Urban Space Regeneration Design using architectural minimal structure
(old market place regeneration using tensile structure)
✓ Research Objectives
✓ Tensile Structures
  ✓ Definition
  ✓ History
✓ Shading in Urban Design
  ✓ Other materials
  ✓ Membrane structures
  ✓ Advantages and disadvantages
✓ Design Proposal
✓ Conclusion

CONTENTS

TENSILE STRUCTURES FOR SHADING IN URBAN DESIGN
✓ Provide the definition and historical applications of tensile structures in the urban context, as well as explaining the properties and environmental benefits of these structures.

✓ Introduce the current options for roof shading with other materials, give examples of membrane roof applications, and list the advantages and disadvantages of its use.

✓ Provide a design proposal for membrane shading roofs, emphasizing the importance of the collaboration between engineers, architects and urban planners.
Spatial structures are those that can cover a long-span space with a lightweight structure.
HISTORY OF TENSILE STRUCTURES

- Circus parade around tents, in lithograph by Gibson & Co., 1874
- Circus in Pittsburgh, Pensilvania, U.S.A, July 16th 1956
HISTORY OF TENSILE STRUCTURES

- The use of tensile structures was not only circus tents
- We can find also examples in street markets all around the world

- Awing and umbrellas covering a shopping street in Taxco, Mexico
- Street market in Casablanca, Morocco
HISTORY OF TENSILE STRUCTURES

FREI OTTO
- Pioneer in tensile structures
- Discovered the NATURAL FORMS of soap bubbles

- Canopy of the Interbau café in Berlin
- Federal Garden Exhibition Cologne, entrance arch
- Four-point net, Federal Garden Exhibition, 1955
- Swiss Regional expo 1964 in Lausanne
By manipulation of boundary conditions of a flat rectangular panel

- Hypar (hyperbolic paraboloids)
  - Raise two corners with cable supported edges

- Conic
  - Introduce central ring and raise

- Barrel vault
  - Introduce curvature to two continuously clamped edges
SHADING IN URBAN DESIGN

Other material roofs

TENSILE STRUCTURES FOR SHADING IN URBAN DESIGN
✓ Borough Market, London (1860)

✓ Old market streets used glass and steel
✓ Heavy structures with a high cost
✓ For new projects these materials are normally not used anymore
✓ Roofing over India Street Pedestrian Mall reminiscent of rainforest canopy

✓ Modern roof made of glass and steel

✓ Outlandish heavy structures with a high cost and cleaning maintenance
OTHER MATERIALS
SHADING
ROOFS

✓ Roof made with steel and translucent PVC plastic

✓ Cost is lower, but it looks heavy and flashy

✓ PVC becomes dirty easily with the weather and the pass of the time

✓ Auxiliary lighting might be needed even during daytime

✓ Ventilation might be not too good

✓ Yangdong Market, Korea

✓ Andong Market, Korea
SHADING IN URBAN DESIGN

Membrane roofs

TENSILE STRUCTURES FOR SHADING IN URBAN DESIGN
Membrane roofs for markets
- Good ventilation
- Lightweight, like floating over the market, because it just need some anchoring points
- Natural lighting

Hatikva Market, Tel Aviv, Israel
MEMBRANE SHADING ROOFS

✓ Membrane roofs for markets

✓ More extravagant project (more complicated supporting system)

✓ Camden Market _ London, UK
MEMBRANE SHADING ROOFS

- Membrane roofs for walkways shading
- Flexible in form and producing less heavy visual impact than other materials

- Capo Soprano_ Gela, Sicily
✓ United Nations PTFE Fabric Security Entrance Canopy _ New York, USA

✓ Membrane roofs for walkways

✓ Design is very versatile and changeable

✓ This project creates a monumental entrance for this building
ADVANTAGES OF USING TENSILE STRUCTURES IN URBAN DESIGN

- **Lightweight:** The major advantage of tensile membrane structures is its lightweightness. Prestressed shapes of the membrane, low mass and wide span provide opportunity to express lightness and stability.

