Structural System in Architecture

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Lecture No -36

Special Structures

Welcome to the NPTEL online certification course on structural systems in architecture. This is the 36th lecture and this is the first lecture of the module 8 or the week 8. And this lecture's topic is Temporary Structures.

Concepts Covered

- Tensigrity
- Pneumatic Structures
- Floating Structures
- Folding Structures
- Cost Effective Building Technology: Filler Slab

Learning Objectives

- Discussing the structural principles and application of various temporary structures.
- To outline the filler slab technology applicable as cost effective building technology.

Tensegrity

- Tensegrity is a special type of structural system comprising of elements subjected to tensile and compressive forces. The word 'Tensegrity' can be break into **Tension** + **Integrity**.
- It is one of the fundamental kind of structures, which was introduced in 1960s by the master Architect **Buckminster Fuller**.

- Tensegrity is a special kind of arrangement where the tensile and the compressive forces are actually neutralize with each other.
- The structural principle of Tensegrity is based on the following two simple criteria:

i. A system of isolated compression members or discrete compression members.

ii. A continuous network of tension.

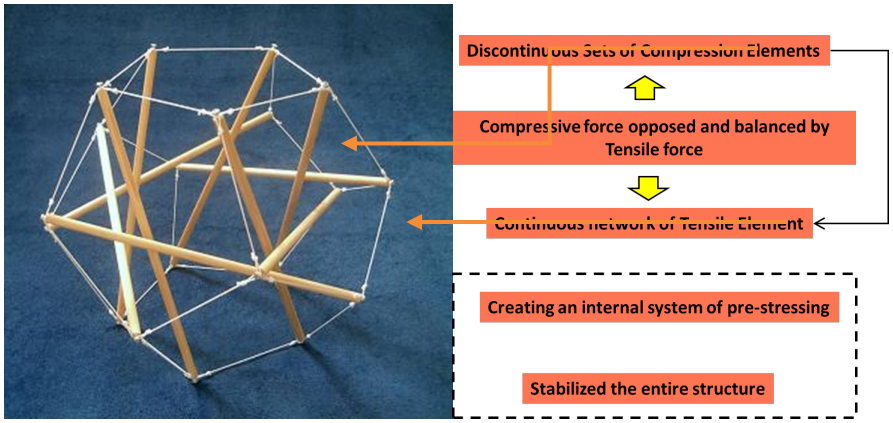


Figure 1 Tensegrity Concept

- **Kenneth Snelson**, a contemporary artist who was also a disciple of Buckminster Fuller had created so many structural elements and demonstrated the tensegrity structural forms through his constructive art form. His artwork is installed in various public buildings and parks.

