually ridge-shaped. The working speed can according to machine size and width of seam, go up 3 m/min including insertion time.

The advantage of high frequency welding is that two layers as well as very thick materials can be bounded in one stages.

Riveting (sealing) is achieved using "pop" rivets placed at short intervals, while the inner membrane is pressed against the outer at the point of overlap. This process is generally little used.

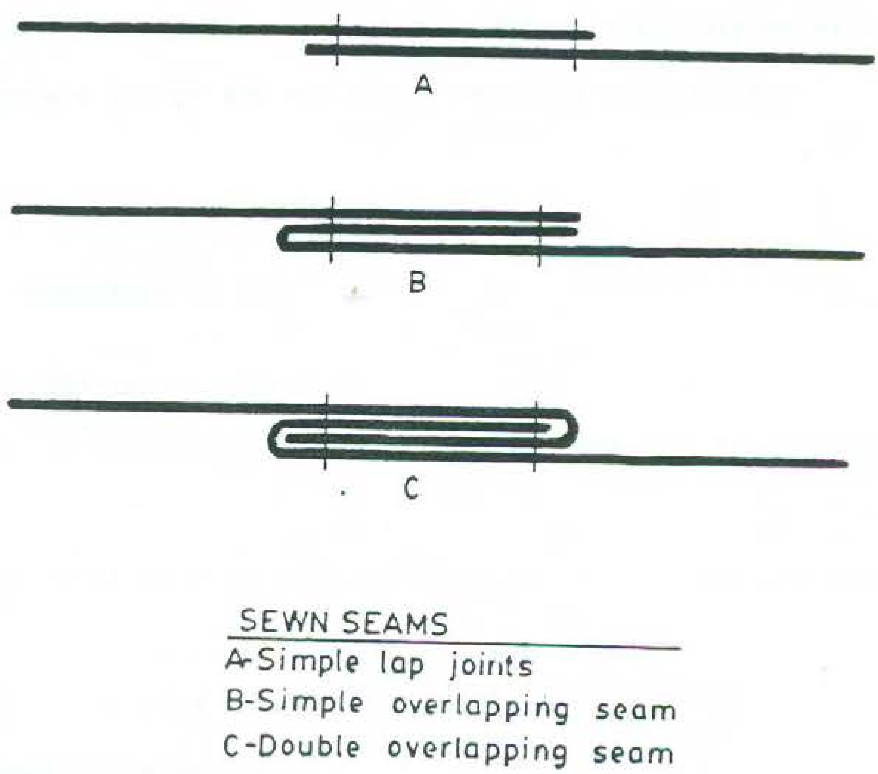


FIGURE. 33 Sewn seams

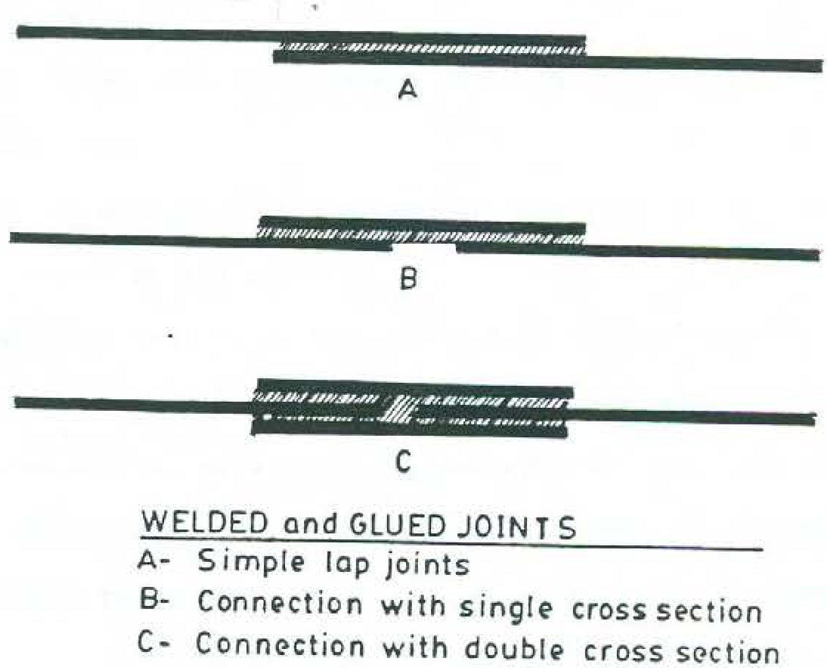


FIGURE. 34 Welded and Glued joints

In clamping, metal clamps which look like large wire staples and which are equally deformed when applied, are shot in with air pistols at short intervals. The process is new and was first used on some temporary structures.

5.1.3.2. Seperable Joints

Seperable joints can be necessary ;

i) In order to be able to insert movable parts within a section of the envelope,

ii) In order to be able to exchange parts of the envelope for other or new parts,

iii) In order to be able to seperate large envelopes into parts suitable for transport and erection,

iv) In order to be able to manufacture large individual sections as standard elements and to combine them into buildings according to individual requirements,

v) In order to be able to achieve a compound structural effect with individual pneumatic parts,

vi) In order to be able , in the case of expansion of reduction of the building, to remove or add sections.

With single membrane structures the possibility of changing size can only be planned into a few places, for inseparable seams are considerably cheaper than any seperation mechanism. Seperable seams, when they lie between zones of different pressure, must be as air tight as possible. If several individual pneumatic designs are joined together and same pressure applies inside the building as outside, then the bondings only have to satisfy mechanical requirements.

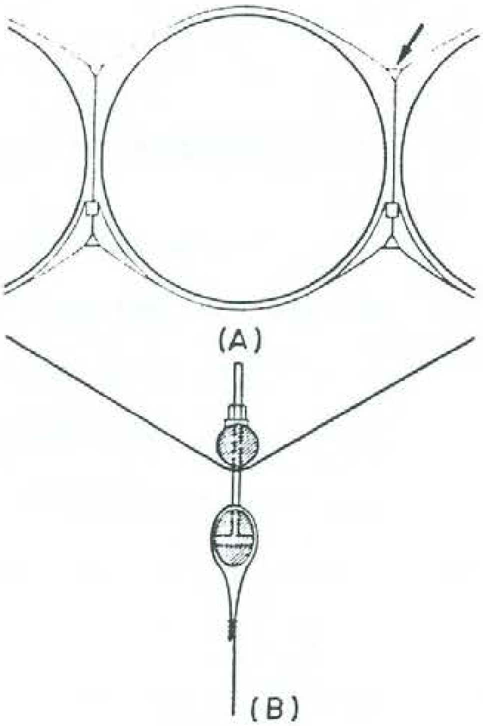
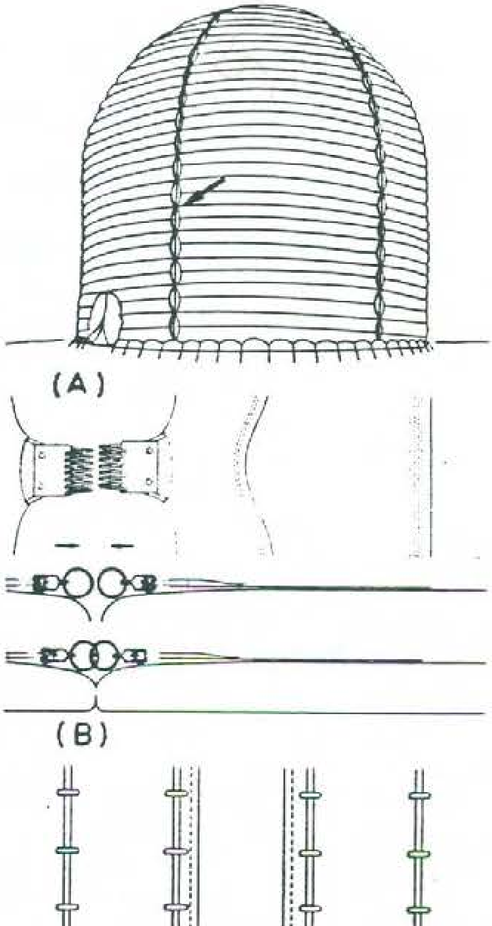


FIGURE. 35 Seperable Joints

A-B SEPARABLE JOINT
FOR HIGH PRESSURES TUBES
Fuji Pavilion, EXPO '70, OSAKA



A, B SEPARABLE JOINTS FOR
FLAT PNEUMATIC FORMS.

C, SEPARABLE MEMBRANE
JOINTS

FIGURE. 36 Seperable joints for flat

Pneumatic Forms

From the technical point of view, practically the following are avaible

* Zip Fastener,
* Press fastener, (Fig.35)
* Peg joints, (Fig.36)
* Connection strips,
* Different combinations of clamps, springs, rings, material loops, membrane belts with inserted cables, link, chains, etc.

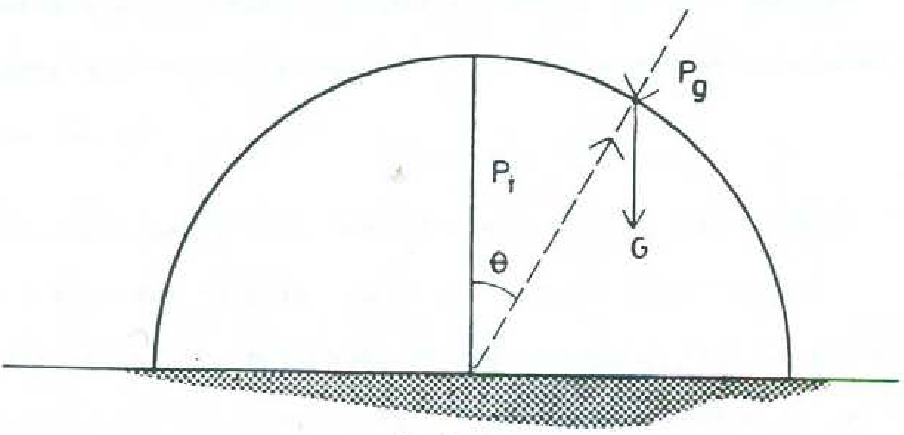
5.2. LOADINGS ON A PNEUMATIC STRUCTURE

In the pneumatic structures very large deformation can occur which affect wind and snow loading through the changed geometry of the envelope. In general there are six different force groups which act on a pneumatic shell. The important load types act to the geometry of any pneumatic form are following:

i) Self weight loading,
ii) Point loading,
iii) Snow loading,
iv) Wind loading,
v) Rain loading,
vi) Internal air pressurisation loading,
vii) Anchorage loading.

5.2.1. Self Weight Loading

The self weight of the structural materials, at present employed in pneumatic construction, is so insignificant, compared to other applied loads that it can usually be neglected for design purposes. However such a



$$P = P_i - P_g$$
$$P_g = G.\cos\theta$$
$$P = P_i - G.\cos\theta$$

FIGURE. 37 Self-weight Loadings

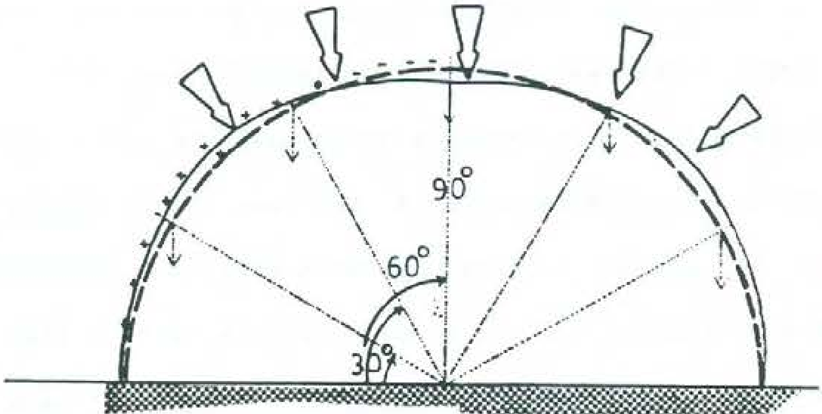


FIGURE. 38 Slight Flatenning Effects cause of Self-weight Loadings

technology, that the synthetic coated fabrics associated with pneumatics will not always be employed.

Heavier materials with perhaps greater strength, perhaps greater performance or even better insulating characteristics may well be used in the future.(Table.12)(10)

For the introductory cases considering a semi-cylindrical shaped structure, with a membrane material whose self weight load intensity is 'G' the total loadings across the membrane, at a given point 'Pg' is given at (Fig.37) and the internal pressure is'Pi'. From the expression it can be seen that the influence of the self weight is greatest on the horizantal plane and deacreases gradually to zero as the vertical plane is approached. Consequently the structure will deformed from its cylindrical shape, taking on a structure (flatter curvature) at its crown. Even with the light materials generally used for the air supported membrane, a very slight flattening effect can still be detected.(Fig.38)

5.2.2. Point Loading

In addition to the self weight, other types of loading may be applied to the membrane. These are often in the form of concentrated point loads which not only deform the membrane quite substantially, but also cause severe local stressing of the membrane. Although experience has shown that air supported membranes can carry some concentrated loading (It is possible for a person to walk over an air supported structure without deforming it very noticeably especially in the large structures.(11) Little is known about the relationships between load magnitudes, internal pressure, the extent of deformation,induced stresses and membrane material

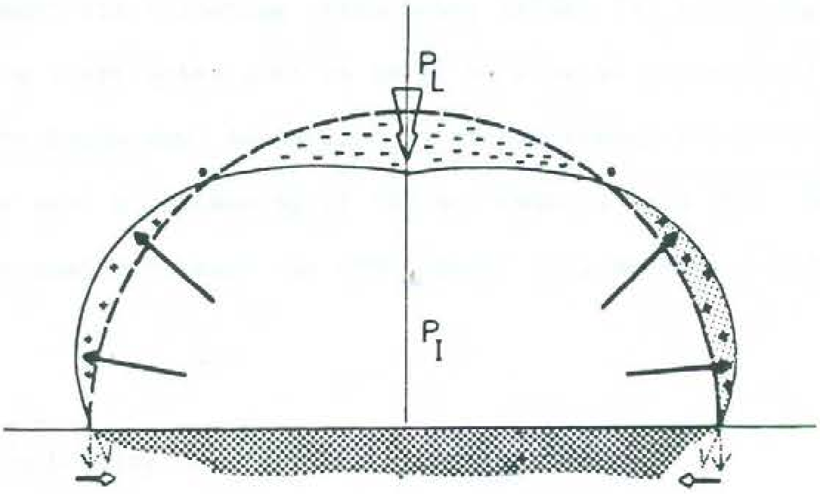


FIGURE. 39 Point Loadings

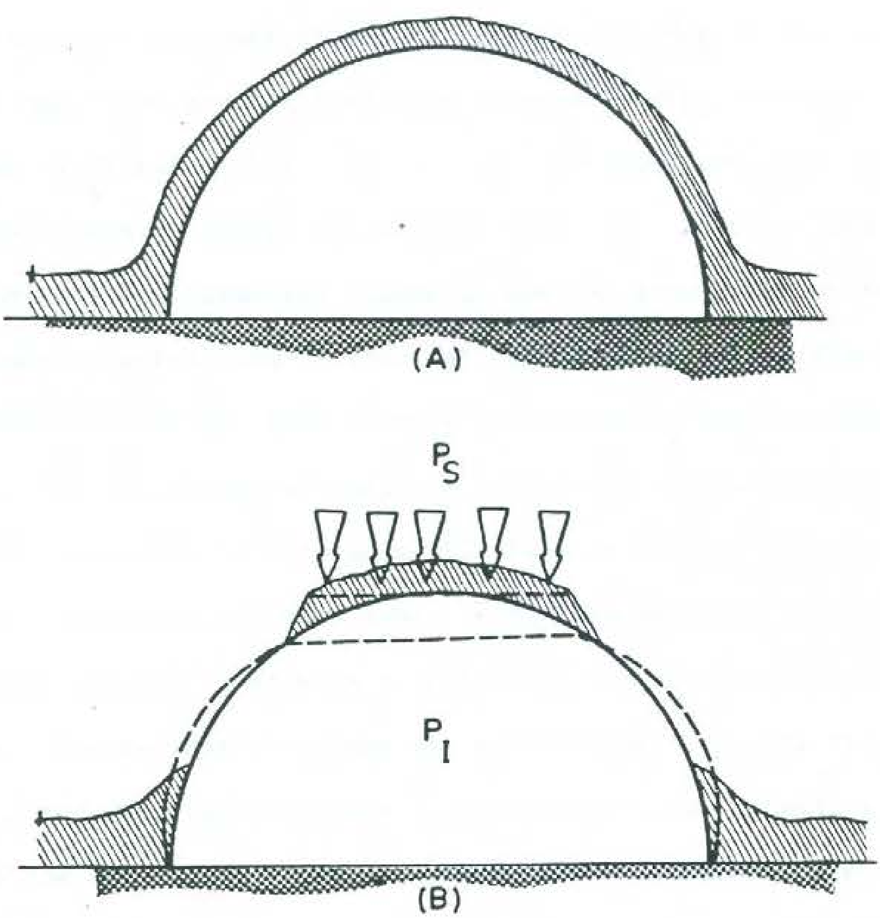


FIGURE. 40 Snow loadings

characteristics.(Fig.39) Where this type of loading is unavoidable, it is advisable to adopt the following prodecures; Either the resulting induced stresses must be distributed over as large on area as possible of the membrane, or the loads must be carried by reinforcement elements, such as cables, nets or even a thickening of the membrane, but in both cases this applied loading must not cause the development of compressive stresses in the membrane.

