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SEZIONE TESI DI LAUREA
DEGREE THESES SECTION

Menzione speciale
Special mention

Strutture pneumatiche adattabili
Adaptive Pneumatics

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THE PROJECT

Adaptive pneus

This project includes two major steps :

1- Research
2- SIte specific design project.

In the first stage Pneumatic material systems have been explored in order to achieve an adaptable system capable of environmental modulation via passive means such as, such as natural ventilation and shadow casting and in latter stage the devised system was applied in a specific environmental and social context.

Research

Pneumatic materials can be widely found in the nature for both structure and adaptation purposes. Besides, in the building industry and architecture Pneumatic structures are among the lightest and cheapest structures known. They present one of the lightest and relatively cheapest means for spatial organisation and environmental modulation. Plus, being capable of bearing tension and compression loads at the same time make them one of most interesting material systems.
The research commences with the interest in exploration of pneumatic material systems. It focuses on unfolding the performative capacities inherent in the pneumatic material system with regard to the specific environmental condition which is in this case Iran. Having ecology in the centre of the design process, a different approach from the traditional architectural and engineering design process has been taken in order to understand the relationship between the material system and the environment. Integrating adaptation to the immediate environment and structural performance in the devised pneumatic material system will be the main focus of the design process. This will be examined in an empirical design method which analyses the construction of the material based on its geometrical features, assembly logic, construction limits and as well as its interaction with environmental conditions and external stimuli. Both physical and generative computational experiments and analyses contribute in the form finding method used for this project.

Adaptation

Stimulation of ecological adaptation to modulate environmental and structural performance by the pneumatic material system was the main focus of the design process. Immediate reaction to the location of the sun throughout the day is the trigger of adaptation. This provides a great opportunity for environmental modulation via passive means.
This approach necessitates a dramatic shift in the architectural design from producing static to environmental responsive objects. It requires the recognition of buildings not as singular and fixed bodies, but as complex energy and material system that have a life span, and exist as part of the environment.
Here adaptability has to do with the responsive action that affects the performance of the whole building and therefore holds a much closer relationship to the biological and natural idea of responsiveness. By embedding functions in each cell, the response takes place locally and independently to the external environmental stimuli without exploitation of electromechanical devices. Then through interrelated links connecting the local, regional and global scale, distributed intelligence takes place and global performance emerges.

Reaction mechanism

In the devised material system components open as a result of turgor pressure increase exerted on the membrane .
Turgor pressure increases as soon as component is exposed in front of direct sunlight and get expanded. They open as the effect of increase in temperature raised from direct sunlight radiation on the elements. Solar analysis enables us to digitally simulate the location of the openings for different times of the day throughout the year. Location of openings should be measured based on the angle of each cell towards the direct sunlight. The numerical data provided in the result charts indicate the angle of each individual cell towards the sun in each specific time of the day throughout the year. Due to the sensors degree of sensitivity, the highest values will be defined as the opening in this specific time of the day.

Performance

Similar to natural systems, Performance of the whole system is informed from that of it in various scales from Local (component level) to global (Envelop). Series of experiments, thereby, have been devised to analyses and improve the performance of the system in different scales.

Energy supply

Thin-film technologies for the energy as the main energy supply can lead to reduced processing costs. Application of thin-film on ETFE or PVC enables systems to produce sufficient energy to run air management units. Vector Foil-tech patented a method of laminating PV cells into ETFE. If enough energy is generated, the surplus could be sold, turning the roof into a solar energy farm.

Site specific design project

The village is located along the busiest road of Iran connecting Tehran to a tourist and holiday attraction. Despite of the critical location of the village, people are suffering from living in a very dense and poorly built neighborhood without communal leisure and social spaces such as gardens and parks. It has left negative effects on youngsters social behavior. Furthermore, the neglected and unsafe view of the village is upsetting the tourist and authorities. Authorities, thereby, planned to demolish the existing houses and replace them with an alternative housing solution.
We believe destroying the existing village will have negative social and economical impacts. Instead of demolishing the existing buildings and constructing a new village, the proposed design project utilizes the existing buildings as the base structure to be covered by the developed adaptive system to:

1- create a climatic skin, improving both interior quality and exterior visual appearance;
2- create more communal area for the village;
3- prevent extra construction cost;
4- avoid repercussions of temporarily sheltering the inhabitants;
5- facilitating the development process;

The sample project provides a second climatic skin that covers a number of buildings, creating a medium roof terrace(as a communal space), improving interior conditions of the existing houses and the appearance of the village.
The budget necessary for demolishing these houses will be paid by developers in the area who are actually charged with the congestion fees by the municipality.
Design loop includes three major steps :

1- form generation based on the spatial and initial criteria;
2- indication of the opening location
3- performance analysis.

