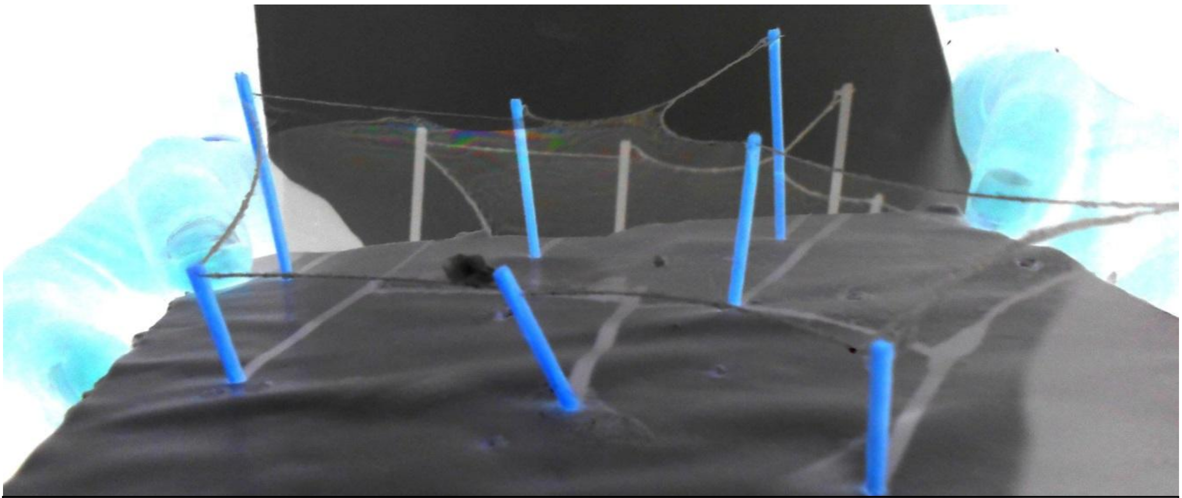
Soap Film Modelling: A form finding experiment

*Students of Architecture experiment with minimal surface technology of soap films "**doing more with less**"*



Form Finding for Tensile Architecture

- Ar. Shreya Sen

" A building is like a soap bubble.
The bubble is perfect and harmonious,
if the breath has been evenly distributed from the inside.
The exterior is the result of an interior."

- Le Corbusier

Introduction

Architecture in the decades to come will be *light, dynamic, thoughtful and "UNIQUE"*. This uniqueness would be as much a result of the exterior form as it's Interior function. So, how do we bring about this uniqueness? "We **Experiment**".

As a practicing faculty interacting with first year students of Architecture it was observed that the learning curve was greatly affected by experimental modelling in the foundation years. This research paper elaborates on a hand on workshop for the purpose of Form Finding through Soap Film Modelling for Tensile Architecture.

Form finding

The geometry of Tensile surface structures can be determined by Form optimization methods. The aim of this form finding process is to achieve a form that is in equilibrium with the given distribution of stresses, i.e. prestress in the surface within the geometrical boundary conditions [1] .

EXPERIMENTAL FORM FINDING

It was during the 1950's that Frei Otto developed the engineering principles for building with membranes. The form finding methods of those days were purely experimental. Physical models made from stretched rubber, fabrics, nets and **soap films** were used to create forms that were in equilibrium.

IMPORTANCE OF SURFACE TENSION : MINIMAL SURFACES

From a mathematical point of view, Soap films are considered as minimal surfaces.

Surface tension which measures the energy needed to create a surface indeed acts as a physical surface minimiser; since surface energy is proportional to the soap film surface, the film deforms to minimize it's surface and thus it's energy [2]. In the 1970's Otto observed that given a set of fixed points, soap film will spread naturally between them to offer the smallest achievable surface area [3]. Thereby resulting in an optimum design reducing the amount of wastage "Doing more with less". In 1974 the german born civil engineer Horst Berger, working in the U.S. came up with the maths that allowed the process to be translated into building structure [3].

Depending on the support provided, the soap film naturally takes the minimal surface, i.e. On a flat support, the soap film is usually flat, whereas on more complex surface geometries, it takes the minimum achievable surface as seen in the image above. Such forms resulting out of form finding experiments are extremely precise and with following photogrammetry can be used for further processing within the design process.