5.2.3. Snow Loading

Like concentrated point loads, snow presents, a loading problem about which very little is known. Although simulation tests on snow loading can be carried out, the true picture of pneumatic behaviour under snow loading can only be obtained by observations of reality.(12)(Fig.40 A-B) In no two cases is the magnitude and the influence of snow loading the same.
The magnitude is dependent, firstly on climatic conditions, and secondly on the individual characteristics of the structure, its curvature and form, its stability, its environmental standards and its insulation properties. With the simple spherical and cylindrical forms at present utilised in pneumatic construction, the snow load is not usually a major problem and in some cases it can be ignored altogether. Due to smoothness of the membrane material, the snow tends to slip down the sides of the structure and only accumulates at the crown. In many cases, even this avoidded by a change of pressurisation load, which effects a relaxation and then retensioning of the membrane. This relaxation causes the snow's adhension with the material to be broken, and when the structure is re-inflated, the expanding movement forces cause the snow to slide off. A cruder but nonetheless effective way of breaking this adhension, is to beat the sides of the structures or to

drag a rope over it. Inflatable tubes distributed over the membrane's surface or even electrically heated wires embedded in the material are more sophisticated methods for preventing snow adhension, but these are yet to be employed. When the influence of the wind on these surface of snow load is considered,the problem becomes even more complex, since drift formations must be taken into account. Snow-drifting is itself a subject about which research has only recently begun. Drifts are caused not only by fresh snow falls, but also by the moment of deposits in different locations. The wind is capable on carrying a specific amount of snow, which is related to it's velocity.(Fig.41 A-B) With an increase in velocity, the wind transports more snown particles,and once it is fully saturated to its maximum carrying capacity,a reduction in velocity will cause deposotion of the snow particle which is no longer capable of carrying. Consequently, natural snow-drifts occur when wind velocities drop, or during periods of snow precipitations. In addition to this surface structures also cause drifting, because of, firstly the adhesion of the snow to the structure, and secondly the wind velocity reduction caused by the structures.(14)

Considering a semi-cylindrical shaped structure under a snow load intensity of maximum value 'S' and assuming negligable membrane weight, the total pressure loading intensity across the membrane at a point is given at (Fig.42).

The ratio of snow loading intensity to the internal pressure loading has not yet been throughly investigated, but some research work undertaken. East German scientists suggest that deformations caused by snow loading can be more pronounced than those due to wind loading.(15) Where pneumatic forms do not possess their usual tendency to prevent heavy snow

$$P = P_i - P_s$$

$$P_s = S_\theta . \cos\theta$$

$$S = S\,f(\theta)$$

$$0 \leq \theta \leq 90^\circ$$

$$S_\theta = S.\cos\theta$$

$$\therefore\; P = P_i - S.\cos^2\theta$$

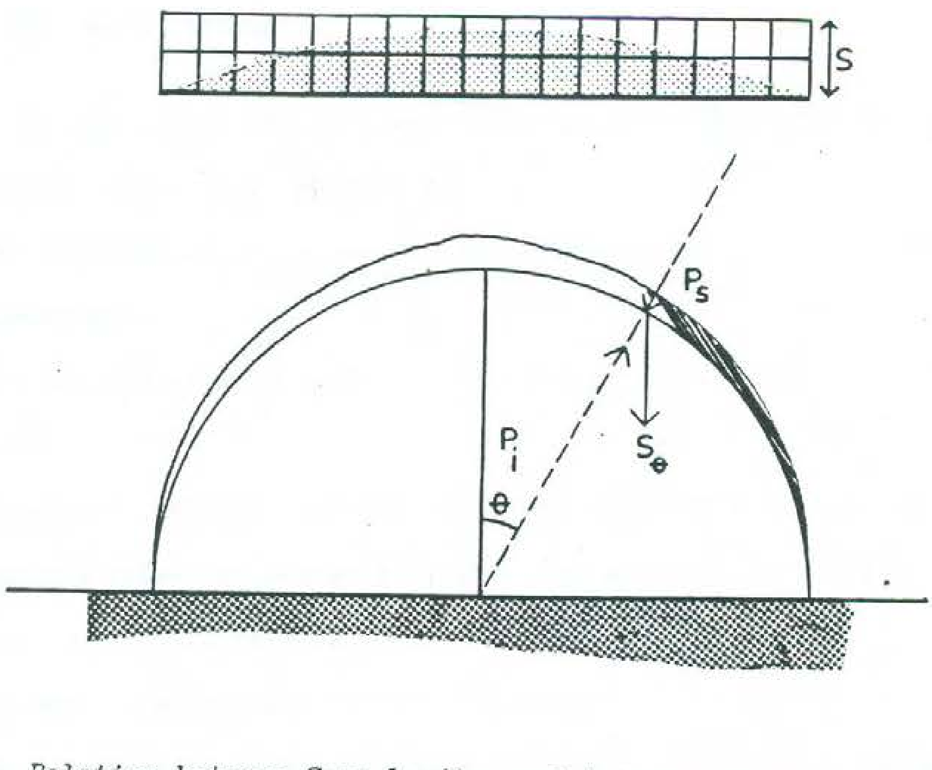


FIGURE. 41 Relation between Snow loading and internal Pressure loadings

accumulation the following condition to avoid folding of the membrane will undoubtedly apply:

$$\frac{Pi}{S} > 1$$

However, for more popular cylindrical and spherical forms, a folding condition less than initialy will be appropriate. This magnitude dependends on form, environmental conditions within and the membrane insulation characteristic.(16)

From existing data derived from wind-tunnel test results, the following conclusion can be drawn for the better understanding of pneumatic behaviour under wind loading;

i) As the profile of the form decrease, so does the condition for folding given by ratio Pi/Q . (Fig.43 A)

ii) Peak loadings occur in the suction zones and are slightly displaced to the windward side.

iii) Deformations greatly influence the pressure distribution on the windward side.

iv) In general the wind load has been considered as a static load of constant maximum value for design purposes, but actually it is indeed a dynamic load, constantly varying.

v) This stabilising characteristic under gust loading makes it permissible to design for maximum mean wind speeds, rather than for gust loading, mean minute speed perhaps being the most appropriate.

vi) Meteorological measurements of the wind speeds are generally taken at a height of about 1 m above the ground level and as many cases structure are below this elevation, an appropriate reduction in the wind speed may be used . BERGER and MACHER have tentatively suggested a possible % 20 percent reduction.(18)

vii) Suggestions for reduction coefficients which not only take into account building height but also consider the surrounding to porgraphy and gust duration.(19)

5.2.4. Wind Loading

When a dynamic structure, such as a pneumatic, is under the action of such variable force as the wind, it is imperative that the nature of wind loading is controlled. Some designers have utilised the much accumulated knowledge of wind behaviour on rigid structures, and accepted them as valid for pneumatics. However, wind tunnel test have shown that these design loads applicable to rigid structures are only approximate for pneumatic structure and indeed inaccurate when large deformations of pneumatics occur.
Although the wind causes positive pressure over some zones.(Fig.43-B), the major part of the membrane's surface is subjected to negative or suction pressures.

The wind loading intensity at a point 'Pw' is assumed to act perpendicular to the membrane surface under consideration and is given by;

$$P_W = C.Q$$

where,

C is aerodynamic coefficient at the point and

Q is dynamic pressure of the wind,

where,

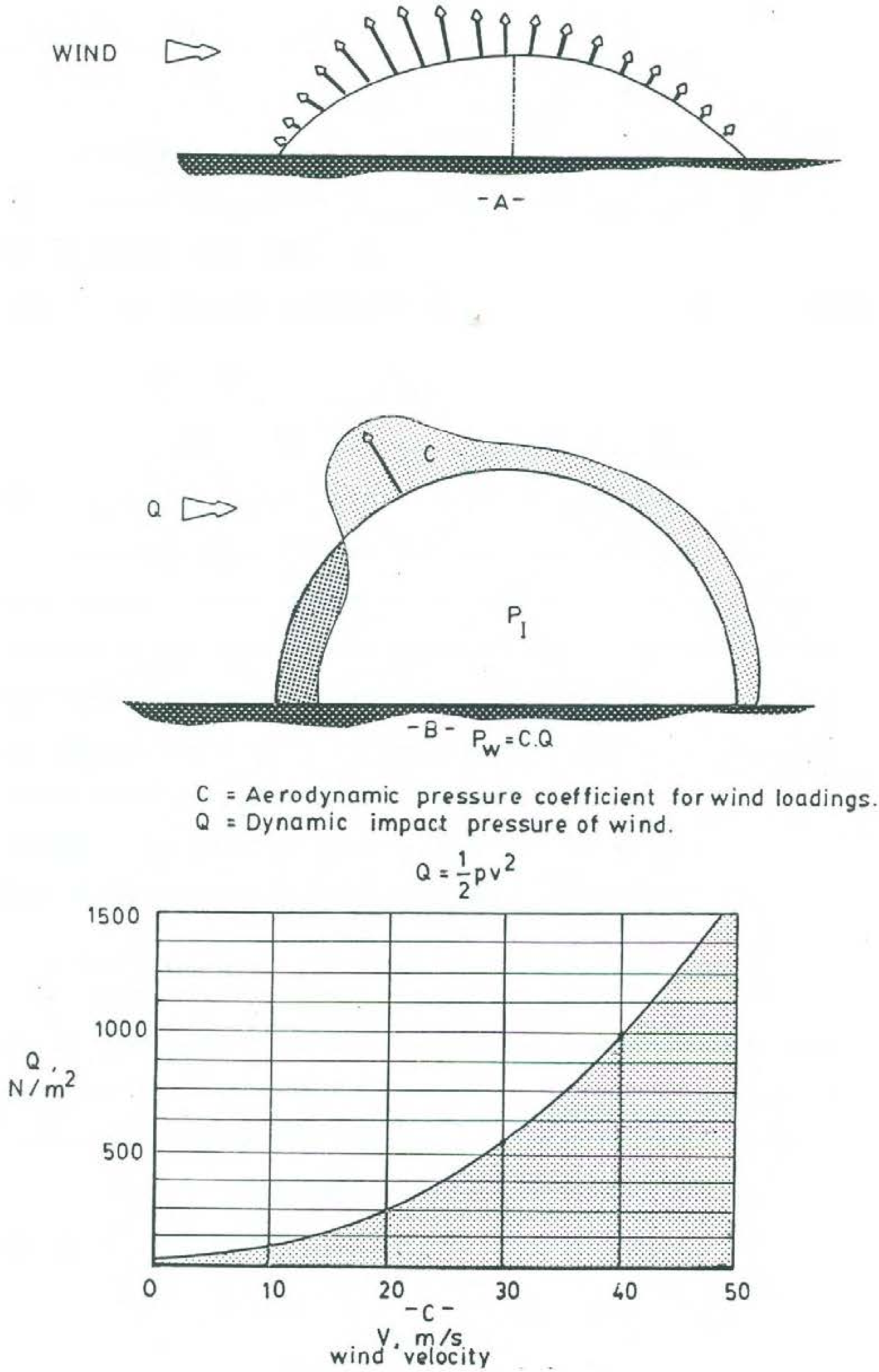


FIGURE. 43 Wind Loading

$$Q = \frac{1}{2} pV^2$$

p is the air density,

V is the air velocity.

The aerodynamic coefficient depends on the shape of the structure, the wind direction and position on the membrane surface of point under consideration

5.2.5. Rain Loading

In all normal circumtances rain does not cause a loading problem since pneumatic form allows rain water to drain of the structure quickly without the formations of water pockets. With the simple spherical and cylindrical forms generally used at present for air supported structures, there is certainly no possibilty of rain water collecting on the membrane. However, with flatter structures employing cable, net intent and interior membrane wall construction there is some danger that water could accumulate in pockets during heavy rainstorm, causing deformation and subsequently collapse of the structure. In such cases careful consideration should be given to the provision of adequate drainage facilities.

5.2.6. Internal Air Pressurisation Loading

All these external surface loads are counteracted by the internal pressurisation loads, which must at all times and at all points on the membrane surface be greater or equal to the total sum of the external surface loads, so that no negative compressive stresses are induced in the membrane as given by the condition. (20)

$$T_{Min} \; (\overline{P_x} + \overline{P_i}) = 0$$

Where P_x : External surface loads,

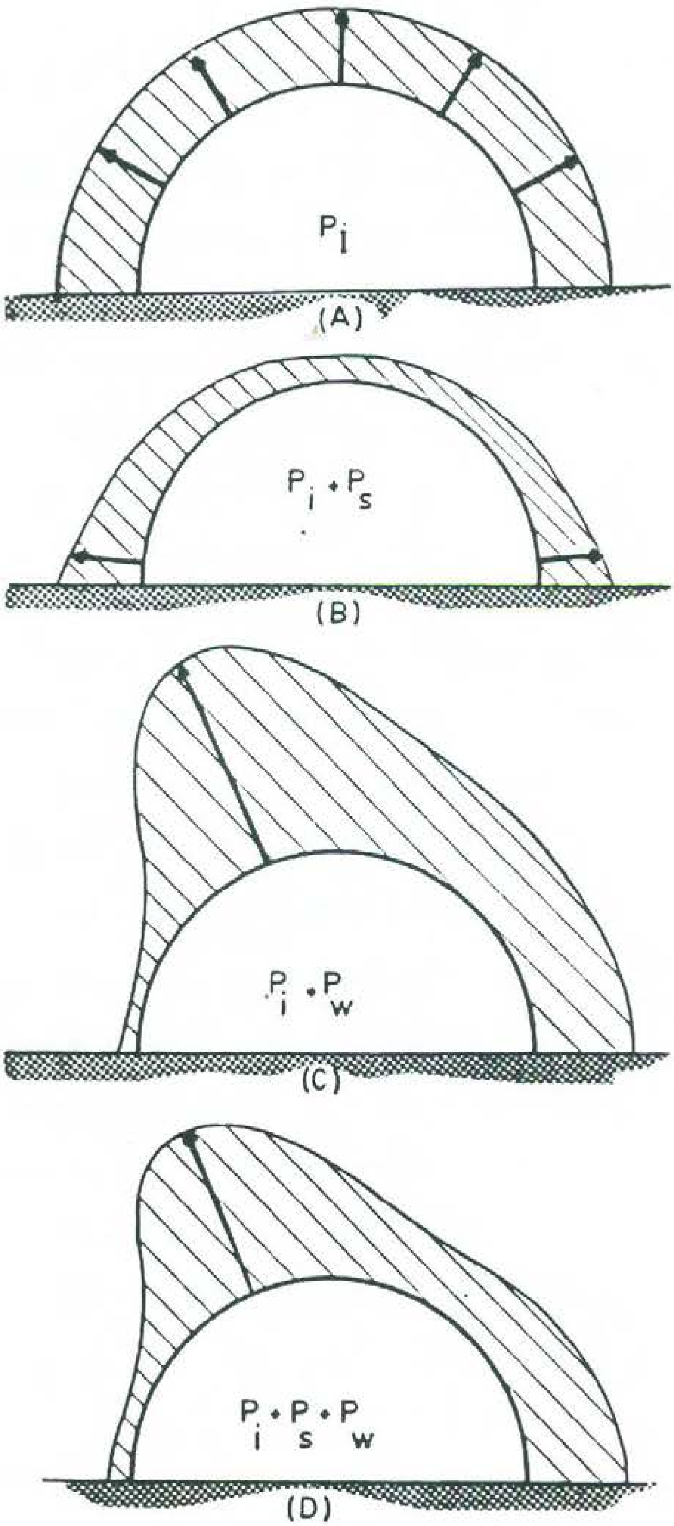


FIGURE. 44 Internal Pressure Loadings

P_i : Internal Pressurisation,

This, the folding condition gives the required internal pressurisation for stabilisation under the various loading conditions.(Fig.44 A-D) If the pressurisation is not sufficient to satisfy the above condition, local folding will occur and dynamic loading the membrane will flutter and be subjected to shock stresses. These shock stresses severly reduce the structural life of the membrane material.

The dynamic character of the pneumatic is once again evident by the very fact that the internal pressurisation load can be altered to suit the varying external load conditions. However, this opportunity to maintain maximum structural efficiency at all times by aoutomatic manipulation of the prssurisation elements is in many cases not used to good advantage. In these cases the internal pressure is maintained at a constant level, sufficient to support the maximum internal pressurisation necessary to prevent folding under all loading conditions. This situation need not necessarily occur under the combined action of all the loadings and therefore, all the different possible combinations of loading must be investigated.(21) With a simple pneumatic forms, without cable and net reinforcement, the worst condition generally occurs under the simultaneous action of the internal pressurisation loading and the wind loading as shown in (Fig.44 C)

5.2.7. Anchorage Loading

Unlike conventional structures, which exert a positive loading on the ground , the pressure differential across the membrane of air supported structures causes uplift forces on the whole of the structure and these forces must be resisted by firmly anchoring the structure to the ground.

