THERMAL COMFORT : A fundamental criterion in Building Design

Meer M. Ali*

The primary objective of a building is to create an environment which is comfortable to live and work in. Proper knowledge of thermal comfort is essential to reach successful design solution of buildings. It is all the more necessary and should be carefully considered where mechanical methods are not available for the control of indoor environment. In the following paragraph factors affecting thermal comfort have been discussed. Some directions towards design solution have also been attempted.

Macfarlane and others defined comfort "As certain thermal conditions in which over 50 per cent of the people are unaware of their climatic environment-that is they do not feel the need to adjust to it."[1] It has also been defined as "That condition of mind which expresses satisfaction with the thermal condition."[2] Some indoor environment may not be equally pleasing to every one. The idea is to create optimal thermal comfort for the group, that.is to create an environment in which highest percentage of the group is in thermal comfort. Thermal comfort does not mean that thermal conditions should be kept at all times at a very precise level. On the contrary some fluctuations in indoor conditions such as temperature and air velocity, are rather helpful. It prevents monotony and stimulates the thermoregulatory system. Thermoregultory system can adjust to comfortable condition within a given set of condition known as comfort zone.

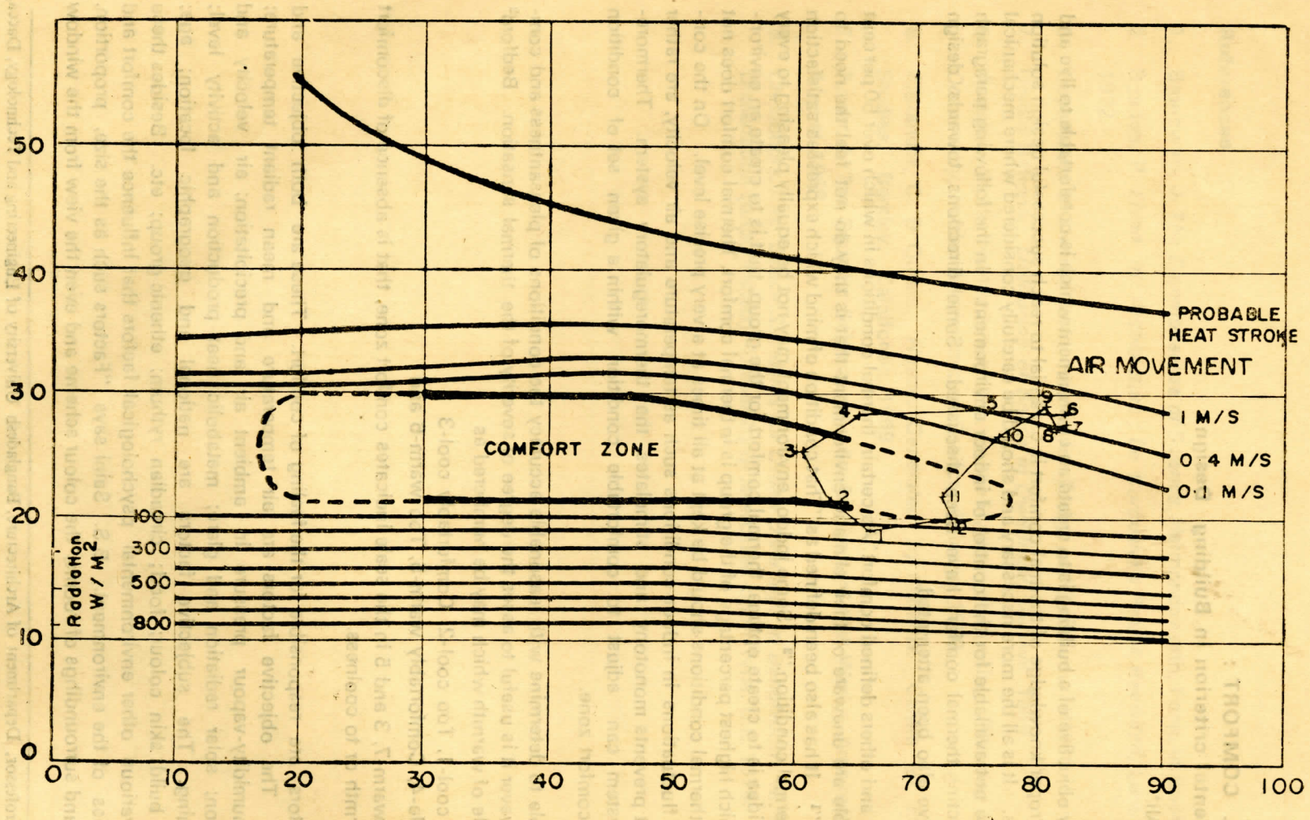
It is possible to determine with reasonable accuracy the conditions of pleasantness and comfort. However it is useful to asses the degree of severity of the thermal sensation. Bedford[2] gave a scale of warmth which may be numbered as

