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Using an Inflatable Structure as a Temporary Shelter

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***Abstract* - This study examines the efficacy of pneumatic structures as temporary shelters during natural disasters and pandemics. Pneumatic structures are simple to construct and transport, do not require heavy or deep foundations to support them, and can span a long distance without the need for intermediate structural elements. It also investigates the structure's climatic suitability, which will be useful in selecting the material typology that will be suitable for our climatic conditions and how thermal comfort can be achieved inside the pneumatic structure. The goal of the study is to determine how it can be used in our context and what changes need to be made to suit it for our context.**

*Key word - **Natural disaster, Relief fund, ETFE, Pneumatic structures, Recyclable***

I. INTRODUCTION

A. Natural disaster

India has a record of being notably susceptible to natural disasters due to its particular geo-climatic environments. Landslides, cyclones, earthquakes, floods, and droughts have all been frequent occurrences. India is more vulnerable than other developed nations. High stream flows, which frequently have catastrophic consequences, overflow the rivers' natural banks to cause floods. Excessive rainfall in riverbeds and inadequate natural drainage are the major causes of floods. In recent years, population growth has compelled extensive settlements along riverbanks, increasing country density. The most common and frequently destructive events are floods.

B. The 2015 Chennai floods

Chennai is the fourth most populous city in India, housing 8,653,521 people. An official water release from the Chembarambakkam reservoir caused heavy downpours, forcing thousands of people to flee their homes. The Tamil Nadu state government reported that 1,716,000 people had been temporarily resettled in 6,605 flood relief camps, 600 boats had been mobilized, 12,294,470 food packets had been distributed, 26,270 medical camps had been held, and 2,565,000 people had been screened.

C. COVID-19

The prime minister of India declared a nationwide lockdown in March 2020 due to the COVID-19 virus. Migrant workers from other states have begun to relocate to their hometowns, and an accident near Aurangabad, Maharashtra killed nearly twenty people. 41 institutions have been given notifications to turn over their facilities to quarantine possible COVID-19 patients. When a person tests positive, they are typically confined to private facilities before being transferred to isolation units in hospitals.

D. Problems identified during a disaster

The built environment has been impacted by natural disasters, leaving many people homeless. Emergency shelters are used to provide temporary housing, but must be flexible, adaptable, cost-effective, and re-usable or recyclable. This study aims to identify which kinds of transitional shelters should be standardized above demands.

E. Issue generated during relocating people

The aftermath of a disaster in Chennai has caused delays and suspensions in essential services. People who have lost their homes must remain in temporary or emergency shelters,while their permanent homes are being rebuilt. The government must offer temporary housing while their homesare being rebuilt.

F. Disaster relief fund

The Central Government administers the National Disaster Response Fund, which is used to cover costs associated with emergency relief, disaster response, and disaster-related rehabilitation. It is analyzed from two angles: how it affects the public purse and whether it helps reduce population vulnerability and risk.

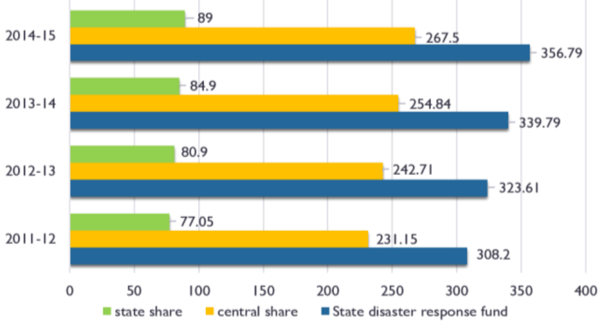


Figure – 1 State disaster response fund 2010 – 2015

https://agricoop.nic.in/sites/default/files/Guidelines%20for%20NDRF%26SDRF-100211.pdf

The annual allotments to the governments for disaster management during 2021–2022 are the same as they were for 2020–2020, but starting in 2022–2023, they are expected to rise by an average of 5% annually.