In the early days of the pneumatic building construction a few structural failures occured because of lack of sufficient anchorage provisions. In these instances anchorage design was by trail and error and was not based on any theoretical calculations what so ever.(22)

Through these trail and errror methods, anchorage designs have evolved, which are quite satisfactory for typical designs of air supported forms. However, if pneumatics are to become universally accepted as a serious form building construction, it is essential that the extent and nature of these uplift forces be known so that suitable anchorage provision can be more precisely designed.

The total vertical uplift force is equal to the sun of the maximum aerodynamic lift and the maximum load due to the inflation pressure, and this is resisted uniformly by the base of anchorage.(Fig.45 A-C) For a simplified assessment of the magnitude of a anchorage reaction, the loading membrane can be represented as having a uniform average value throughout. This average value can be taken as acting on the horizontal projection of the pneumatic form and therefore the total vertical uplift force is the product of the average membrane loading and the plan area of the structure. The force is uniformly reacted around the structure's perimeter and consequently the vertical anchorage reaction per unit length is given by approriate expressions.(Fig.45 A)

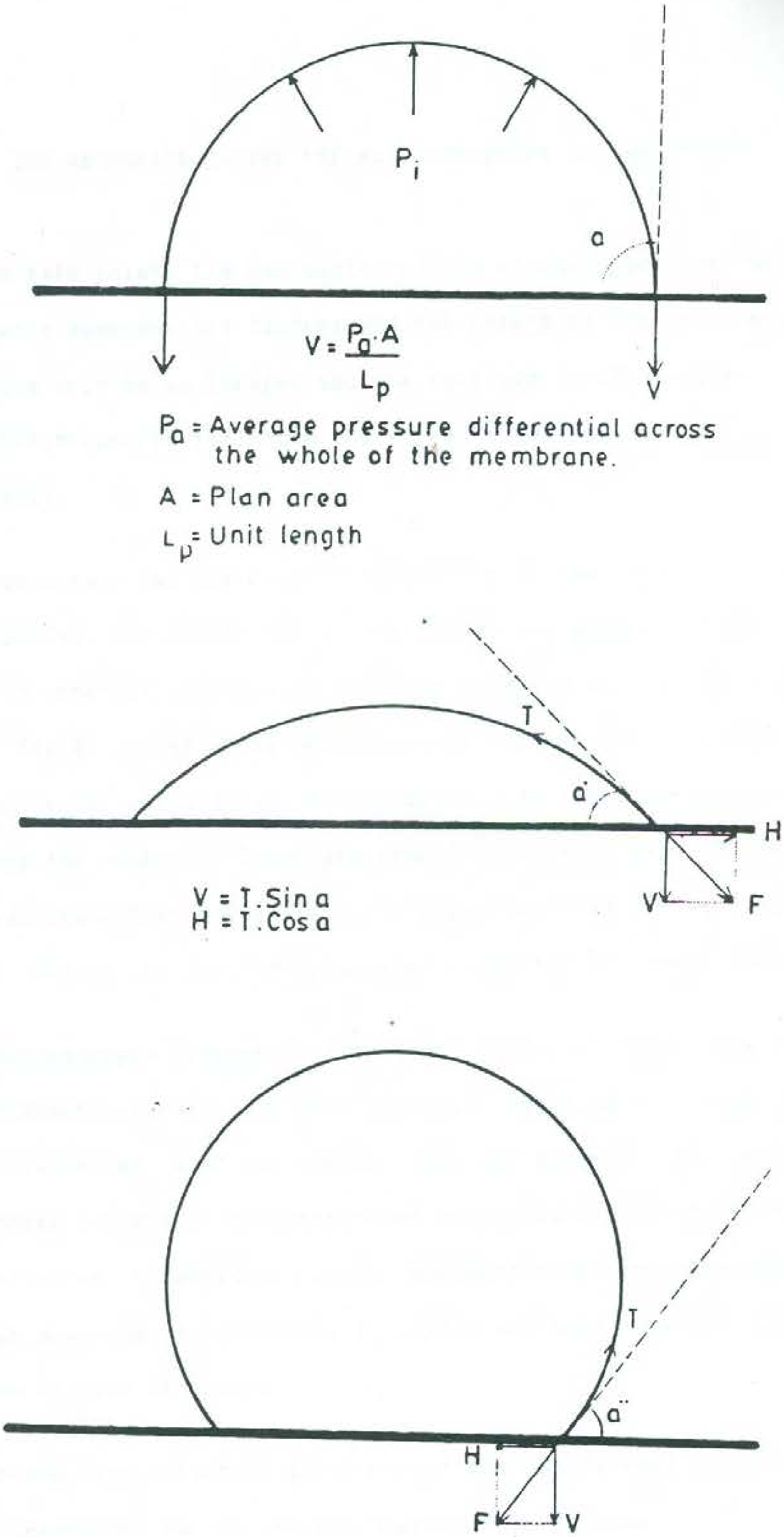


FIGURE. 45 Anchorage Loadings

5.3. THE ANCHORAGE OF THE PNEUMATIC ENVELOPE TO THE GROUND

Up to this point, the discussion on the stress conditions within the pneumatic membrane has disregarded the effect of the boundary restrictions such as anchorages and the openings in the membrane, but these restrictions can influence the stress conditions quite substantially .

The anchorage has the task of conducting to the foundations the vertical and the horizontal forces carried by the membranes.These forces result from internal positive or negative pressure and the external loadings. Fig.45 A-C show the dependence of the vertical and horizantal force components, which stress the anchorage, on the tangential angle at the base of the membrane. These are tensile forces.To take up the vertical forces either the passive earth pressure and directly adjacent ground is used or the friction generated along the anchorage surface.

Most anchorages represent mixtures of different types. Fig.46 (24) gives a schematic survey, the most important types of anchorages being breifly illustrated. What ever method used for anchoring the structure, the anchorage force must be distributed uniformly around the perimeter of the strucutre, to avoid any stress concentrations in the membrane, unless the membrane is reinforced by cables and nets,in which case point anchorages will be necessary.

There are five different group anchorages can be used to connect the pneumatic envelopes to the ground in general as follows ;

i) Water ballast anchorage systems,

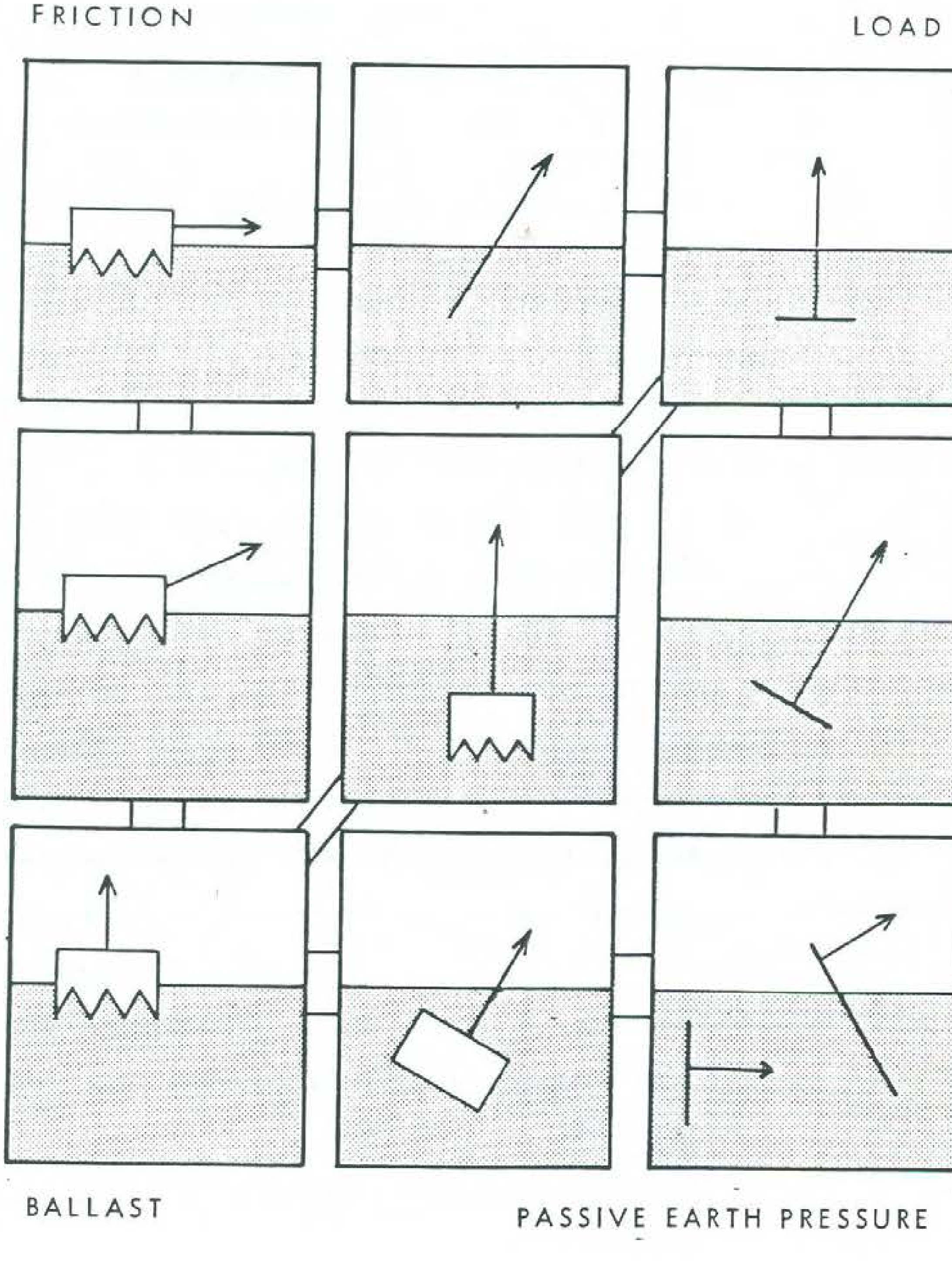


FIGURE. 46 Schematic Survey of the various Types of Anchorages

ii) Earth ballast anchorage systems,

iii) Ground anchorage systems,

iv) Surface ground anchorage systems,

v) Underground anchorage systems.

5.3.1. Water Ballast Anchorage Systems

Ballast anchoring is mainly used for structures that are frequently moved from one site to another. Since site conditions can vary considerably ballast methods may be appropriate. (Fig.47 A-B) On first reflection the use of water ballast would be ideal, since water cost little and is readily avaible. However a continuous tube of water is vulnerable to vandalism as well as accidential damage.(25) And it only needs a single hole to render the structure unsafe.If loading conditions produce high local lift of forces, the water will tend to flow away from this point, leaving it locally with no anchorage provision. For this reason the tube must be compartmented so that local failure does not effect the stability of the whole structure. For safe anchorage, very large quantities of water are required and this generally proves to be too cumbersome.

In Fig. 48 A-B are shown some examples of the water ballast anchoring systems which were used in temporary pneumatic structures.

5.3.2. Earth Ballast Anchorage Systems

Another method is to fill the ballast tube with solid matter such as earth sand or ground. The ballast tube is attached to the perimeter and is split along the outside to the facilities filling and emptying. (Fig.49 A-J) When the tube has been filled it is laced or zipped up so

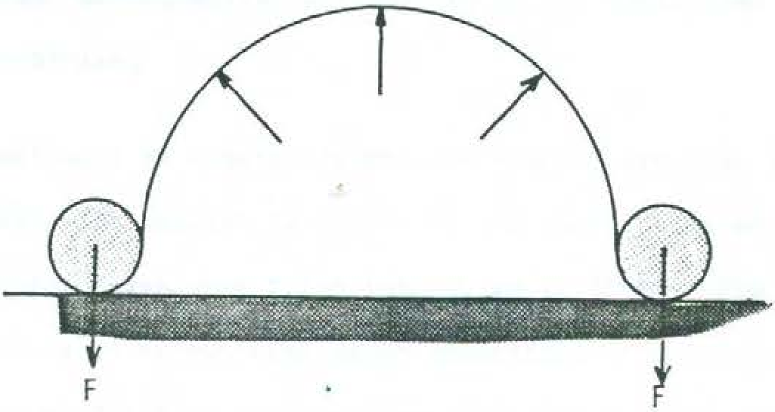


FIGURE. 47 Water Ballast Anchorages

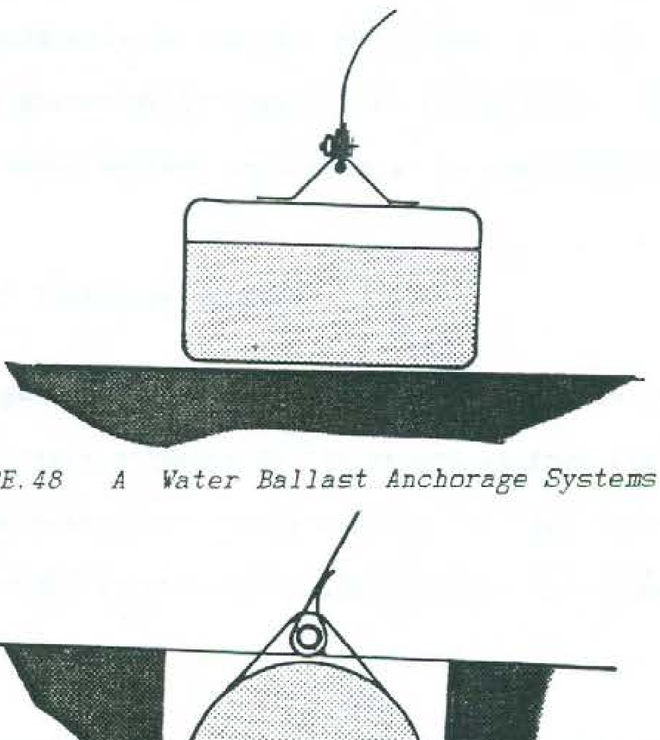


FIGURE. 48 A Water Ballast Anchorage Systems

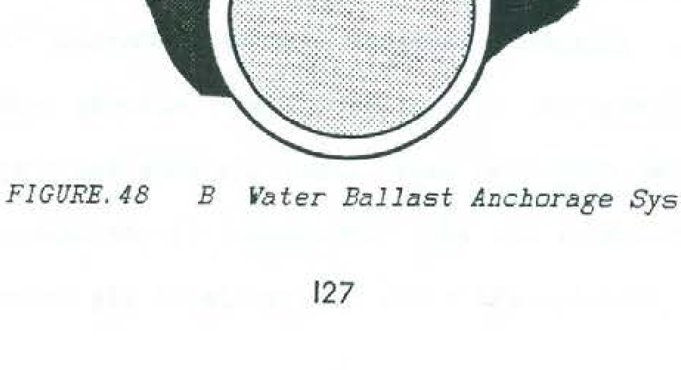


FIGURE. 48 B Water Ballast Anchorage Systems

that it is firmly attached to the structure. Another variation of this method is to dig a perimeter trench into which surrounding skirt of the structure is placed; subsequently back filling of the earth over the skirt provides anchorages.

Denser ballast,such as concrete slabs and stones, are also suitable here again (Fig.49). The ballast is placed as the surrounding skirt. Although ballast anchorages were first introduced in 1950's, the high forces on the anchorages,encountered under conditions of maximum loading made them impractical for most applications.(26) Several early failures of the ballast anchorages especially earth ballast anchorages occured. Ballast methods should only be used for structures of a very temporary nature where ground anchorage is impractical proposition. Where these methods have to be used, extreme caution must be exercised.(Fig.49)

5.3.3 Ground Anchorage Systems

Ground anchorage systems are now used almost universally. The membrane being positively attached to the ground at frequent intervals the anchorage forces must be uniformly distributed into the membrane around the perimeter of the structure, and this can be accomplished in many ways.

