A Study on the Impact of Tensile Fabric Structure in Semi-Outdoor Spaces of Tropical Cities

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Abstract- This paper discusses the impact of membrane structure on thermal comfort of semi-outdoor spaces. For study purpose of this paper warm-humid climate of an urban area, Dhaka, Bangladesh has been chosen. Tensile fabric structure is a light weight structure and it can be used as a temporary structure. The investigation was carried out by using PMV-PPD model and field survey. For this study we collected data from two existing tensile structures in Gulshan area of Dhaka with reference to semi-outdoor, outdoor and indoor spaces. From the data collected it can be shown that the use of tensile structure in semi-outdoor space can reduce the temperature to a certain level.
Keywords –Thermal comfort,tensile structure, warm humid climate, semi-outdoor space, PMV-PPD Model.

I. INTRODUCTION

Bangladesh is located in the tropical monsoon region of Southeast Asia. The Tropical monsoon zone is usually warm and experiences mild winds. In Bangladesh, the summer monsoon is associated with heavy rainfall. The pre-monsoon hot season from March through May, and the rainy monsoon season which lasts from June through October. As the winter from November to February ends, warm, moist air from the southwest Indian Ocean blows toward this region. The summer monsoon brings humid climate and torrential rainfall to this area. A low wind always blows over this region as a result, humidity and temperature become anissue for this climate. The most striking feature of its climate is the reversal of the wind circulation between summer and winter which becomes an integral part of the circulation system Bangladesh. The Rural, Traditional and contemporary architecture of Bangladesh respectively follows these significant characteristics of tropical monsoon climate.

II. TENSILE STRUCTURE

Tensile or tensionedFabric structure (short form TFS) isanadvanced roofing structure that using polymer textile to be roofing material. This is form of contemporary architecture that satisfying all the primary needs of tropical monsoon climate of Bangladesh.

Tensile roofs and façade are those in which every part of the structure is loaded in tension force only and no compression or bending moment forces.

Tensile Membrane Structure is a light weight structure and is architecture of new generation as well as possibility to supplement traditional architectural solutions. Tensioned membrane material is considered to be the fifth construction element after metal, stone, glass and concrete. Tensile membrane structure is advanced structure using polymer textile to be roof material. This light weight material allows architects and engineers to freely innovate exciting experimental solutions for their building's solutions. There are many reasons that convince to use 5th materials of construction refer as tensile membrane structure.

Some of them are as follows

- Light weight material
- Free forms
- Economical
- Rapid for construction
- Recycling (eco-friendly)
- v1. Wide range of applications from large scale building to urban design untilsm, all cover walk way .(James, 2016)

Tensile Membrane Structure is a light weight structure compare with conventional R.C.C roof the weight of tensile membrane structure is very low may be 7%-10% of R.C.C structure enabling long spans of column-free space. Tension fabric structures are somewhat unique in that they require minimal maintenance when compared to an

equivalent-sized conventional building. In daylight, the translucency of fabric membrane offers soft diffused naturally lighted spaces that reducing the artificial interior lighting costs. While at night the artificial lighting creates an ambient exterior luminescence. For using in exterior it also gives natural wind most tensile membrane structures have high sun reflectivity and low absorption of sunlight, resulting in less energy used within a building and ultimately reducing electrical energy costs.

III. ADAPTABILITY OF TENSILE STRUCTURE FOR BENGAL

As a fifth construction material Tensile Structure can be a good solution for Bangladesh to face most of the climatic complexities and natural calamities. Tensile membrane structures are often chosen because of their ability to span large spaces without intermediate supports and give an unentrapped enclosed space. For that reason, they are mostly suitable for enclosing single large volumes. And most importantly it provides shades and cross ventilation of air. So it perfectly serve the purpose of semi-outdoor space.As well as,tensile architecturecan be a temporary solution for disaster-prone areas of this region.

Light weight roof or fabric structures have been used throughout history of Bengal. They were originally used to provide shelter where materials were scarce or mobility was required. Nowadays, the issue of using this Structure not only for scarcityor mobility but also to save energy. And here tensile membrane structures can have a potential role to play. Tension fabric structures are somewhat unique in that they require minimal maintenance when compared to an equivalent-sized conventional building.In Urban area of Bangladesh,tensile roofing are suitable for covering park, circulation spaces , gallery, semi outdoor spaces Railway station and many other public spaces.Most of the features of TFS are required for the climatic complexities of Bangladesh.As these are light and flexible structures they are also potential for folding the fabric membranes to change their function at different times of the day or seasons of the year.

IV. ENVIRONMENTAL PROPERTIES OF TFS

When adopting TFS as part of the building enclosure or for any shading of spaces it is important that the designer should fully understand the environmental implications implicit in their use. When designer think to use TFS and to increase their acceptability they need to clearly understand the environmental and micro-climatic behavior of the Fabric.