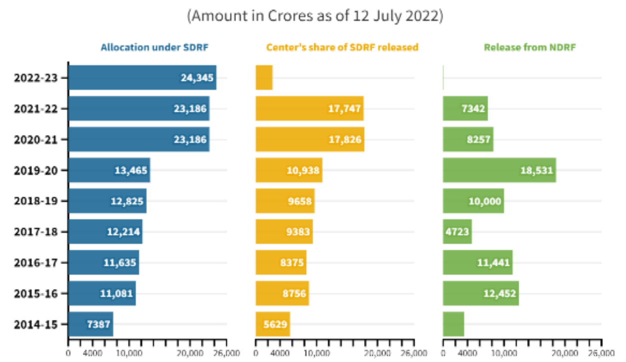


Figure – 2 Allocation and release of funds under SDRF & NDRF
Source - https://factly.in/explainer-what-are-the-disaster-relief-funds-sdrf-ndrf/

II. HISTORY AND BACKGROUND

A. Natural origin of pneumatic structure

The pneumatic structure idea was based on the soap bubble theory. When soap bubbles are blown, they are very light weight and they are blown up in the air, but when they come down and fall on a surface level, they stick to it, forming a dome shape.

The pneumatic structure idea was based on the soap bubble theory, which states that when soap bubbles are blown, they stick to a surface and form a dome shape. This air pressure stabilizes the membrane and gives shape and rigidity to the structure.

B. The Evolution of Pneumatic Structure

The word pneumatic is derived from the Greek word "pneuma" which means breath of air. It is used for protecting radar devices from extreme weather conditions such as snow, rain, and wind. In 1948, Walter Bird and his team achieved the construction of a 15m diameter large dome like air-supported pneumatic structures for protection of radar devices.

In 1970, a world expo was held in Osaka, Japan, where all the buildings and pavilions were made using these same structures. Numerous new techniques were followed to make them as good as possible.

C. General pneumatic structure principles

Pneumatic structures are light-weight structures stabilized bycompressed air, held in place with network cables, and can span long distances without intermediate support. They are portable and versatile, requiring less labor and lifting machinery each time they are used.

III. TYPES OF PNEUMATIC STRUCTURES

A. Pneumatic structure supported by air

Air-supported pneumatic structures are single membrane structures filled with air, providing stability and regular maintenance. They are anchored using ballast anchorage or ground anchorage systems, and require equipment such as blowers, airlock doors, compressors, and pumping motors. They can span huge distances without intermediate supports and be easily erected and dismantled.

Functions of air supported pneumatic structure

Air-supported pneumatic structures are used to cover playgrounds, football grounds, basketball courts, exhibition spaces, outdoor camps, and display structures from environmental factors such as rain, wind, heat, and snow.

Types of air-supported pneumatic structures

There are two basic types of air-supported pneumatic structures:

- High profile structure
- Low profile structure

B. Air-inflated pneumatic structure

Air is pumped in between two membranes of the fabric to inflate the structure to the desired shape. Openings can be given wherever needed, and it does not require air locks or revolving doors for protection. Numerous forms and shapes can be made using an air-inflated pneumatic structure. Materials such as ETFE, PVC, and nylon can be used for the membranes.

Functions of an air-inflated pneumatic structure

Air-inflated pneumatic structures can be used for inflating small-scale objects to large-scale structures. They are used for partition walls, inflating kids' playthings, making air- inflated bridges in the military, making air-inflated shelters and medical camps, and making large structures such as roofsof large stadiums, pavilions, and aero hanger structures. Theycan be easily erected and transported from one place toanother.

IV. CONSTRUCTION METHODS AND TECHNOLOGY USED

A. Anchorage system

The anchorage system is an essential part of pneumatic structures. The entire structure stability mainly depends on the anchorage system.

For an air-supported structure, it mustbe firmly attached to the ground around the entire perimeter of the structure. The anchorage has the task of conducting tothe foundations the vertical and horizontal forces carried by the members.

These forces result from the internal positive or negative pressure and the external loading.

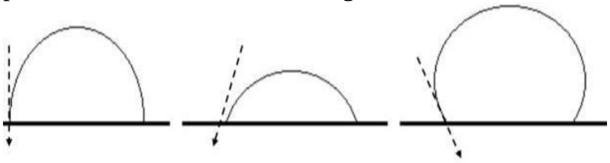


Figure- 3 Force components at the membrane edge
Source - Thomas Herzog (1976) page no 116

Two major types of anchorage systems are followed. They are

1) Ballast anchorage
2) Ground load anchorage

1) Anchorage for ballast

Ballast anchorage is also known as positive ground anchorage ballast anchorage is a satisfactory method of securing an air supported pneumatic structure to a deck, the anchor loads uniformly to the envelope so that excessive stress concentrations will not occurs.