In order to analyze and improve performance of the system at the global scale, first the location of the openings at different times of the year has to be indicated.
After exploring the location of openings by solar analysis the performance of the system was measured. In performance analyses, shadow casting, natural cross ventilation and well distribution of fresh air through out the interior of the envelop has been assessed. The data driven from analyses were used for the modification of global geometry for the next iterations. The design loop was repeated until the desired performance was achieved.
Wind is complex phenomenon and cannot be measured precisely with regard to the macro climatic data. In order to measure wind behavior more accurately, a micro environment, including main buildings and their vicinity, had been simulated. By applying the global prevailing wind direction and speed as the air input , a precise analysis on wind behavior in the chosen site was conveyed.
The first developed geometry had poor performance in terms of natural cross ventilation in the mornings and well distribution of the fresh air in the evenings. Through some generations of geometrical manipulation, considering initial spatial criteria, fabrication logic and assembly and environmental performance, the desired geometry was achieved. The final geometry benefitted from natural ventilation throughout the day and provided more than 80% shading in the
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the open state, throughout the course of summer.

PROJECT DESCRIPTION

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and in latter stage the devised system was applied in a specific environmental and social context.

RESEARCH

Pneumatic materials can be widely found in the nature for both structure and adaptation purposes. Besides, in the building industry and architecture Pneumatic structures are among the lightest and cheapest structures known. They present one of the lightest and relatively cheapest means for spatial organisation and environmental modulation. Plus, being capable of bearing tension and compression loads at the same time make them one of most interesting material systems.

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Final Component, Prototype - C
State.

ADAPTATION

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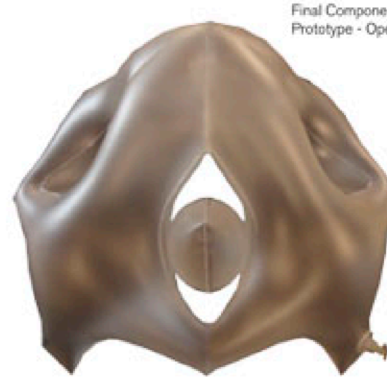
This approach necessitates a dramatic shift in the architectural design from producing static to environmental responsive objects. It requires the recognition of buildings not as singular and fixed bodies, but as complex energy and material system that have a life span, and exist as part of the environment.

Final Component,
Prototype - Open State.



3-distributed and collective Global intelligence

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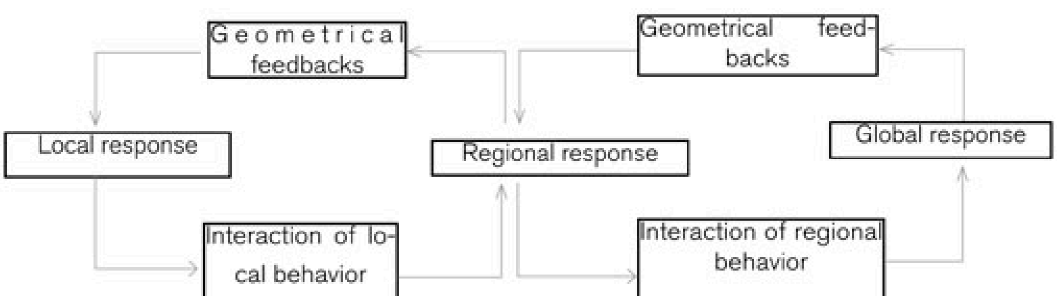


1-Local response

Local Scale CFD analysis

Local analyses CFD experiments (as you can see some examples here) suggest that, as the components get more oriented towards the wind the angle of openings should decrease, for the inputs (windward side), and the angle of openings should increase for the outputs (leeward side) in order to achieve a higher level of performance. Plus, If the components stand with less than 45⁰ against the wind, for both input and out put, 4 opening elements on four sides contribute in benefit of natural ventilation. Once they stand with an angle greater than 45⁰ openings, the leeward side openings interrupt with the functionality of the components and has to be closed.

