CHAPTER THREE

RESEARCH DESIGN

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The human thermal comfort is affected by many physical and personal variables. The principle physical variables are air temperature, mean radiant temperature or surface temperature, air movement and humidity. Among these physical factors influencing human thermal comfort in indoor environments, the most used for the research design process, to operation management of energy efficient and comfortable buildings are air temperature and humidity. So in the research, procedures are totally based on indoor plants, air temperature and relative humidity data.

3. 1. RESPONSE DATA

The built environment has a great influence on the health comfort of the occupants, their working efficiency and safety, where people spend 90% of their time. The indoor thermal environment is much different compared with the outdoor thermal environment, because of thermal inertia of building materials and furniture, different heat gain processes, number of people and levels of activity etc. So it is a well-known fact that the thermal neutrality or thermal comfort is important to life and never more important than in home where people spend most of their life.

In this study all the other variables are assumed as constant, except air temperature, relative temperature and air movement. The experimental studies are conducted in a model situation where only the air temperature, relative humidity and air movement can be varied, with the use of indoor plants. In studying thermal comfort variables if there are lot, it is also difficult because most of the variables are independent variables, acting simultaneously.

To understand the human thermal comfort indication it is needed to have a thermal comfort standard.

3. 2 THERMAL COMFORT STANDARD OF SRI LANKA

The design of thermal comfort standard for Sri Lanka is still not properly recognized, as in other countries. As a tropical country, where the heat is the dominant problem, where for a greater part of the year buildings serve to keep the occupants cool, rather than warm, so development of thermal comfort standards are much difficult. On the other hand thermal comfort is also a matter of personal preference. It would be difficult to provide a standard of thermal comfort to suit every one. So many standards give the neutral temperatures (where the temperature which is the greatest percentage of people are experiencing neutral thermal sensation) and relative humidity that is related to the neutral temperature.

In Sri Lanka annual mean temperature is very high (nearly about 27°C) and the relative temperature is also high (about 75%)

fig. 22. Monthly mean Air Temperatures in 1998 (°C)

	J	F	M	A	M	J	J	A	S	O	N	D
Monthly mean max	32.4	33.3	33.8	34.2	33.4	32.1	31.4	33.3	31.5	31.2	31.2	31.4
Monthly mean min	23.0	24.1	24.5	25.3	26.2	26.1	25.9	26.3	25.6	24.9	23.8	22.7
Monthly mean average	9.4	9.2	9.3	8.9	7.2	5.9	5.5	8	4.9	6.3	7.4	8.7

fig . 23 . Monthly mean Relative Humidity in 1998 (%)

	J	F	M	A	M	J	J	A	S	O	N	D
Monthly mean max a.m.	67	62	64	71	79	80	80	80	77	79	78	75
Monthly mean min p.m.	90	87	87	92	90	88	86	89	87	89	93	95
Average	78.5	74.5	75.5	81.5	84.5	84	83	84.5	82	84	85.5	85

It is necessary to study the design standards for thermal comforts used in various countries, to understand the requirements of the indoor thermal environment.

There are various neutral temperatures proposed by different investigators, which are as follows.

Investigator	Temperature Range	Relative Humidity
Webb(1960) Singapo	24 C- 27 C	50%- 75%
Gragge (1971)	22 C- 25 C	25%- 70%
Koenigsberger (1973	22 C- 27 C Day	Above 70%
	17 C- 20 C Night	
Evans (1980)	25.5 C- 27.5 C Summer	50%- 70%
	20 C- 26 C Winter	
ASHRAE (1981)	22 C- 26 C	20% -70%
Bill(1983) Singapore	24 C- 27 C	75%- 50%
Wang (1987)	23.5 C-25.5 C	40%- 60%
Chow (1992)	23 C- 27 C	Above 55%

When considering the temperature ranges and humidity's the suitability for a tropical country like Sri Lanka, it is a problem where the air temperature and relative humidity is very much higher during all around the year.

Singapore also has similar climatic conditions like Sri Lanka, in Koenigsberger's "Tropical House Manual" book. Both these countries have been categorized in the warm-humid climates Webb's equatorial comfort index develop in Singapore during 1960, temperature range 24°C – 27°C and relative humidity between 50% - 75%. Again Bill in 1983 used the same comfortable range in Singapore for indoor thermal comfort design standards. Wang (1987) in Hong Kong used some thing similar to Bill but unlike the Singapore Hong Kong has seasonal variations too.

Analyzing all the above temperature ranges and relative humidities found by different investigator's many of them are not suitable for tropical countries, and they are for the temperate climates with seasonal variations. Koenigsbergers indexes are done according to the tropical climates. But Koenigsberger, the humidity range is not specifically stated

comparing with the other investigators. AHSRAE temperature scale is normally standards for air-conditioned spaces, and it is more applicable to dwellers in the temperate countries. It applies less to the tropics, due to clothing and possibly also due to acclimatization. So studying all these investigations the more suitable comfort index for Sri Lanka should be 24^{0}C-27^{0}C temperature range and 50% - 75% relative humidity range which is suggest by Webb and again used it by Bill in Singapore.