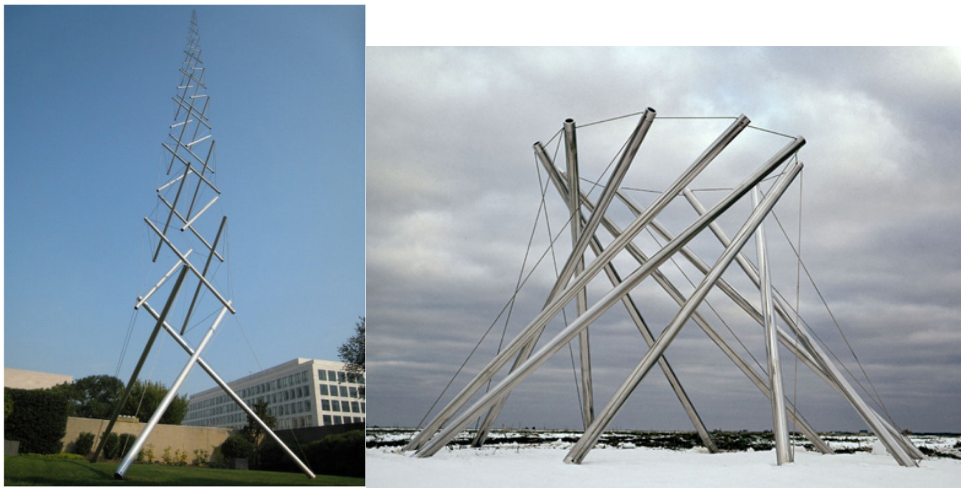


Figure 2The Needle Tower, Washington, USA

Structural Examples

Kurilpa Bridge, Brisbane

- Kurilpa Bridge is the world's largest hybrid tensegrity bridge.
- Only the horizontal spars conform to tensegrity principles.
- The Kurilpa Bridge is a multiple-mast, cable-stay structure based on principles of tensegrity producing a synergy between balanced tension and compression components to create a light structure which is incredibly strong.
- Members are loaded either in pure compression or pure tension.
- Pre-stressed tension cables allow the whole system to maintain the structural integrity.
- The structure becomes stronger as it is loaded.
- Due to the configuration of the structural elements, no member experiences bending moment and shear force.

Figure 3Kurilpa Bridge

Photo Source:https://www.arup.com/projects/kurilpa-bridge

Pneumatic Structures

- Pneumatic Structure is a type of tensile membrane structure.
- The system component of Pneumatic Structure is supported by air, in the same manner that of a balloon.
- The tensile stress in the membrane is executed by internal air pressure.

Structural Principle

- Air higher than the atmospheric pressure support the envelope.
- Air locks or special types of doors help maintaining the internal pressure.
- A support system is required to maintain the continuous air pressure
- The structure is anchored to the ground.
- Every precaution is taken to stop any air leakage.

Classification of Pneumatic Structure

Pneumatic structures on the basis of **nature of support system by high air pressure**can be majorly classified into two types:

- Air Supported Pneumatic Structure
- Air Inflated Pneumatic Structure

Pneumatic structures on the basis of **Profile** can be classified into two types:

- High Profile Pneumatic Structure
- Low Profile Pneumatic Structure

Air Supported Pneumatic Structure

- Air is introduced inside the **single layer** flexible membrane profile higher the atmospheric pressure.
- Under the high air pressure flexible membrane inflated to the given shape.
- The membrane produce tensile stress.
- Supporting cable system stabilizes the tensile stress created by the membrane.
- Finally the cable system is attached to the foundation to transmit the loading.

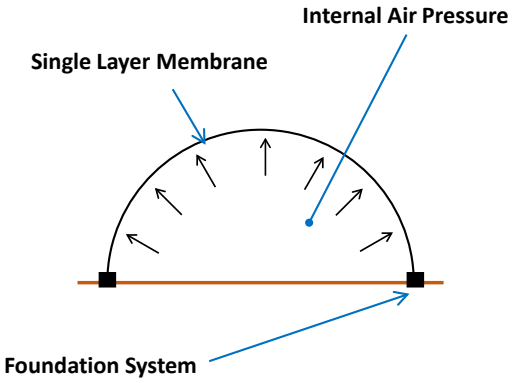
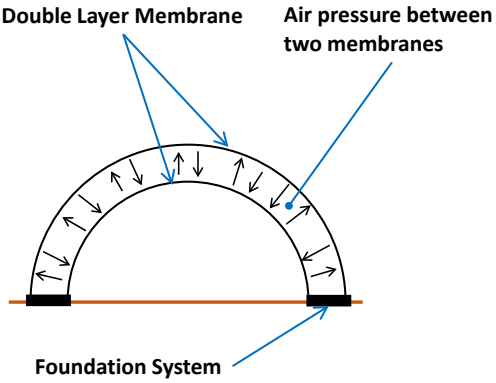


Figure 4Single Layer Pneumatic Structure

Air Inflated Pneumatic Structure

- Air is introduced inside the double layer flexible membrane profile higher the atmospheric pressure.
- The stiffener members (metallic plate) are also attached to specific locations.
- Under the high air pressure flexible membrane and stiffener positions are inflated to achieve the given shape.
- The double layer membrane produce tensile stress.
- The double layer system can be used as roof covering directly.
- Otherwise supporting cable system stabilized the tensile stress created by the membrane.