SOME EARLIEST MINIMAL SURFACES

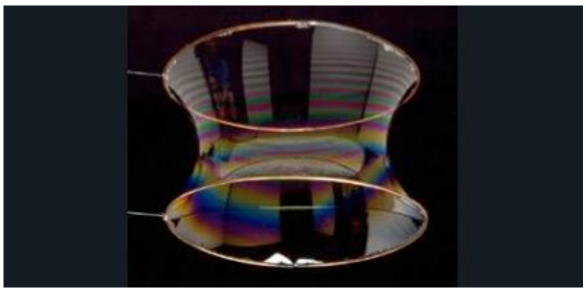


Fig 1 : Catenoid form
Source : http://soft-matter.seas.harvard.edu/index.php/Soap_films

Costa, Catenoid and Helicoid are some of the earliest minimal surface forms [4]. Catenoid is the shape that minimizes the area of soap films between two circular wands [Fig. 1]. The study of Soap films has been a common research area for both scientists and mathematicians alike. Frederic Braz in his research paper denotes the physical form finding approach as "***Dynamics***" & mathematical approach as "***Statistics***" [4] . In this paper we will be exploring the dynamics of soap film modelling which elaborates on the experimental forms generated.

Fig 2 : Helicoid form [Left] & Costa form [Right]

Source : Author

Methodology of the workshop

The workshop stressed on the physical form finding process as it would be easily understood by students of the first semester. The reason being that with a physical rather than digital model, we not only have a shape of the object designed but also get a vague idea of it's structural behaviour through elementary empirical tests that can be carried out on it.

An experiment with soap films

The brief given to a group of 30 [Sem I] architecture students was to create an interesting framework [support] for the soap film model with either thread and toothpicks or copper wire on a 15 cm square base. The design strength would be tested on the durability of the delicate film on the support structure as well as the photographic documentation of changing film as it reforms to adapt to a change in the support framework [Fig. 3]. By default covering the minimal surface within the specified framework. A step by step workshop proceedings is elaborated below.

Stage 1 : PREPARING THE SOAP SOLUTION

A soap solution was prepared in a wide rimmed bucket by proportionally combining water, dishwashing liquid and glycerine, with the concoction being regularly tested by a sample framework for the durability of the soap film so generated [Fig 4].

