PERFORMANCE EVALUATION OF SHADING DEVICES USED IN TALL OFFICE BUILDINGS OF DHAKA CITY

by

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ABSTRACT

One of the characteristics of tall office buildings in Dhaka city is the extensive use of glazing on the building facades. This increasing use of glass has caused considerable changes in the relationship between interior and ambient climate, where the problem of overheating has become a major concern. So facades of tall buildings need protection from solar heat gain to achieve desirable indoor environment and to reduce the energy consumption in the buildings by the air conditioning system. External shading devices can be utilised to block the solar radiation before it reaches the window surface and hence more effective than internal shading devices.

The problem was approached by performance evaluation of selected commonly used shading devices of tall office buildings through simulation study. Shadow simulation allows study of the effect of changes in one aspect, keeping other factors constant. The observations of simulated performance that occurs due to changing parameters allow the identification of elements, the reduction or introduction of which in the design contribute to solar heat gain. Through simulation study, it is possible to analyse the performance of shading devices for any period of the year. The simulation studies were conducted for the months from March to September representing hot-dry and warm-humid period, which is most significant in terms of climatic severity. The simulation studies were performed to evaluate performances of shading devices and identify the effects of different parameters and correlation among parameters in terms of reducing solar heat gain. This study also helped to understand the influence of window orientation on the performance of shading devices.

After all the investigations and critical evaluations, a parametric study to explore the strategies for optimum shading was pursued through a series of simulations as solar geometry is a predictable phenomenon and much of its impact is quantifiable. Parametric study allows study of various alternatives with reference to performance of the model and identifying the best one. Based on the parametric study, design recommendations and design guidelines were derived.

The findings of this thesis are concerned with the problem of solar heat gain in tall office buildings in tropical climate like Dhaka city. The results of the simulation studies and parametric studies have been expressed in terms of a number of climate responsive shading design guidelines. It is expected that the application of these guidelines will reduce solar heat gain in comparison to that of present practices.

Dedicated to my parents

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PREAMBLE

PREAMBLE

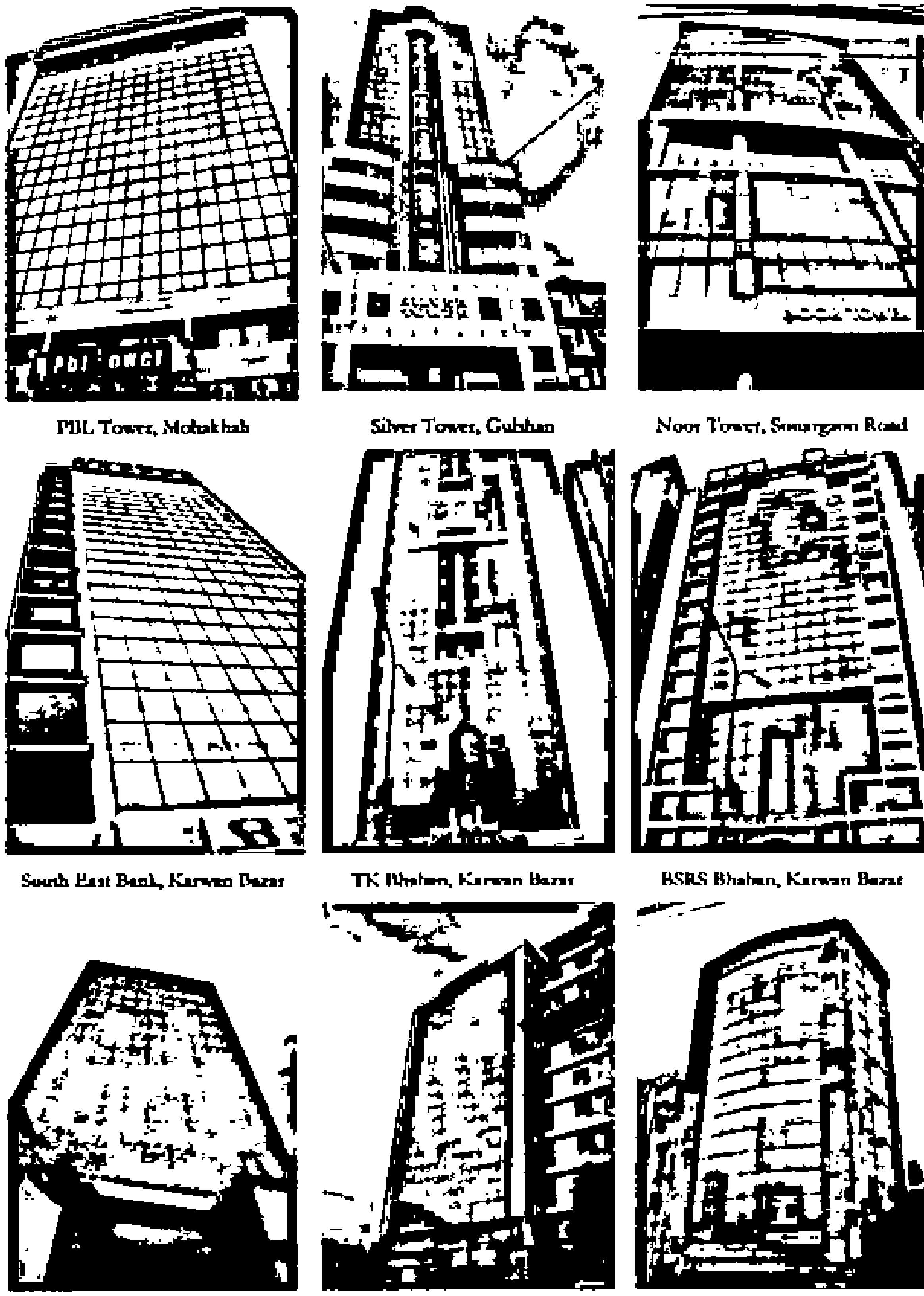
1.1 Introduction

The trend of recent development has shifted from low to high-rise buildings due to the pressure of population in much of the world, and Dhaka is no exception (Ahmed, 2003). Construction of tall office buildings in urban areas of Dhaka is characterized by extensive use of glass. These glass facades remain unprotected or barely protected from the scorching solar radiation of the tropics. These often lead to green house like situation (Givoni, 1969).

Along with the high out door air temperature, solar radiation is a major source of heat gain for building in tropics (Koenigsberger *et al*, 1973). Vast vertical surfaces of tall buildings are exposed to solar radiation and glass facades may act as heat trap for incoming solar radiation (Ahmed, 2003). So facades of tall buildings need protection in view of generating desirable indoor environment. Solar radiation transmitted through unprotected windows or transparent walls also cause a great increase in the cooling requirements of an air-conditioned building or high air temperatures in buildings without mechanical cooling systems (Stephenson *et al*, 1962; Goulding *et al*, 1992). This heat is particularly unwanted in summer and has to be expelled by the cooling system.

Solar radiation gain may be reduced by intercepting the radiation before it reaches the building surface. External solar shading can be beneficial in preventing unwanted solar heat gain thus reducing cooling load and thus can enhance thermal comfort. Moreover, the thermal effect of a glazed wall section depends on the shading provided and the spectral properties of glass (Givoni, 1969). Shading the glass affects the property of incident radiation and hence modifies both the heat flow to the interior and the indoor temperature.

Limitation of energy resources and ever increasing energy prices and the global warming, the necessity to reduce the energy consumption in the buildings can be an important issue in a developing country like Bangladesh. In such a context the need to develop passive means of solar control is important and efficient design of shading devices may address this issue significantly.



PBL Tower, Mohakhali | Silver Tower, Gulshan | Noor Tower, Sonargaon Road

South East Bank, Karwan Bazar | TK Bhaban, Karwan Bazar | BSRS Bhaban, Karwan Bazar

UTC, Panthapath | Haq Chamber, Panthapath | CADD Tower, Panthapath

Figure 1.1: Tall office buildings showing present trend of façade design in Dhaka city.