- Finally the cable system is attached to the foundation to transmit the loading.

Figure 5 Double Layer Pneumatic Structure

High Profile Pneumatic Structure

- It is a freestanding structure.
- The cover membrane is connected to a foundation system.
- It is mall in size.
- Whole system integrate to a bulky voluminous individual building form.

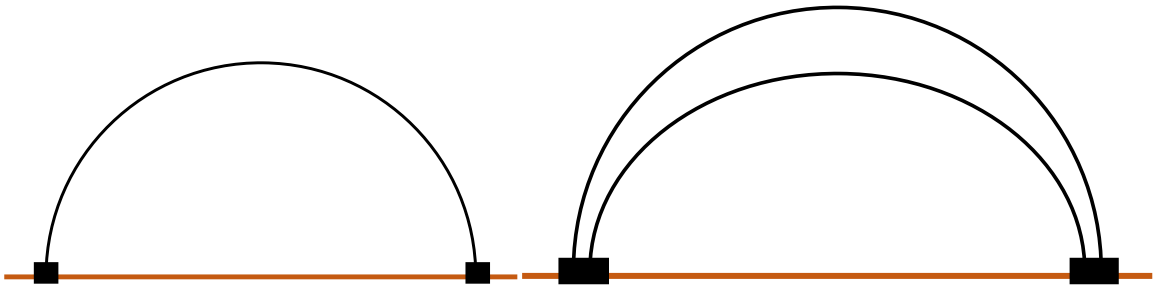


Figure 6Pneumatic Structure

Low Profile Pneumatic Structure

- It is mostly used as roof covering only.
- It is used for greater span and to cover large arenas like sports complex.
- Large in size.
- It is connected to other structural system to distribute the load.
- It is not connected directly to the foundation.

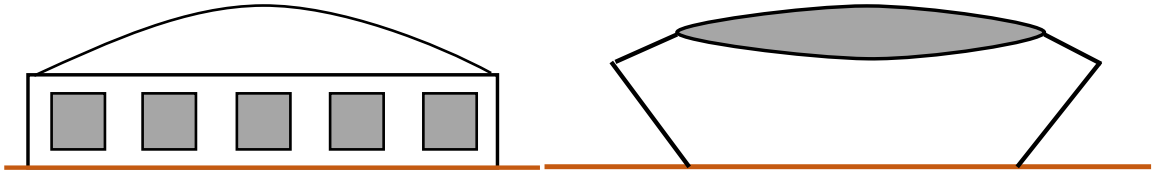


Figure 7 Low Profile Pneumatic Structure

Component of Pneumatic Structure

- **Cover Membrane**: Which generates the roof form and decides the shape of building.
- **Supporting Cable**: It stabilized the tensile action and transfers the load.
- **Ground Anchorage System**: It transmits the load to the foundation and ground.
- **Air Pressure and ventilation Control System**: It maintains the internal air-pressure in order to keep the basic shape intact.