- **Translucency:** Translucency is one of the great qualities of tensile membrane structures. It offers aesthetic opportunity to design with natural and artificial light. Translucency depends on the type, coating and color of membrane material. Translucency can vary from 10% to 40%.
ADVANTAGES OF USING TENSILE STRUCTURES IN URBAN DESIGN

✓ **Flexibility:** Tensile membrane structures are not rigid. Membrane shape deforms in response to snow and wind load. It finds efficient shape for different loading conditions which offers better flexibility. Unique sculptural shapes can be achieved through membrane structures. It offers a floating quality defying gravity. With the help of artificial lighting it offers an opportunity to design a tensile membrane structure into a sculpture of light.

✓ **Natural ventilation:** Membrane material with open structure can be used for shading and stimulate natural ventilation. The open air feeling and impression of lightness of tensile membrane structures are reinforced by the translucency of membrane material.
ADVANTAGES OF USING TENSILE STRUCTURES IN URBAN DESIGN

ENERGY SAVING
- Insulation (Use of ETFE)
- Renewable Energy (Solar & Geothermal Power)
- Heat Exchanger
- Free Cooling (Using Outdoor Air)
- Light Control
- Congeneration

INDOOR COMFORT
- Natural Lighting
- Natural Ventilation
- Less Chemical Materials

MATERIAL SAVING/ RECYCLING
- Rainwater Usage
- Recycle Water Usage
- Underground Water Usage
- Reduced Self-Load
- Less Material Usage
- Reduced CO₂ Emissions
- Recyclable Building Skin

ENVIRONMENTAL COMPATIBLE ASPECTS
ADVANTAGES OF USING TENSILE STRUCTURES IN URBAN DESIGN

ENVIRONMENTAL COMPATIBLE ASPECTS

✓ **a & b**: In winter close the structure to prevent wind, making good use of thermal mass
✓ **c**: Inducing air flow in fabric membrane structures for hot climates, as natural ventilation
✓ **d**: Retractable canopies can be useful as opening the structure at night to permit cross ventilation and also re-radiate the heat absorbed during the day to the night sky.
✓ **e**: Stack effect is effectively used in these structures
✓ **f**: Used as a buffer zone between the external environment and the internal one
DISADVANTAGES OF USING TENSILE STRUCTURES IN URBAN DESIGN

✓ **Uniqueness of each project:** The form of this membranes needs to be calculated for each project by engineers, and specially in more complicated projects it can increase the time and cost

✓ **Cost issue:** Material is not expensive and construction can be easy, but as this projects are unique, they need of very expertized professionals, both engineers and architects, so the cost is increased a lot.

✓ **Lack of design guidance:** This material is quite new compared with commonly used materials as steel or concrete. Because of that, there is a lack of design guidance
DESIGN PROPOSAL

Theory

TENSILE STRUCTURES FOR SHADING IN URBAN DESIGN
It can be applied to different layouts, sizes and programs like festivals, events or just shading areas.

Permit flexible space can be set in urban contexts or green spaces.
This small company has created a prototype with conic shaped membranes.
ANALYSIS AND DESIGN OF TENSILE STRUCTURES

ARCHITECT

MODELING

ANALYSIS

SAFETY CHECK

Choosing and drawing of model and main directions

Modeling of the elements

Form-finding analysis

Stress-deformation analysis

Displacements

Stress distribution

Safety check (>4)

Collaboration to obtain the FINAL DESIGN

ARCHITECT

ENGINEER

Displacements in x

Node position

5 10 15 20 25 30

Displacements in x (cm)

-20

-10

0

10

20

Case 1_Model A

Case 1_Model B

Case 2_Model A

Case 2_Model B

Direction

Sherfill II (kN/m)