1.2 Statement of the Problem

A good answer to overheating problems is controlling solar radiation incident on the buildings. Using solar-protective glazing is one simple solution which can be easily integrated into the building design (Olgyay and Olgyay 1957). One major drawback of solar-protective glass is that it reduces solar gains in the building even during winter-time. Therefore, in countries with dominant heating requirements, a moveable device is a better solution (Dubois 1999). But again manual control of movable shading devices is not reliable and may cause a constant disruption for the occupants and most of the people of our country can't afford the system of dynamic control of motorized shading devices. Shading provision should be considered as an integral part of fenestration system design, especially for facades with high solar gains. Shading devices may control solar gains, block direct sunlight and transmit diffuse daylight in the room, eliminating glare and high contrast and creating a pleasant luminous environment (Haque, 2004). It is necessary, on the one hand, to classify the shading devices by their geometric characteristics; on the other hand, to analyse their energy and luminous performance through the definition of man made parameters and calculation methodology.

In the context of Dhaka, there is no tested rule for shading devices. According to construction act, 1952 (E.B. Act II of 1953) section 18, (Rajuk, 1996) which is enforced by RAJUK, it is said that maximum depth of shading device will not exceed 0.5 m over compulsory setback areas. But this rule may not have come from any investigation or analysis of shading performance nor any comparative study and evaluation for different climatic situations. Therefore, buildings are being constructed without proper attention to the performance of shading devices.

Due to our increased concern about energy efficient buildings and thermal comfort as well, experiments and analysis should be made for different types of shading devices. By thorough study of the relationship between depth and other parameters of shading device and amount of shade that cast on the windowpane, which is essential for thermal comfort and exclude heat gain (energy consumption) from solar radiation should be established and eventually incorporated in the design process.

1.3 Objectives of the Study

The study is an attempt to investigate the performance of commonly applied shading devices on facades of tall office buildings as a method of passive cooling with the following objectives:

1. To evaluate the existing shading devices as solar control tool used in tall office buildings.
2. To assess the impact of shading device on indoor environment as they relate to the solar heat.
3. To propose a guideline for designing efficient shading device for control of solar radiation in tall office buildings.

1.4 Methodology

To achieve the above objectives the methodology that was followed for the entire work is stated below.

The problem was approached first by a survey of published information that provided the knowledge base for the research and information about the state of the art regarding solar shading systems. By theoretical studies the meaning and purpose of solar shading device was explored. Moreover, this study helped in analyzing factors influencing solar heat gain. The climatic characteristics of Dhaka City were studied to set the climatic imperatives with regard to solar heat gain in tall office buildings in Dhaka City.

A physical survey was conducted to record and to identify the characteristics and performance of commonly applied shading devices in reference to tall office buildings. It helped in forming the models for simulation study.

The simulation process was pursued in two phases. The first one was conducted to ascertain the performance of commonly used solar shading devices in reducing solar radiation gain. Simulation models with the external shading devices similar to the real ones in tall office buildings were simulated for different orientations. By the simulation study findings and results was analyzed to identify the effects of different parameters and correlation among parameters in terms of reducing solar heat gain. The second stage involved a parametric study pursued through series of simulations to explore possible climatically sensitive design guideline for solar shading device.

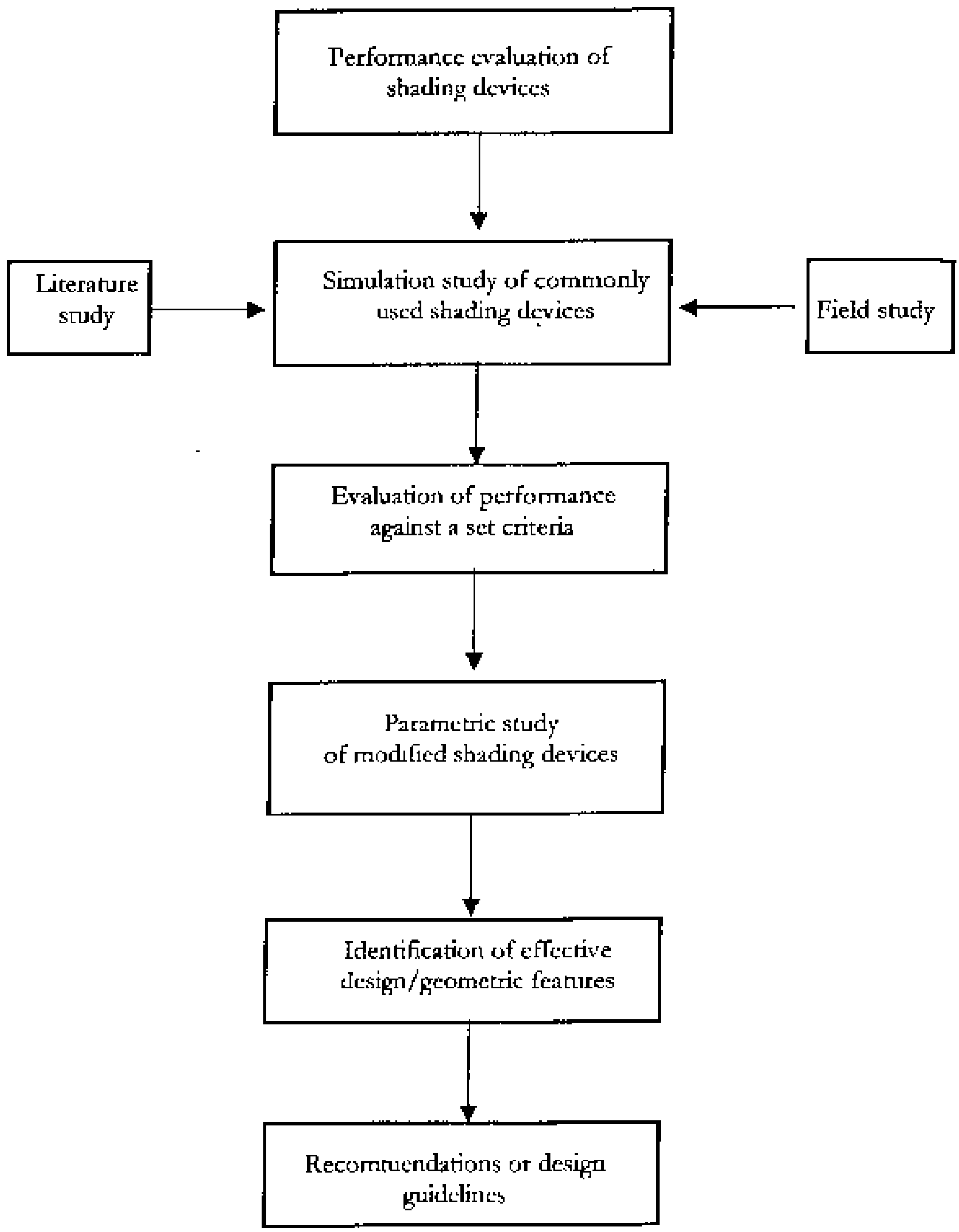


Figure 1.2: Structure of the work.

1.5 Scope and Limitations

The research work presented in this study concentrates on performance evaluation of various shading devices in reducing solar heat gain in the tall office buildings in Dhaka city. Although solar heat gain is a combined effect of direct radiation from the Sun and diffuse radiation reflected from surrounding environment, most of the solar heat gain to buildings is caused by direct radiation through windows. The study is limited to the role of geometry of the shading devices to cut off direct solar radiation hence reducing solar heat gain. Recommendations and design guidelines are made regarding geometry of shading devices. Other aspects like material of the devices, installation or construction systems are not considered in this research.

Besides, shading device has impact on daylight, ventilation and view through window. The performance of shading devices regarding daylight, ventilation and other aspects are beyond the scope of this research.

With these opportunities and constrains, research on performance of shading devices with special reference to Dhaka city was carried out and described in the following chapters.

