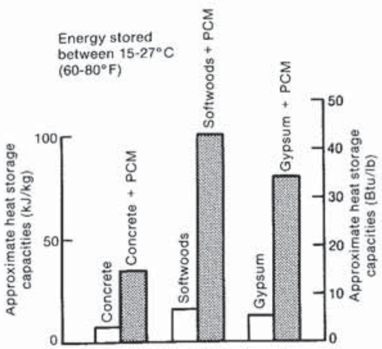

Figure 1. A Comparison of the Heat Storage Capacity of Conventional Building Materials and Similar Materials in which Pore Volume has been Filled with the PCM Neopentyl Glygol

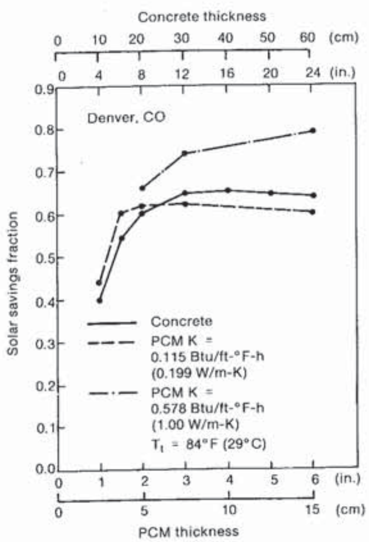

Figure 2. Solar Savings Fraction as a Function of Trombe Wall Thickness for PCMs and Concrete

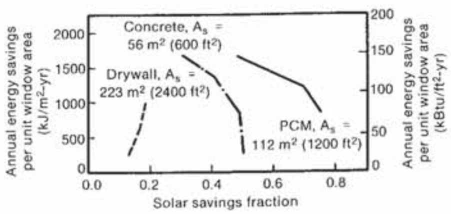

Figure 3. The Net Energy Savings per Unit Window Area for Different Heat Storage Materials in a Direct Gain Passive Solar Heated Building

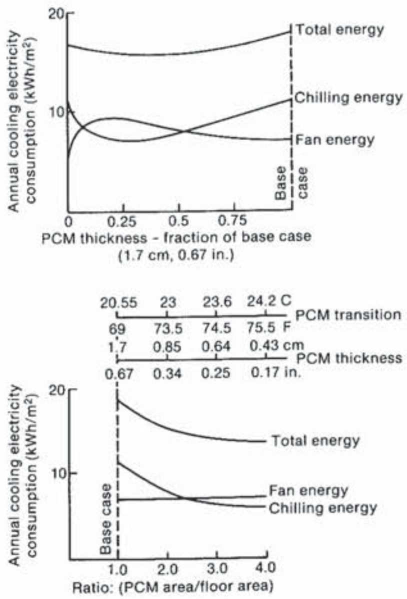

Figure 4. Cooling Energy Requirements: A, as a Function of PCM Thickness; B, as a Function of PCM Surface Area/Floor Area Ratio

Role of Orientation in Thermal Environmental Control of Buildings

Garg N.K. and Gupta T.N.

Central Building Research Institute
Roorkee - 247 667. India

KEYWORDS

Orientation, Thermal Comfort, Quantification, Simulation

ABSTRACT

For years together, architects and planners have been guided by the assumption that, for better thermal performance, buildings should be oriented towards south as far as possible. It is believed that windows not facing south contribute to the higher indoor temperatures and add to increased thermal discomfort during summer months. Normal practice has been to orient buildings towards south and position windows on their south face to capture low winter sun and to curtail high summer sun. As a result, rows and rows of south facing building blocks, parallel to each other may be seen, often neglecting important parameters of design like, quality of resultant spaces and character of building sites.

Recently, research studies have been conducted on quantification of contribution of thermal discomfort in building envelopes with respect to several factors of building design including orientation. These studies have shown that role of orientation (with respect to pattern of solar radiation) in the thermal performance of building envelopes becomes insignificant, if other factors like quality of surfaces of building envelope and shading of openings are minutely considered.

Methodology of computer simulation has been adopted and internationally accepted program for simulation of thermal performance of building envelopes, have been used for these studies. The results are graphically presented.