Tensile membrane structures tend to create internal thermal environments that differ strongly from thoseencountered in more

conventional buildings and, as such, strongly influencethe environmental design strategy.

Fabric membranes are thin translucent materials that have insufficient mass to significantly affect their thermal behaviour. At any instant, it is reasonable to assume that their thermal behaviour results from their surface heat transfer and their characteristic thermal optical properties at that instant.4

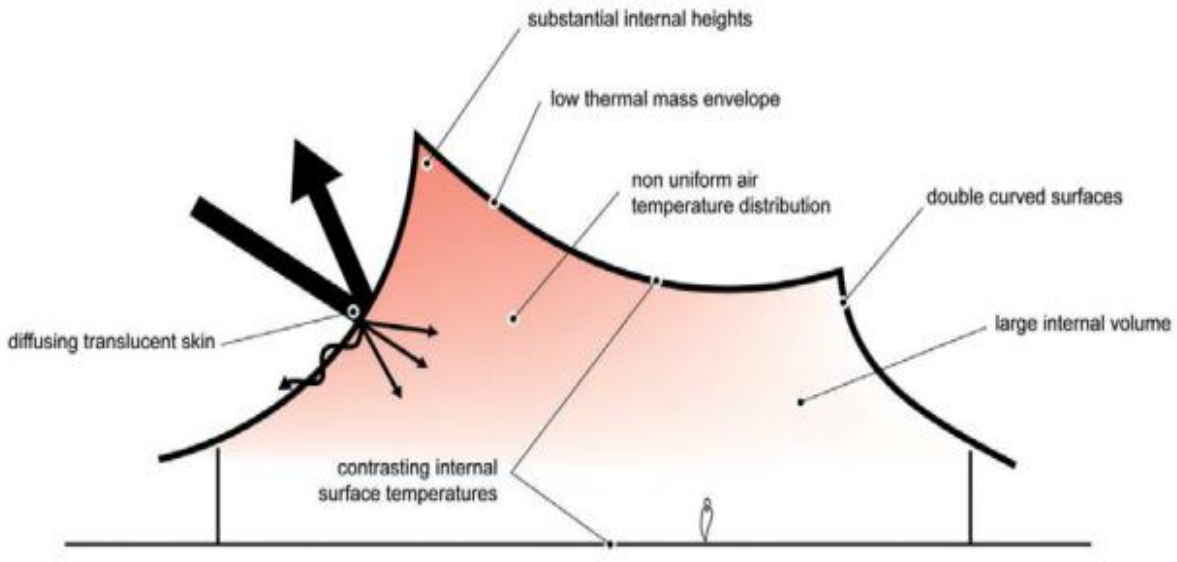


Figure 1 Characteristics of TFS enclosure.(B. Forster)

These peculiarities arise both from the properties of the textile skin as well as from
the topology of the space they enclose.(B. Forster)
Amount and direction of the conduction of
the heat through the fabric structure depends greatly on the internal and external air temperatures, the wind speed, and on the thickness of the fabric and whether it is single or double membrane.(Navvab)
Tensile structures can be used as microclimate modifiers in a number of different ways depend on material specification and environmental issues.