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CHAPTER: TWO

THE CLIMATIC CONTEXT: DHAKA CITY

THE CLIMATIC CONTEXT: DHAKA CITY

Amongst the innumerable constraints that the Architect faces during the design of buildings, climate probably is considered as one of the major factors. The climate of a region presents a set of conditions, which need to be addressed adequately in order to produce climate-responsive buildings. Climate-responsiveness results in comfortable, energy-efficient, environmentally friendly buildings. Buildings constructed without regard to surrounding climate can, no doubt, operate given enough energy input to correct resulting problems, whether they concern over heating, or darkness. But access to such energy is beyond the reach of much of the population of developing countries.

The chosen location for this work is Dhaka, the capital city of Bangladesh. The country is surrounded by India on the west, north and north-east. The Bay of Bengal bounds it in the south and with Myanmar on its south-eastern part. The geographic location of Dhaka is, longitudes: 90° East- 90°30' East and latitudes: 23°40' North - 23° 55' North.

The following section is concerned with the analysis of climate of Dhaka city in terms of its challenges and potentials. This analysis will help to determine the climatic forces to be manipulated to provide satisfactory design solutions for tall structures in tropical situations from the view point of energy efficiency.

2.1 Climate of Bangladesh - General Overview

The climate of Bangladesh is categorized as warm-humid, based on the widely used classification of tropical climate by Atkinson (Koenigsberger *et al*, 1973). There are three distinctive seasons, the hot humid, the hot dry and the cool dry season (Reported in, Mallick, 1994). Generally, the winter is short and dry while the summer is long and wet. The hot dry period is between March and May, the hot humid period covers June to September and the cold dry seasons starts from mid October to February.

Again, meteorologically the climate of Bangladesh is classified into four distinct seasons – winter, pre-monsoon, monsoon and post- monsoon (Reported in, Ahmed, 1995), where the winter is cool and dry, the pre-monsoon is hot and dry; monsoon and post-monsoon are hot and wet.

The winter months, December to February, are characterized by infrequent rains, cold northerly winds, mean temperature 21°C and mean maximum below 26°C. The pre-monsoon period covers the months March, April and May and is characterized by occasional thunderstorms, and an average maximum temperature of 34°C. The monsoon is the longest season covering the months June to September, a period with torrential rains, with the average relative humidity above 80% and an average temperature of 31°C. The post-monsoon season ranges between the months October and November. It is also regarded as a transitional (to winter) period with infrequent rains and temperatures below 30°C.

2.2 Microclimate of Dhaka City

The climatic characteristics of Dhaka city differ from that of other cities of the country due to its dense physical developments and location. Again, within the same city these characteristics are further modified in different locations (Ahmed, 1995). It is due to the surface quality of the area – hard or soft, density of built environment, building type, building height and their orientations, proximity between buildings, material used for construction, dependence on electrical and mechanical appliances and other related factors.

Figure 2.1: Dhaka city: view of Dilkusha commercial area.

Table 2.1: Climatic data of Dhaka.

Climatic period	Hot-Dry	Warm-Humid		Cool-Dry
Months	March-May	June-Sept (Monsoon)	Oct-Nov (Post-Monsoon)	Dec-Feb (Winter)
Climatic Factors				
1. Air Temperature (°c)				
a. Maximum	37.80	36.10	34.90	32.40
b. Minimum	13.80	20.90	13.30	6.80
c. Average	28.02	28.8	25.42	19.43
d. Diurnal variation (average)	11.60	7.12	11	14
2. Relative Humidity % (average)	69.91	84.78	82.59	76.70
3. Rainfall (mm) (average)	156.70	317.50	125	23.33
4. Global Radiation (W/m^2) (average)	495	373	412	431
5. Sunshine Hours (daily average)	7	4.5	7	8
6. Wind Speed (m/s) (average)	2.6	2.2	1.5	1.5
7. Wind Direction	S, S-E	S, S-E, S-W	S, S-E	N, N-W

(Source: Khan, 2005)

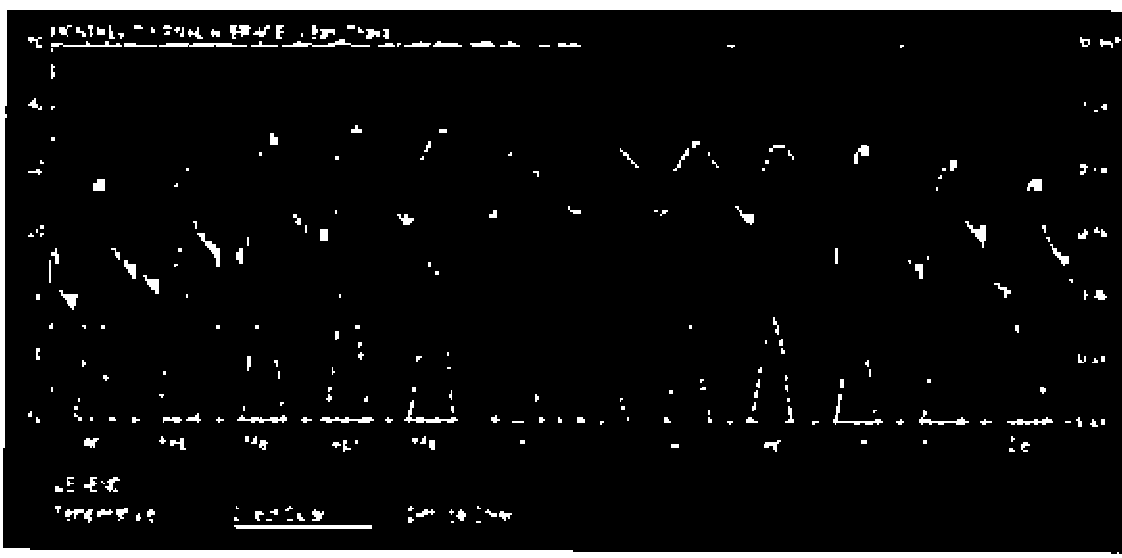

Figure 2.2: Yearly weather data showing temperature profile and solar radiation *(Ecotect Weather Tool output)*.

2.2.1 Temperature

On the basis of meteorological data, the temperature profile of Dhaka city shows similarity with that of the regional pattern. The highest temperature is recorded in the month of March, April and May, which reaches to 37.8°C maximum in April. In the monsoon and post monsoon period, from June to October the temperature remains steady at an average of 28.8°C. In cool period it drops to 19.43°C on average (Table 2.2).

Table 2.2: Air temperature in Dhaka city.

	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean maximum air temp (deg C)	26.2	27.9	32.3	34.2	33.0	31.8	31.2	31.1	31.7	31.3	28.8	26.4
Average air temp (deg C)	19.0	21.2	26.0	29.0	29.0	28.8	28.7	28.6	28.8	27.5	23.5	19.8
Mean minimum air temp (deg C)	11.8	14.5	19.7	23.8	25.0	25.8	26.2	26.1	25.9	23.7	18.2	13.2

(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2005)

Overheating due to inexorable urban growth of Dhaka city is now a major environmental concern (Ahmed, 1995). Meteorological observation in pre-monsoon period records a maximum temperature of 37.8°C, indicating a possible trend towards the increase of temperature and overheating.

2.2.2 Solar Radiation

Solar radiation can be considered as a single most deciding factor for assessing the climate of an area, because it affects the temperature and density of air and thus affects the wind velocity, direction and humidity (Ahmed, 1994). Renewable Energy Research Center of Dhaka University collects radiation data for Dhaka city.

Figure 2.3 shows that in the hot dry period, particularly in the months of March, April and May solar radiation is high in comparison with that in the rest of the year and it is maximum in April (5.5 KWh/sqm/day). From July to November (monsoon to post-monsoon) the radiation remains fairly constant.

From Figure 2.4 it has been observed that, the horizontal surface (commonly the roof surface of a built form) receives the maximum amount of solar radiation round the year in comparison with other common external vertical facades. But this is true for low rise buildings only. For tall buildings, horizontal surface is very negligible in comparison to other four vertical surfaces and only the top floors of the tall buildings are affected by incurring radiation on the roof of the buildings. This result depicts the importance of adopted strategy for vertical surfaces of the built forms in tropical architecture.