With clamped anchorages, a rope belt is usually sewn round the bottom edge of the membrane material, and steel channels, angle irons pipes or even timber grounds, are bolted through the fabrics, just behind the belt to flush anchors. These steel or timber section form continuous bond around the perimeters and they are attached at approximately 1 m centers to the flush anchors which are generally set in

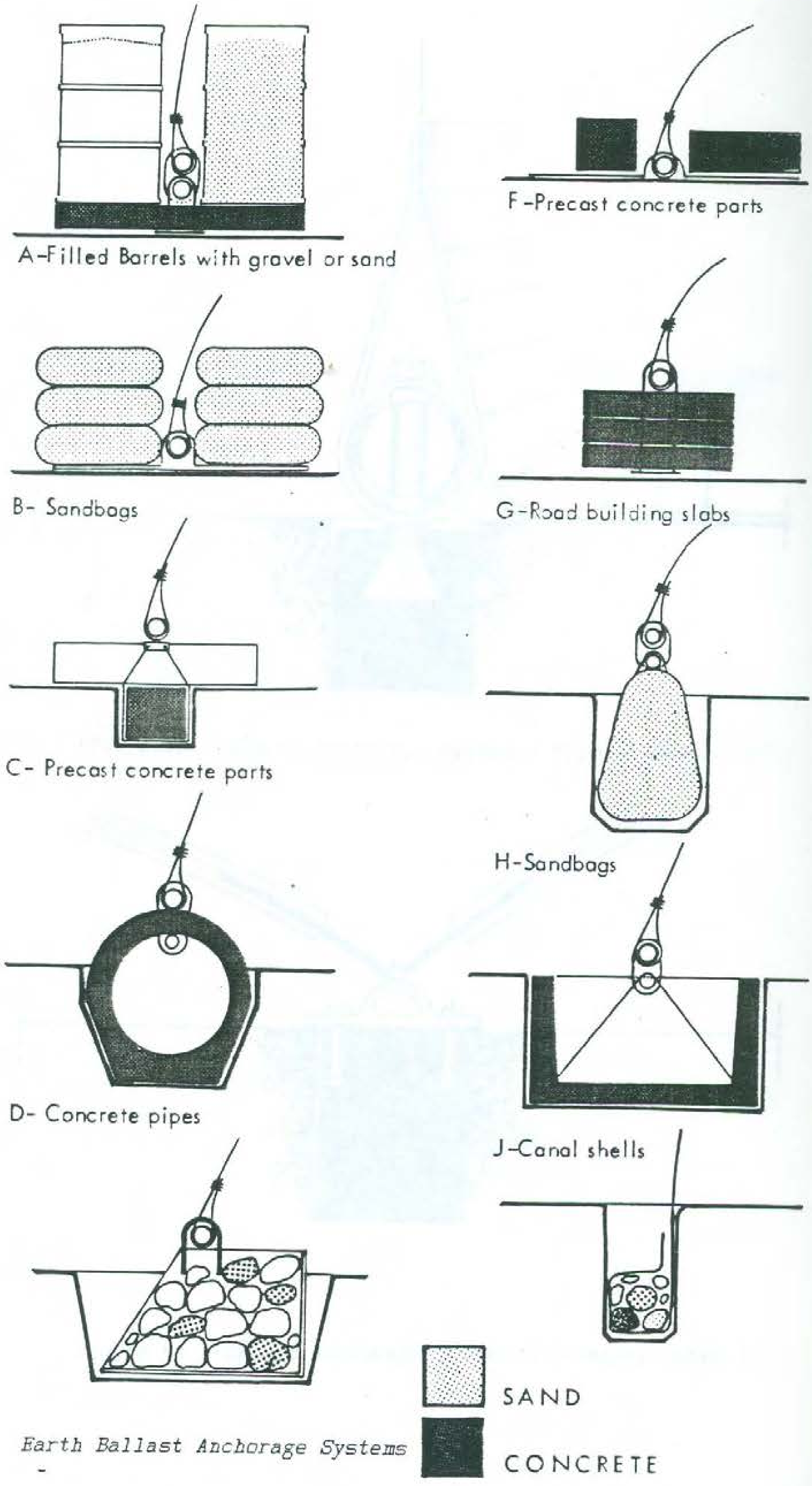


FIGURE. 49 Earth Ballast Anchorage Systems

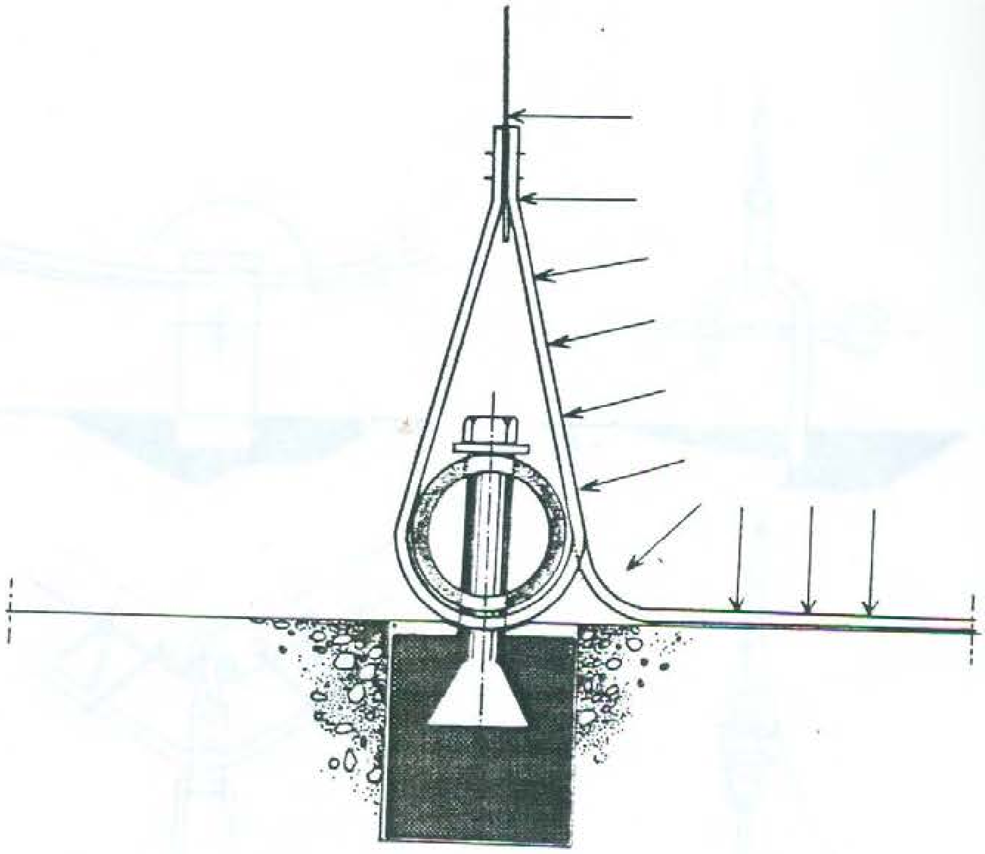


FIGURE. 50 Ground Anchorage System (Pipe-in-Hem)

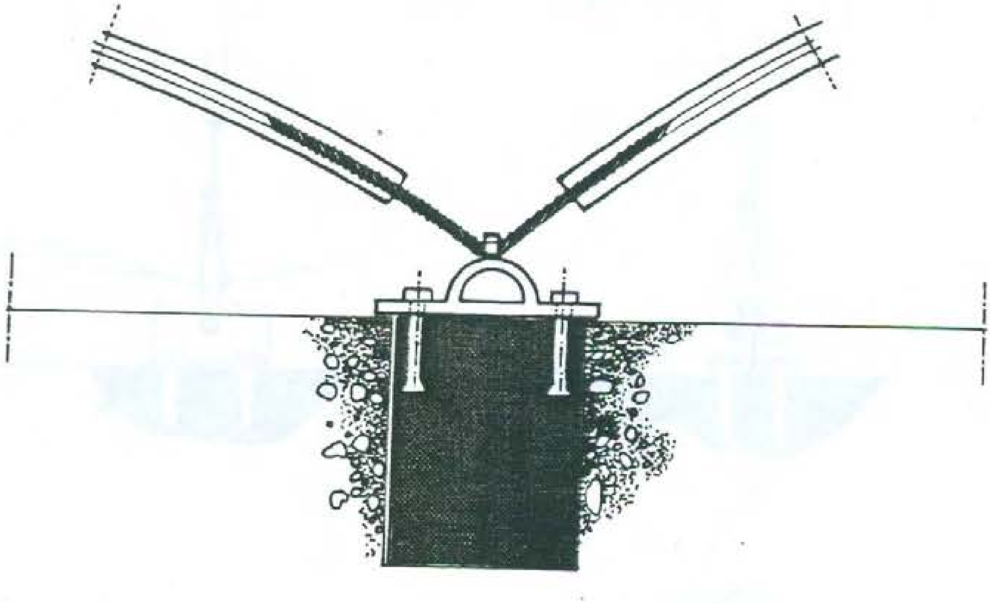


FIGURE. 51 Ground Anchorage System (Catenary Cable)

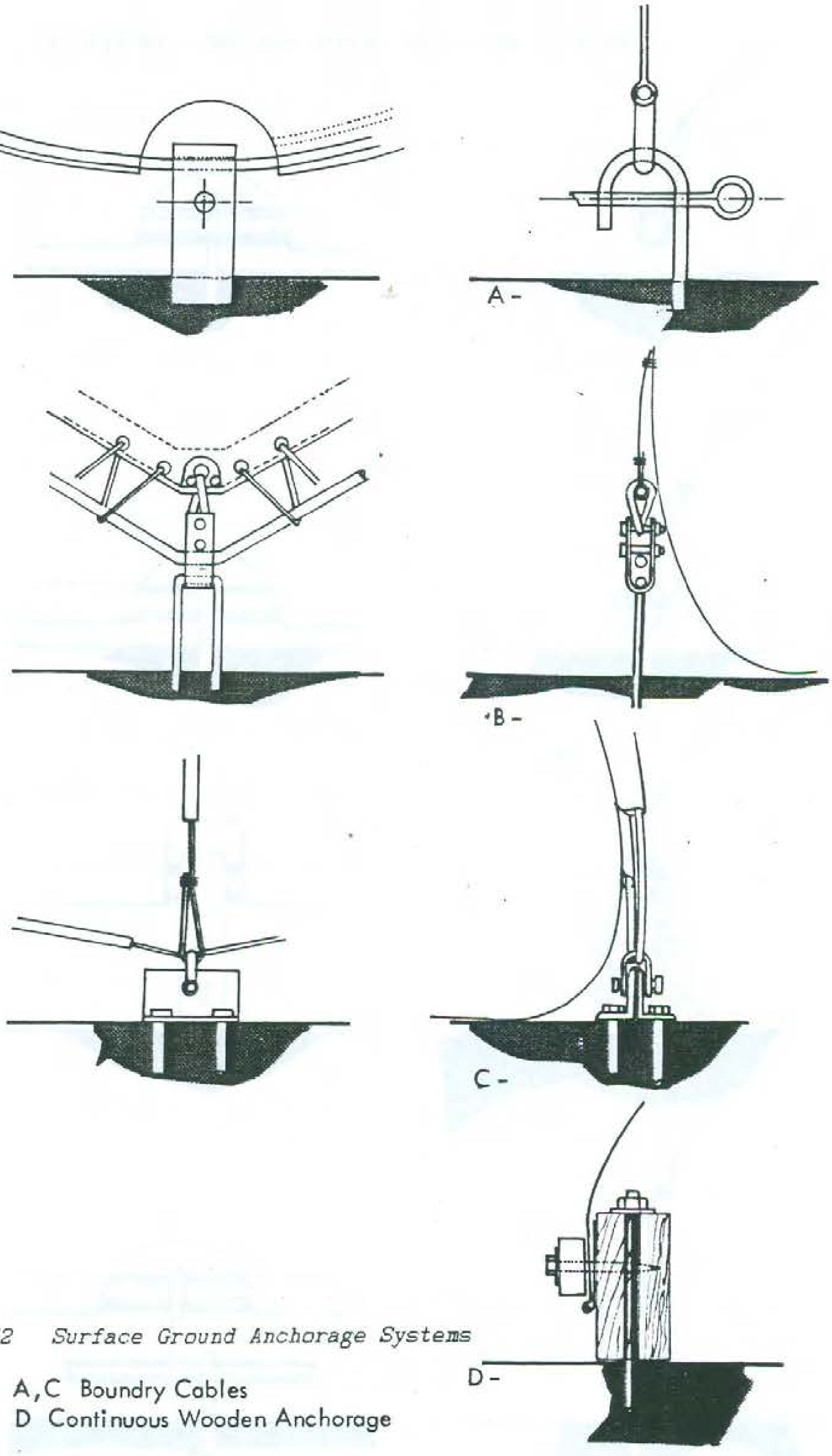
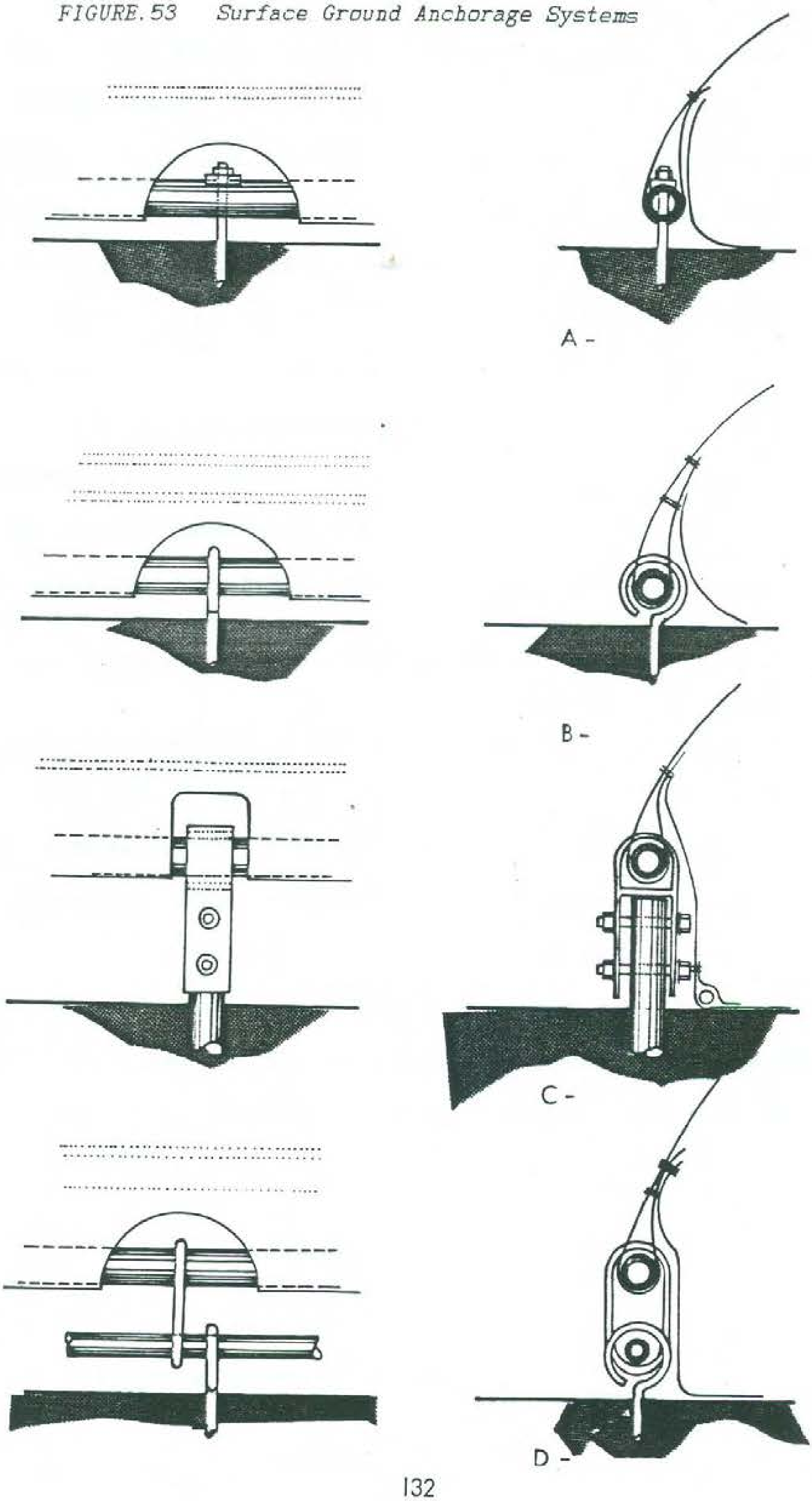


FIGURE. 52 Surface Ground Anchorage Systems

A, C Boundry Cables
D Continuous Wooden Anchorage

FIGURE. 53 Surface Ground Anchorage Systems



concrete.

The pipe-in-hem (Fig.50) anchorages consist of an open hem, sewn round the bottom edge of the membrane, with semi-circular cutouts at approximately 1 m intervals. Pipe sections are inserted in this hem and are attached to anchorage at the cut of the point. Quite often steel cables or ropes are employed in the hem, instead of the rigid pipe sections but these are not as satisfactory,since the uneven distribution of the anchorages forces into the membrane causes local stress concentrations. Despite this cables are frequently employed because of their cheapness.(Fig.51 Catenary cable anchorage) In all the above methods, the membrane material is attached to ground anchors which can be loosely classified into two groups surface and underground anchors.