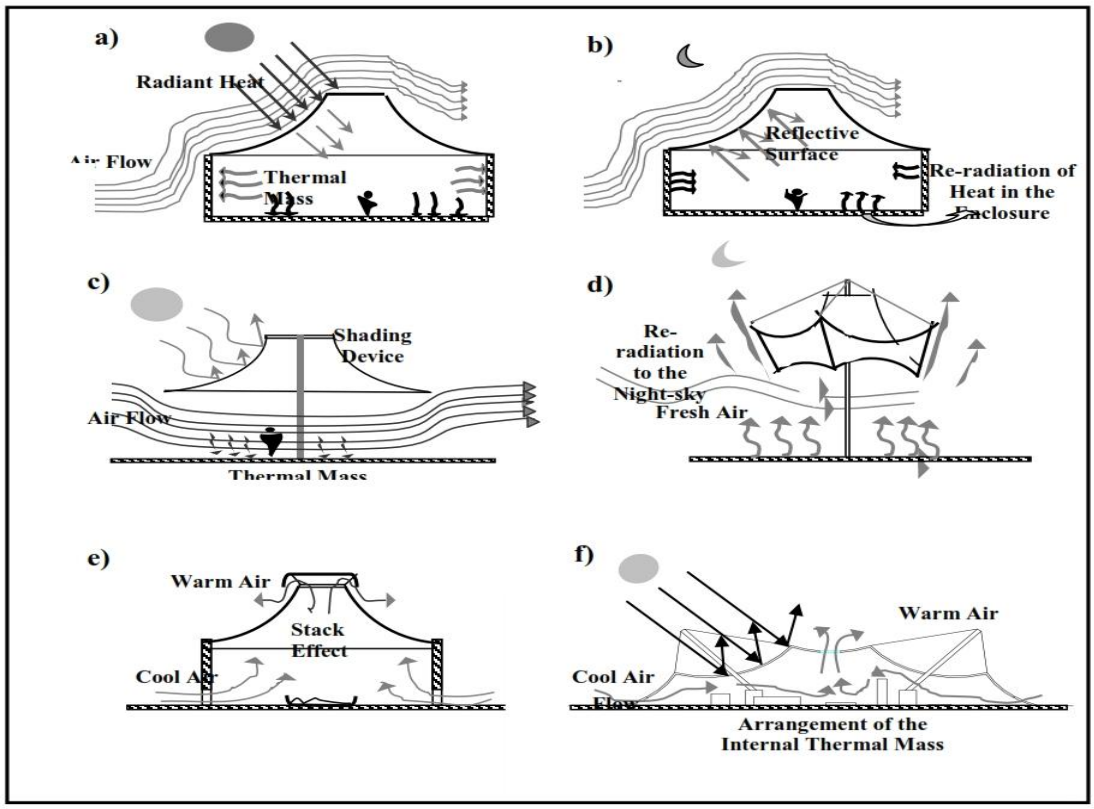


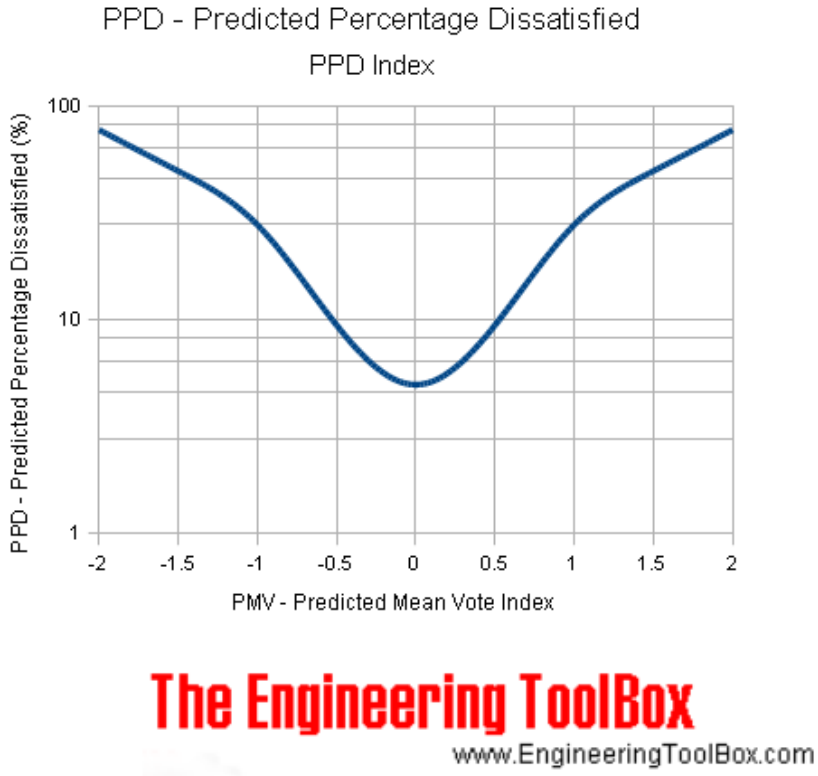
Figure 2 Using topology in manipulating internal comfort within or underneath the structure.(A. Elnokaly)

For example the use of retractable fabrics or canopies, the arrangement of the internal thermal mass, as shading device.

V. COMFORTABLETHERMAL CONDITIONAND PROCESS

It has been shown that the productivity will be increased by 15% when occupants are satisfied with their thermal environments (K . Kim, B.S .Kim , 2007).(P.O. Fanger, 1972)believed that human intellect performance and perception in general will reachits maximum potential if human being is in a comfortable thermal condition.A quality night sleep has been observed to play a significant role in allowing adequate daytime functioning: concentration, attention and comprehension as well as learning level (S.C. Sekhar, and S.E. Goh, 2011).Respondents demanding for cooler environment and more air movement were more numerous than those demanding for warmer and less air movement and that they did not provide a significant cooling potential during hot season in warm-humid tropical climate.
Different people may have different response regarding comfort in the same space due to certain factors.The factors affecting human thermal comfort are: *metabolic activity (met), clothing insulation (clo), air temperature, mean radiant temperature, air movement and humidity.* (P.O. Fanger)
The PMV *(Predicted Mean Vote) and* PPD *(Predicted Percentage Dissatisfied)* models are tools to determine thermal comfort conditions. **PMV** *(Predicted Mean Vote)* is used to express the human perception of thermal comfort. The index has been defined by statistical research of a large group of individuals. Individuals are to evaluate their own perception of thermal comfort in a certain indoor climate. The index includes the combination and interdependencies of the following factors of thermal comfort: *metabolic activity (met), clothing insulation*

(clo), air temperature, mean radiant temperature, air movement and humidity. **PPD** *(Predicted Percentage Dissatisfied)* describes the percentage of occupants that are dissatisfied with the given thermal conditions. 5% PPD is the lowest percentage of dissatisfied practically achievable since providing an optimal thermal environment for every single person is not possible.