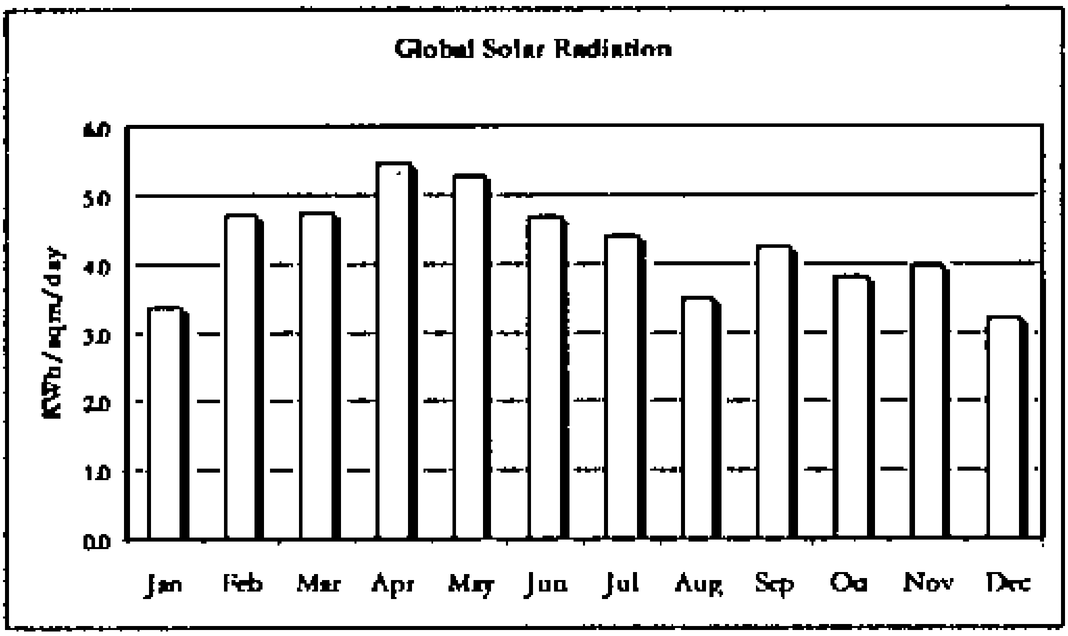

Figure 2.3: Monthly average daily solar radiations in Dhaka *(Source: Renewable Energy Research Centre, Dhaka University, 2005)*.

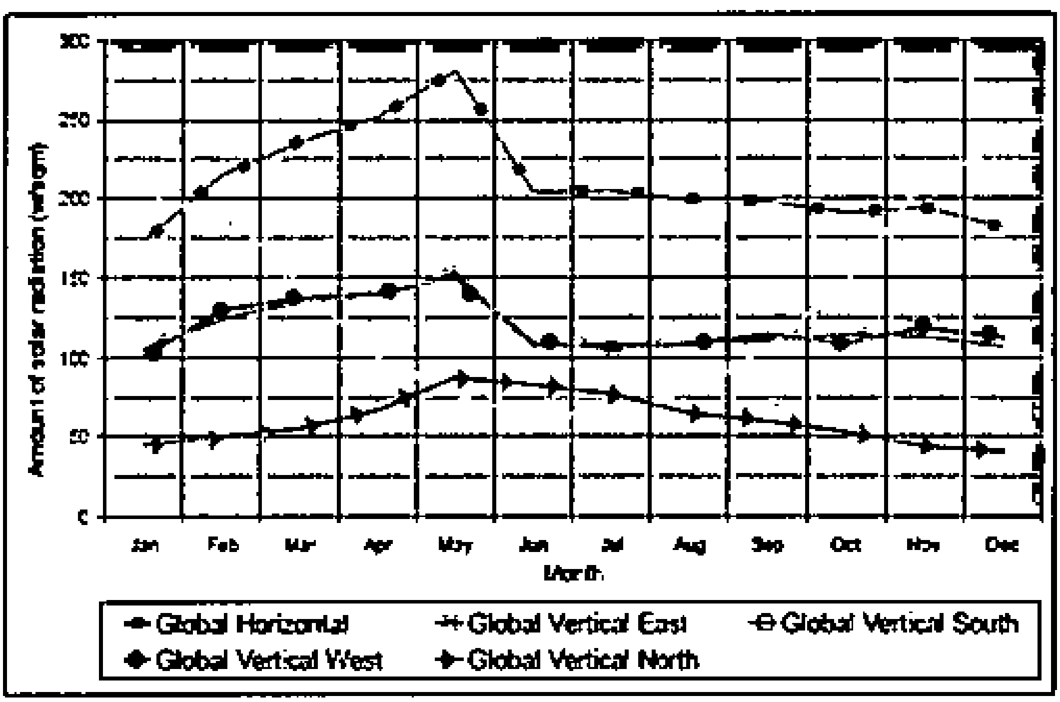

Figure 2.4: Amount of solar radiation on different surfaces (horizontal and vertical) for a year *(Source: Khan, 2005)*.

As overheating is one of the key problems for the given climate, the issue of heat gain from solar radiation is highly significant and the vertical surfaces are observed as more important than horizontal surfaces of the built forms (for tall buildings, specially when the sun is at a low angle).

2.2.3 Relative Humidity

The humidity of Dhaka city is high and the mean annual relative humidity is 77% (Table 2.4). If all conditions remain the same, then the relative humidity is inversely proportional to the temperature. So, higher temperature yields lower relative humidity levels. Since air temperature and radiation depend on the density of the built form, the humidity varies with the density of the surrounding built environment.

Table 2.4: Relative humidity in Dhaka city.

	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Relative Humidity	69%	63%	61%	70%	79%	85%	86%	85%	86%	81%	75%	71%

(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2005)

2.2.4 Cloud Coverage

The cloud cover is only 38% for the whole pre-monsoon and post-monsoon period (Table 2.5). This clear sky condition enhances the direct solar radiation to reach on building surfaces. The cloud coverage is very high in monsoon period and is almost 70%. The cloudy atmospheric condition during this period helps in decreasing the incoming solar radiation to the earth surface.

Table 2.5: Sky condition in respect to cloud cover for a year.

Type of Sky	Hot-Dry	Hot-Humid		Cool-Dry
	Pre-Monsoon (March-May)	Monsoon (June-Sept)	Post-Monsoon (Oct-Nov)	(Dec-Feb)
Clear Sky	67%	31%	64%	85%
Overcast Sky	33%	69%	36%	15%

(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2005)

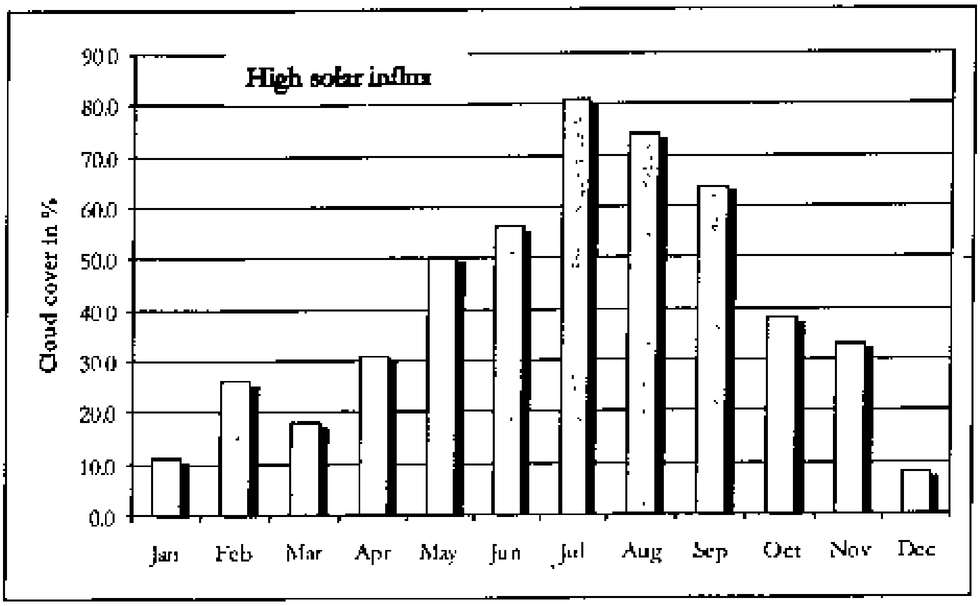

Figure 2.5: Monthly average cloud cover *(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2005).*

2.2.5 Sunshine Hours

The amount of solar radiation received by the surfaces also depends on the duration of sunshine (Reported in, Ahmed, 1994). The sunshine hour in pre-monsoon and post-monsoon is quite long than that of monsoon period (Figure 2.6).