Ultimate tensile strength

Warp

137.5

Fill

98.1
RESEARCH PROPOSAL

URBAN DESIGN

Need of Design of membrane shading roofs

ARCHITECTURE DESIGN

Need of Modeling and analysis before getting the final design

STRUCTURAL DESIGN

Collaboration

RESEARCH TO CREATE DESIGN GUIDANCE

✔ Reduce cost and time to implement membrane shading roofs in urban projects

Need of Design of membrane shading roofs
DESIGN PROPOSAL
Application proposal
TENSILE STRUCTURES FOR SHADING IN URBAN DESIGN
PARAMETRIC STUDY

REGULAR BARREL VAULT SHAPED MEMBRANES

ASSUMPTIONS

- Material properties
  - $E_{11} (\text{kN/m})$: 1230
  - $E_{22} (\text{kN/m})$: 950
  - $V_{12}$: 0.804
  - $V_{21}$: 0.62
  - $G$ (kN/m): 96.26

- Loading conditions
  - Snow downwards loading
  - Wind upwards loading

- Safety factor > 4
  - Maximum stress in warp = 34.38 kN/m
  - Maximum stress in fill = 24.53 kN/m

PARAMETERS

- 3 parameters to analyze all possibilities for regular barrel vault shaped membranes
  - Arch curvature
  - Width
  - Arch Scale

ARCH CURVATURE

- Same span
- Different height

WIDTH

- Same span
- Different width

ARCH SCALE

- Same arch curvature
- Different span
PARAMETRIC STUDY

REGULAR BARREL VAULT SHAPED MEMBRANES

REGULAR SHAPE

CONCLUSIONS

Regardless of scale

- WRINKLE LIMITATIONS
- MAXIMUM WIDTH WITH MAXIMUM CURVATURE

APPLICATIONS FOR MARKET STREETS AND WALKWAYS AREAS

- WIDTH LIMITATIONS
- WRINKLE LIMITATIONS
- MAXIMUM WIDTH WITH MAXIMUM CURVATURE

SAFE DESIGN COMBINATIONS AND LIMITATIONS

ARCH CURVATURE

- WIDTH
- ARCH CURVATURE
By the choice of 2 different arch curvatures we can create space between the arches for natural ventilation.

Besides, shading and natural lighting will be obtained in the market street.

Design applications in market street.

Panels chosen for the design.
Panels chosen for the design

- 6 m WIDTH
  - 38° ARCH CURVATURE

- 3 m WIDTH
  - 74° ARCH CURVATURE

Design application in market street

- Bigger openings
- Higher buildings
- Besides, difference height between arches is also bigger to create more ventilation

This design is located in a higher level and the rhythm between the panels is different 3-6m
PARAMETRIC STUDY

ONE GRADE OF IRREGULARITY BARREL VAULT SHAPED MEMBRANES

- Two new parameters are analyzed, both of them are symmetric by one axes
- More variety of limiting combinations are found

ASYNMMETRIC ABOUT THE TRANSVERSAL AXIS
- Same arch curvature and scale
- Different opening angle for the arch in plan

ASYMMENTRIC ABOUT THE LONGITUDINAL AXIS
- Same width and curvature
- Different arch scale between the 2 arches: inclination angle

Limitation graphs for each parameter
Panels chosen for the design

Design application

With the irregularity related with the opening angle, one more parameter is included, so the design can be adapted to curved and more organic situations.
Tensile membrane structures are a good solution for shading roofs in urban design due to its environmental compatible characteristics as flexibility, lightweight, and natural lighting and ventilation.

The application of these structures for urban projects may be costly because of the need of very expertized professionals in both engineering and design. Besides, the lack of design guidance makes each of these structures to be unique projects.

By the collaboration between engineers and designers in the research stage, new design guidance can be created to help the easier implementation of membrane shading roof into urban projects.

This research provides the guidance for regular and irregular barrel vault shaped membranes design combinations, as well as some examples of the possible applications.
THANK YOU