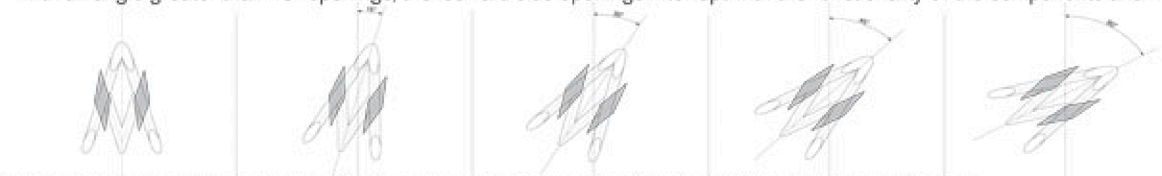
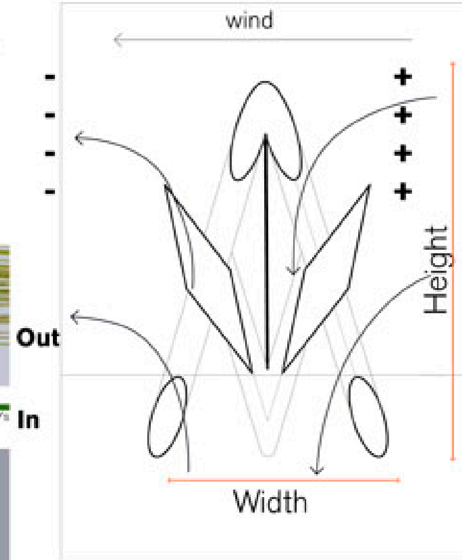
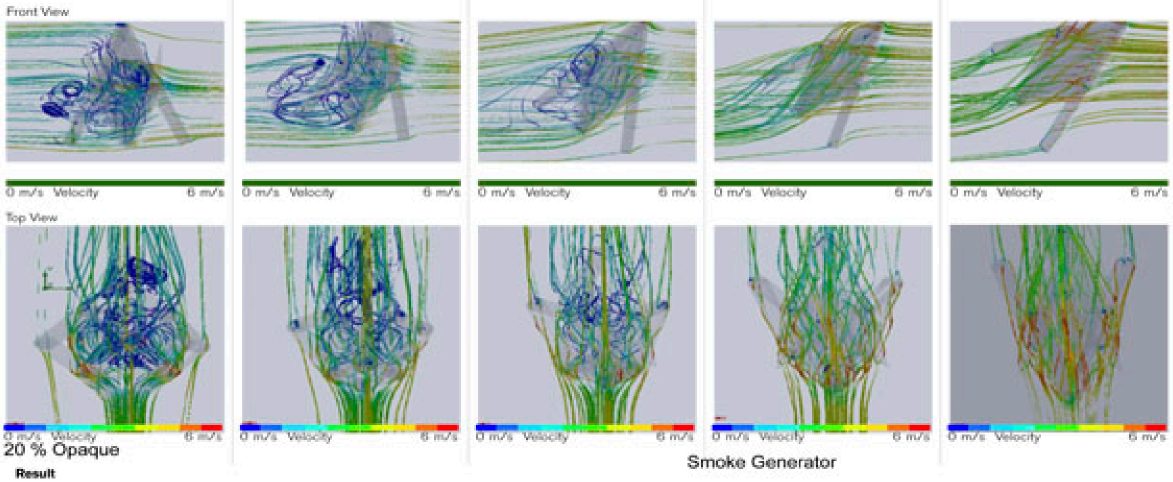
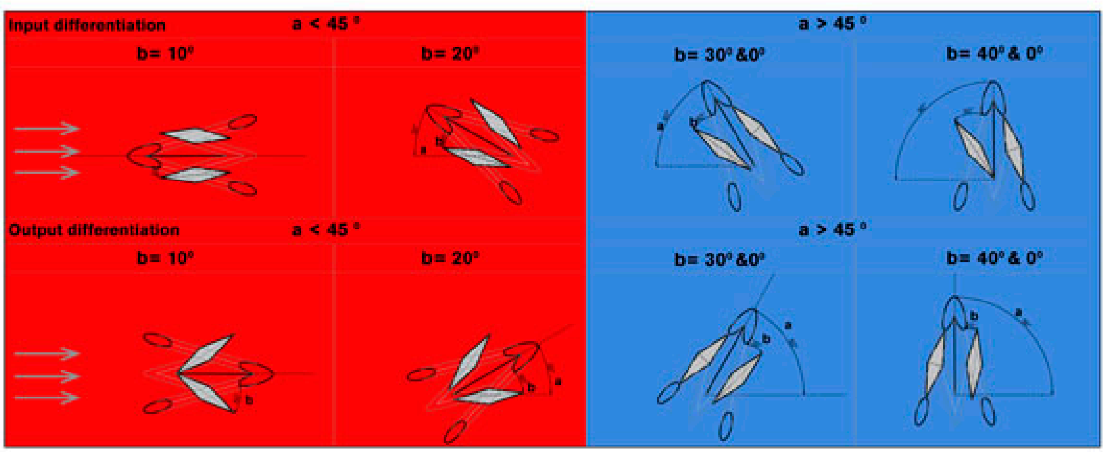