5.3.4. Surface Ground Anchorage Systems

The most common methods of anchoring the air supported structure to the ground is to attach it to a concrete foundation with flush surface anchorages, such as rugbolts when the structure is installed on existing concrete, steel anchors are inserted by electric impact hammers or by drilling and grounding in the anchors. Self drilling expansion anchors can be used with new concrete foundation such methods can also be used after, the concrete has set. However a much more satisfactory anchorage is accomplished by attachimg the anchors to reinforce rods before the concrete is poured.(Fig.52-53)

5.3.5. Underground Anchorage Systems

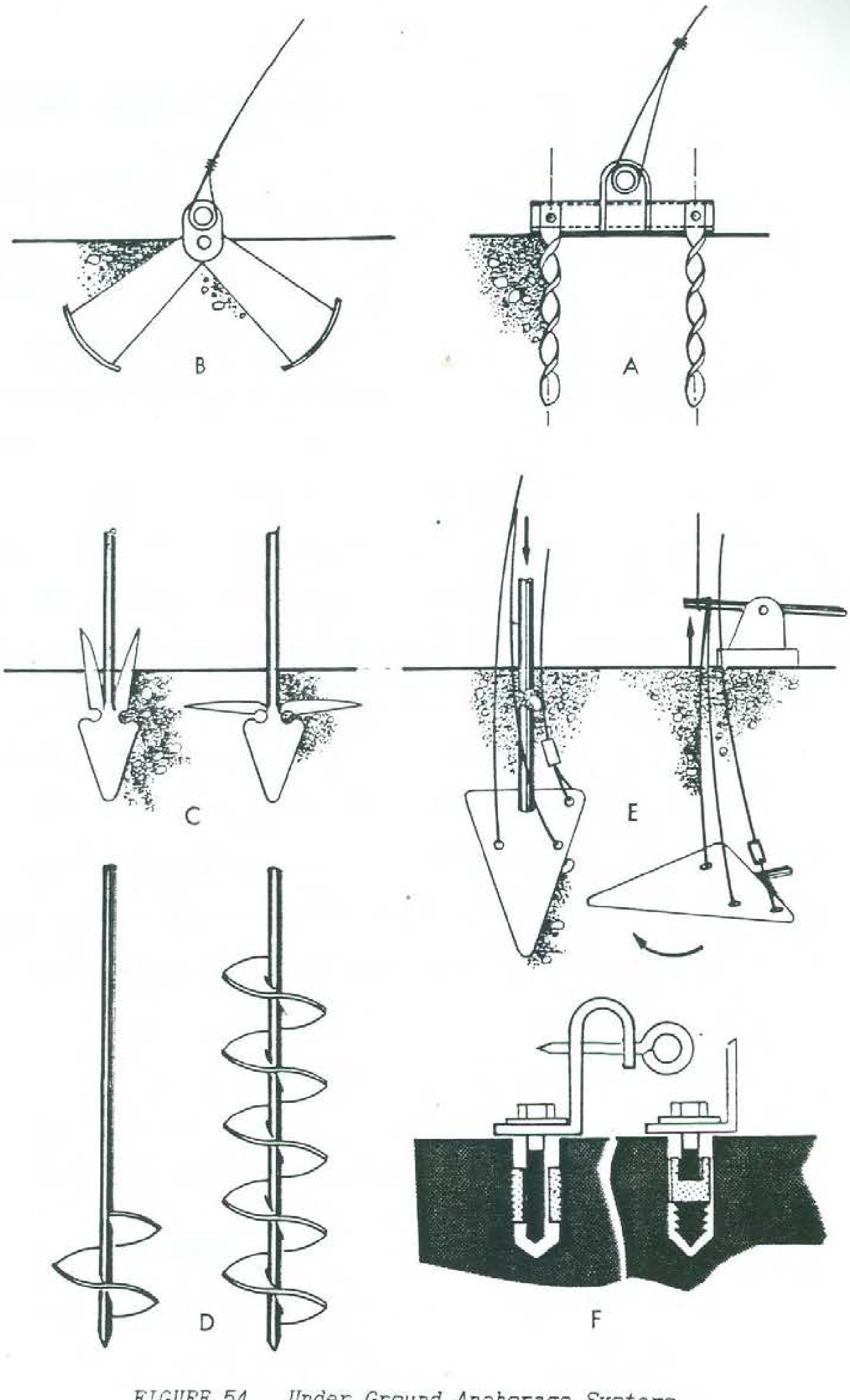


FIGURE. 54 Under Ground Anchorage Systems

The basic types of the underground anchors are ;

* Spiral Screws
* Helical Plates
* Spreadings
* Driven-Heat Anchors (Fig.52)

However a great number of anchors have to be positioned accurately underground obstructions such as stones often considerably hamper the installation. One of the most efficient and reliable of the anchors is the steel expansion type.This is installed in augered ground holes 0.25m diameter and 2 m deep.(27) Underground obstacles pose few problems for augering equipment. The anchors are placed in the holes and expanded into the undisturbed earth. The hole sare back-filled with consolodated earth,leaving a neat threaded steel stud a flush internally threaded socket to the surface for connection to the structure's anchorages points. Vertical underground concrete columns are also very satisfactory providing rather a more permanent type anchorage.(Fig.54)

The load bearing capacity of screw anchors is calculated as follows;

$$P_z = \frac{1}{V_s} q_r . l . d_s . n$$

Where P_z is permissible bearing capacity (kg)

V_s is safety factor

q_r is specific frictional resistance (kg / cm^2)

L is screw length (cm)

d is screw diameter (cm)

5.4. ACCESS CONSTRUCTION

Buildings whose utilization space has a higher or lower pressure than the exterior need special access structures which are as tight as possible when closed and keep the leakage of air as low as possible during the passage of persons.

5.4.1. Passage of Persons

Alongside the rigid conventional doors which are generally used in building there some special constructions for installation in membranes.

Trapdoors which are situated in cable reinforced round sections of the envelope (Fig.55.A) are kept in balance under a central axis of the rotation the regulation of pressure must be achieved by means of spring or weights. The loss of air controlled by the period of opening. Trapdoors are only permitted as supplementary doors.

Simple trapdoors (Fig.55 B) are the most allowed in primitive "bubbles" which do not require authorization. The same applies to all other access openings not intendend as emergency exists.

Slipping-through doors consist of two membrane of which the inner door is pressed against the outer one.(Fig.55 C) They are difficult to open from both sides the apex and the base are in danger of splitting.

Lip doors, are easy to open from the outside but less easy from the inside (Fig.55 D) here also the apex and the base at the risk.

In a cushion doors two elongated rools pressed against each other by their interval pressure. (Fig.55.E)

Revolving doors are always under stable balance(Fig.55 F) They are the most frequently used type of access and permit constant through traffic in both directions without great losses in pressure.

5.4.2. Access of Materials

Because of the high loss of pressure from large openings, single doors can only be used in the case of automatically controlled short period of opening or in large structures.

Air locks must have doors at both ends of the airlock which open and closed alternately. They are particularly for the transport of bulk goods and the use of vehicles with in the buildings. A particularly expensive air locks is figured in (Fig.55 I-J),in which the doors are positioned in the center. In order to produce the necessary pressure inside the air lock small supplementary fans can be installed in the walls of the air lock which itself can consist of stiff material or of a frame work with a skin covering.

The connection between the flexible membrane and the stiff access construction is particularly difficult. Abrupt tension differentials always occur in the membrane when no transition elements are provided. Therefore the tension from the membrane must be properly intercepted.

In the last decade thousand of pneumatic structures have been constructed and yet from the asthetic point of view, it will hardly be possible to find among them any satisfactory solutions for those structural elements which are not part of the membrane.

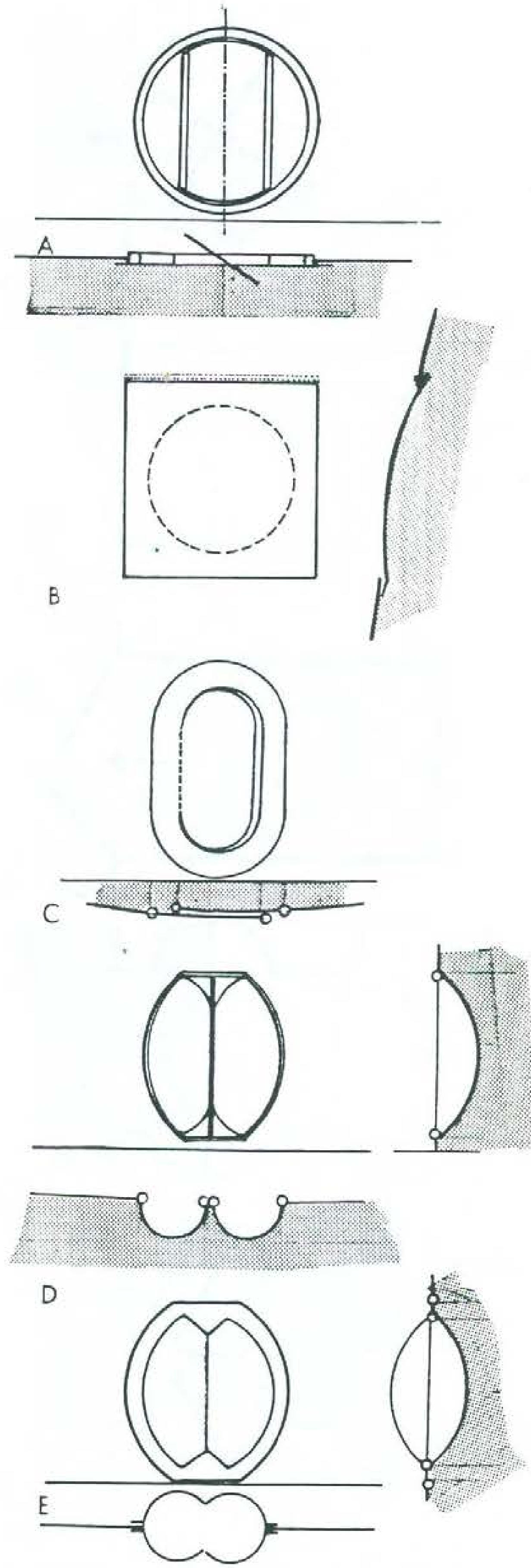
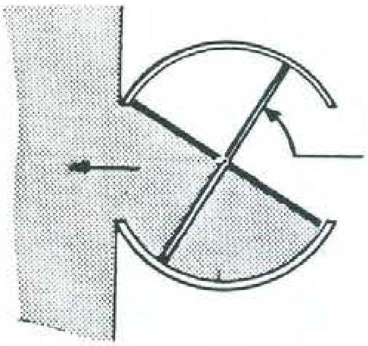


FIGURE. 55 Access Constructions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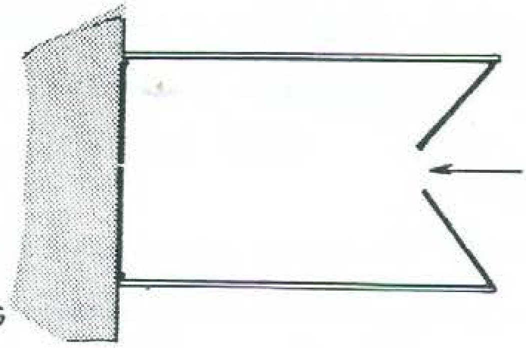
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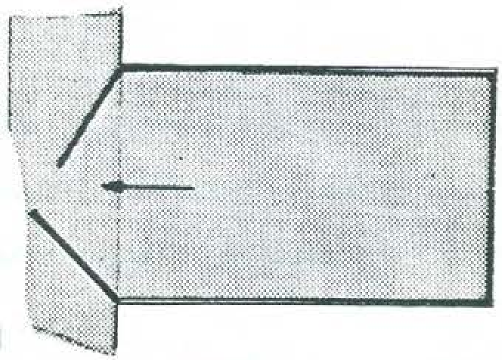
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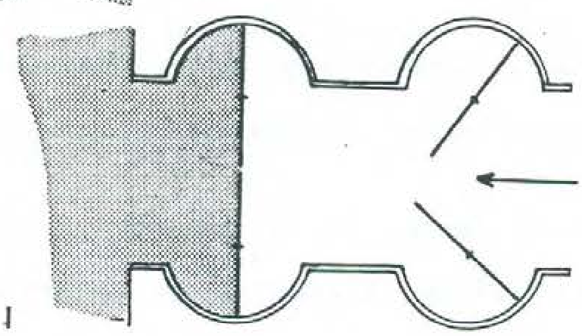
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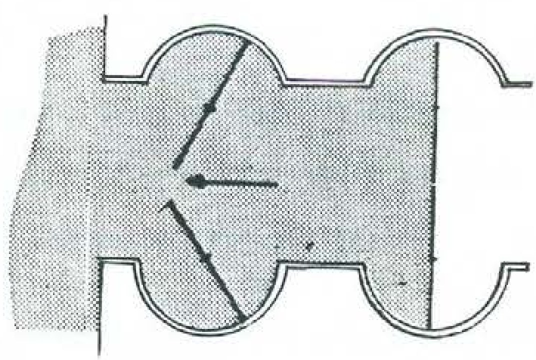
J

5.5. STABILIZATION

The stabilizing pressure of the membrane is an important structural element in a pneumatic phenomenon especially in air stabilised constructions. Structural stabilization in the pneumatics needs special technical equipment. Their productions and maintenance as well as its constant control require the provision of special technical equipments.

In the case of buildings and building elements the stabilizing pressure is usually produced by inflation devices which are arranged on the outside of the structure.

As an additional measure for positive pressure structures, especially those with large spans, it has been repeated suggested that the wind pressure b eintercepted by large funnels and conducted into the interior of pneumatic structures.

A distiction is made between axially, radialy and the tangentially working inflation devices according to the control of air current.

In the case of axially working devices, the air current flows in the direction of the axis of the device, whereby several devices can be arranged in series.(Fig. 56 A)

In the case of radially working devices, the air sucked in side ways. (Fig.56 B)and forced outwards centrifugally by the rotation of a cylinder and blow out at right angles to the air intake.

In the case of tangentially working devices, a shaft with fins which act as impellers revolves inside a cylinder.(Fig.56 C) The air sucked in tangentially in the area of cylinder casing and also blown out tangentially. This device is usually only produced in small sizes. It is used in preference where increased demands for operational quietness are present. A slightly higher pressure can be produced with blowers than with fans.

Compressors, as the the name suggested are appliences with high compression and therefore high pressure production. Aerodynamic compressors are expensive high speed machines of which the main disadvantages in the high temperature of discharged air. (over 200 C) For the conventional air supported halls the following rules can be compiled for the establishment of stabilisation equipment. (28);

i) The fans installations must be suitable for continuous operations and be designed in such way that they meet even maximum demands. The maximum stabilization pressure must be quickly and realiably attainable.

ii) Two or more fans, where under normal conditions only one would be operated, guarantee that in the event of mechanical defects, another fan can be switched on. Valves prevent loss of air due to non-functioning fans.

iii) Care must be taken that no snow can collect in the area of the fan intakes so that the supply of airs is not reduced.

iv) The injection pressure should be just above the internal pressure this will make the best use of energy supplied.