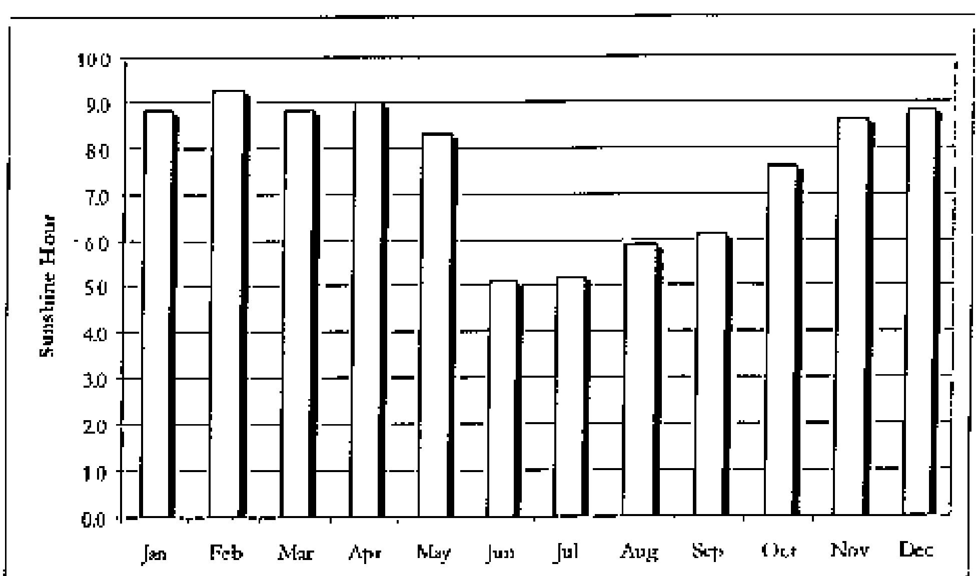

Figure 2.6: Monthly average sunshine hours *(Source: Climate Division, Bangladesh Meteorological Department, Dhaka, 2005).*

2.2.6 Wind Flow and Direction

Wind speed in Dhaka in Hot period is relatively high and the direction is predominantly southerly and south-easterly (Table 2.5). For winter period the direction of wind was found mostly from north and north-west. According to the diurnal pattern of wind flow, in summer (except April) the wind speed is low between 12:00 and 15:00 hours (Reported in, Ahmed, 1995). During that period airflow may not be considered as reliable resource for cooling, rather depending on shading of surface from solar radiation would be more preferable.

Table 2.5: Monthly average wind speed and direction.

Months and seasons	Wind speed in m/s	Wind direction
January (Cool-Dry)	1.4	NW
February (Cool-Dry)	1.6	N
March (Hot-Dry)	2.6	SW
April (Hot-Dry)	3.7	SW
May (Hot-Dry)	4.4	S
June (Warm-Humid)	3.8	SE
July (Warm-Humid)	3.9	SE
August (Warm-Humid)	3.3	SE
September (Warm-Humid)	3.4	SE
October (Warm-Hunid)	2.5	N
November (Warm-Humid)	1.4	NW
December (Cool-Dry)	1.5	NW

(Source, Climate Division, Bangladesh Meteorological Department, Dhaka, 2005)

2.3 Problems in Designing in the Hot-Humid Climate

The hot-humid climatic zone is characterized by high ambient temperatures, high humidity, high and fairly evenly distributed rainfall, small diurnal and annual variations of temperature, little seasonal variation, light winds, and long periods of still air.

The physiological thermal requirements and hence the building characteristics are the same for the whole year, as the seasonal climatic variations are low (Yeang, 1990). The main cause of discomfort is the subjective feeling of skin wetness (Koenigsberger *et al*, 1973). Continuous ventilation is, therefore required to ensure a sweat evaporation rate sufficient to maintain thermal equilibrium and minimum sweat accumulation of the skin. Radiation solar heat gain should be prevented.

The hot-humid zones present two problems to designers:

- Avoidance of excessive solar radiation, and
- Provision for moisture evaporation by breezes.

To cope with these, the structures and settlements need to be built to allow free air movement. The roofs need to be insulated and provided with large overhangs to protect against sun and rain.

Under hot conditions, the thermal controls in the building should:

- Prevent heat gain.
- Maximise heat loss
- Remove any excess heat by mechanical or passive cooling.

2.4 Conclusion

Although for most of the period, overheating is a major environmental concern for Dhaka, the nature of the problem is dictated by the combination of the environmental factors in the ambiance during those periods. From March to May there is high air temperature associated with high solar radiation, while from June to October, conditions with high humidity is associated with high air temperature. So from March to May, reducing the impact of solar radiation can potentially moderate the overheated condition and optimizing shading can play a vital role towards moderation. For a tropical warm humid climate like Dhaka city the minimum solar heat gain with the help of adequate shading is the major considerations to achieve thermal comfort.

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CHAPTER: THREE

TALL BUILDING AND SOLAR HEAT GAIN

TALL BUILDING AND SOLAR HEAT GAIN

Increased land value, limited urban accessibility, expanding urban population, globalization of national economy and locational preferences of business make the tall building inevitable. In addition to accommodating living space for the purpose of habitation, tall buildings are now extensively used as working space. Although the principles of designing with climate are relatively advanced for low-rise and mid-rise buildings, adequate attention and research yet to be directed towards the tall building type (Yeang, 1990). A brief discussion on tall and high-rise buildings, with special reference to their climatic characteristics has been presented in the following sections.

3.1 Tall Building

3.1.1 Definition

The experts differ in defining the physical parameters of tall buildings. According to the Council for Tall Buildings and Urban Habitat (CTBUH), a tall building is not strictly defined by the number of stories or its height. It also depends upon the context in which it stands. CTBUH defines tall buildings as a building whose built form, by virtue of its height, requires its own special engineering systems (Yeang, 1997). The important criterion is whether or not the design, use or operation of the building is influenced by some aspects of tallness.

As stated by Eli Attia in his seminar paper in 'Fourth World Congress on Tall Building: 2000 and beyond' David Fisher defines the tall buildings as 'We build tall buildings of necessity; how we build them is a reflection of society. Tall buildings do not have to be beautiful, they simply must be functional; so it is the degree of our concern for their beauty that serves as a measure of our humanity' (Attia, 1990).

According to Ken Yeang (Yeang, 1997), a tall building can be characteristics by

a) A small foot-print in comparison to its total built-up space
b) Tall facades due to its height
c) Small roof-area in comparison to external-wall area
d) Special engineering systems, different from the low building type simply because of its height.

According to Taranath, to define tall building from structural aspects, from structural design and construction point of view, it is simpler to consider a building tall when its structural analyses and design are in some way affected by the lateral loads (Taranath, 1998).

3.1.2 Justifications for Designing with Climate

Ken Yeang (Yeang, 1990) justifies the reasons for designing the tall buildings with climate very clearly. The most obvious justification must be the lowering of costs as a result of lowering the energy consumption in the operation of the building. This can be by as much as 40% of the overall life-cycle energy costs of the building. Significant savings in operational costs would justify incorporation of climatically-responsive design features despite a higher initial capital construction costs.

Another rationale is from the impact on the users of the tall building. The climate-responsive tall building would enhance its users' aesthetic well-being while enabling them to be aware of and to experience the external climate of the place. The climate-responsive design would provide the building's users with the opportunity to experience the external environment (and the diurnal and seasonal changes where existent) and avert the blindness of spending their working hours over a significant part of their day in an artificial environment that remains constant throughout the year.