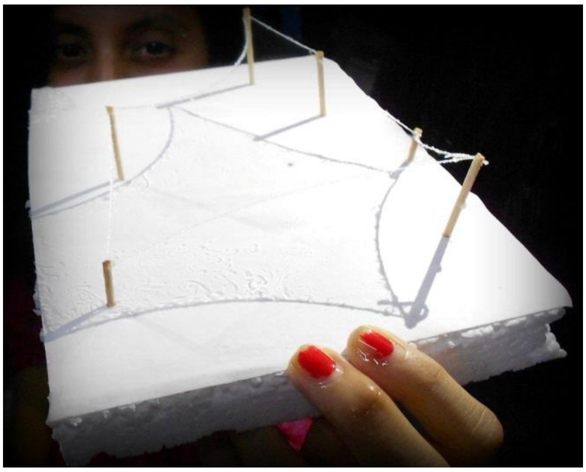


Fig 4 : Demonstration model used for testing the soap solution
Source : Author

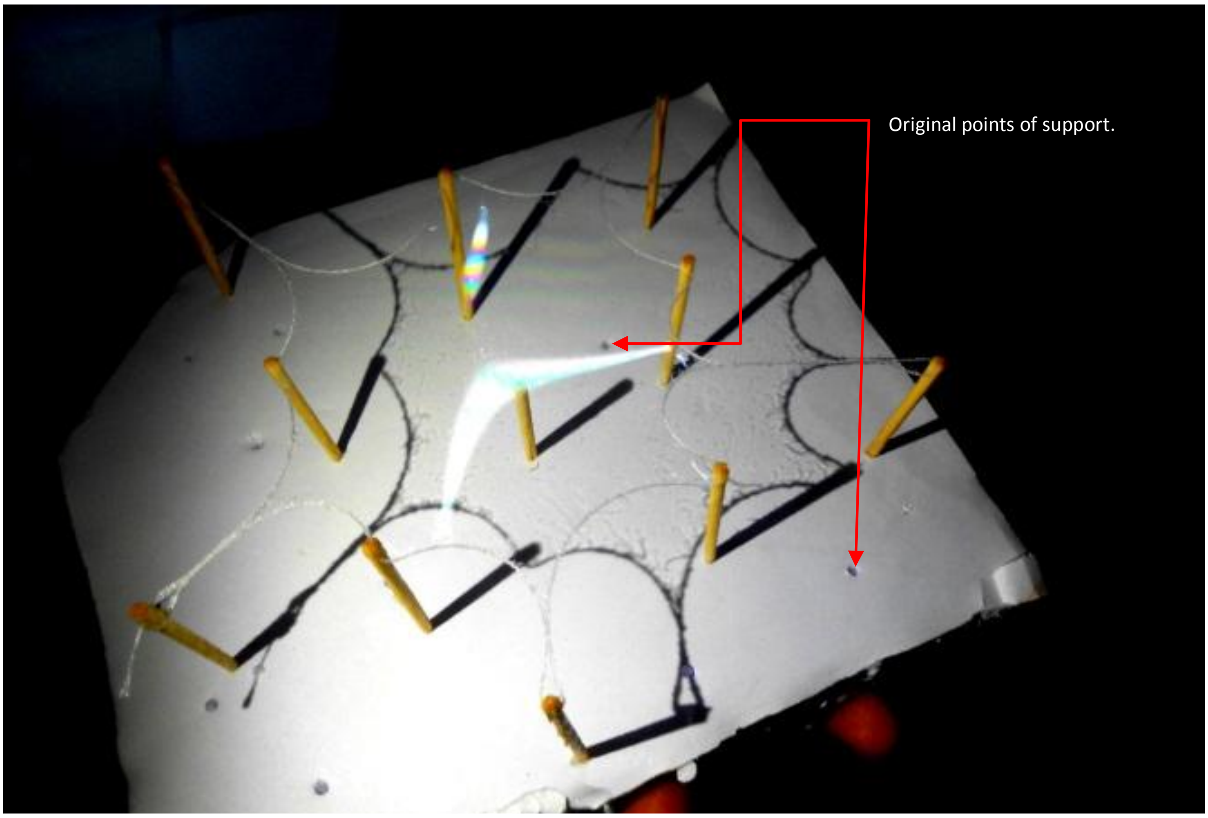
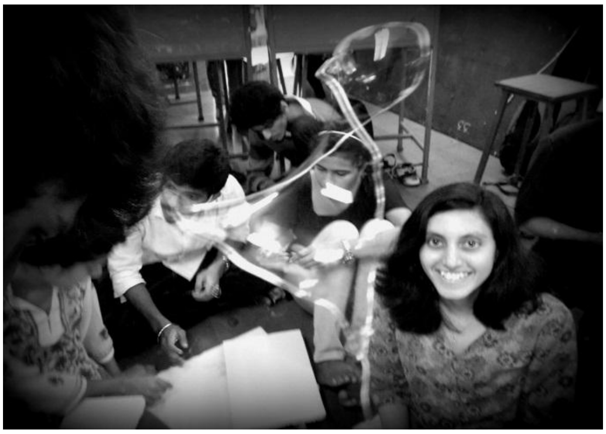


Fig 3 : Changing soap film boundary as it reforms to adapt to a change in the support framework [MINIMAL SURFACE]
Source : Author



Stage 2: DEFINING THE BOUNDARY CONDITION

A copper wire or thread is basically a ***line*** which can be organised, folded, twisted to form complex geometric ***shapes.*** Students were encouraged to design their own unique support framework for the ensuing soap films. Each student develops a minimum of two designs, the first one utilizing ***cotton thread***, thus proposing a design with ***flexible boundary condition*** [Fig 3 & 7]. The second design involving a comparatively ***sturdy*** framework made of ***copper wire*** [Fig 5]. Students were enthusiastic to explore this modelling experiment and came up with many innovative forms, some of which are shown on the right. [Fig..6,7 & 8]