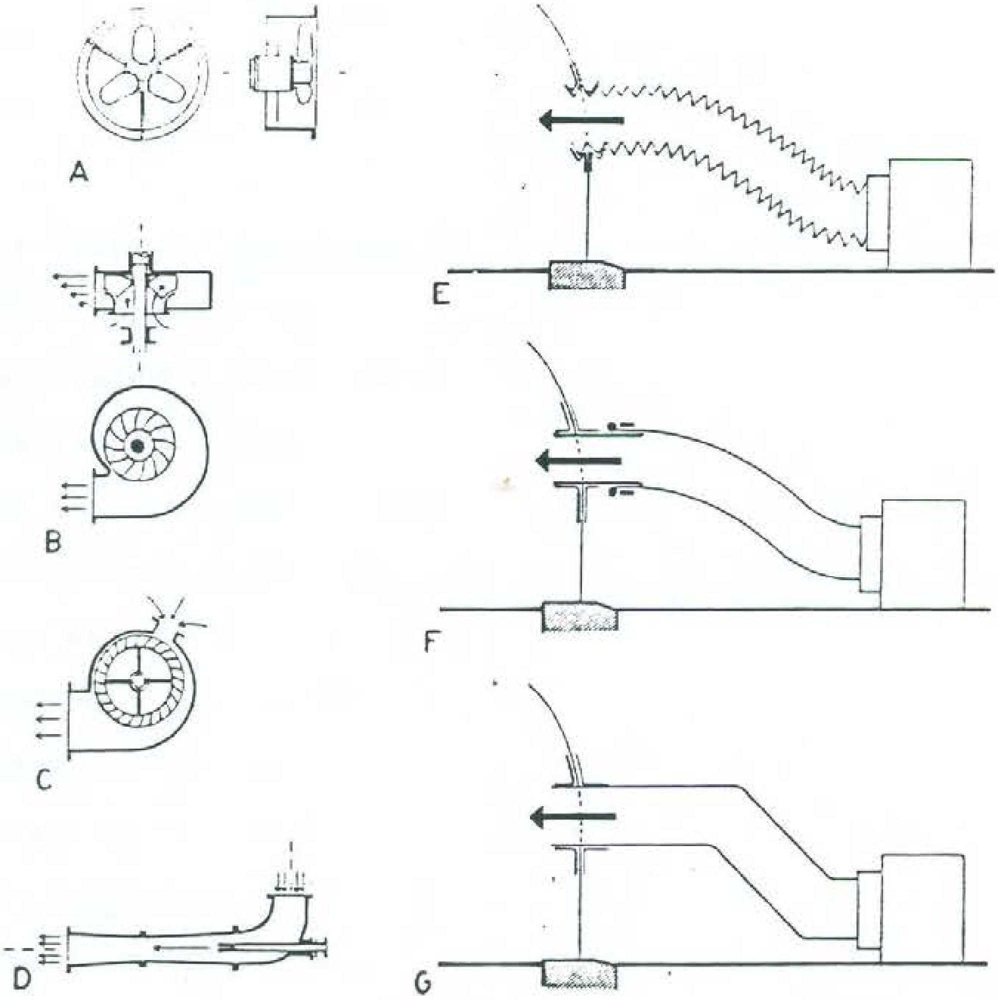

FIG (65)

A / Axial fan
B / Radial fan
C / Tangential fan
D / Jet compressor

FIGURE. 56 Diagrams of various possible joints Between Fan and Envelope

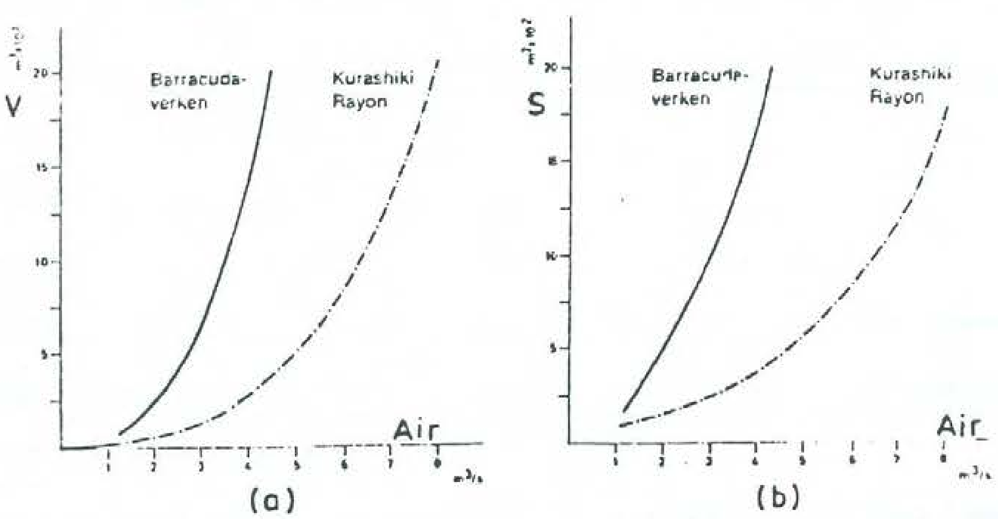

FIGURE. 57 Relationship between Fan Capacity and Building Volume

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6. APPLICATION OF PNEUMATIC STRUCTURES AS DISASTER EMERGENCY SHELTERS IN TURKEY.

6.1. EVOLUTION OF EMERGENCY PERIODS OF DISASTERS IN TURKEY

Turkey lies on one of the most active earthquake zones of the earth, and Turkey is subject to frequent and hazardous disasters due to its location. Also floods, landslides, rock falls and avalanches, etc. are the important impacts which often strike especialy in the rural areas. Around % 60 per cent of the total population of Turkey lives on primary and secondary earthquake zones. 310.000 and more houses have been lost due to earthquakes between 1930 and 1985. (1) The most critical earthquake regions in Turkey is Northern Anatolia especially. This region is one of the most active fault zones on the earth. The mean period of earthquakes in the region is about 14 per month. (2)

98.3 per cent of the total industrial investments of Turkey lie on earthquake zones and 74 per cent of these investments in primary zone and the remaining parts in the secondary and other zones. (3)

As a result of the frequence of natural disasters in Turkey, the predisaster preparedness concepts become more important. Precautions that are taken before and after the event have an vital importance for minimizing the losses. The cashable value of earthquake losses and post disaster works sum up to huge amounts in an under-developed country like

Turkey, the large portion of the country's limited economic resources has to be spent for the compensation of these losses.

The first state office to organize aids to victims of natural disasters was the Bureau of Earthquakes established in 1953 under the Chairmanship of Building and Construction in the Ministry of Public works. In 1955 this bureau has been organized as a branch of DE-SE-YA (Earthquake, flood,fire) and following the establishment of the Ministry of Development and Housing by the law of 7116 number and date of 9.5.1953, the works related to the natural disasters have been begun to be undertaken by this Ministry. In the 1965, the chairmanship has been re-organized as the General Directorate of Disaster Works and regional Engineership offices have been founded under the General Directorate. In 1969 Earthquake Research Institude has been established under the General Directorate of Disaster Works and in 1971 the Institude has been re-organized under the dependence of Ministry.

It is obvious that the duties, responsibilities, and the obligations of the state towards natural disasters have continuously changed hands between different establishments and thus it has been impossible to achieve a regular and decisive organization until 1966. Both the quality and the quantity of services presented during this search for an organization reflect the same uncertainity and for example one can not obtain any information about earthquake-related works before 1966, through the General Directorate of Disaster Works.

The duties of the State according to Law no 7269 enacted in 1959 can be grouped under 3 headings ;

i) Precautions to be taken before the disaster,

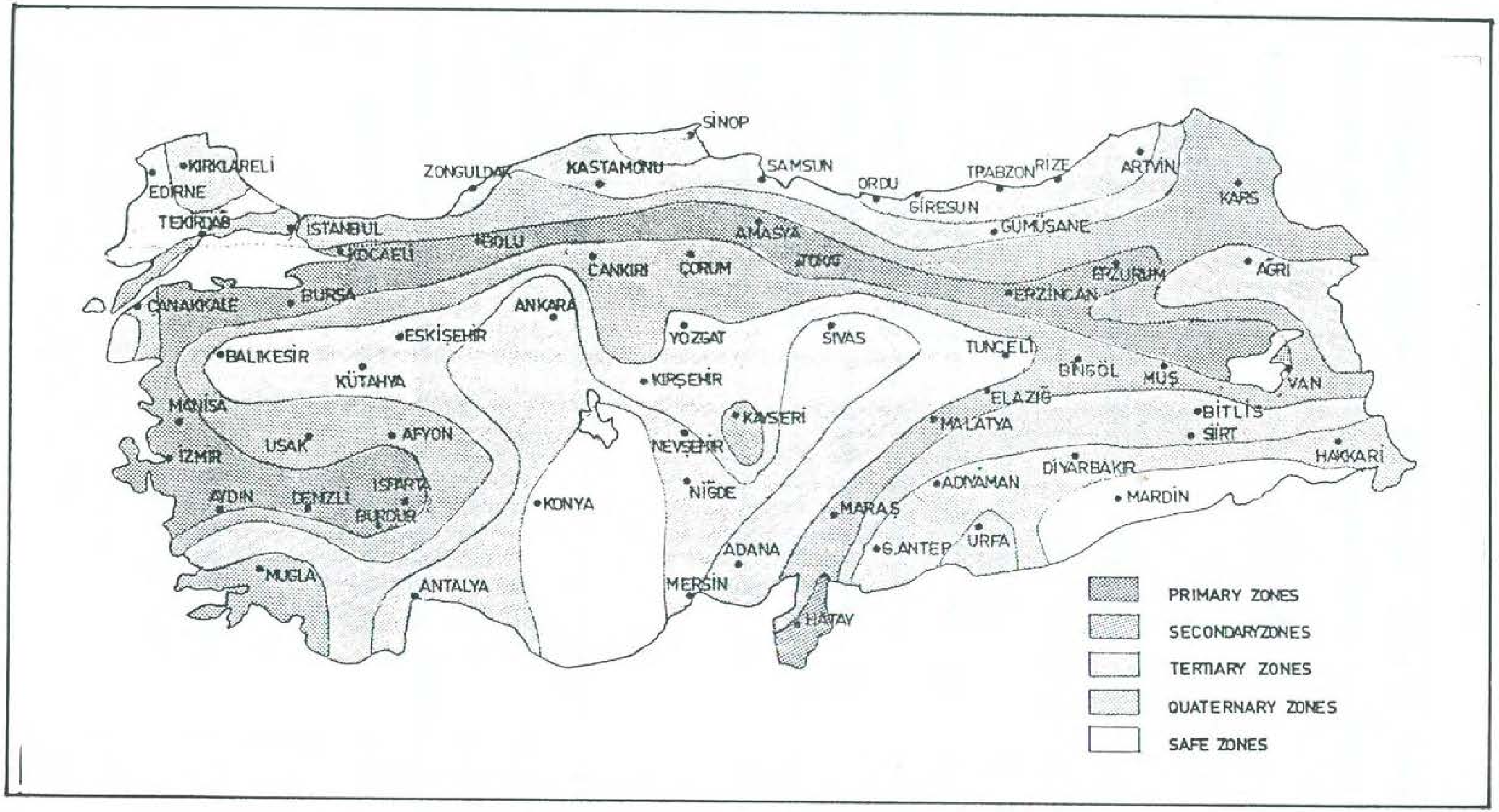

FIGURE. 58 The Earthquake zones map of TURKEY

ii) Urgent-aid services to be presented during the disaster,

iii) Long term services to be presented after the disaster.

According to the same law amended by no 1051.

Article 2;

" The regions with probabilities of earthquakes, land-slides, rockfalls and avalanches are determined by the Ministry of Development and Housing and the borders of these regions are indicated on zoning and construction plans for towns and cities or on maps for villages and towns without a zoning plan. These regions are then declared ' Disaster-prone Regions ' through the proposal of the Ministry and decree of the Council of Ministers and the borders thus determined are announced at the regions by the Governor's office through the requisition of the Ministry."(4)

Article 3;

" The technical specifications of the state or private owned buildings to be reconstructed, modified, expanded or restored in the disaster regions announced according to article 2, are determined through a regulation (Buildings to be Constructed in Disaster Regions) prepared by the Ministry of Development and Housing taking the opinions of the Ministry of Public works."(5)

The " probable disasters" in these regions usually turn into " occured disasters " as the precautions are delayed in time. Most of the time these warnings and proposals of the organizations have not been taken into consideration and the people of the critical regions have in a way been condemned to lose their lives and properties in occured disasters. Besides the insufficient execution of the necessary precautions in the disaster prone regions, there is also the problem of inefficient application of the "Regulation of Buildings to be constructed in Disaster Regions", due to absence of technical services and the lack of organizations and control. According to the 4th, article of the law 7269, the first 15 days period after the disaster has been accepted to be " Urgent Aid-Period " and the power of extending this period as required has been given to the Council of Ministry. The duties and the obligations of the state during this period are ;

i) Picking up of the wreckage, rescuing the victims and cleaning of debris,

ii) Taking care of the wounded, burying up the deceased, preventing the contagious diseases,

iii) Feeding and clothing the victims,

iv) Providing temporary settlements for victims.

The state , inspite of the experiences gained through the frequent occurance of the disasters and the powers granted through the laws, is still unable to fullfill the aims of works and activities in the disaster prone areas because of the insufficiencies in the achievement of high and low level co-ordination and therefore the event of disasters are still used as mean of providing benefits for certain beneficiary groups.

It is obvious that the emergency shelter problem in the disaster area are of great importance especially in the urgent aid-period. But still in these period are used the "Cone tent" and the occupation of these lasts from months to several years. These temporary shelters are built as temporary and some how they become permanent. For the countries which are pre-developed and subjected to the frequently earthquakes like Turkey, primary attention must be paid to the development of temporary shelters.

6.2. PRODUCTION POSSIBILITIES OF THE PNEUMATIC STRUCTURES IN TURKEY

6.2.1. Evolution and Material Selection

The production of pneumatic structures started after 1982 in Turkey. The ON firm is the only firm that deals with the production and the application of the pneumatic architecture in Turkey. They are producing three different kind of pneumatics which are;

i) Sport halls (Standart halls)

ii) Ware-Houses (standart halls)

iii) Hybrid structures (Additional point and linear support construction)

Each group has different dimension possibilities. Also ventilation, heating, seperation, etc.,are the variations which are included the firm's services. The original pattent used by the ON firm belongs to the German firm BALLONFABRIK. Also The membrane material, which is laminated PVC both in and out surfaces, is imported by the ON firm from Germany. They also use another PVC material and the technical specification of it is the following;

PVC Material (FRG)

PVC coated high-strenght Trevira Fabrics(PES)

Type of fabric : 1100 dtex

Intensity of the fabric(cm): 9/9 threads/cm

Linen wave : 1/1 L

Tearing resistance

warp : 3500 N/5 cm
weft : 3500 N/5 cm

Breaking elongation (%): % 15 Warp direction

: % 20 Weft direction

Cold Thermal resistivity : - 30 C Continuous

High Thermal resistivity : 70 ^{o}C Continuous

Flame resistance : O.K.

Folding Resistance : 100.000 times

Ultraviolet resistance : 12 years Continuous

6.2.2. Critism of The Production of Pneumatic Structures In Turkey.

In studying the development of pneumatic structures, it quickly become obvious that they have evolved quite independently of conventional structures and the present state of art is one which ranges from high quality forms down to cheap goods of doubtful quality and limited durability. Most of the time adaptation of high technologies in conventional and traditional applications necessitate more patience. The conceptional frame work of the applications must be expanded and demostrated. Also the encouragement of high technologies like pneumatic ones lead to many new concepts which emerge and foreshadow some of these new structural forms. The new structural forms are caused by the high technologies and unsaturated necessities.

Transferred technologies like pneumatics must be completely adapted to the local conditions of a country like Turkey, after the definition of the applications possibilites of the production centers must be organized.

The existance of the pneumatic technologies in Turkey consists of the technologies, materials, structural forms and the services which are transfered by a firm from Germany. The production and the application possibilities of the firm are resricted by the origin. There is no absolute contribution of the firm to the research and development of the structural form nor the materials used in pneumatic phenomena.They use, the same membrane material which is ' polvinyl chloride coated high strength trevira fabric' in all application possibilities can be adopted to the local conditions more easily.Also present dimensional possibilities limited the applications. If the dimensional possibilities, especially small scale applications are improved than the market possibilities can be increased in time. The firm produces only the air stabilised structures and same hybrid examples.The air stabilised structures require the special technical equipment which might create problems especially in the rural areas. In the case of air inflated structures or the double membrane constructions, the first production cost increases according to the single one. But the possibilities of any failure in the technical equipment or in the maintenance problems decrease rapidly. Because of different usage necessities both air stabilised the air inflated structures have the different market demands. But if the production line of the firms based on only the air stabilised structures the market area might be narrowed.

Especially, one of the great clear strategical mistake of the firm's applications is to show the pneumatic technology similar to any other construction technologies and the firm applications are rather permanent such as ware-houses, sport-halls, etc. The temporary applications or the easy dismontability capacity of the pneumatic technology is neglected in the firm's strategy. Thus all of the great advantages of pneumatic that are transportability, quick erection facilities, demontability, storage, etc. are lost by these permanent applications.

6.3. COST ESTIMATIONS

In Turkey, when using half of the potential of pneumatic technology it is not easy to propose new application areas such as temporary pneumatic structures which must be generally used in disaster. Because of the instant and the temporary nature of disaster area housing, especially produced by a rotating capital state organizations, the sector of post disaster temporary housing production is not a desirable invesment for the private enterprises due to uncertainties in the size of the market demand potential, properties of time. That is not to mean that the present structural forms which are produced by the firm, are not suitable for the post disaster relief activities. They can be used as temporary first aid or medical services structures structures, cafeterias or seperated interior areas and used for housing, for the ware-houses etc.

Present production and application levels of the firm's services have completed erection in 2 days and dismounting completed in a day. The present production investment of such a standard-hall including the technical equipments , access, anchorages, transportation and the erection is approximately (90 DM/ m^2) or (28.890 TL/ m^2). This investment is the first cost and each new usage means an additional % 8 to % 25 new cost to the first invesment than after 5 times usages the cost of(TL/m^2) is;

(1) $$C_n = \frac{C + C(n-1)(\%8)}{n} + K$$

K, is cost of maintenance and repairment

$$C_{1\,min} = \frac{C + C(1-1)(\%8)}{1} = 28.890\ TL / m^2$$

$$C_{2\,min} = \frac{C + C(2-1)(\%8)}{2} = 15.600\ TL / m^2$$

$$C_{3\,min} = \frac{C + C(3-1)(\%8)}{3} = 11.700\ TL / m^2$$

$$C_{4\,min} = \frac{C + C(4-1)(\%8)}{4} = 8.956\ TL / m^2$$

$$C_{5\,min} = \frac{C + C(5-1)(\%8)}{5} = 7.627\ TL / m^2$$

$$C_{Av} = \frac{C_1 + C_2 + C_3 \ldots\ldots C_5}{5} = 14.450\ TL / m^2$$

(2) $$C_{n\,max} = \frac{C + C(n-1)(\%\ 25)}{n} + K$$

$$C_{1\,max} = \frac{C + C(1-1)(\%25)}{1} = 28.890\ TL / m^2$$

$$C_{2\,max} = \frac{C + C(2-1)(\%25)}{2} = 18.056\ TL / m^2$$

$$C_{3\,max} = \frac{C + C(3-1)(\%25)}{3} = 14.445\ TL / m^2$$

$$C_{4\,max} = \frac{C + C(4-1)(\%25)}{4} = 12.639\ TL / m^2$$

$$C_{5\,max} = \frac{C + C(5-1)(\%25)}{5} = 11.556\ TL / m^2$$

$$C_{Av} = \frac{C_1 + C_2 + C_3 \ldots C_5}{5} = 17.017\ TL / m^2$$

(3) $$C_{Av} = \frac{C_{avmax} + C_{avmin}}{2} = 15.734\ TL / m^2$$

After using five times, the average cost is 15.734 TL / m^2 and add the K value for maintenance and repair. It is obvious that the cost of the pneumatic structures is rather cheaper than other construction technologies especially in the temporary usage.