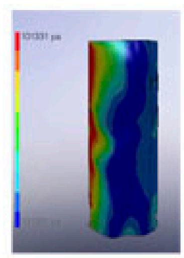
Figure 13. CFD Analyisis of the component in different angle varation and opening angle to examine the performance in different circumstances.



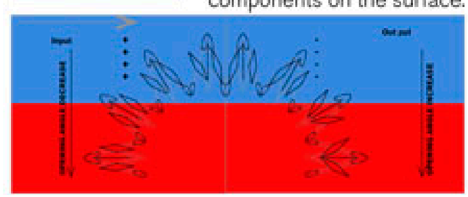


The experiment set up was set according to the site specific data such as 5 m/s speed blowing from west to the east side. With height/ width manipulation the functionality of the component in terms of air exchange potentials was examined

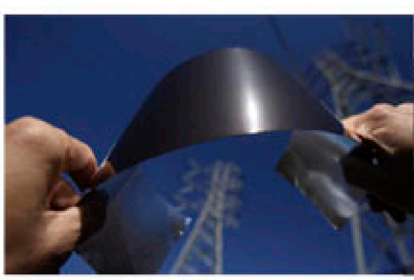


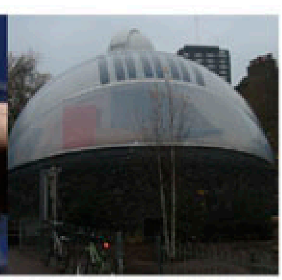


Finally, the pressure map driven from the wind streams blowing on the surface indicated the location of inputs and outputs. having understood the location of the inputs and outputs, I have proliferated and differentiated the components on the surface.



ENERGY SUPPLY





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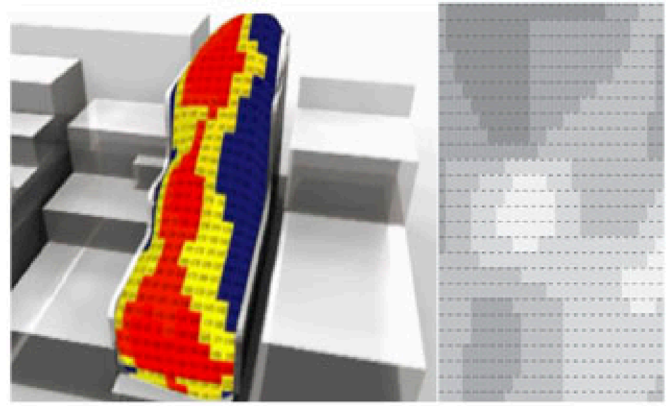


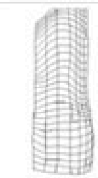
REACTION MECHANISM

In the devised material system components open as a result of turgor pressure increase exerted on the membrane . Turgor pressure increases as soon as component is exposed in front of direct sunlight and get expanded. They open as the effect of increase in temperature raised from direct sunlight radiation on the elements.