A further justification is the ecological one. Designing with climate would result in the reduction of the overall energy consumption of the building by the use of passive structural devices (i.e. non-mechanical). Cost savings in the operational costs means less use of electrical energy resources which is usually derived from the burning of non renewable fossil-fuels. The lowering of energy consumption would further reduce the overall emission of waste heat thereby lowering the overall heat-island effect on the locality.

3.1.3 Façade Design of Tall Buildings in Tropical Climates

In passive low-energy tall building design, attention should be given to the facade design. For low volume-to-surface ratio, tall buildings have more external surface than same volume of low rise building. In case of tall buildings, generally facades do not get mutual shading from its surrounding like low rise buildings. That's why; external surfaces of tall buildings should be designed as an environmentally-responsive filter.

The façade should be multi-functional in its design. For instance, it can provide for reducing solar heat gain to the space through external shading devices, fresh air ventilation, acoustic barrier, maintenance access and a contribution to the building's aesthetic.

Tall buildings are exposed more directly than others to the full impact of external temperatures and direct sunlight. The greatest source of heat gain in the tropical climate can be the solar radiation entering through the window. This solar heat gain can be reduced by using shading devices. These shading devices cut the huge solar heat gains directly through window. This enables the designer to use clear-glass, to give better daylight entering the internal spaces, which then reduces the lighting energy-load (Yeang, 1997).

3.2 Solar Radiation

Solar radiation influences the indoor thermal climate by direct heating on penetrating the windows, and indirectly by heating the external envelope of the building. Heat flow through the wall and roof then determines the indoor surface and air temperatures. The effect of solar radiation on internal temperatures, as mentioned at the beginning, may be divided into two parts: 1) the effect on the temperatures of the external surfaces and roof and the resulting heat flow and indoor heating, 2) heating caused by penetration of radiation through glazed or open areas (Givoni, 1969).

Solar radiation is an electromagnetic radiation emitted from Sun (McMullan, 1992). The Spectrum is broadly divided into two regions i.e. the visible radiation and non-visible radiation. Solar radiation reaching the earth's surface consists of about 47 percent visible, 48 percent short-wave infra-red (heat), and about 5 percent ultra violet radiation (Lechner, 2001).

Sunlight contains no heat, both in the visible region and in the non-visible region (mainly infra-red with some ultra-violet) in about equal proportions. It is only when radiation falls on surfaces that it is converted into heat. The non-visible part of the spectrum often referred to as 'thermal radiation', implying that only this part is the cause of heating. But the visible part still carries half the energy that potentially can become heat (Steemers *et al*, 2002).

3.2.1 Visible Radiation

The wavelengths of electromagnetic radiation that are visible to the eye range from approximately 380 nm to 760 nm [1 nanometre (nm) is 10^{-9} meter]. If all the wavelengths of light are seen at the same time the eye cannot distinguish the individual wavelengths and the brain has the sensation of white light (McMullan, 1992).

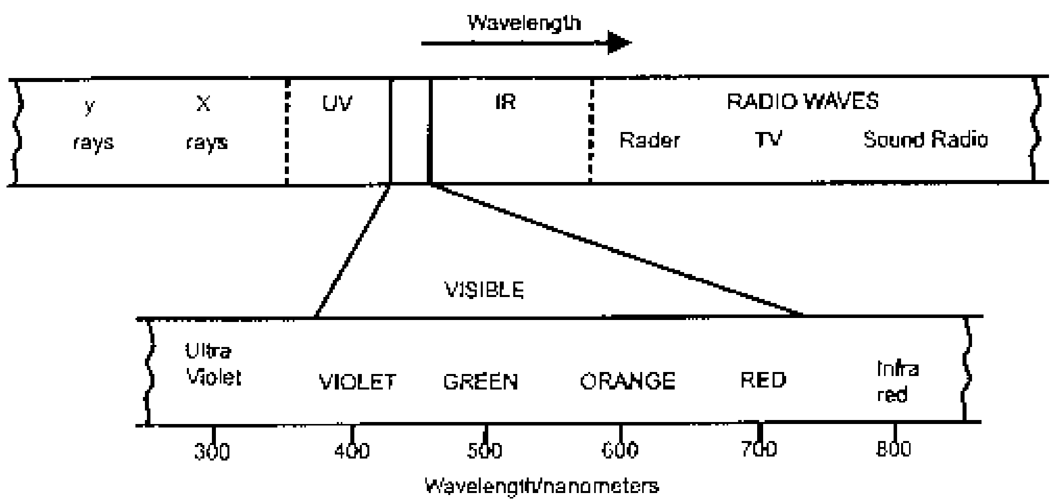

Figure 3.1: Electromagnetic spectrum *(Source: McMullan, 1992).*

White light is the effect on sight of combining all the visible wavelengths of light. White light can be separated into its component wavelengths. One method is to use the different refractions of light that occur in a glass prism. The result is a spectrum of light, which is traditionally described in the seven colours of the rainbow although, in fact, there is a continuous range of hues (colours) whose different wavelengths cause different sensations in the brain. Monochromatic light is light of one particular wavelength and colour. If the colours of the spectrum are recombined then white light is again produced. Varying the proportions of the individual colours can produce different qualities of 'white' light.

3.2.2 Non-Visible Radiation

Electromagnetic radiations with wavelengths outside the range of visible wavelengths cannot, by definition, be detected by the human eye. However, those radiations immediately adjacent to the visible range of wave lengths are emitted by the Sun, along with light, and are often relevant to lighting processes (McMullan, 1992).

Infra-Red

Wavelength range of infra-red is from 760 nm to above. Infra-red (IR) radiation has wavelengths slightly greater than those of red light and can be felt as heat radiation from the Sun and from other heated bodies. Infra-red radiation is made use of in radiant heating devices, for detecting patterns of heat emissions, for 'seeing' in the dark, and for communication links.

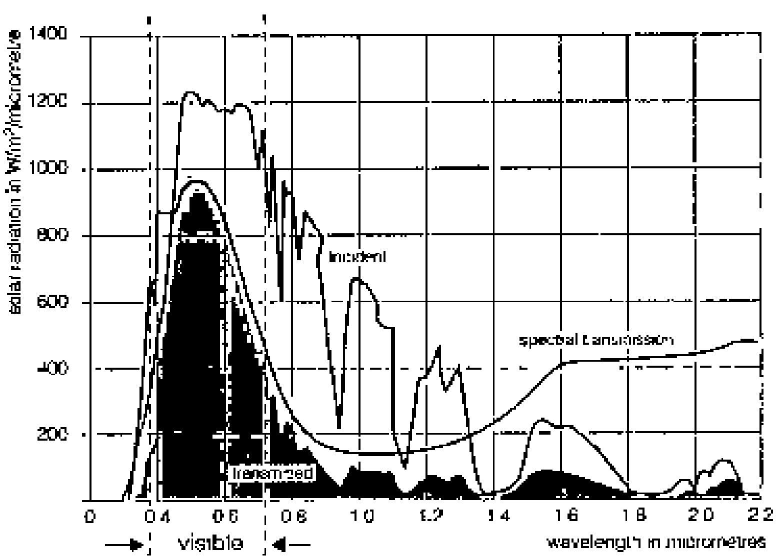

Figure 3.2: Solar spectrum *(Source: Stemmers et al, 2002).*

Ultra-Violet

Wavelength range of ultra-violet is below 380 nm. Ultra-violet (UV) radiation has wavelengths slightly less than those of violet light. It is emitted by the Sun and also by other objects at high temperature. Ultra-violet radiation helps keep the body healthy but excessive amounts can damage the skin and the eyes. The composition of the Earth's atmosphere normally protects the planet from excessive UV radiation emitted by the Sun. Ultra-violet radiation can be used to kill harmful bacteria in kitchens and in hospitals. Certain chemicals can convert UV energy to visible light and the effect is made use of in fluorescent lamps.