Le Role d' Orientation dans le Control Thermique des Batinents

Garg, N. K. and Gupta, T. N.

Central Building Research Institute
Roorkee, India

MOTS-CLES

Orientation, Consolation Thermique, Quantification, Simulation

SOMMAIRE

Depuis quelques anne es les architects et les contructeurs Se Sont guide' d' apre's le presumtion que pour obtenir des meilleurs perfornences thermiques le face des batinents doit etre oriente's vers le Sud contribuent a l'augmentation de le temperature interieure et aussi a un discomfort specialnent pendant les mois d' e'tle'. Practiquement les fenetres des batiments ont e'te' oriente's Vers ie Sud pour recivent pendant l' hiver les bas rayons de soleil et pendant e'e'te' de ne pas perme'tte' les haut rayons de soleil.

Les presuntions qui out e'te' dit Ci-dessus ont considere's seulement e' orientations des batiments et ont neglige' e' inportance de e'envelope exterieure des batinents.

Les e'tudes actuels montre que le role d' orientation des batinents reletif a le disconfort thermique interieur est non significatif si on negligait l'inportance de l'envelope exterieure des batinents.

On a adopte' une methodologie de simulation compaterise'e et on a Utilise' un programme international accepte' pour la simulation des performances de l'envelope exterieurs des batiments. Les re'sultats obtenu Sont presente's en forme grafique.

INTRODUCTION

A study has been undertaken with an objective to quantify the contribution of various characteristics of building envelope on the resultant thermal environment. Orientation of building envelope with respect to pattern of solar radiotion has been one of the significant prameters, the effect of which has been evaluated together with other related parameters like thermophysical properties of building envelope. Methodology of computer simulation has been adopted for this study. The computer program used, the reference building envelope taken up for studying the thermal performance in different situations, the climatic data adopted and the index of thermal performance evaluation accepted for the study are narrated in following paragraphs.

THE PROGRAM

Program 'Temper' developed at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia has been used for this study (1). The program calculates the sensible and latent air conditioning loads for a specified indoor temperature within the building or alternatively, indoor temperature for a specified external thermal environment. It consists of a heat transfer model of a building, which is subjected to specified external climatic environment and an internal loading according to building usage and occupancy. The heat flow through all solid boundaries is calculated by finite - difference method, using the specified climatic and internal load data and full account is taken of the thermal storage effect of the structure of the building (2). The program broadly requires the following input data:

(i) Details of building components and their distribution into zones.
(ii) 24 hourly values of ambient temperature for each day.
(iii) 24 hourly values of direct radiation for each day.
(iv) 24 hourly values of diffuse radiation for each day.
(v) Number of days for which simulation is to be done (max 8 days).
(vi) Internal loads.

There is a catalogue of thermophysical properties of commonly used building materials built into the program (3). With the help of input data (i) it Calculates the 'overall heat transfer co-efficients' for different heat transfer paths and carries out heat transfer calculations with respect to input data (ii) to (vi) A validation study of the modified program has been conducted at the Bartlett School of Architecture and Planning, University College, London, U.K.(4). It has also been extensively validated in several Australian Projects.

THE BUILDING ENVELOPE

A building may be defined as an organisation of rooms which cooperate with each other for different environmental/functional purposes. A judicious organisation of these rooms on the ground can improve their thermal environment. Therefore, the building envelope of an isolated room is most crucial from the point of view of its thermal environment. For the purpose of this study, therefore, building envelope of an isolated single enclosure with following details has been taken as a reference building envelope :

Plan dimensions of envelope - 3m X 4m,
Hight of envelope - 2.7m
walls - 230mm traditional brick walls with 15mm cement plaster on both sides.
Roof - 100mm reinforced concrete slab + 100mm brick layer over it and 15mm plaster on both sides.
Door - 1m x 2m in size, of hard wood, of 50mm average thickness, in north facing wall.
Window - 1m x 1.2m, of 6mm plain glass, in south facing wall.
Floor - 100mm brick floor over ground, with 50mm concrete screed.
Colour of walls - brick red., Colour of roof - grey
Infiltration - Zero air changes per hour.