Fig 5 : Students working on their individual designs
Source : Author

Stage 3: PHOTOGRAMMETRY OF THE SOAP FILM MODELS

The finalized support framework is then dipped in the pre prepared soap solution thereby resulting in the development of a thin soap film naturally adhering to the minimal surface within the boundary condition. This soap film model is further photographed immediately in a dark room for the purpose of recording and tracing the form geometries. This procedure is called as photogrammetry[Fig 6, 7 & 8]. Some of the built examples in the field of Tensile Architecture which utilized this procedure of photogrammetry as a part of form finding are as follows :-

- **Tanzebrunnen in Cologne ,1957**
- **Pavilion of the Federal Republic of Germany, World Fair, Montreal, 1967**
- **Air hall at Expo 1975, New York**

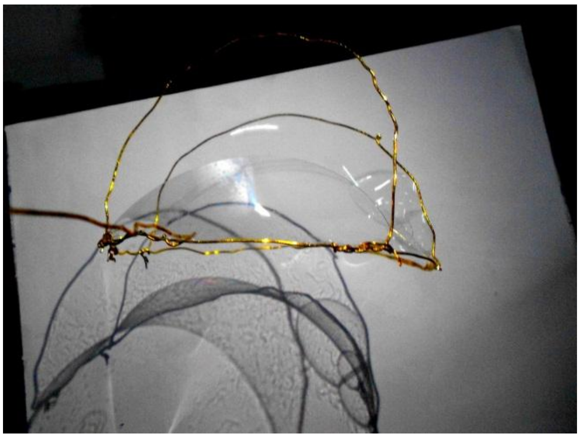


Fig 6 : Bridge design [Variation of the basic catenoid form]
Source : Author

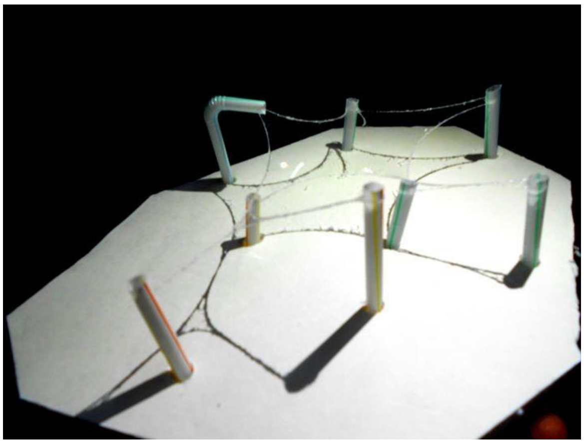


Fig 7 : Minimal surface soap film model confirming to flexible boundary condition.
Source : Author

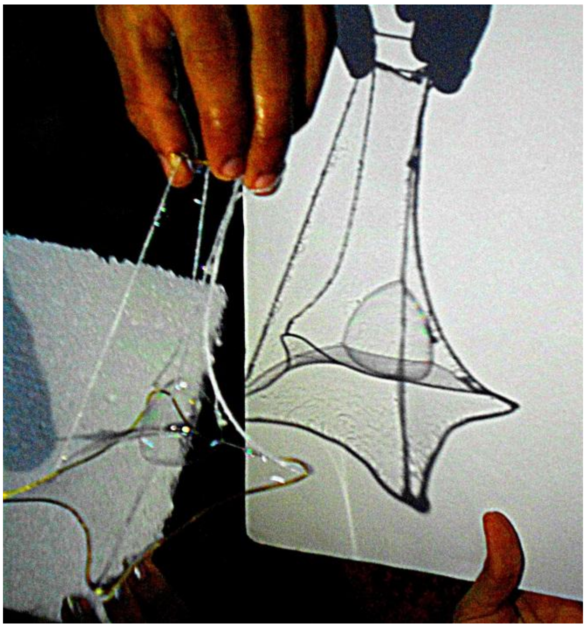


Fig 8 : Tower design [Combination of the basic catenoid & costa form]
Source : Author

Stage 4: ANALYSING THE MODELS AND PERFORMING EMPIRICAL TESTS

In the words of Architect Frei Otto, " New building culture needs work on basics [6]." he coined the term " **Gestaltwerdung**"- i.e. the **Emergence of form –**in nature, technology and architecture. On developing a new form of light and natural, adaptable and changeable building from the understanding that flows from research [5]. The research institutions that he founded and directed, the Institute for development of lightweight construction in Berlin, and the Institute for lightweight structures in Stuttgart where I learnt the technique of Soap film modelling under the tutelage of Ar. Jurgen Hennicke, are unique places for basic interdisciplinary research. It is only this kind of basic research involving in – depth analysis and tests, which is seriously neglected in the field of architecture, that can produce new questions and solutions [5].