Solar analysis enables us to digitally simulate the location of the openings for different times of the day throughout the year. Location of openings should be measured based on the angle of each cell towards the direct sunlight. The numerical data provided in the result charts indicate the angle of each individual cell towards the sun in each specific time of the day throughout the year. Due to the sensors degree of sensitivity, the highest values will be defined as the opening in this specific time of the day.

PERFORMANCE

Similar to natural systems, Performance of the whole system is informed from that of it in various scales from Local(component level) to global (Envelop). Series of experiments, thereby, have been devised to analyse and improve the performance of the system in different scales. (See the global performance experiments in the next sheet)



Global Scale- The global geometry is informed from multi design criteria. Global geometrical manipulations will directly affect the project's environmental performance.

Parametric relationships, from which component has been designed, allow for geometrical variation. Here, controlled geometrical variation increases the local performance of the material system in terms of wind exchange and shadow casting.

LIGHT PENETRATION CONTROL

One of the contributing factors to passive cooling is the affect of direct sun light penetration into the building. High level of transparency in the devised system and the opening action, resulting in high level of direct light transmission into the building. This harms passive cooling performance.

The aim of this series of experiments was to work out a component that avoids direct sun light penetration into the interior environment via self shadow casting and active light penetration control. In the first series of experiments harmless smoke was employed to turn the component from transparent to translucent when necessary. In order to prevent the direct sun light penetration when the component is open, a series of geometrical manipulation experiments were conveyed to find the desired geometry that self shades when open, yet allows for air exchange.

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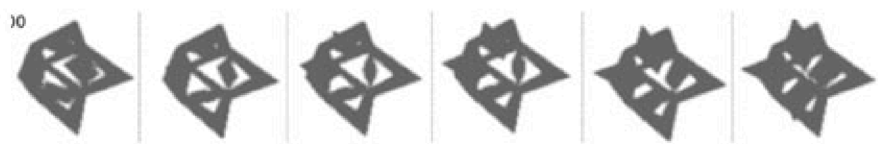


Figure 14. An example shadows before geometrical manipulation

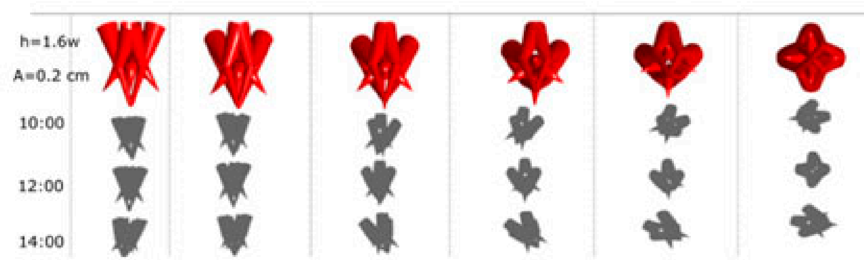
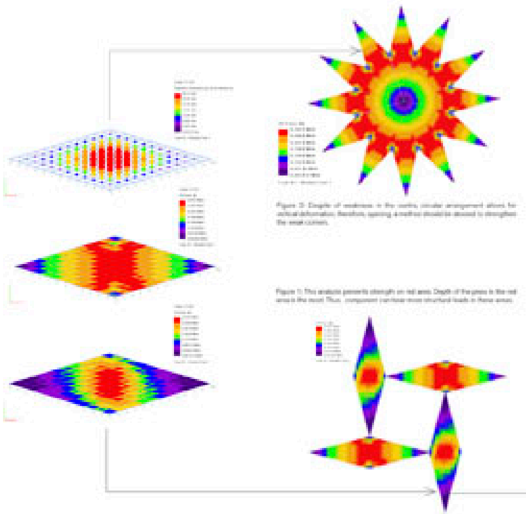


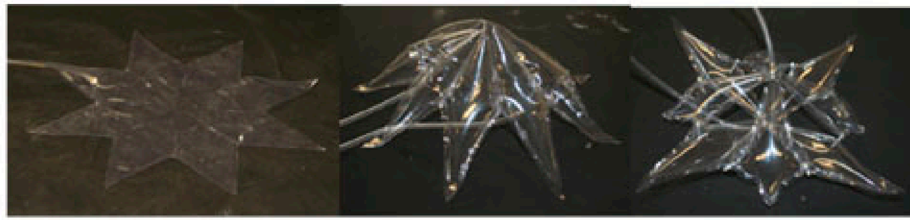
Figure 15. Shadows in created form the components in different vertical angles toeards the sun ,after geometrical manipulation

ALTERNATIVE-01/ FORM- FINDING EXPERIMENTS

From finding experiments started thorough structural and deformation studies of the base pneumatic element in both deflated and inflated states. As a result of different methods of element arrangements two major components were developed. One a porous component with structural capacity (figure 4) and the other with two states of open/ close (Figure 3). By combination of the two the final component was achieved, being capable of bearing structural loads, yet permeable.