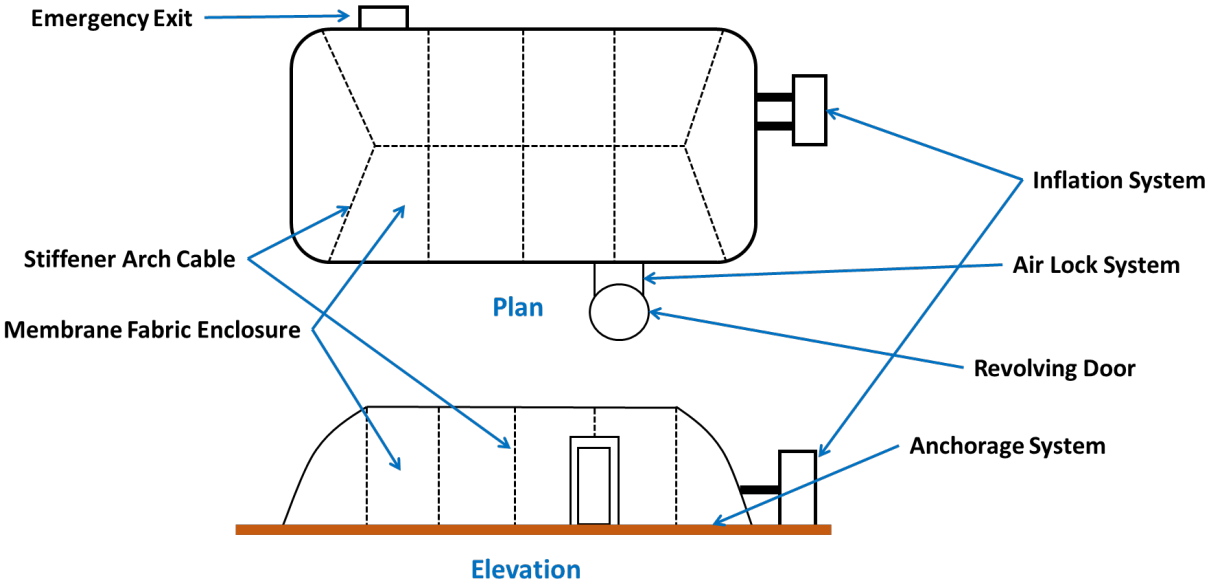


Figure 8 Component of Pneumatic Structure

Advantages of Pneumatic Structures

- Pneumatic Structure is light weight.
- It can support a wide span.
- The cost of construction is low.
- The erection and dismantling operation can be executed rapidly.
- The pneumatic roof can allow good amount of daylight penetration.
- The structure is safe.
- Pneumatic structures are best for short term use.

Disadvantages of Pneumatic Structures

- Pneumatic Structure cannot take live loads.
- The profile of Pneumatic roof is mostly curvilinear.
- It can be used for only single floor application.
- It can't withstand high wind load.
- It has relatively short life.

Application of Pneumatic Structure:

There are various applications of pneumatic structures some of them are listed below

i. Sports arena
ii. Recreational centres
iii. Military structures
iv. Emergency Disaster Management application
v. Storage of food and medicine
vi. Green houses and Horticulture
vii. Botanical Gardens
viii. Zoological Parks
ix. Exhibitions
x. Convention centres
xi. Survey Camps

Floating Structures

- Floating Structures are applicable in some special areas having specific requirement.
- This type of structures are constructed in marine environment.
- The special structural system allows the structure to float as per the level of water.

Structural Principle

- It should have a floating foundation system.
- The super structure load is balanced by buoyancy.
- The super structure should be light weight.
- Reduction in live load.

- Float control adjustable mechanism should be adopted in the structure.