Analysis of the soap film models is therefore one of the most crucial stages in this modelling experiment. The results of student work analysis acted as an eye opener in the field of form finding. As seen in figure 9, the two L shaped frames are joined together at the top and base. In the language of planes as seen in Figure 10, the expected joinery between the two l shaped planes would be a single line.

HOWEVER , PHOTOGRAMMETRY OF THE SOAP FILM MODEL SEEN IN THE IMAGE ON THE RIGHT SUGGESTS THAT THAT THERE IS AN EYE SHAPED OPENING IN BETWEEN THE TWO SOAP FILMS, FORMING THE L SHAPED PLANES. THE SAME BEING THE MOST STABLE DESIGN UTILIZING MINIMUM MATERIAL "DOING MORE WITH LESS" [FIG. 9].

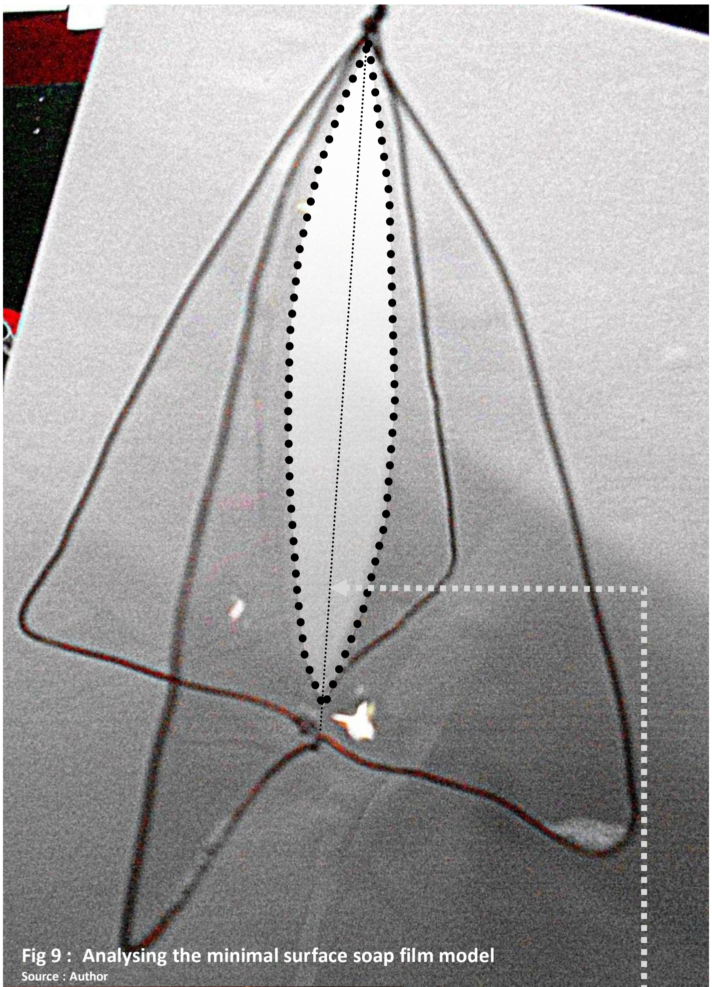


Fig 9 : Analysing the minimal surface soap film model
Source : Author

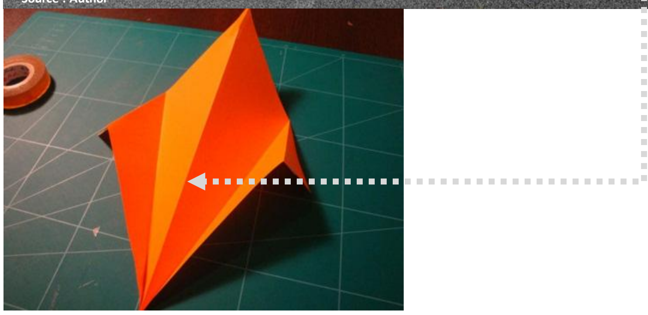


Fig 10 : Paper Origami
Source : diyourself.ru

Outcome of the workshop

Students were encouraged to document the entire process right from conceptualization of the framework design to analysis of the models and ultimately proposing a use for the spaces so designed. Which were explained through sketches and photographs. This documentation was done in the form of a report, some of which are as seen in the figures below.