There are different typesin which ballast anchorage can be done. They are

- Anchorage with sand bags
- Barrels filled with gravel or sand
- Tanks filled with water
- In situ concrete strip
- A metal box filled with stones
- recast concrete parts

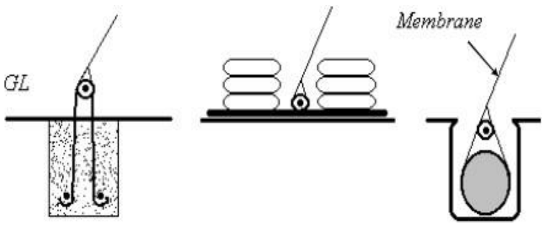
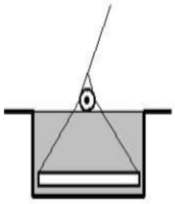
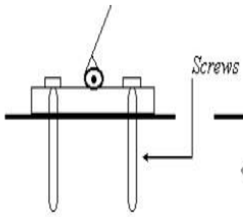


Figure – 4
Source - study and adaptability of pneumatic structures

2) Ground load anchorage

In a ground load anchorage system, the load of the earth is utilized for anchorage by inserting or placing instruments into the earth. Anchor plates are made of steel or reinforced concrete and have enough rigidity to resist torsion stress and buckling. Screw anchors are cheap and can be moved with simple equipment and machinery.





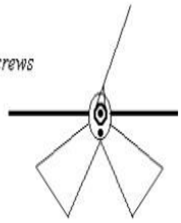


Figure - 5 Anchor plates *Figure – 6 Screw anchor* *Figure -7 Driven in Anchor*

Source - study and adaptability of pneumatic structures

B. Cables

a) Cables are an important part of the construction process because they help to position the structure and prevent it from moving due to external wind loads.
b) Cables will connect with the anchoring system for proper structure anchorage and will distribute load to the anchoring system.
c) The size and number of cables will vary depending on the structure's size and span.
d) Some of the essential properties that the cable must have in order to have a good and long lifetime are as follows:

- Low weight
- Resistance to corrosion and abrasion
- High flexibility
- Good stretch and rotational behavior.

C. Membranes

Pneumatic structures are the major parts of pneumatic structures. There are many different types of membranes that are used as roofs in pneumatic structures. They include fabric materials, hyperplastic materials, and composite materials. Membranes will give the pneumatic structure its rigidity and form. They are the outer envelope of the pneumatic structure. Different types of membranes will have different behavior.

Membrane cutting pattern

Cutting patterns are important for designing membranes and fabric of pneumatic structures. There are some problems when cutting membrane materials, such as a shortage in the length of materials. If two membranes are to be joined, an overlap of 2-4 cm is required to ensure proper expansion and stretch ability. Overlaps are formed by localized linear reinforcements of the skins, which can lead to a reduction in the radius of curvature of the skin.

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D. Jointing Methods

There are two kinds of joints that are used to connect the components of a pneumatic structure; they are

1) Inseparable joints
2) Separable joints

1) Irreversible joints

Inseparable joints are done for strong fixing of the membrane. It cannot be separated once it is fixed. The main features of using inseparable joints are strength equal to that of the skin material. As much flexibility as possible so that no kinks or break points occur in inflating and deflating the envelope .In low relief so that there is little susceptibility to meteorological factors, inseparable joints are produced by using the following technique:

- Sewing
- Cementing
- Vulcanizing
- Welding
- Riveting
- Clamping

2) Disconnect able joints

A separable jointing technique is also required for some of the cases. to insert movable parts into a section of an envelope. To separate a large envelope into parts suitable for transport and erection. to achieve a compound structural effect with individual pneumatic parts. Separable jointing can be done with the help of the following techniques:

- Zip fasteners
- Press fasteners
- Lacings
- Peg joints
- Metal springs
- Clamp joint

E. Pneumatic structure access construction

Normally, rigid conventional doors are used in buildings, but such rigid conventional doors cannot be used in pneumatic structures. Some of the special types of doors that must be provided for pneumatic structures include

For air-supported pneumatic structures, special doors areused for preventing the leakage of air from the structure. Different types of air-lock doors which are used in air- supported pneumatic structures are

- Trap door
- Lip door
- Cushion door
- Revolving door
- Door that is airtight

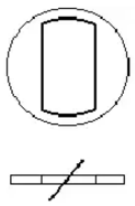

Figure - 8
Trap door

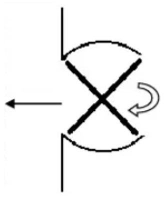

Figure -9
Revolving door

Figure -10
Lip door

Source - study and adaptability of pneumatic structures

F. Mechanical apparatus

Mechanical equipment such as fans, blowers, and compressors which are used for pumping the air inside the structure is necessary. The fans which are used here are working in different directions, so which typology is required? Such a type is usedfor inflating the structure.