3.2.3 Direct, Indirect Solar Radiation

Solar radiation is a dominating influence on all climatic phenomena. Of the total energy radiated by the sun towards the earth, part is reflected off clouds outwards, part is absorbed by water vapour, pollutants, dust particles and other atmospheric conditions, being re-emitted as diffuse radiation, and the rest of it is directly transmitted to the earth's surface.

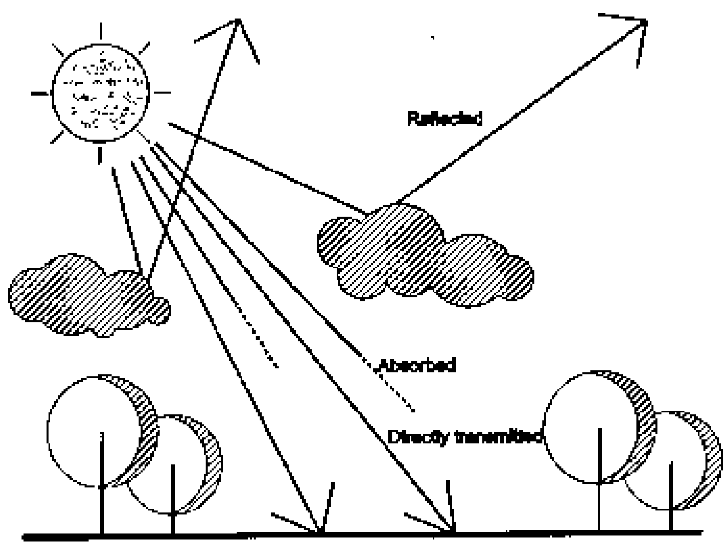

Figure 3.3: Direct, indirect solar radiation *(After Ahmed, 1987)*

Whereas direct radiation is dependent only on the altitude of the sun, and is independent of geographical position, diffuse radiation varies with the time of the day, the weather, the cloud cover and the portion of the sky from which it is received. According to Jones, no specific direction can be assigned to diffuse radiation and therefore there is no directional shadow associated with it. Diffuse radiation also varies with solar altitude, as direct intensities reach their highest values at midday, and there is much more radiation available for scattering than when the sun is low in the sky (Reported in, Ahmed, 1987).

3.3 Solar Heat Gain

The heat gain in a building by radiation from the Sun depends upon the following factors (McMullan, 1992):

- The geographical latitude of the site, which determines the height of the Sun in the sky.
- The orientation of the building on the site, such as whether rooms are facing south or north.
- The season of the year, which also affects the height of the Sun in the sky.
- The local cloud conditions, which can block solar radiation.
- The angles between the Sun and the building surfaces, because maximum gain occurs when surfaces are at right angles to the rays from the Sun.
- The nature of the window glass and whether it absorbs or reflects any radiation.
- The nature of the roof and walls, because heavyweight materials behave differently to lightweight materials.

Solar radiation falls on a surface varies throughout the day and the year. Most solar heat gain to buildings is by direct radiation through windows. The maximum gains through south-facing windows tend to occur in pre-monsoon and post-monsoon period when the lower angle of the Sun causes radiation to fall more directly onto vertical surfaces. The solar heat gains for a particular building at a specific time are relatively complicated to calculate, although it is important to do so when predicting summer heat gains in commercial buildings.

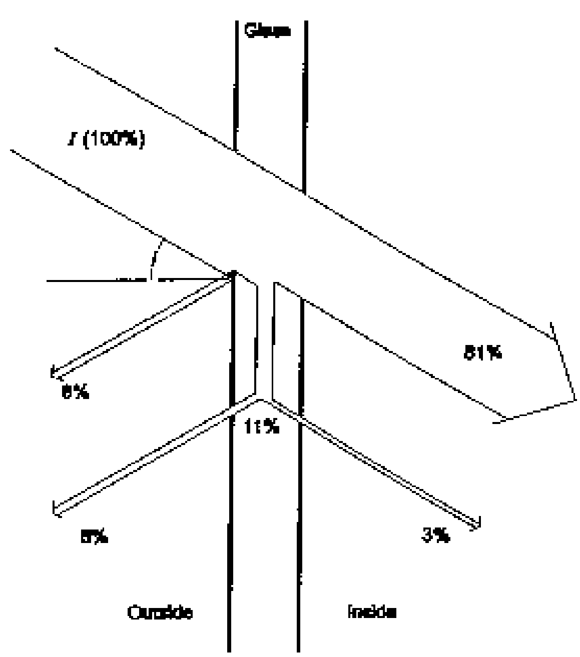

Figure 3.4: Typical proportions of incident solar radiation, reflected, absorbed, transmitted and retransmitted by glass *(Source: Smith et al, 1982)*.

The solar radiation falling upon a clear glass surface is reflected, absorbed and transmitted in proportions similar to those indicated in Figure 3.4. These quantities depend upon the angle of incidence (i) and the proportion of direct and diffuse radiation. The angle of incidence (i) is the angle measured between the incident light beam and the normal to the plane of the glass (Smith *et al*, 1982).

The absorbed radiation heats the glass and part of this heat reaches the room surfaces by convection and radiation from the inside surface of the glass. The solar heat gain is obtained by adding this inwards released heat to the directly transmitted component of the incident solar radiation. Absorption of this solar heat gain by the internal surfaces raises their temperature. These heated surfaces behave as low temperature, long wave radiators. Since glass transmits shortwave radiation in the range 0.3 to 2.8 μm but is opaque to long wave radiation from low temperature surfaces, the solar heat gained is trapped within the enclosure causing an internal temperature rise. This phenomenon, frequently referred to as the greenhouse effect, may give rise to solar overheating. Heat gain is directly proportional to the area of glass exposed to solar radiation and therefore large glazed areas will permit a large and rapid heat gain.

3.4 Conclusion

The extensive use of glazing in the building façades is one of the characteristics of modern architecture. This, and the increasing use of lightweight structures has caused considerable changes in the relationship between interior and ambient climates and the problem of overheating has become a major concern. To face this problem, in most of the cases mechanically cooling system is the solution. But this becomes a burden on total energy load of the country. The idea of a climate-responsive tall building may change the preference to one away from the present fully artificial working environment. Tall buildings designing with climate are evidently justified on the ground of recurring savings in cost and energy use in the operation of the building.

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CHAPTER: FOUR

SOLAR CONTROL AND SHADING DEVICES

SOLAR CONTROL AND SHADING DEVICES

Tall buildings are exposed to the full impact of direct solar radiation, which is the greatest source of heat gain in the tropical climate. Heat gain through window is directly proportional to the area of glass exposed to solar radiation and therefore large glazed areas permit a large and rapid heat gain. Shading is a key strategy to reduce solar heat gain in overheated periods. The most efficient solar control is provided by external shading devices. This chapter presents a brief discussion on methods and principles of solar control emphasising on external shading devices. It helps to develop a clear understanding of the issues involved for the further development of design strategies of shading devices in the later sections of this work.

4.1 Solar Control

Direct solar radiation can be prevented from reaching all or part of the walls, roof or windows of a building by the use of shading. Shading can be provided by natural vegetation, neighbouring buildings or the surrounding landscape. Shading devices on the building (fixed or movable, the latter being manually or automatically controlled) can prevent direct radiation reaching critical parts, such as windows, doors and even roofs. Indirect solar gain from the sky, or reflected from the surrounding buildings or the ground and air heated by irradiated surfaces also enhance significantly to the cooling load.

4.2 Method of Solar Control

The greatest source of heat gain can be the solar radiation entering through a window. This could, in fact, increase the indoor temperature far above the out-door air temperature, even in moderate climates, which is known as the 'greenhouse effect' (Koenigsberger *et al*, 1973). Window glasses are practically transparent for short-wave infra-red radiation emitted by the sun, but almost opaque for long-wave radiation emitted by objects in the room. The consequence of this is that the radiant heat, once it has entered through a window, is trapped inside the building.