Inspired from movement by muscles in nature, through contraction and expansion of pneumatic muscle movement was developed.(Figure 5)





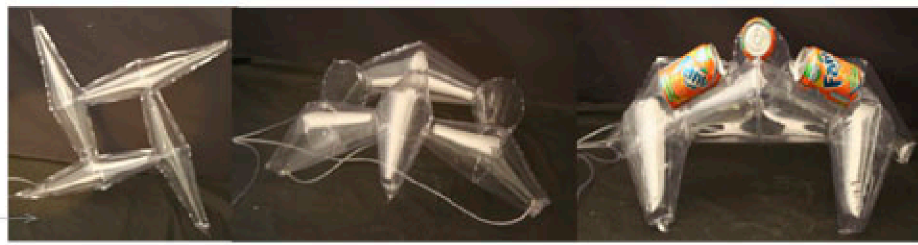
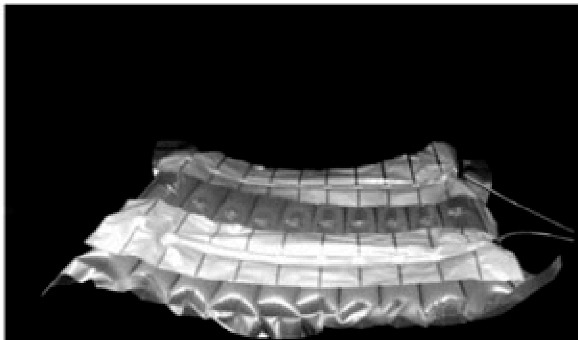
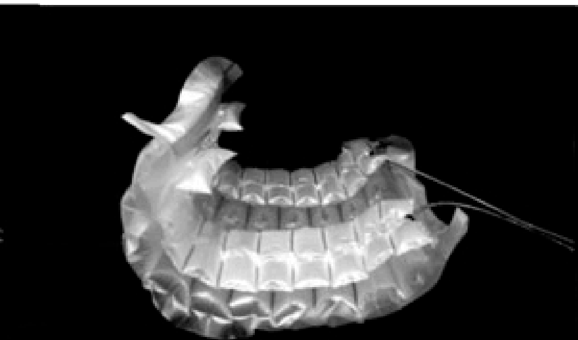


Figure 2. 3x3 meter Adaptive pneumatic prototype. Installed in AA Emtech Studio garden.

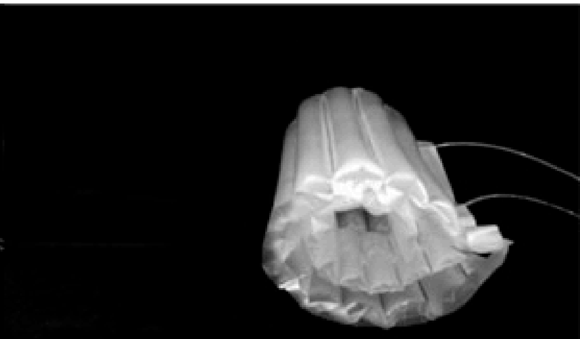
FORM- FINDING EXPERIMENTS- ALTERNATIVE-02



Opening Component - Close State.
The Opening Muscle is Deflated.



Opening Component - Semi-Open State.
The opening muscle is semi inflated.



Opening Component - Open State.
The opening muscle is fully inflated.

Later in the Form-Finding stage another alternative with same capacities was developed to achieve more economical solution for the roof cover.
Here, movement is being done through contraction of the second layer

The whole process of manufacturing has been done via planar high-frequency sealing, making the project suitable for mass production, yet functional. The fabricated prototype was being exhibited in London Design Festival 2009.For more information and see the video please refer to the CD.