3. 3 COLLECTION PROCEDURES

Necessary data's to check the comfort scales:

1. Outdoor Dry- bulb temperature
2. Outdoor Wet- bulb temperature
3. Outdoor Humidity
4. Indoor Dry-bulb temperature
5. Indoor Wet-bulb temperature
6. Indoor Humidity

Measuring Equipment's:

Dry bulb temperature and Wet bulb temperature is measured by a wet and dry Hygrometers. The relative humidity was found by subtract the wet bulb reading from the dry-bulb reading to find the wet bulb depression. Noted the difference and founded the relative humidity from a standard chart.

Field Measurements:

All the following measurements were taken all through out the day in everyone hour time.

1. Out door data - Out side the house (1m above the ground level)
2. Indoor data - Inside the house

The measurements were taken at the middle of the courtyard within the plant leaves approximately in 1m height, 1.5m away from the middle of the courtyard in 1m height and 3.5m away from the middle of the courtyard and in 1m height.

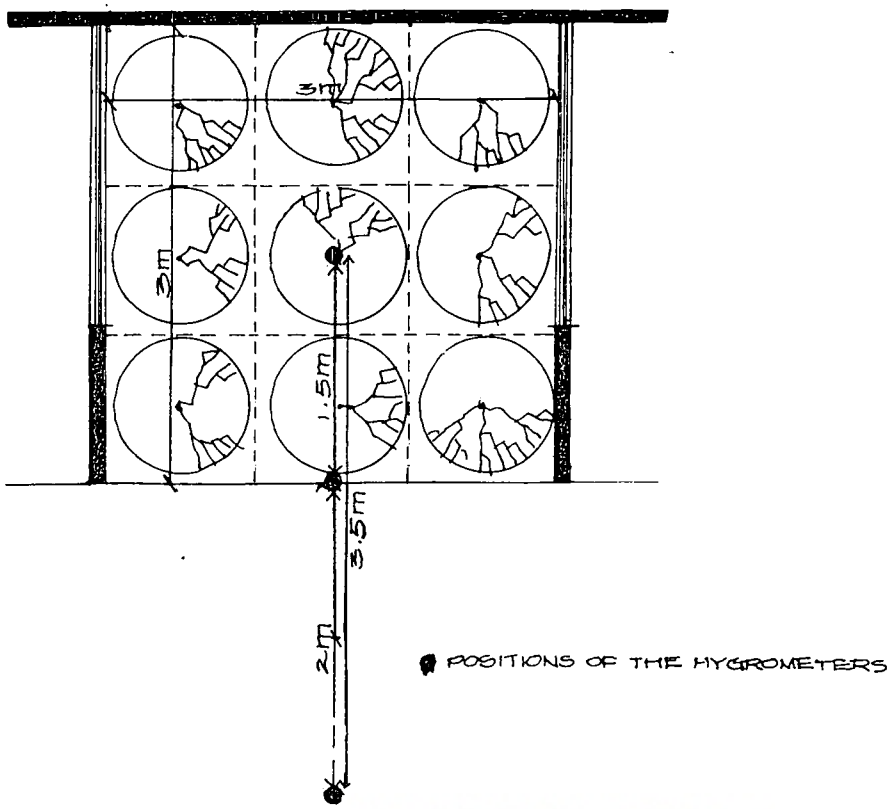


Fig. 25. The floor plan of the courtyard

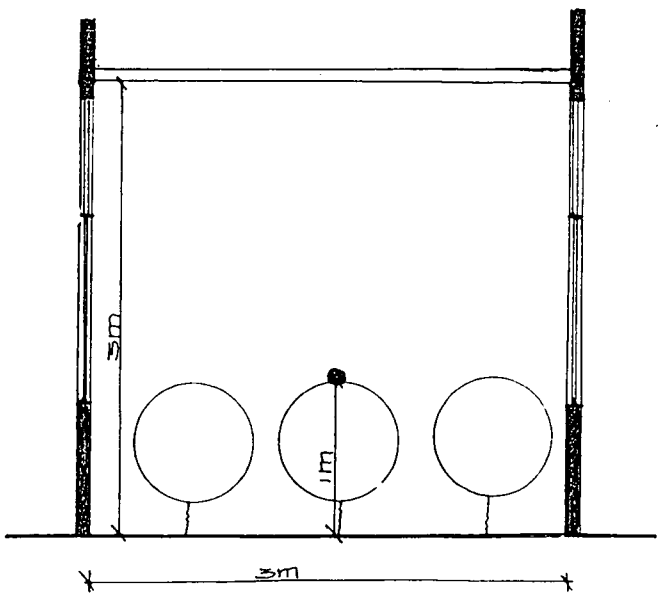
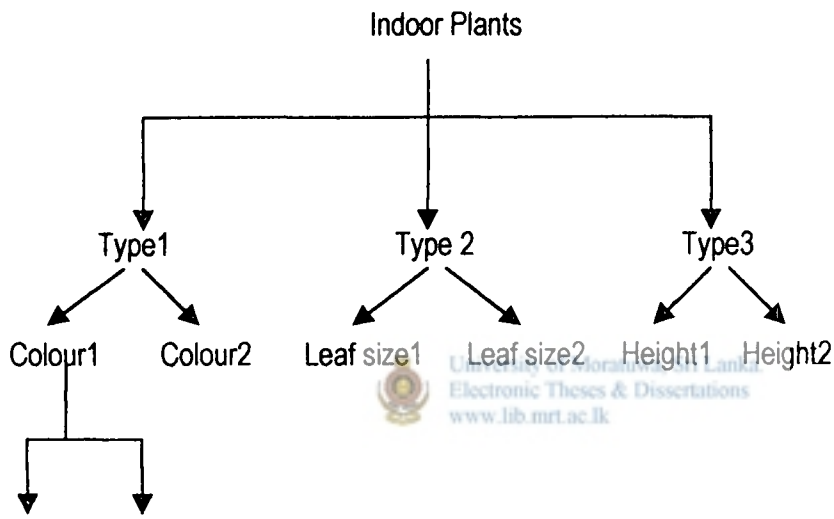


Fig. 26 . The section of the courtyard

3. 4 THE TYPES INDOOR OF PLANTS

The common widely using 3 types of indoor plants were used for the experiment, and these three types are categorized as to observe the differences that brought with the difference characters of plants. The characters are:

1. The color of the plant
2. No of plants
3. Leaf size
4. Height of the plant



3. 4.1 Type 1. Schefflera arboricola (finger plant)

This family was chosen to observe the of color differences, and differences effect form plant number

- Schefflera arboricola – green
- Scheflera arboricola – yellow

fig . 27. The Schefflera arboricola green plant

fig .28. The Scheflera arboricola yellow plant

3. 4. 2 Type 2 . Palm trees

This type was chosen to observe the effect of leaf differences.

- Areca lutescens (cane palm)
- Livistona rotundifolia (queen palm)

fig.29. The cane palm plant

fig. 30. The queen palm plant

3. 4. 3 Type 3. Plemele reflexa

This type was chosen to observe the effect of the plant height differences.

Fig. 31. The Plemele reflexa plant