The PMV index predicts the mean response of a larger group of people according the ASHRAE thermal sensation scale. (P.O. Fanger)

PMV	-3	-2	-1	0	+1	+2	+3
Thermal Sensation	cold	cool	Slightly cool	neutral	Slightly warm	warm	hot

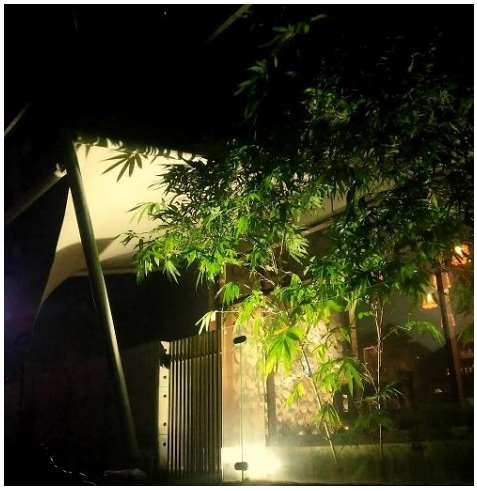
The PMV index is expressed by (P.O. Fanger)as
PMV = (0.303 e-0.036M + 0.028) L (1)
where PMV = Predicted Mean Vote Index
M = metabolic rate
L=thermal load-defined as the difference between internal heat production and the heat loss to the actual environment- for a person at comfort skin temperature and evaporative heat loss by sweating at the actual activity level

VI. CASE STUDY

In this study, a prototype for the examination of thermal comfort in two public spaces was presented using PMV-PPD model. The field survey was carried out in two restaurants at Gulshan, Dhaka. Dhaka is located on latitude 23.7000° N, 90.3667° E within a warm-humid tropical area.

General Information regarding the study area:
BAY'S EDGEWATER, GULSHAN 2, DHAKA:
Bay's Edgewater is an exhibition hall of renowned capital of Bangladesh. At the semi-outdoor space of this exhibition hall, TMS has constructed.

Case Study 2:
'BISTRO FANTASTICO', DHAKA:
There are many other projects which have achieved their complete goal by constructing TMS. Here are some images of tremendously suitable project 'BISTRO FANTASTICO' of Dhaka, Bangladesh.

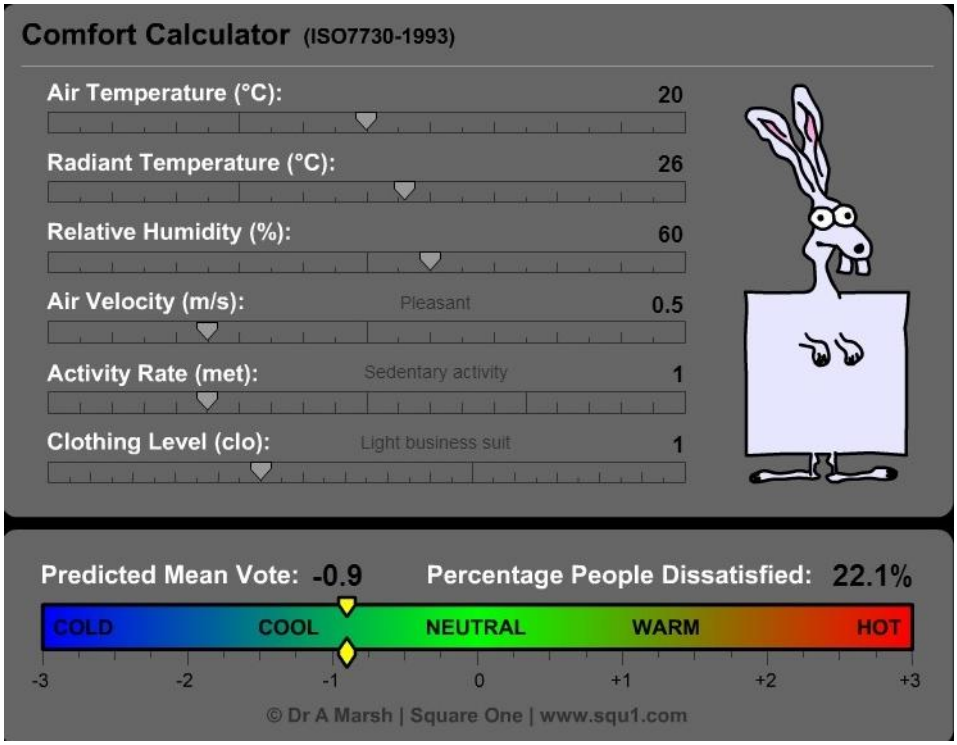



VII. METHODOLOGY

The selected method in this research is field survey. Field study allows for analyses of many of the contextual factors than those that can be simulated in climate chamber, as the subjects provided responses in their everyday habitats, wearing their everyday clothing and behaviour without any additional restrictions. In the field survey people are able to act as "meters" of their environment(M.A. Adebamowo, and O. Olusanya, 2012). The field study is conducted in the month of March which is spring in Bangladesh and Meteorological data showed that hot season in Ile-Ife is characterised by high humidity and temperature with low air movement.