THE CLIMATE

This study has been limited to summer days in May when the global radiation is maximum in New Delhi, India (Lat.=29 deg N.Long.=77 deg E). The data for New Delhi, recorded by the Meterological Department, India, as compiled by A.Mani (5), has been adopted for this study.

THE INDEX

Maximum indoor temperatures may be a good index to evaluate the relative thermal performance of building envelopes. However, there may be some situations where the peak value of temperature is not high but its persistence is longer. Therefore, the 24 hourly values of indoor temprature in deg C, above the accepted limit of thermal comfort 27 deg C (4) have been integrated and the net value of thermal discomfort in'deg C. hours' has been taken as the basis of comparison.

STRATEGY OF EVALUATION

Wall thickness, shading of windows, colour of external surfaces and ventilation are the relevant parameters which have been considered in following steps of this study to evaluate the effect of orientation on thermal performance of the reference building envelope.

1. In step 1, the reference building envelope which is most commonly adopted in Delhi Region of India, has been simulated and 24 hourly values of resultant indoor temperature have been received as the output of the computer program. From these values the integrated value of thermal discomfort (deg C. hour) is calculated. This exercise is carried out for eight orientations of the building envelope and the resultant thermal discomfort values ranging from 144.2 to 152.6 deg.C.hour are shown in Fig.1.

2. In step 2, the wall thickness of the reference building envelope is reduced to 120mm and 75mm. respectively. This brings out the effect of thermal mass with respect to orientation of the building. The integrated values of thermal discomfort with these wall thicknesses range from 151.5 to 156.8 and 151.5 to 158.4 deg.C.hours and are shown in Fig.2 and Fig. 3 respectively.

3. In step 3, the unshaded window of the reference building envelope is completely shaded and the integrated values of thermal discomfort are plotted in Fig.4.

4. In step 4, the colour of the external surfaces of the reference building envelope is changed to white (absorptivity = 0.12) and dark grey (absorptivity = 0.8). The discomfort values are plotted in Fig.5 and Fig.6 respectively,

DISCUSSION

1. A study of Fig.2 & Fig.3 together with Fig.1 indicates that thermal discomfort with 75mm thick walls ranges between 151.5 to 158.4 deg. hour in different orientations. With 120mm thick walls the thermal discomfort ranges between 151.5 to 156.8 deg.C.hours.

   With further increase in wall thickness to 230mm, it ranges between 144.2 to 152.6 deg.C.hour. Therefore, as the wall thickness decreases, thermal discomfort increases in all orientations but with change in orientation, thermal discomfort is not significantly changed.

2. A study of Fig.4 together with Fig.1 indicates that thermal discomfort with unshaded window ranges between 144.2 to 152.6 deg. hour in various orientations. With completely shaded windows it ranges between 136.4 to 138.8 deg. hour. Therefore, adequate shading of windows is significantly important in all orientations.

3. A study of Fig.5 & Fig.6 together with Fig.1 indicates that thermal discomfort with dark colour surfaces, ranges between 175.4 to 184.4 deg. hour in various orientations. With medium colour surfaces, it ranges between 144.2 to 152.6 deg. hours. With white washed surfaces, it ranges between 105.1 to 109.8 deg. hour. Therefore, as the colour of the building becomes lighter and lighter, the thermal discomfort significantly decreases in different orientations.

4. A Similar study (4) for similar situation has indicated that with ventilation during morning & evening hours, the thermal

discomfort can be reduced by 52.3 percent. Givoni has reported that for effective ventilation, the orientation of the buildings may vary upto 45 deg. on either side of the prevalent wind direction, (6).

CONCLUSION

It may be concluded that orientation of building envelopes with respect to pattern of solar radiation becomes insignificant if the windows are adequately shaded (Fig.4, variation in thermal discomfort = 2.4 deg. hour only) and external surfaces are light coloured (Fig.6, varitation in thermal discomfort = 4.7 deg. hour only). Ventilation at appropriate times is much significant for thermal comfort in building envelopes and should govern their orientation in hot climates. Since effective ventilation can be achieved in a fairly wide range of orientations, the planning layouts should be governed by relevant parameters like character of building sites and quality of resultant spaces.