The research data were taken throughout whole day in every one hour. This data includes the outdoor air temperature and relative humidity at the courtyard, 1.5m away from the courtyard and 3.5m away from the courtyard. Firstly the indoor air temperature and relative humidity at all three conditions were analyzed, from this it can get a general idea about behavior in the indoor situation with out plants. Then indoor air temperature and relative humidity with plants analyzed but the results are obtained in different days, so the outdoor conditions were different (the environmental conditions may different from day to day). So the indoor conditions also adjust according to this outdoor variations. By considering outdoor and indoor temperature differences and outdoor, indoor relative humidity differences may be much accurate to compare results with these different plant types.

OUTDOOR TEMPERATURE - INDOOR AIR TEMPERATURE
(Courtyard, 1.5m distance and 3.5m distance)

If the difference is a 'plus' value that means indoor air temperature is less than outdoor air temperature. If the difference is a "minus" value that means the indoor air temperature is higher than the outdoor air temperature.

OUTDOOR RELATIVE HUMIDITY – INDOOR RELATIVE HUMIDITY

(Courtyard, 1.5m distance and 3.5m distance)

If the difference is a 'plus' value that means the indoor relative humidity is less than outdoor relative humidity. If the difference is a 'minus' value that means the indoor relative humidity is higher than the outdoor – indoor differences.

The observed data of all types of plant were compared with the indoor data those obtained without plants. The indoor data obtained without plants were also taken as the outdoor indoor differences.

The data obtained in every hour and there are some short changers in the environment, so these 'minor' changers in the environment effect the research data, so some of these minor matters were not considered in analyzing the observed data.

Normally in Sri Lanka the outdoor environment conditions specially the air temperature and relative humidity acting more similarly in each and every day (not much change during the year). Usually the highest air temperature was found during daytime from 12 noon to 4 p.m. and the lowest air temperature was found normally during in early morning from 2 am to 6am. Normally in tropical countries relative humidity is higher all through the day, the lowers relative humidity range found during day time 1pm to 4pm and highest relative humidity range found during nighttime, normally after 11pm up to 4 am on the following morning.