Much too cool-1, Too cool-2, Comfortably cool-3
Comfortable-4, Comfortably warm-5, Too warm-6 and

Much too warm-7, 3 and 5 in the scale indicates comfort zone, that is absence of discomfort due to warmth or to coolness.

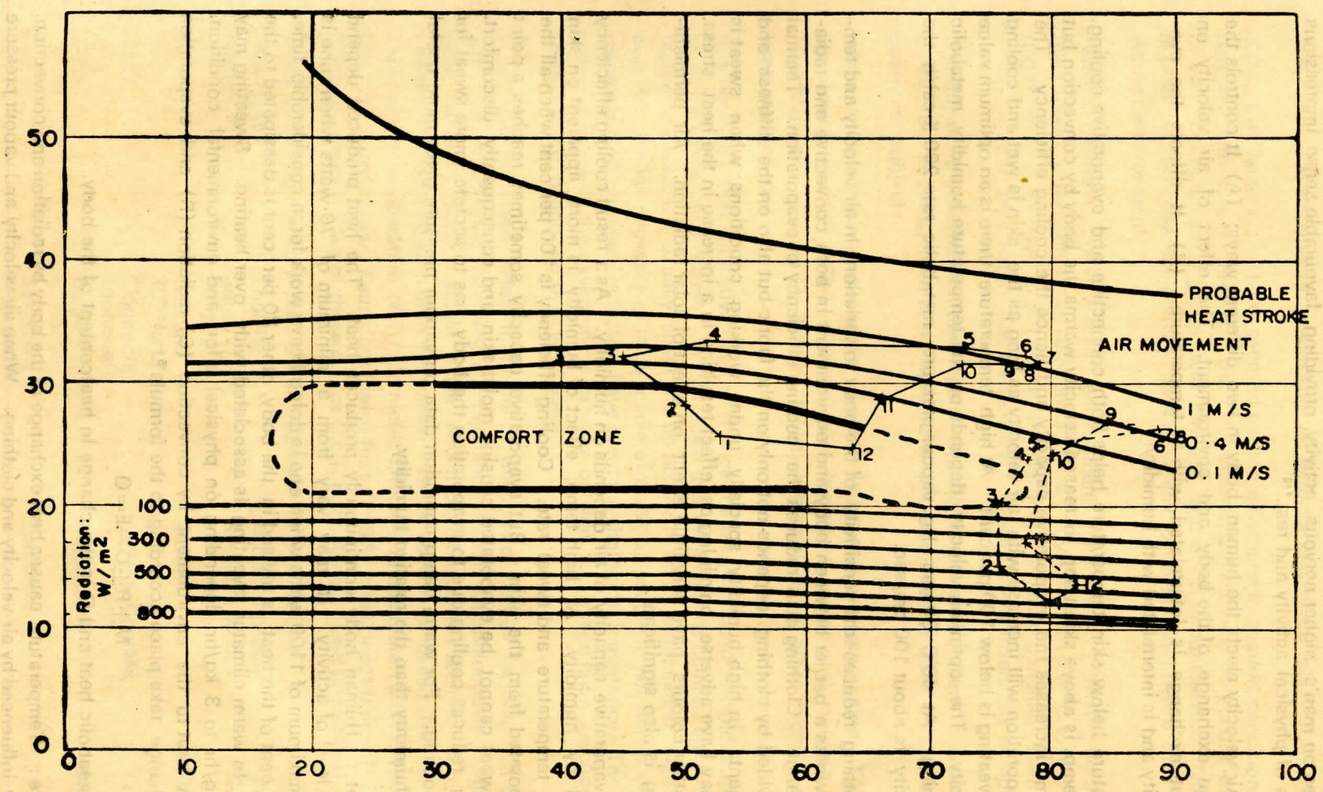
Many factors are responsible for the feeling of comfort. These are both objective and subjective. The objective factors are air temperature and mean radiant temperature; relative humidity-vapour pressure in ambient air and precipitation; air velocity and air pollution; solar radiation and glare; metabolic heat production and activity level; and clothing. The subjective factors are national and geographic location; age; sex; body build; skin colour; food; circadian rythum; ethenic group; etc. Besides these there are various other environmental psychological factors that influence the comfort and pleasantness of the environment. B.S. Saini says "Factors such as the size, proportion, character and surroundihgs of rooms, the colour scheme and even the view from the window

*Associate Professor, Department of Architecture, Bangladesh University of Engineering and Technology, Dacca, Bangladesh.