Thermal analysis was based on 50% occupancy during weekdays and 90% occupancy during weekends. Number of inhabitants was assumed to be same for all the rooms.

Using the thermal comfort calculator (ISO-7730-1993) the PMV and PPD values of the different zones have been calculated.



7.1 Data Collection and Findings

Temperatures, Air velocity, Relative humidity of the different zones of the two case studies are collected 3 times at 5 minutes interval using Thermo-Anemometer and Hygro-thermometer. And the average value of each zone is finally put in the comfort calculator(ISO-7730-1993) to determine PMV and PPD.

Data collected from the reading of Thermo-Anemometer and Hygro-thermometer are given below

Bay Edge Water

Zone: 01: Outdoor Space

Time	Wind Velocity (m/s)	Max temp °C	RH%
2:30 pm	0.4	30.9	20%
2:35 pm	0.3	31	20%
2:40 pm	0.1	32	20%

Zone: 02: Semi-outdoor space having tensile structure

Time	Wind Velocity (m/s)	Max temp °C	RH%
2:45 pm	0.1	29	20%
2:50 pm	0.4	28.5	20%
2:55pm	0.6	28	20%

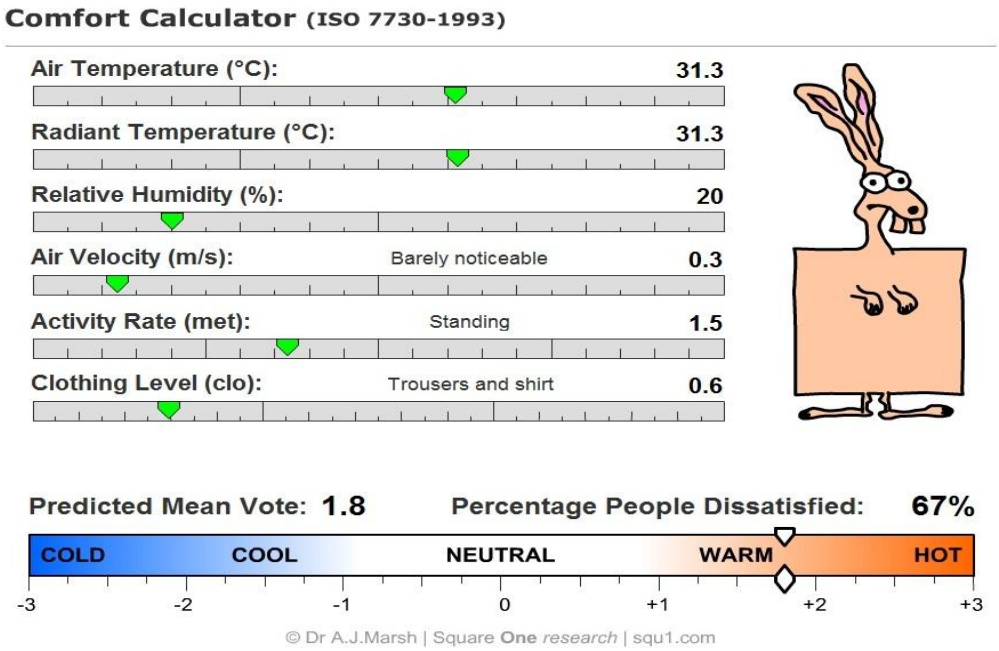
Zone: 03: Indoor Air-Conditioned Environment (Air-condition was switched off, no provision for natural ventilation, combination of glass and fair face facade)

Time	Wind Velocity (m/s)	Max temp °C	RH%
3:00 pm	0	29.2	20%
3:05 pm	0	29.8	20%
3:10 pm	0	31.1	20%

Analysis:

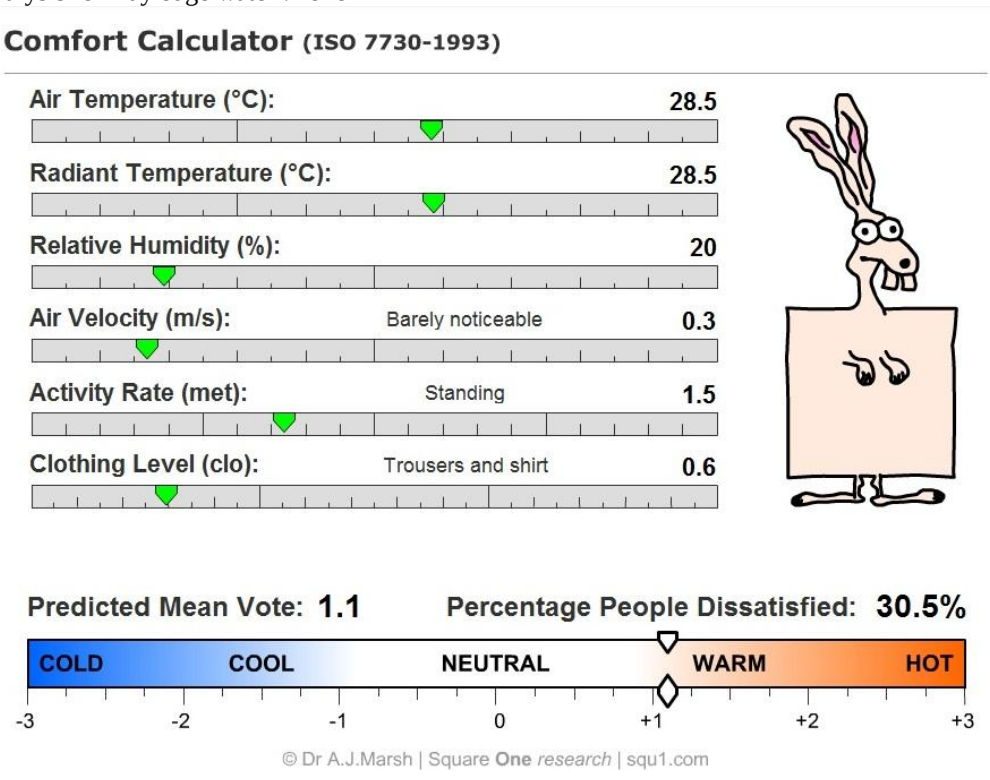
From the reading of thermo anemometer and hygro-thermometer it is seen that zone two has average temperature of 28.5 c which is the lowest among the three zones. Therefore it can be said that using tensile roof in the outdoor space has reduced the average temperature which was 31.3 c in case of zone 1. The relative humidity is constant for

all zones. In case of zone 3 the average temp is 30.03 c. Though zone 3 was air- conditioned. There was no air movement. For that reason the average temperature is higher than zone 2.

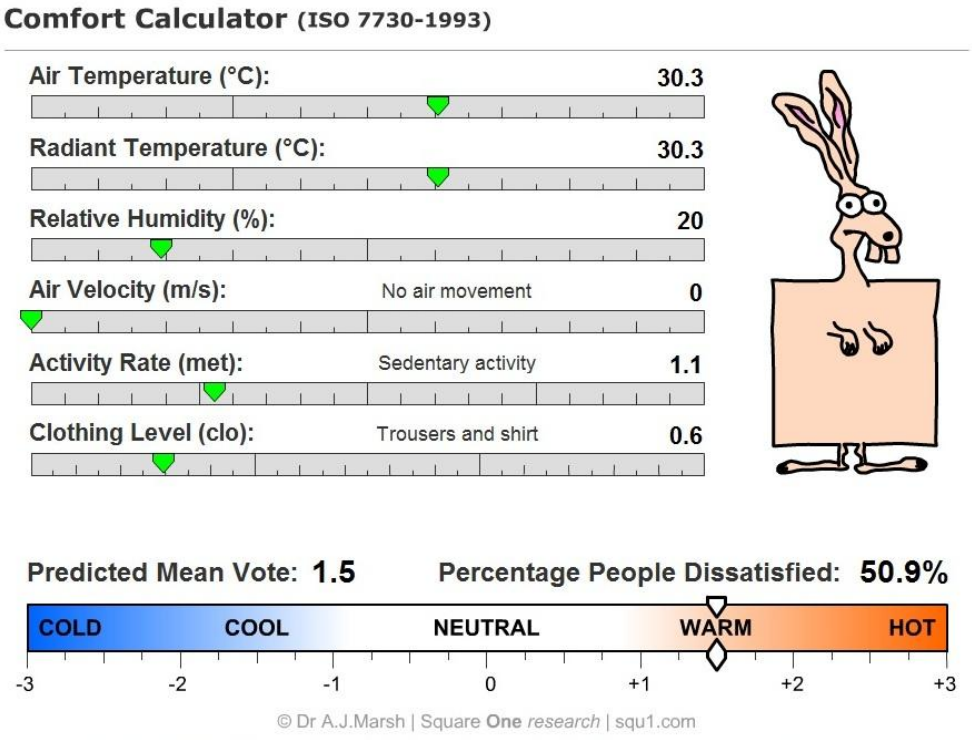


Comfort Analysis for Bay edge water : zone-1

Comfort Analysis for Bay edge water : zone-2



Comfort Analysis for Bay edge water : zone-3



So Putting the average values of each zone in the thermal comfort calculator (ISO-7730-1993) we can get PMV and PPD rate.