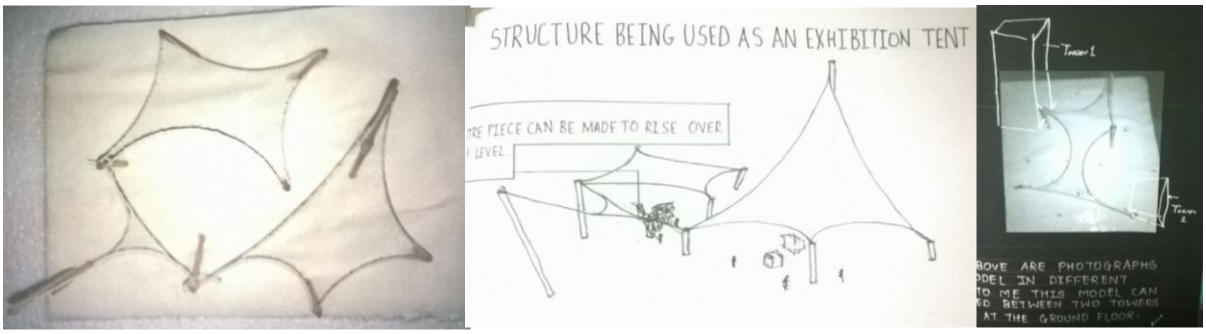


Fig 11 : Images of student's report
Img courtesy :Nush Wadia & Aditi Shinde [students of First semester B. Arch at Dr. Baliram Hiray College of Architecture, Mumbai]