REFERENCES

1. N.K.Garg, M.J.Wooldridge, J.Longmore, Thermal Environmental Control of Buildings and TEMPER, Energy Developments, Proceedings of Energy'84, Global Energy Forum, 14-19 May, 1984, edited by Fred A.Curtis, Pergamon Press.

2. M.J.Wooldridge, Air Conditioning Load Using computer Program TEMPER, Journal of Australian Institute of Refrigeration Air conditioning and Heating, Vol.27(12), (1969).

3. M.J.Wooldridge, User Manual for computer Program TEMPER, CSIRO Division of Mechanical Engineering, issued by Association for Computer Aided Design, Melbourne, Australia, (1975).

4. N.K.Garg, Thermal Environmental control of Buildings in the Context of India, Ph.D thesis, Faculty of Environmental Engineering, University College, London, U.K., (1984).

5. A. Mani and S.Rangarajan, Solar Radiation over India, Allied publishers, New Delhi, (1982).

6. B.Givoni, Man Climate and Architecture, Applied Science Publishers Ltd, London, (1981), Chap.11, pp.290.

ACKNOWLEDGEMENT

The Authors are thankful to Director, CBRI, for supporting this study and for permitting its publication.

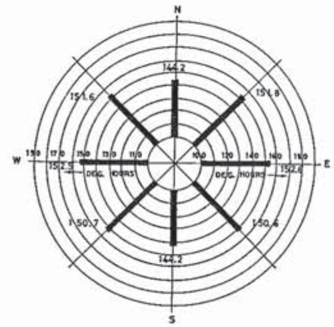

FIG.1 THERMAL DISCOMFORT IN DIFFERENT ORIENTATIONS IN REFERENCE BUILDING ENVELOPE

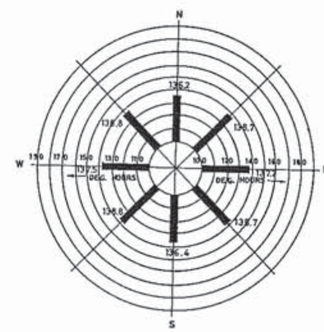

FIG. 4 THERMAL DISCOMFORT IN DIFFERENT ORIENTATIONS WITH COMPLETELY SHADED WINDOW

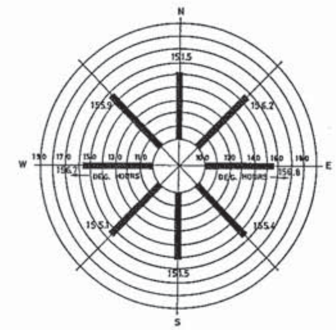

FIG. 2 THERMAL DISCOMFORT IN DIFFERENT ORIENTATIONS WITH WALL THICKNESS REDUCED TO 120MM

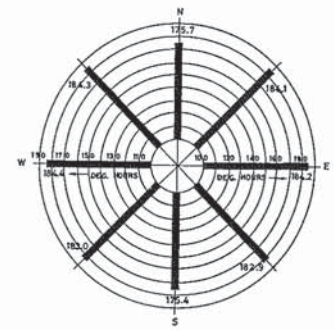

FIG. 5 THERMAL DISCOMFORT IN DIFFERENT ORIENTATIONS WITH DARK COLOUR SURFACES

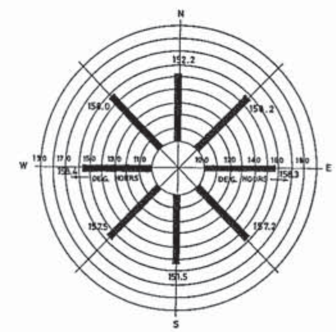

FIG. 3 THERMAL DISCOMFORT IN DIFFERENT ORIENTATIONS WITH WALL THICKNESS REDUCED TO 75 MM

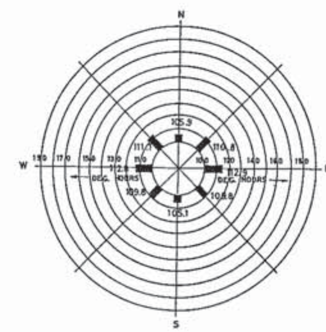

FIG. 6 THERMAL DISCOMFORT IN DIFFERENT ORIENTATIONS WITH WHITE WASHED SURFACES