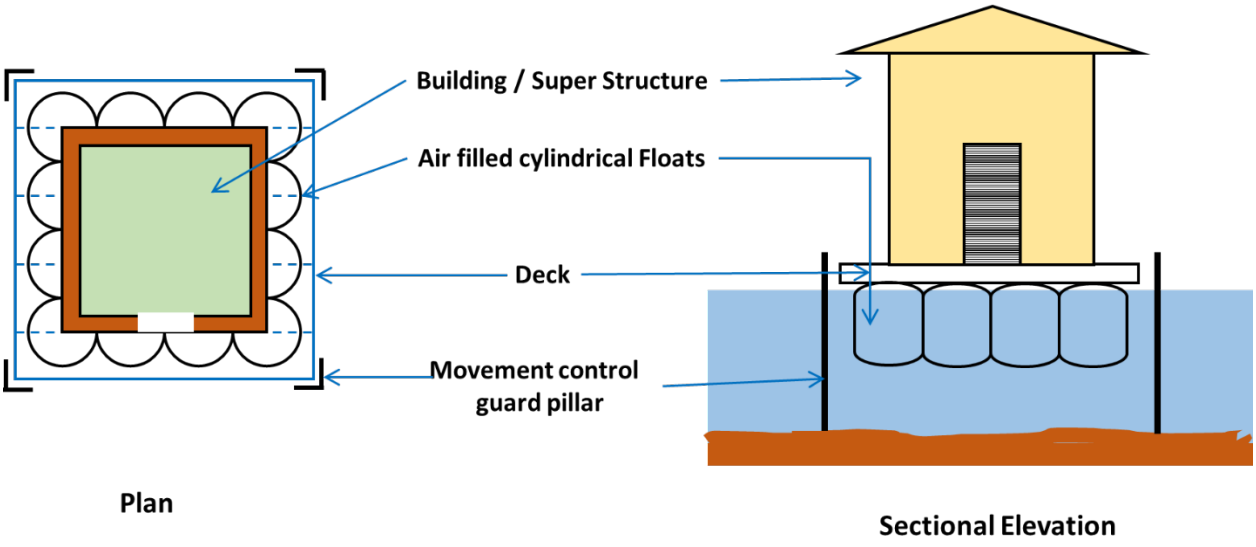


Figure 9 Floating structure where water level is steady

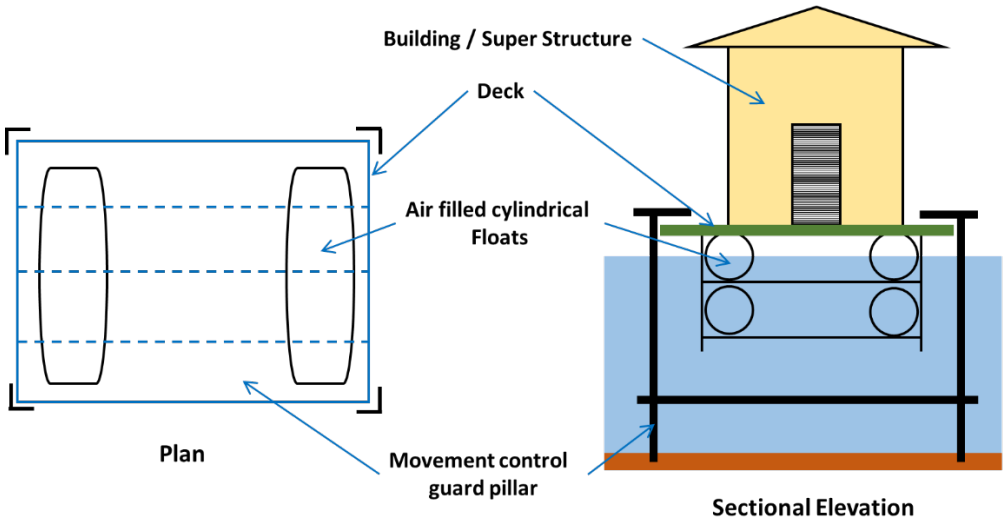


Figure 10 Floating structure where water level varies

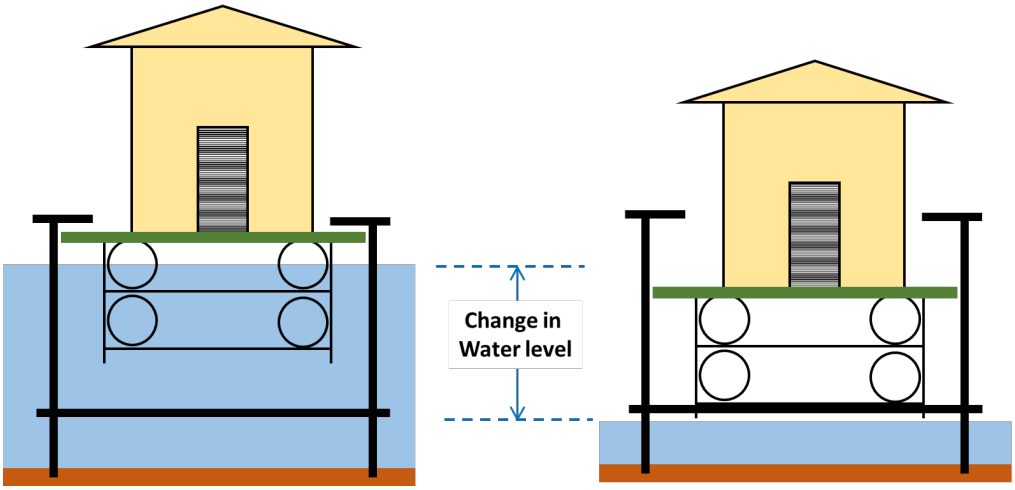


Figure 11 Change in water level

Application of Floating Structure

- Housing in the water logged area.
- Housing in the flood prone area.
- Water sports and recreation.
- Military structures.
- Emergency Disaster Management application.

Folding Structures

- Folding Structures are applicable for specific requirements.
- Folding structures are mostly mobile.
- This type of structures are constructed in small scale.

Structural Principle:

- The structural system adopts mechanical arrangements.
- The super structure should be light weight.
- It should be of modular type.
- Special design consideration should take for transportation of the structures.

Working Principle:

- The entire structure is divided into various identical modules and these modules have designed in a way that it can be folded into a very lesser form.These forms now can be transported in trucks and lorry to the desired destinations.
- At the destination these forms now can be expanded to the designed shape and form.

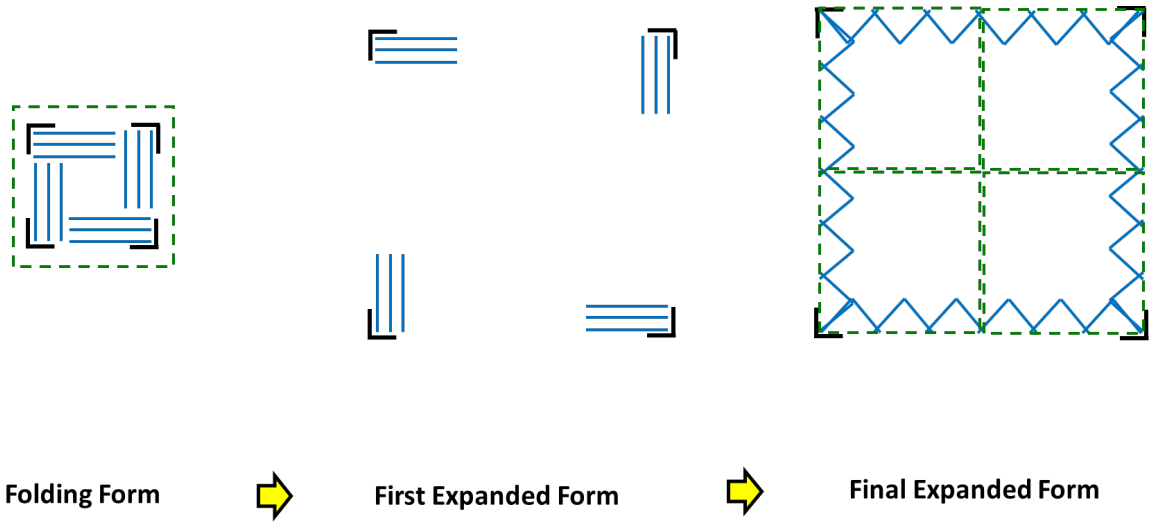


Figure 12 Folding wall structures

Applications of Folding Structures

- Road side shops
- Medical assistance in rural areas
- Temporary structures in fair and public gatherings
- Movable toilets
- Emergency Disaster Management application

Cost Effective Building Technology: Filler Slab

- The filler slab a technology developed by the Architect Laurie Baker, and widely practiced in Kerala, and then other parts of the country.
- This technology is based on the principle that for roofs which are simply supported, the upper part of the slab is subjected to compressive forces and the lower part of the slab experience tensile forces.