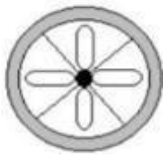

Figure - 11
Axial fan

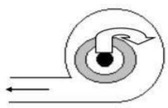

Figure-12
Radial fan

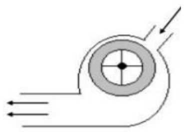

Figure - 13
Tangential fan

Source - study and adaptability of pneumatic structures

- An axially working device
- Tangentially working devices
- Radially working device

1) Blowers

In blowers, slightly higher pressure can be produced than in fans. The best yield is offered by circulating displacement blowers, in which no internal compression develops.

2) Compressors

A compressor is used to increase internal pressure and maintain a higher air temperature. Rules for conventional air-supported structures must be followed, with two or more blowers and no snow collecting in the area of fan intake. Injection pressure should be just above internal pressure.

G. Accessory equipment is required for the pneumatic structure.

Air-supported structures require equipment to be suspended from the fabric envelope, which must be reinforced or designed to avoid stress concentrations

1) HVAC system
2) Lighting system

1) Heating and cooling system

It is required for large projects because to maintain a comfortable temperature inside the structure by maintaining constant ceiling to floor temperature, resulting in decreased demand for heat, the entire system is assembled and contained in an insulated exterior housing. It should be protected from the weather.

2) Lighting design

It is also an important pneumatic structure. There are two types of lighting systems which are used as per the requirements of the structure and for the purpose for which it is built.

V. CASE STUDIES

A. Fuji Pavilion, Osaka, Japan in 1970

The Fuji Pavilion in Osaka, Japan was the largest multi-membrane structure ever built. It consisted of 16 arched tubes with a diameter of 4m and a length of 78m, whose bases defined a circle with a diameter of 50m

The tubes were held together at 4m intervals by an encircling horizontal band of 50cm in width. The center arch was semi-circular and the others arched higher and higher as their bases came closer together. The exterior was coated with Hypalon and the interior with PVC. The lower ends were anchored in steel cylinders. The internal pressure was normally 1000 mm of water pressure and 2500 mm in storm conditions. All tubes were connected to a central turbo compressor by means of a peripheral system of steel pipes.


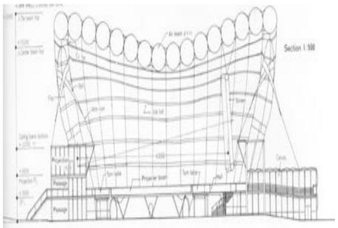

Figure - 14 *Figure -15*

Source - https://www.tensinet.com/index.php/projects-database/projects?view=project&id=3765

B. Ricoh Pavilion

The light source of 300 electronically controlled lamps was installed inside a luminous yellow balloon at the World Expo in 1970. It had a linear anchoring of cables and membrane ribs to give it its characteristic shape and reduced the radii of curvature. The balloon was drawn in by means of winches and is a temporary structure that can be easily transported to another place.


Figure - 16 *Figure – 17*

https://www.ricoh.com//Media/Ricoh/Sites/com/about/company/history/pdf/1970_1984/197003.pdf

C. Air Forest in Denver, Colorado (USA)

This temporary pavilion was created for Dialog City, an arts and cultural event in Denver, Colorado, USA There are about thirty-five columns which are inflated by blowers at the base.

The 56m long and 25m wide pneumatic structure absorbed passing wind currents to maintain its 4m high array of nine hexagonal canopies. The membrane was made up of nylon and coated with a gradient of reflective silver dots that mirrored its surroundings, casting a playful shadow pattern and emanating an iridescent speckled glow when illuminated at night.

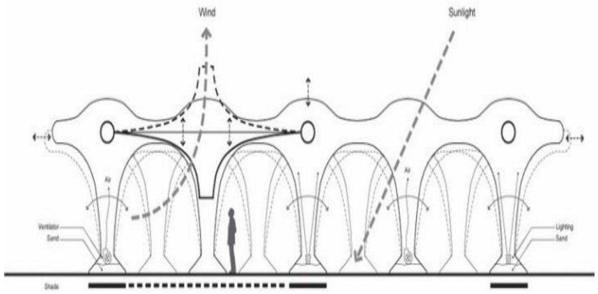

Figure-18 https://www.archdaily.com/tag/inflatable-structures

D. Inflatable domes for coronavirus patients

Colombian architects have created mobile, inflatable coronavirus patient chambers that can be set up in gyms or parking lots. Each dome is 5 meters (16 feet) wide and has space for two patients. Designers from around the world have created additional inflatable or pop-up structures to handle the influx of COVID-19 patients. The version used at La Salle University in Bogota costs about $15,000 and has eight interconnected spires that can accommodate 16 patients. Three sets of spires have already been delivered to cities in Colombia, and the university has so far produced 12 sets.