RH% NUMBERS IN THE GRAPH INDICATE MONTH OF THE YEAR
POINTS ARE PLOTTED WITH AVERAGE VALUES OF TEMP. & R.H.

FIG-1



RH : % NUMBERS IN THE GRAPH INDICATE MONTH OF THE YEAR
9 A.M. HUMIDITY (HIGH) & LOW TEMPERATURE, ASSUMED NIGHT CONDITION ------
6 P.M HUMIDITY (LOW) & HIGH TEMPERATURE, ASSUMED DAY CONDITION ——

FIG. 2

have a great psychological effect. There is the combined effect of sun, fresh air and greenery which impinges on man's higher nervous activity, providing favourable sense impressions during periods of physical activity and rest."[4]

Air Velocity : Air velocity elects the human body in two different ways; (A) It controls the convective heat exchange of the body and environment. The effect of air velocity on convective heat exchange is interrelated with air temperature. (B) It effects the evaporative capacity and is interrelated with humidity.

An air temperature below skin temperature helps both connective and evaporative cooling. When the air temp. is above skin temp. increased velocity warms the body by convection but at the same time increases the evaporative capacity and hence the cooling efficiency. The cooling by evaporation will increase with air velocity as long as the skin is wet and cooling efficiency of sweating is below 100 per cent. At high temperature there is an optimum value of the air velocity. The optimum velocity depends on the temperature humidity, metabolic level and clothing. At 40'C 30 mm. Hg. vapour pressure, metabolic rate 200 K cal/h the optimum velocity is about 100 cm/sec.

Clothing : Clothing reduces the sensitivity of the body to variations in air velocity and temperature, also works a barrier between body and environment in both convective and radiative heat exchange. Clothing also reduces the cooling efficiency of evaporation. Thermal resistance provided by clothing depends not only on the fabric but also on the stiffness and fit of the garment. In high humidity specially under working conditions when sweat is increased, it may have adverse physiological effect resulting in a increase in the heat stress. Beside black other colours have very little effect on effect of solar radiation. Air permiability of clothing is also significant.

Humidity : Evaporative capacity of air depends on humidity. As a result cooling effeciency is determined by humidity. At high temp, effect of humidity is more apparent on skin wetness, skin temperature and sweat rate. Cooling effieiency is 100 per cent when all the sweat is evaporated from the skin. But evaporative capacity sometimes reaches a point when all the sweat cannot be evaporated causing moist skin and consequently discomfort. When clothing reduces cooling due to evaporation the body has to secrete more sweat for the required cooling. For warm damp condition data on vapour pressure gives more useful expression of humidity than the relative humidity.

Metabolic heat : Human body continuously produces heat. The heat produced depend greatly on the level of activity. It may vary from a minimum of 70 watts when one is sleeping to a maximum of 1100 watts when one is doing heavy work for a considerable time. Only 20 per cent of the heat is utilised in the body, other 80 per cent is dessipated to the environment. In warm climates sweating is associated with over heating. Sweating may vary from 2 g/hr to 3 kg/hr depending on physical effort and environmental condition. Body releases heat to the environment by convection (C) radiation (R) and evaporation (E). Heat exchange take place according to the formula'[5]

$$M \pm R \pm C - E = Q$$

Where M is metabolic heat and Q is the change in heatcontent of the body.

Air temperature : Temperature causes heat exchange of the body by radiation and convection. This is greatly influenced by air velocity and clothing. When air velocity and vapour pressure

is constant, rise in air temperature results in the increase of skin temperature and sweat rate. The increase is dependent on existing air velocity and sweat rate.

Subjective factors : There seem to exist a difference in comfort condition between young persons and elderly persons. But the difference becomes very significant when groups of very old age, say a group with average age of 65 is considered. One of the reasons is probably because the activity level of elderly people is low hence they prefer a slightly warmer environment.