6.4. OVERALL EVALUATION

As a result of all these mentioned critism; present production levels, structural forms and material qualities do not comprise a desirable solution to the problems of Turkey, when compared to the present sub-standards dwellings according to the cost,flexibilty, the production duration, storage possibilities, transportation,erection, energy losses and dismountability , etc.

The pneumatic structures are highly prefarable to the others. Especially the hall forms they can be easily used by an emergency temporary medical station in the first-aid period and for the social services in the rehabilitation period.

If the appropriate membrane materials are selected according to the territories and small scale designs are produced within the scope of the environmental conditions and the predisaster planning organizations are completed before point of impacts, the desirable solutions will be achieved.

NOTES

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7. RECOMMENDATIONS

Any alternative design solution to the temporary pneumatic structure in disaster area applications should have to fullfill some vital requirements that have been underlined in this section. This chapter attemptsto put together all posible design recommendations in the form of tables and the requirements which are suitable for all possible structures and they must be checked before the application of the design.

These recommendations have been further classified as quantitative and qualitative groups. The quantitative recommendations are generally related with the quantitative values ; such as number of units to be produced each year, number of storage centers, erection time, number of erector labourers average floor areas and the cost of each unit,etc. The qualitative group or the recommendations on the other hand are those which are related with the quality of each unit to be designed, such as behaviour and the material specifications of the membrane envelope, type of anchorage systems, site selection, erection, dismantling and maintenance, etc.

7.1. DEFINITION ACCORDING TO TYPE OF USAGES

a. Units that have to be erected immediately after the occurance of a disaster; temporarly, in a large numbers, in a shortest possible of time, within a economic constraint.

b. Units that have to be erected in disaster prone areas aim only to serve as a basic shelter and temporarly satisfy the vital requirements of the inhabitants.

Units that have to be erected in the first-aid period, are called ; " Emergency Shelters ". They serve to protect the inhabitants life against the environmental conditions until the temporary units is completed. In desirable situation, this period is between 2 to 3 weeks, but in reality this period usually becomes 4 to 6 months or even more when it overlapes with the high winter conditions.

There is an urgent need for medical aid especially just after the point of impact. Such units that have to be erected after the point of impact are called " Emergency First-Aid Stations". They serve as a medical service units to inhabitants during the emergency period.

Units that have to be erected just before the rehabilitation period are called " Social Service Stations ". They serve for continuous food supply for inhabitants and workers in the disaster area and also as rehabilitation centers during this periods. They should contain complete kitchen units and power sources,etc.

The demand for closed areas in disaster areas especially in the rural section reaches the highest point after the point of impact.The absolute demand remains constant during rehabilitation and reconstruction periods. Units which have been erected before the rehabilitation period and come to serve as ware-houses,sites, to the period of permanent units constructions. They are used as storage centers of the temporary shelters. Than temporary shelters are erected, they come to serve as ware-houses, sites etc. to the period of permanent housing construction. Simple units called " Temporary Shelters " have been erected and completed just before the rehabilitation period begins. They serve not only as a basic shelter but satisfy some of the vital requirements of the inhabitants during the rehabilitation phase as well.

All possible alternative design groups are classified in this chapter according to the type of usage as follows ;

i) Emergency stations, (2-3 weeks)

ii) Emergency shelters, (2-5 weeks)

iii) Temporary units, (3 month to 1 year)

iv) Social service stations, (during the rehabilitation period)

v) Warehouses, etc. (rehabilitation to reconstruction period)

All necessary constraints of pneumatic structures in disaster area application according to the types of usage are breifly described in (Table 13) and the usage cycles of the pneumatic structures referenced with the disaster periods are also described in (Table.14)

In addition to all these constraints, there are several vital requirements which determines the characteristic of the pneumatic structure in the disaster area applications. These requirements will be grouped and analyzed at the next stage.

TYPE OF USAGES	MEBRANE WALL	ACCESS	STABILISATION EQUIP.	ANCHORAGE SYSTEMS	POWER SOURCES: LIGHTING	POWER SOURCES: HEATING TE	POWER SOURCES: HEATING CE	POWER SOURCES: COOLING TE	POWER SOURCES: COOLING CE	SANITARY SYSTEMS	INTERNAL SEPARATION	AVERAGE SURFACE (m^2)	EQUIPMENTS	ERECTION PERIOD (hours)	ERECTOR LABOUR (person) Q	ERECTOR LABOUR (person) UQ	PERIOD
A1 EMERGENCY SHELTER (only environmental protection)	✓	✓	✓	✓	_	_	_	_	_	_	_	8-10	_	2 3	1	1	SHORT (2-3 WEEKS)
B1 TEMPORARY HOUSING Protection+satisfy vital requirements	✓	✓	✓	✓	✓	_	✓	✓	_	.	✓	30	.	12	2	2	LONG (4-6 MONTHS)
A2 EMERGENCY STATIONS 1) Medical First-Aid	✓	✓	✓	✓	✓	–	✓	✓	–	✓	✓	200	✓	24	8	0	SHORT (2-3 WEEKS)
AB1 2) Social Services	✓	✓	✓	✓	✓	_	✓	✓	–	✓	.	200 +	.	24	8	0	LONG
AB2 3) Warehouses (Special)	✓	✓	✓	✓	–	–	–	–	–	–	.	200 500	.	24 48	8 +	+	LONG

CE Cold Environment
TE Temparate Environment
Q Qualified Labourer
UQ Unqualified Labourer

TABLE 13. The necessary constraints of the pneumatic structures in disaster area application according to type of usage.

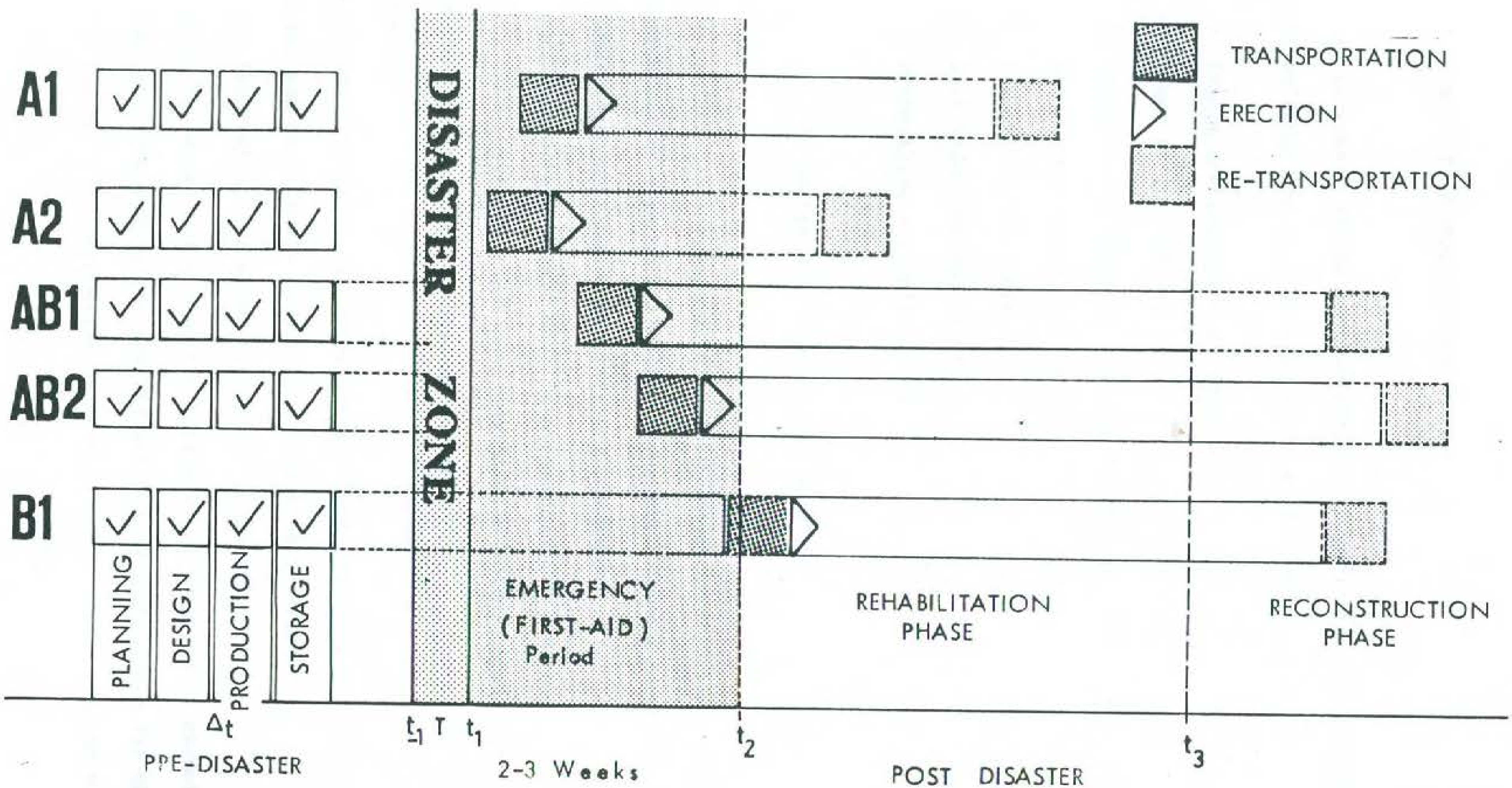

TABLE 14. Usage cycles of the pneumatic structures referenced with disaster periods.

7.2. DESIGN RECOMMENDATIONS

The pneumatic design recommendations in disaster area applications are classified according to a logical order as follows;

1. Design and selection of geometry,
2. Proof of load safety,
3. Selection of material and calculations of thermal properties,
4. Structural design requirements,
5. Production and storage,
6. Site selection and erection,
7. Dismantling and maintenance.

7.2.1. Design and Selection of Geometry

i) In general a pneumatic structure should be free from wrinkles.This condition can only be fulfilled for a pneumatic formed geometry in which the tensile forces occur under internal pressure.

ii) The membrane should develop no compression forces.

iii) The curvature of the membrane must be steady. Even with complex geometries the curvatures must change over from one to another as uniformly as possible.

iv) Small jumps in the curvature must compensated for by elasticity of material and only rarely lead to the formation of wrinkles.

v) The flat corner areas are often undesirable.

vi) With larger and the more complicated structures the geometry and the membrane forces should always be defined by test before the application

vii) Regular and large surfaced patterns should be preffered to a

' patched ' pattern because the seams in the inflated membrane can be clearly recognized.

viii) The parts, units and equipments should be standardized as much as possible.

7.2.2. Selection and Calculation of Material and Thermal Properties

7.2.2.1. Material Properties ; The material properties of the synthetic films and coated fabrics cover a very wide range. They are not fully described by tensile strength, rupture strains and subsequently tensile strength, even with the seam strengths determined by short term tests. In particular, aging under ultraviolet radiation reduces the material strength. Table.15 gives a general example of material check list for pneumatic structures for disaster area applications.

i) After five years of use the tensile strength can decrease by % 25 or even by % 50 under the ultraviolet radiation.

ii) The long term tensile strength of synthetic material is relatively low , the tensile strength of woven fabrics is usually around 500 kg/5 cm.

iii) In order to cover the strength losses caused by aging and permanent loading, the safety factors,

$$k_s < \frac{n}{\max n}$$

are necessary. (max n Largest calculated membrane forces)

(n Normal membrane forces)

iv) For temporary applications (under high ultraviolet radiations),

$k_m < 5$ is laid down for membrane $k_s < 3.5$ for the seam. (4.1.2.)

v) The safety factor k_s is not applicable in air supported structures older than 12 years.

vi) The safety factor k_s states nothing about a possible increase in load. the non- proportional growth of the membrane forces can only be determined by a limit design investigation.

vii) After 10 years the water permeability (watertightness) can decrease by % 65.

viii) For temporary usage the isotropic materials should be prefered. (4)

ix) The tearing resistance of the membrane must be greater than 2500 N / 5 cm both warp and weft directions.

x) The breaking elongation of the membrane should have at least % 15-20 for both directions.

xi) The intensity of the material has to around 10 / 10 threads / cm.

xii) The folding resistance must be at least 100.000 times.

xiii) The ultraviolet resistance should extend at least over 12 years.

xiv) The desirable continuous thermal durablity is around $-40\ ^{o}C$ to $+70\ ^{o}C$

7.2.2.2. Thermal properties;

i) In disaster area applications thermal transmittance is a vital factor for the inhabitants. For cold climates, the thermal transmittance (U) value must be less than (3 $Kcal/\ m^{2}\ h\ ^{o}C$) and for temperature climates, U value should be (4 to 4.5. $Kcal/\ m^{2}\ h\ ^{o}C$).

For the calculation of the thermal transmittance (4.2.1.), a further possibility of achieving a higher thermal insulation is the use of multi-layerd membranes with enclosed air cushions.

ii) Unprevented snow deposits may cause an increase in the thermal transmittance.

iii) The water permeability (watertightness) level also affects the thermal transmittance. (Condensation in the fabric).

iv) Light transmission (transparency) can only be preferned at heights above 2 m.

v) The heating of the air inside the membrane in strong sunlight is only a problem when a problem when the hall is low in height. For that reason shields (4.2.1.) should have used both solar gain and protection for high ultraviolet rays.

vi) For a considerably long duration of usage, ventilation, cooling heating and similar concepts become important. But in the case temporary usage or small halls being less than 5.5 m high, cooling the supplied air is not feasible for economic reasons.

vii) Moisture penetration is even a desirable concepts in the temporary usage.

viii) For high thermal insulation, thick foam sheets can be used on the membrane surface and these sheets can removed when the structure is erected or dismantled.

ix) For temporary usage, the fresh air (external) and the inblown air (internal) volume is so proportioned that a temperature difference of at most 26 ^{o}C can be bridged with the usual fans for protection the excess humidity. (artificial humidity)

x) Ventilation flaps are desirable for natural cooling in temporary usage.

Material Name : ______________			
Membrane Envelope	Reference	actual	check
Anisotropic / Isotropic	isotropic		√
Weight (g/m^2)	$x < 1.200$		
Intensty Warp Weft	$x < 10$ $x < 10$		
Thickness (mm)	—		
Tensile strength	—		
Tearing resistance	2500/5cm		
Specific Gravity(kp/m^3)	$0.8 < x < 1.6$		
Folding Resistance	100.000		
Breaking Elongation %	%15		
Air Permeability	High Resistance		
Water Tightness	Resistance		
Chemical Resistance	High		
Thermal transmittance ($KCal/m^2hC^o$)	$4.0 < x_h < 4.5$	$x_c < 3.0$	
Continuous Thermal Resistivity	$-40\ C^o$ $+70$		
Wheather resistance prop.	Good		
Light Transmittance	—		
Imcombustibility	High		
Type of Jointing	Sewing		
Cost	Low		

x_c — cold environment

x_H — hot environment

TABLE 15. Material check list for pneumatic membrane envelopes in disaster area application.

7.2.3. Structural Design Requirements

7.2.3.1. Membrane cutting pattern

i) Regular and large surface patterns are preffered. At the sides overlaps 4 cm are required.(4.1.2)

ii) Seam nodes are undesirable. If seam nodes can not be avoided, then as few seams as possible should converge at one point,

iii) To offset the reduced strength in the seam area, seams parallel to the greatest main tension are more economical.

iv) The wastage is generally less in short lengths than in long lenghts.(4.1.2.) (Fig.31)

v) Seams running parallel to the steepest gradient facilities the slipping off snow and the membranes dry more quickly after rain.

vi) Shear strains of % 5 to 8 are possible without wrinkles forming.

vii) In the larger structural applications, an elongation of the membrane due to the internal pressure about % 1 to 3 should be taken into account in the cutting pattern.

7.2.3.2 Jointing requirements

i) For inseparable joints, the strength of the jointing material must be equal to the main material.

ii) For inseparable joints, the jointing area must have as great flexibilty is possible in order to prevent the area from kinks and break points.

iii) The jointing area should have enough density to prevent the escape of air and penetration of surface water.

iv) Seperable joints should be prefered in order to be able to insert movable parts with a section of envelope.

v) Seperable joints are also suitable in order to be able to seperate large envelopes into parts especially for transport and erection of temporary structures.