Figure - 19 *Figure – 20*

Source - https://www.dezeen.com/2020/03/31/sheltair-gregory-quinn-coronavirus-isolation-pods/

VI. MATERIAL AND CLIMATE ANALYSIS

A. Tropical Climate Characteristics

Chennai has a humid and dry tropical climate, with an average high temperature of 35.13 degrees Celsius and a typical low temperature of 22.29 degrees Celsius. Most of the year is spent in warm, humid weather. The northeast monsoon season is when the city experiences the majority of its rainfall, and storms and rains are occasionally brought by tropical cyclones in the Indian Ocean.

B. Material analysis

The performance of an air-supported structure is most impacted by the structure of the membrane. Low-pressure inflatable systems are supported by mild temperatures and high humidity levels, making it easy to attain adequate internal comfort parameters. Environmental factors such as temperature, humidity, heavy precipitation, breeze, and solar radiation influence how low-pressure inflatable systems behave. Recent advances have been made in regulation of solar radiation and natural lighting, with new materials like ETFE having high levels of sunlight and UV absorption and self-cleaning capabilities.

C. ETFE Material

ETFE, or ethylene tetrafluoroethylene, is a synthetic fluoropolymer that has a good reputation as a building material. Some of the properties of ETFE materials are discussed below.
Flame resistance Fire tests have been done to check the resistance of the material. The ETFE films seem to be translucent, so when installed, they will provide the good ventilation to the building's interior, reducing the expense and energy required for additional lighting.

USE OF ETFE IN CONSTRUCTION TECHNOLOGY
Depending on the structure's needs for insulation, lighting, and aesthetics, ETFE can be managed to install over it.

SINGLE LAYER
In this instance, a single layer of ETFE is installed, connected to the main structure, and reinforced with wire cable, aluminum, or light steel.

VII. DISCUSSION AND CONCLUSION

A. Inferences and discussion

In places like Chennai, good ventilation is required, so the main advantage of using an air-inflated pneumatic structure is that openings can be provided wherever they are needed, and it also provides some thermal insulation inside the structure due to the air cavity present in between the membranes.

Due to ETFE's transparency, which allows daylight to enter the structure during the day, it can be used as a membrane material for an air-inflated pneumatic structure in our context. On the membrane's outer layer, reflective silver dots are used to reflect sunlight that strikes the building.
Thin solar foil can also be used on the top membrane of an air-inflated structure because it can generate electricity from sunlight that falls on it.

The hang light or stand light can be used to provide services such as electrical service to the structure, or if the membrane is transparent, light can be fixed inside the membrane itself so that when it glows at night, the entire structure looks elegant and becomes an attracting feature.

Distances without the need for intermediate supports, and can be easily The stack effect, in which hot air rises and coldair enters from the bottom, can be used to reduce humidity inside the structure, the structure should be designed to allowfor this movement of air so that humidity can be reduced inside the structure. ETFE membrane is water resistant, it can be used on the structure during the winter season as well, and the structure will not deteriorate due to moisture and weather.

B. Conclusion

The foregoing and an examination of pneumatic structures, including their types and the materials utilized in their construction, make it very clear that they are the ideal structures for developing emergency shelters. They are suitable in terms of price, design, and purpose, and they are simple to assemble, transport, and install. Additionally, they can be recycled and have a long life expectancy of several years.

Pneumatic structures can be constructed from a variety of materials, depending on their fire resistance, heat, cold, wind, and snow load resistance, as well as their ability to withstand environmental conditions. It will reduce the impacts to environments during the construction of the structure.

These structures are ideal for use in Chennai during a disaster because ETFE materials can also be used to their advantage. Each type has a unique set of characteristics that define it. Supporting wires are occasionally added to increase resistance, but they require fans for constant air support to provide an air pressure that is slightly higher than the airflow in order to maintain their stability and shape.

As for the high-pressure structures, they are tubular in shape and are either single, interconnected, or continuous, where the air pressure supports the structure in obtaining the required shape and resisting the loads imposed on it.

The research recommends the use of pneumatic structures by the concerned government agencies for accommodation and resting places for large areas according to a clear plan and specific places to preserve cities

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