Outcome of the workshop

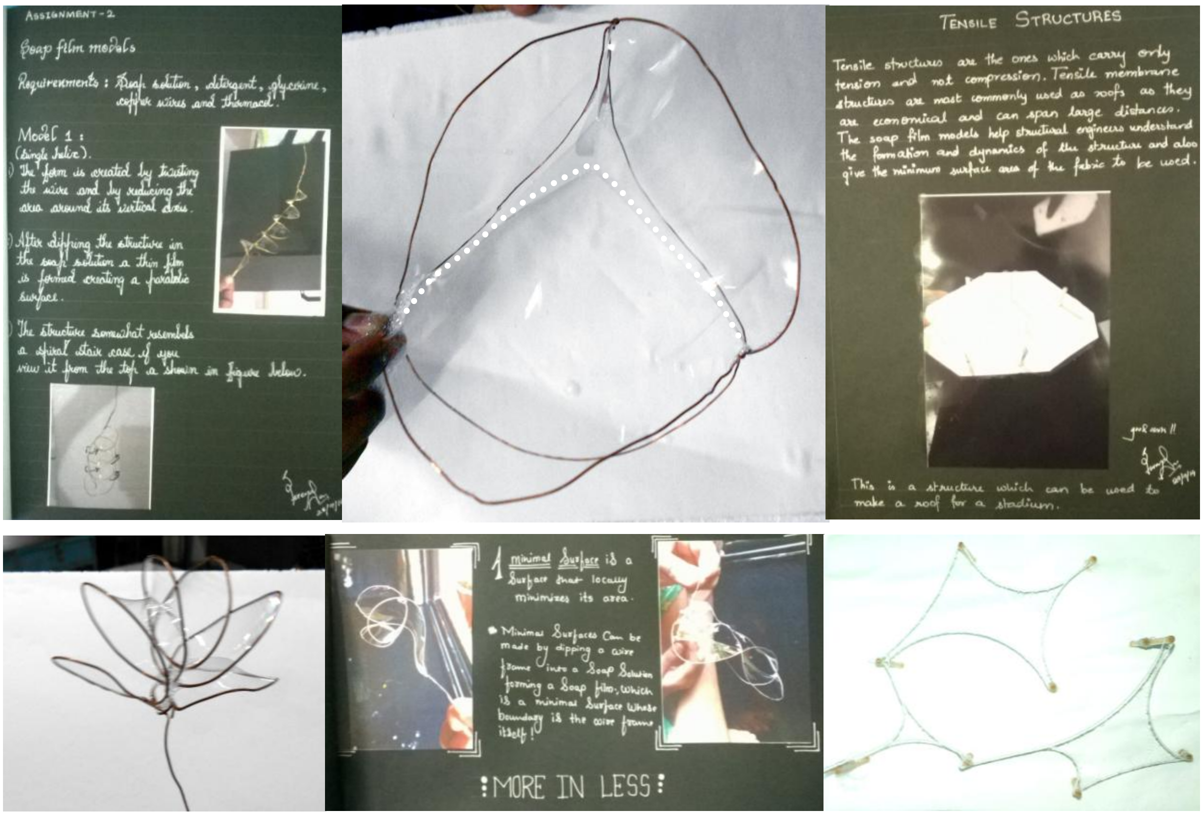


Fig 11 : Images of student's report

Img courtesy :Mihir Salunkhe , Yogini Polaji & Laxmi Kudtarkar [students of First semester B. Arch at Dr. Baliram Hiray College of Architecture, Mumbai]

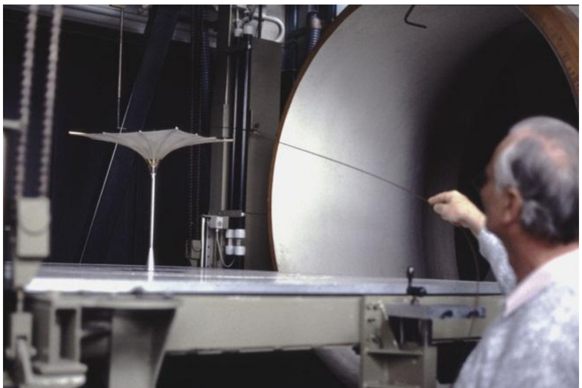
On field Execution methodology by experts

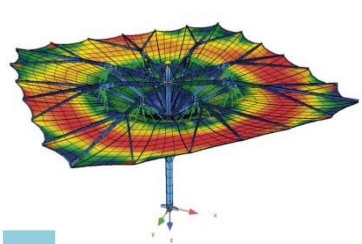
Minimal surfaces, as tension equilibrium forms, are the ideal basis to build the most efficient lightweight tension membrane structures with a minimum of mass and materials [7]. However, this is just the first stage of form finding and is followed up by four other stages as detailed below [Fig 12]. This execution methodology is followed by S.L.Rasch. GmbH ,one of the leading firms in this field of Tensile Architecture which follow a scientific method towards execution of a design project.

Fig 12 : Stage wise execution methodology

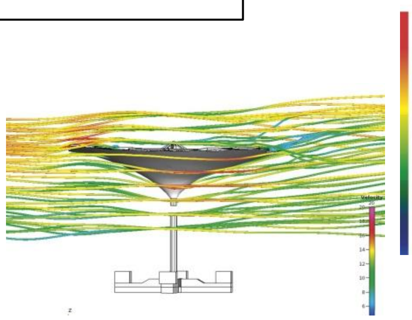
Source : http://www.sl-rasch.de/engineering

FORM FINDING





STRUCTURAL SIMULATION



COMPUTATIONAL WIND ENGINEERING TESTING OF DESIGN

CONSTRUCTION OF A SCALED PROTOTYPE FOR TESTING

Application of Knowledge gained

Lightweight Structures obtain their shape through the interplay of boundary conditions, external loads and/or internal states of pre-stress. It is necessary to incorporate the physics of the shape-finding process into the architectural and structural design process, since geometric shape and mechanical behaviour are coupled [7]. **This form finding workshop exposed students to the first stage of designing a lightweight structure**.

It was observed that, by experimenting with the geometric shape [boundary condition] the resulting mechanical behaviour of the soap films were critically analysed through Photogrammetry . Thereby achieving the objective of the workshop i.e. **to find the optimum design.** This methodology could be used by them for any future project concerning lightweight structures.

It can be concluded that an experimental, hands on modelling approach to architectural education may pave the way forward towards a better future. Embedding in young minds the importance of structural stability for the futuristic new forms created. Thus resulting in a beautiful as well as **responsible tomorrow.**

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Photographs : By students