7.2.3.4. Anchorage requirements

i) Temporary pneumatic structures have to be erected and removed easily. The membrane anchorage should be adaptable and economic so as not to prejudice later use of the site, the withdrawal or dismantling of the anchorage should not involve any great expense.

ii) Especially in disaster area applications, the variation of the earth surface from one place to another makes the anchorage system selection very important. The anchorage must have sufficient inherent rigidity against the buckling and torsion stress which arises at every possible conditions.

iii) The screw anchorages are the most suitable system for disaster area applications.

iv) The load bearing capacity of screw anchors is calculated as follows

$$P_z = \frac{1}{V_s} q_r \cdot d \cdot II_s$$

v) With regard to the possible loosening of the subsoil when screwing down, a safety factor of at least V_s 3 should be incorprated as the basis of calculation of loadbearing capacity of screw anchorage in disaster area applications.

vi) To prevent different tensions occuring in the membrane, the distance between the anchors should usually be 60 to 90 cm.

vii) If the different tensions occur in the membrane, because of the geometry of its surface, then the anchorages should be correspondingly tensioned. They must be dimensioned according to the strongest tension or be adapted to the different tensions.

viii) To prevent the possible corrosion on the anchorage systems, the parts must be processed with chemical threatments.

7.2.4. Proof of Load safety

In pneumatic structures very large deformations can occur which affect wind and snow loading through the changed geometry of the envelope. The load is approximately applied to the underformed membrane and affixed there.

Conservative loads, such as deadweight and snow remain true to direction, internal pressure and wind act always normal to the deformed membrane.

In disaster area applications in such pneumatic safety requirements should be clearly determined in every possible condition, such as ,

i) Internal pressurisation requirements,

ii) Deadweight requirements,

iii) Wind load requirements,

iv) Snow load requirements

7.2.4.1. Internal pressurisation requiremens;

i) The magnitude of the internal pressure depends on the geometry of the membrane, loadings and permissible deformation.

ii) A minimum internal pressure of $p = 30\ kg/\ m^2$ is prescribed for envelopes with a height of more than 8 m. Also $p = 18\ kg/\ m^2$ for envelopes with a height up to 4m.

iii) For any geometry the minimum internal pressure can be detemined by restriction of displacements and by a margin of safety against folding it.

iv) The maximum possible internal pressure is called " Bursting - pressure " P_{Br} which depends on the geometry and on the fabric strength. In disaster area applications critical internal pressure P_{crit} should be less than P_{Br}.

v) P_{crit} is the pressure at which the membrane suddenly expands and changes to another state of equilibrium.

$$(1) \qquad P_{crit} = 0.296\ D / R_o$$

where R_o is the radius of underformed sphere ,

D is the tensile stiffness of the membrane,

$$(2) \qquad D = E.t$$

where E is the modulus elasticity of the material,

t is the membrane thickness,

vi) The internal pressure must be controlled with the air valves when ever necessary.

vii) The safety factor must be (k= 1.2) for internal pressurisation

7.2.4.2. Deadweight recommendations

i) If the specific gravity (G) of the membrane material lies between 0.8 kg / m^2 and 1.6 kg / m^2 per mm fabric thickness, the dead load can be ignored in structural calculations.

ii) The deadweight loading of the membrane material can also be approximately disregarded if the working pressure exceeds the internal pressure used. ($P_i \leq P_G$)

iii) The selfweight load is taken into consideration where heavy insulating materials are being used, such as foam up insulating materials on the inside of the fabric in order to reduce the loss of heat in winter and over heating in summer.

iv) The self weight load is calculated as follows ;

$$P_D = P_i - P_G \quad (3)$$

v) A safety factor (k = 1.0) should be used for deadweight load.

7.2.4.3 Wind load requirements

For dimensioning of an air supported structure, the load condition " Internal pressure and wind " is decisive. The membrane forces arising purely from wind pressure are generally greater than those caused by internal pressure.

i) The wind loading intensity Pw at a point is assumed to act perpendicular to the membrane surface and calculated by ;

$$P_w = C \cdot k \cdot Q \quad (4)$$

where C is aeorodynamic coefficient at the point ,

k is the safety requirements,

Q is the dynamic pressure of the wind. ($Q = \frac{1}{2} p.V^2$) (5.2.5)

ii) The back pressure(leeward side) pressure called (q) is dependent on the wind speed (V), the geographical position and profile of the form.

iii) P_i / Q ratio decreases when the profile of the pneumatic form decreases.

iv) The safety requirements of the wind is ($k = \frac{5}{2}$) for rural area applications.

$$P_w = C. \frac{5}{2} . Q$$

7.2.4.4. Snow loading requirements ;

The snow loading of a membrane is dependent on the geometry, the stability of the form of the membrane.

i) The internal temperature must not less than $12^{o}C$ if no snow will settle on the membrane.

ii) Snow loads reduce membrane tensions. A standard snow load of ; $P_s = 35\ kp / m^2$ is suggested, in buildings for temporary uses for calculation.

iii) Snow deposits over 10 cm high must be shaken off by varying the internal pressure.

iv) The minimum internal pressure, which prevents bulging is determined approximetly as ;

$$P_s \overset{\leq}{=} P_i$$

7.2.5. Production and Storage Requirements

7.2.5.1. Production requirements

i) The selected model should be tested in all possible conditions before the production.

ii) Selection of production centers and decisions on the production size are important design factors.

iii) A sub-organization for co-ordination and relalization of the whole production process should be established.

iv) Accessory equipment productions(fans, anchors, shields, access etc.,) must be provided for.

v) Organization and education of all continuous labourers for production should be planned.

vi) In the case of two or more alternative productions,the sub-parts must be standardized for economic reasons and for better service conditions.

vii) The production system design must be as flexible as possible in such a way that new prototypical production may be completed in very short period of time.

7.2.5.2. Storage Requirements

i) All produced parts of each unit must be packed together for disaster area applications.The packets,must be as compact and strong as possible for quick transportation.

ii) The dimensions of packets should be chosen in such a way that they can be transported with all vehicles.

iii) The packets should be designed for multi usage especially in the disaster area applications.

iv) Selection of storage centers and organization must be completed within the optimum distance to disaster prone areas.

v) An equipment park and services should be established within the optimum distance to storage centers and disaster prone areas.

7.2.6. Site Selection and Erection Requirements

7.2.6.1. Site selection requirements

i) After the disaster, the exterior spaces, such as streets, plazas gardens, courts etc. become more important. They must be prefered for the erection platforms.

ii) In the case of earthquakes, the erection site must be located near the settlement but it must far enough from the critical zones of the buildings.

iii) In the case of floods, the erection site must be located higher than the water level and it must be far enough from the danger zones of the flood.

iv) In the case of land slides, rockfalls and avalanches the erection site must be located far enough from the danger zones.

v) Excessive wind on the structures is undesirable and must be prevented.

vi) In order to be able to reduce the wind effect on the structure, it must be located in such away that the smallest profile of the structures are placed against the dominant windward side.

vii) The pneumatic structures must be placed in such away that the access of each unit are placed in the leeward side.

viii) The site planning of the units must be designed by taking into consideration of geographical characteristic of the disaster area.

ix) The remaining infrastructure is also the important decisive factor in the site selection concepts.

7.2.6.2 Erection Requirements

i) Organization and education of continuous constructor laborers for rapid erection must be completed in the predisaster period.

ii) The temporary pneumatic structures must be erected in 12 hours by two qualified and 2 unqualified persons.

iii) The anchorages systems must be completely fixed before the erection.

iv) The air stabilization equipment must be prefabricated and it must be constructed before the erection. .

v) The access equipment must be prefabricated and it must be constructed before the erection.

vi) The stabilization pressure must be quickly attained after the complete check have been fullfilled.

vii) The stabilization process must be completed when the internal pressure reached the desirable level.

7.2.7 Dismantling Requirements

The units must be carefuuly dismantled according to the logical order as follows :

i) Enject the stabilized air inside the membrane,

ii) Dismantle the access and other parts,

iii) Seperate the stabilization equipments

iv) Dismantle the anchorages systems and cables,

v) Fold the membrane carefully,

vi) Pack the parts according to the instructions.

CONCLUSION

There is serious effort by the Ministry of Reconstruction and Resetlement to solve the problem of temporary shelters. The widest usage of temporary shelters were shown in the Varto and Gediz earthquakes inwhich were used 16 different types of units partly built by the Ministry and partly donated by the international organizations. Instead of developing an efficient solution to the temporary shelter, the Ministry tries to solve the problem by temporary settlement of people in other cities. Many new social and the cultural adaptation problems exists result from this aim. There is no doubt that temporary resettlements are not fullfilling people's needs and the beliefes especially in Turkey.

As a definition, the temporary shelter has to fulfill the vital and functional requirements of the people during the rehabilitation phase. But in Turkey , the occupation of the temporary shelters lasts several years due to the long process of the completion of permanent houses completed. Also temporary shelters must be suitable to be demounted and mounted again another time in another place. Most of the time in Turkey, these shelters are built as temporary and after a while they become permanent.The erection or the construction of the temporary shelters is completed in the emergency phase that is determined by regulations. According to the Ministry, the production of the temporary shelters such as standard dwelling completed permanently in 4 or 6 months.

It is obvious that it is difficult to come to a desirable solution without solving the organization problems. The pre-disaster planing and the post disaster preaperdness are the most vital concepts of these organizations and these levels directly act to the after affects.

The design and development process of the favourable production system of the temporary shelters is only a part of predisaster planning. Then any individual solution to the problem of temporary shelters has no meaning without completion of the necessary organizations. It is more preferable to propose an appropriate technology than an individual design solution.

For countries like Turkey, primary attention must be paid to the development of temporary shelters. The design requirements have to be established as a result of the compromise between goals and the constraints The planning before the disaster must be systematically completed. Then the next step is try to figure out an appropriate high standard technology which fullfilles all necessary requirements. Proper design alternatives must exist before the production process is completed. In order to start to industrialized mass production, the location of production centers must be chosen by taking into consideration the factors of planning. The location of the storage enters should have to be established within the optimum distances to the primary disaster prone areas.

According to the mentioned requirements, pneumatics with high capacities and limitations in an appropriate solution to the temporary shelter problem in Turkey. All advantages and the additional features of the pneumatic technologies, which are criticised in this thesis, show that it can be an alternative solution to the disaster area housing problem especially in the first-aid and the rehabilitation periods. The production possibilities, flexibility, compactness, transportation quick-erection capacities, easy demountability, maintenance and the repairment qualities and with reasonble prices, etc., of the pneumatic technology are quite reasonable for the all temporary usages in disaster areas.

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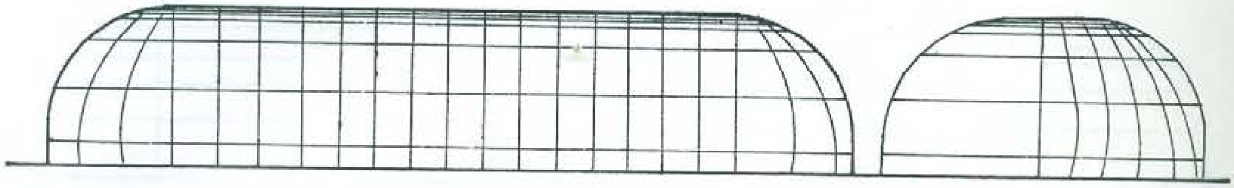
APPENDIX A

FIRM	Type	Surface Area	Usage
Turkiye Elektrik Kurumu , Cayirhan Termik Santrali	15 B	572 m^2	Sport Hall
Silahli Kuvvetler Temel Savas Beden Egitimi Ok.Kom.	13 B	526 m^2	Sport Hall
Istanbul Tenis Klubu,Macka Istanbul	13 B	526 m^2	Sport Hall
Beden Terbiyesi Bolge Md. Ataturk Genclik Sarayi Adana	13 B	526 m^2	Sport Hall
Bizim Tepe A.S Arnavutkoy Istanbul	14 B	549 m^2	Tennis Court
Ankara Tennis Klubu Ulus Ankara	15 B	572 m^2	Tennis Court
Hacettepe Universitesi Ankara	15 B	572 m^2	Sport Hall
Hava Harp Okulu Kom. Yesilyurt Istanbul	13 B	526 m^2	Sport Hall
Mehmet Koc Arslan Silivri Istanbul	15 B	572 m^2	Sport Hall
Essan Esans ve Tad Mad. San.veTic.Kagithane Istanbul	25 B	802 m^2	Factory
Turkiye Komur Isletmeleri Cayirhan Ankara	25 B	802 m^2	WareHouses
Turkiye Komur Isletmeleri Cayirhan Ankara	30 A	1469 m^2	Social Center
Ozel Dost Okullari Trabya Istanbul	13 B	526 m^2	Sport Hall
Mintax Deterjan Sanayii A.S Arnavutkoy Istanbul	9 B	433 m^2	Sport Hall

There are 20 applications of Pneumatic structures in Turkey. The list of applications and the some technical informations are above;

APPENDIX B

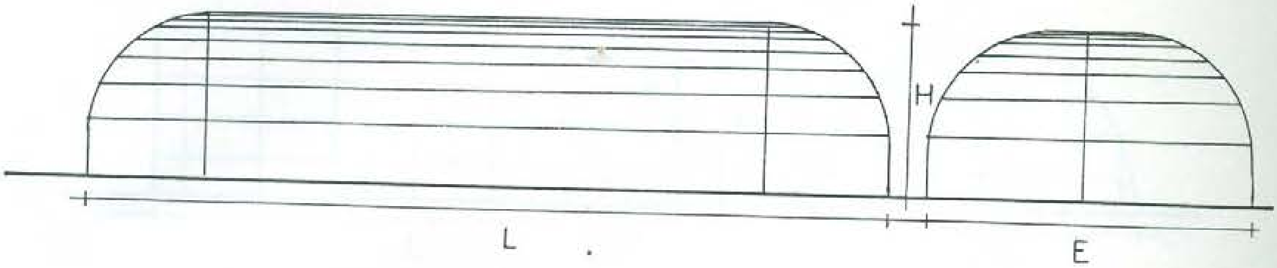
Type Name ; STANDART HALLS



Type	Width(m)	Length(m)	Height(m)	Closed Surface(m^2)
B	17.00	17.00	7.25	227
3B	17.00	21.05	7.25	296
5B	17.00	23.75	7.25	342
8B	17.00	27.80	7.25	411
10B	17.00	30.50	7.25	457
13B	17.00	34.55	7.25	526
15B	17.00	37.25	7.25	572
18B	17.00	41.30	7.25	641
20B	17.00	44.00	7.25	687
22B	17.00	46.70	7.25	733
25B	17.00	50.75	7.25	802

Dimensional specification of the standart Sport Halls produce in Turkey.

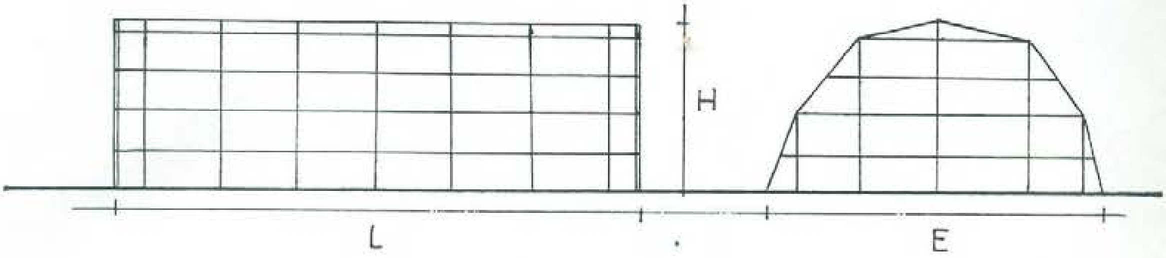
Type Name ; WAREHOUSES



Type	Width(m) E	Length(m) L	Height(m) H	Surface S	Volume V
A	24.50	25.54	8.90	479	2474
3A	24.50	28.59	8.90	578	3125
6A	24.50	32.64	8.90	677	3776
9A	24.50	36.69	8.90	776	4427
12A	24.50	40.74	8.90	875	5078
15A	24.50	44.79	8.90	974	5729
18A	24.50	48.84	8.90	1073	6380
21A	24.50	52.89	8.90	1172	7031
24A	24.50	56.94	8.90	1271	7682
27A	24.50	60.99	8.90	1370	8333
30A	24.50	65.04	8.90	1469	8984

Dimensional Specifications of the standart Warehouses produce in Turkey.

Type Name ;Polygon WareHouses(Hybrid Structures)



Type	Width(m) E	Length(m) L	Height(m) H	Closed Surface(m^2) S
5B	17.00	13.00	8.90	221
7B	17.00	17.88	8.90	304
9B	17.00	23.00	8.90	391
11B	17.00	28.11	8.90	478
13B	17.00	33.23	8.90	565
15B	17.00	38.35	8.90	652
17B	17.00	43.47	8.90	739
19B	17.00	48.58	8.90	826
21B	17.00	53.70	8.90	913
23B	17.00	58.82	8.90	1000
25B	17.00	63.94	8.90	1087

Dimensional specifications of the Polygon Warehouses produce in Turkey.