Bay edge water	Met (Activity rate)	Clothing Level (Clo)	PMV	PPD
zone 1	1.5	0.6	1.8	67%
zone 2	1.5	0.6	1.1	30.5%
zone 3	1.1	0.6	1.5	50.9%

Analysis:
After putting all the value in thermal it can be concluded that in zone 2 the percentage people dissatisfied (PPD) is lowest which
30.5% where tensile roof has been used and predicted mean vote of zone 2 is also most satisfactory which is 1.1.

BISTRO FANTASTICO
Zone: 01: Outdoor Space

Time	Wind Velocity (m/s)	Max temp °C	RH%
1:00 pm	0.3	27.9	20%
1:05 pm	0.2	28.5	20%
1:10 pm	0.1	28.8	20%

Zone: 02: Semi-outdoor space having tensile structure

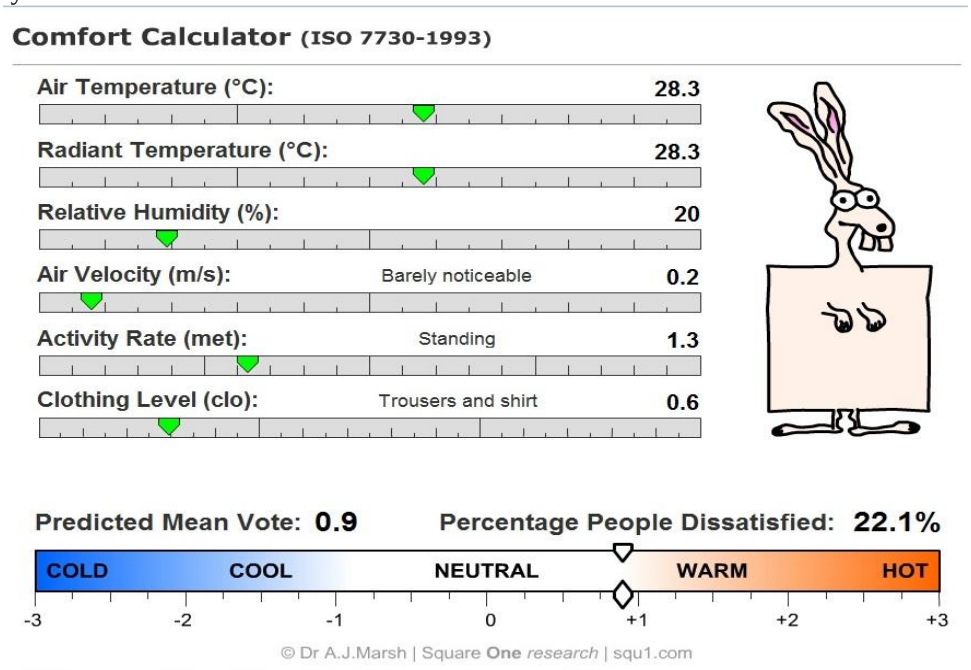
Time	Wind Velocity (m/s)	Max temp °C	RH%
1:15 pm	0.2	26.3	20%
1:20 pm	0.5	25.8	20%
1:25 pm	0	26.5	20%

Zone: 03: Indoor Air-Conditioned Environment (Air-condition was switched on, no provision for natural ventilation, glass facade)

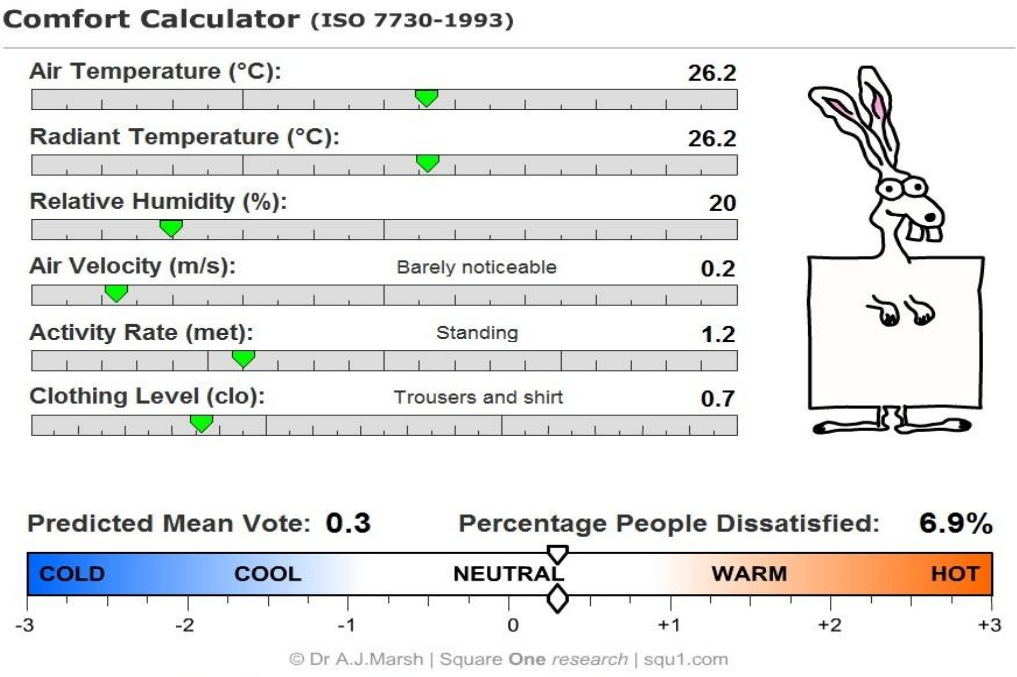
Time	Wind Velocity (m/s)	Max temp °C	RH%
1:30 pm	0	25.5	20%
1:35 pm	0	26.2	20%
1:40 pm	0	26.5	20%