- Concrete is very good in withstanding compressive forces and steel bears the load due to tensile forces. Thus the lower tensile region of the slab does not need any concrete except for holding the steel reinforcements together. Therefore in a conventional RCC slab lot of concrete is wasted and it needs extra reinforcement due to added load of the concrete which can otherwise be replaced by low-cost and light weight filler materials, which will reduce the dead weight as well as the cost of the slab to 25% (as 40% less steel is used and 30% less concrete).
- The filler slabs also result in fewer loads getting transferred to the load-bearing walls and the foundations.
- The air gap in between the tiles makes it a good heat insulator and the ceiling looks attractive as well.

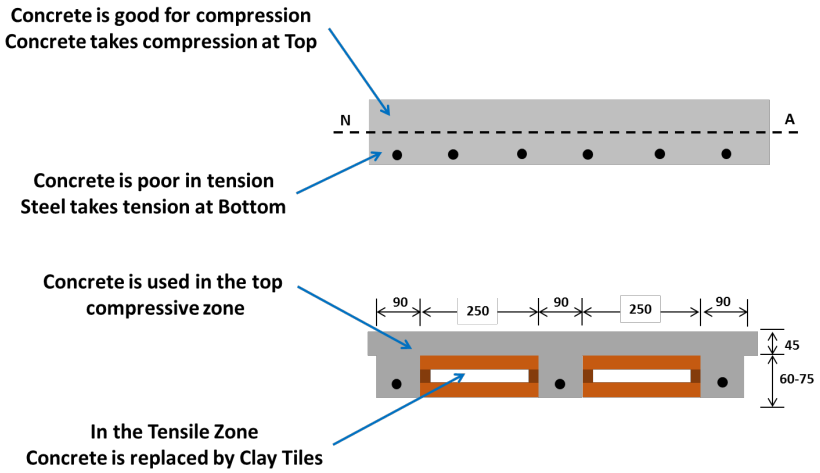


Figure 3 Working Principle of Filler Slab

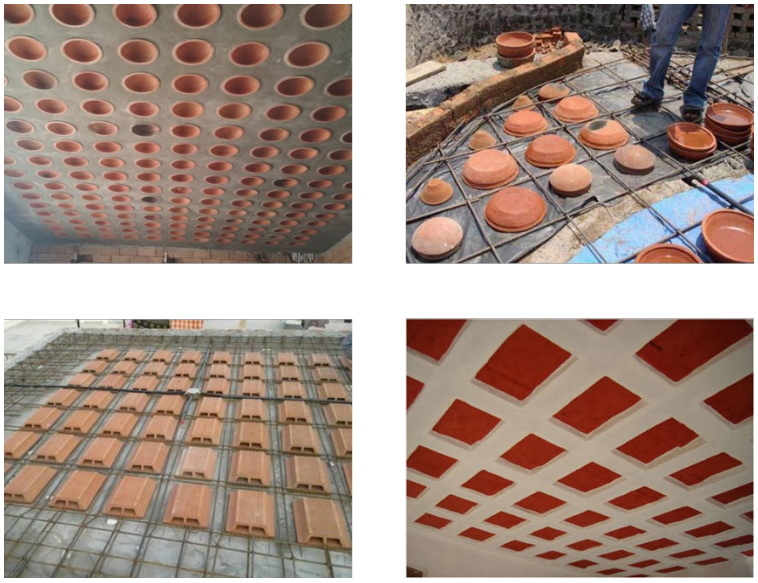


Figure 14 Examples of Filler Slab

References

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Conclusion

In conclusion I'd like to state the following:

- Pneumatic, floating and folding structures are essential and applicable in various requirements.
- They are designated as a temporary type of structure.
- Filler slab can provide cost effective solution.