Females generally prefer warmer environment than males. The degree of variation have been found to be different in different studies. It varies from 0.3 °C to 1°C. The difference might have been due to difference in clothing. Women generally have slightly slower metabolic rate than men. They also have a slightly lower insensible perspiration.

It is popularly believed that obese persons prefer cooler environment than persons of slighter build. But in reality than is no significant influence of body build on comfort conditions of sedentary subjects.

Intake of food causes a certain increase in internal heat production. This have influence on thermal comfort. This is all the more important in low cost housing situation where food is usually taken in the kitchen which is warmer than other rooms because of more heat production.

It is observed that subjective factors change the physical comfort conditions of the environment by a very small degree. In fact when any difference in comfort level due to subjective factors do exist, it is usually small and do not alarm much engineering significance. However factors like necessity of large intake of water by people in hot humid climate cannot be overestimated. Subjective factors have great psychological importance. The influence of the colour scheme of the environment or view outside, say, green lawn as opposed to the bare sandy patch, cannot be over emphasised.

It has been described before that comfort depends of various factors. So designer is faced with the problems of handling independent variables simultaneously. Many efforts have been made to devise a single scale which combines these factors. In doing so, various researchers came up with different scales. These scales are called Thermal Indices. These are Effective Temperature (E.T.) Corrected Effective Temperature (C.E.T), Resultant Temperature (R.T.) Predicated. Four Hour Sweat Rate (P^4 SR), Heat Stress Index (H.S.I.) and Index of Thermal Stress (I.T.S.) of these E.T. or C.E.T. is mostly used and understood.

Some of the experimental results from Lippseier is given below

Investigator	Locality	Group of people	Comfort Zone
A.S.H.R.A.E.	South U.S.A. 30° North	Research worker	69 to 70°F
Rao	Calcutta 20° North	Indian	68 to 76°F
Webb	Singapore Equitorial	Malays, Chinese	77 to 81°F
Mom	Batavia 6° South	Indonesian	68 to 79°F
Ellis	Singapore Equitorial	European	72 to 79°F

This is interesting to note that Webb and Ellis arrived at slightly different results under similar conditions. This however should not be attributed to difference of subjects as Asian and European.

It is observed that D.B.T. values correlate much better with subjective judgement than E.T. values. V. Olgyay argues that there is no point in going for complicated calculations in constructing a single figure Index as all the variables are controlable by different means. He developed the bioclimatic chart where the comfort zones are defined in terms of D.B.T. and Relative Humidity. He also charts the effects of air velocity and radiation. The former pushes the comfort zone upward and the latter draws it downward.

Climatic data of Dacca have been plotted on the chart to show the periods of comfort and discomfort and degree of deviation from the comfort condition. Fig. 2 is plotted with set of data indicating day and night time situation based on mean monthly values. Fig 1 is plotted with set of data based on average monthly data.

From these two charts a reasonably clear picture can be obtained about comfort condition in relation to climate. During summer months from April to October the prevailing conditions are well above the comfort zones. So continuous movement of air between 1 and 2 m/s. is necessary to attain reasonable comfort level. And also the effect of radiation should be less. From the chart it is observed that day times of December, January and February are within the comfort zone and are quite pleasant. Nights are cold and below comfort zone. In March and November nights are pleasant and days are a bit warm but not very un-pleasant. For winter months no comfort ventilation is necessary, infiltration of cold wind should be restricted specially at night. Sun rays should be allowed to enter the interior spaces and insolation of the walls should be more. In March and November some air flow during day time will bring in comfort condition.

References :

1. Macfarlane, W.V. et al. "Thermal comfort Zones" *Architectural Science Review* Vol. 1. No. 1 1968.
2. Fanger P.O. *"Thermal Comfort"* Danish Technical Press, Copenhagen, 1970.
3. Bedford, T. *"Basic Principles of Ventilation and Heating"* H.K. Lewis & Co. Ltd. London 1948.
4. Saini, B.S. *"Building Environment" Sydney,* Angus Robertson in association with RIAA.
5. Koenigsberger, O. et al. "Manual *of Tropical Housing & Building"* Longman Group Ltd. 1974.
6. Lippsmeier, G. *"Building in the tropics"* Callway Publicrion Munich-Germany 1969.
7. Givoni, B. *"Man Climate and Architecture"* Elsevier, 1969.
8. Muktadir, M.A. *"Climatic Aspects of High Density Urban Housing in Warm Humid Tropics with particular Reference to Dacca"* Ph.D. Thesis, University of Edinburgh, 1975.