Analysis:
From the reading it can be observed that establishing tensile roof in zone 2 has decreased the average temp to 26.2 c which was 28.4 in case of zone 1.

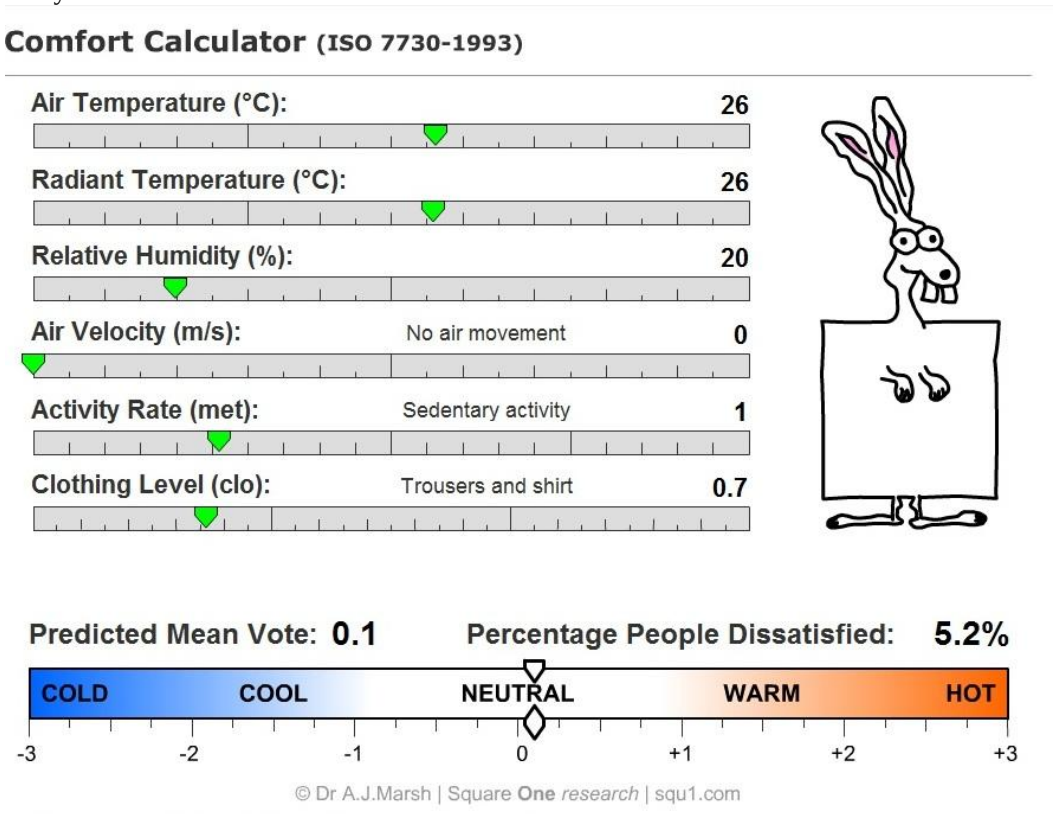
Comfort Analysis for BISTRO FANTASTICO: zone-1



Comfort Analysis for BISTRO FANTASTICO : zone-2



Comfort Analysis for BISTRO FANTASTICO: zone-3



So putting the average values of each zone in the thermal comfort calculator (ISO-7730-1993) we can get PMV and PPD rate.

BISTRO FANTASTICO	Met (Activity rate)	Clothing Level (Clo)	PMV	PPD
zone 1	1.3	0.6	0.9	22.1%
zone 2	1.2	0.7	0.3	6.9%
zone 3	1	0.7	0.1	5.2%

VIII. CONCLUSION

From the analysis it is seen that there is a significant temperature difference between the outdoor space and semi-outdoor space of the respective study areas. Therefore, it can be said that the use of tensile structure in the semi-outdoor space have enabled the temperature change.

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