There are four methods available for the reduction of solar heat gain through windows:

1. Window Orientation

2. Internal blinds, curtains

3. Heat absorbing/reflecting glasses

4. External shading devices

4.2.1 Window Orientation

Building orientation affects the indoor climate in two respects, by its regulation of the influence of two distinct climate factors (Givoni, 1969):

a. Solar radiation and its heating effect on walls and rooms facing different directions.

b. Ventilation problems associated with the relation between the direction of the prevailing winds and the orientation of the building.

The effect of window orientation on the indoor temperatures is largely determined by the ventilation conditions and the degree and efficiency of the window shading. When shading is not effective, solar radiation enters through the windows and directly heats the building interior, the temperatures of which will obviously be influenced by the orientation of the windows. The heating effect of solar energy penetrating a glazed wall or closed unshaded windows is magnified, as the energy is transformed in the exterior or by longwave radiation, to which the glass is opaque.

In the equatorial location, if solar heat gain is to be avoided, the main windows should face north or south (Koenigsberger *et al*, 1973). At higher latitude, an orientation away from the equator would receive the least sunshine, but here it may be desirable to have some solar heat gain in the winter, when the sun is low — so an orientation towards the equator may be preferable. In both locations only minor openings of unimportant rooms should be placed on the east and west side. Solar heat gain on the west side can be particularly troublesome as its maximum intensity coincides with the hottest part of the day.

4.2.2 Internal Blinds and Curtains

From an energy-rejection point of view, the external shading devices are the most effective. But for a number of practical reasons, the interior devices, such as curtains, roller shades, venetian blinds, and shutters, are also very important. Interior devices are often less expensive than external shading devices, since they do not have to resist the elements. They are also very adjustable and movable, which enables them to easily respond to changing requirements. Besides shading, these devices provide numerous other benefits, such as privacy, glare control, insulation, and interior aesthetics (Lechner, 2001).

Since internal devices are usually included whether or not external devices are supplied, we should use them to our advantage. They should be used to stop the sun when it out flanks the exterior shading devices. They are also useful for those exceptionally hot days during the transition or under heated periods of the year, when exterior shading is not designed to work. In the form of venetian blinds or light shelves, they can also produce fine day lighting.

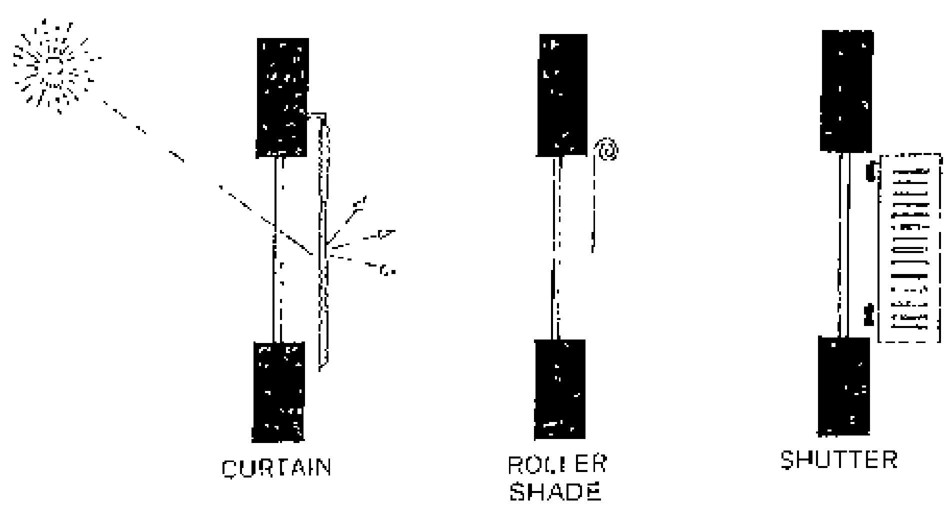


Figure 4.1: Interior shading devices for solar control *(Source: Lechner, 2001).*

One of the main drawbacks of interior shading devices is that they are not always discerning. They cannot block the sun while admitting the view, something that can be effectively done with an external overhang. Since they block the solar radiation on the inside of the glazing, much of the heat remains indoors.

It is true that they stop the passage of radiation, but they themselves absorb the solar heat and can reach a very high temperature (Koenigsberger *et al*, 1973). The absorbed heat will be partly convected to the indoor air and partly reradiated. Significant portion of this reradiation is outwards, but as it is of a long wavelength, it is stopped by the window glass. The usual narrow space between the window and the blind will thus be quite substantially overheated. The hot surface of the blind causes the indoor MRT to rise far above the air temperature.

As a broad generalization the daily average solar gain factor of a single glazed window will be:

θ = 72% without any solar control device, and

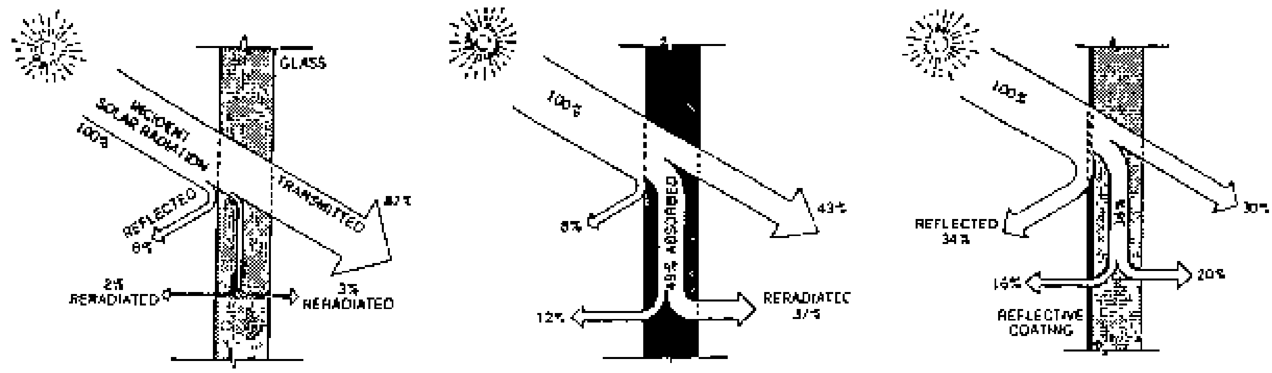
θ = 55% with an internal venetian blind [i.e. the reduction is only 17%]

4.2.3 Heat Absorbing/ Reflecting Glasses

Even the clearest and thinnest glass does not transmit 100 percent of the incident solar radiation. The radiation that is not transmitted is either absorbed or reflected off the surface. The amount that is absorbed depends on the type and thickness of the glazing. The amount that is reflected depends on the nature of the surface and the angle of incidence of the radiation (Lechner, 2001).

One type of tinted glazing is called heat absorbing because it absorbs the shortwave infra-red part of solar radiation much more than the visible part. But even this type of glazing reduces the solar heat gain by only a small amount. Although tinted glazing reduces the light transmission, it usually does not decrease the heat gain by much because the absorbed radiation is then reradiated indoors (Givoni, 1998).

Glazing also blocks solar radiation by reflection. The amount of solar radiation that is reflected from glazing can be increased significantly by adding a reflective coating. One surface of the glazing is covered with a metallic coating thin enough that some solar radiation still penetrates. The percentage reflectance depends on the thickness of this coating, and a mirror is nothing more than a coating that is thick enough so that no light is transmitted. Reflective glazing can be extremely effective in blocking solar radiation while still allowing a view.



Clear glass | Heat-absorbing glass | Reflective glass

Figure 4.2: Heat gain through different types of glazing *(Source: Lechner, 2001).*

When reflective glazing became available in the 1970s, it quickly became popular for several reasons. It blocked solar radiation better than heat-absorbing glass, and did so with out any color distortion.

Although tinted and reflective glazing systems can be effective shading devices, they are very undiscerning. They do not differentiate between light from the sun and light from the view. They filter out light whether daylight is desired or not. And they block the desirable winter sun as much as the undesirable summer sun. Thus, tinted or reflective glazing is not appropriate where either day lighting or solar heating is desired. It is also not appropriate when only the sun should be excluded, but not the view. When glazing is expected to do all the shading, it has to be of a very low transmittance type. The view through this kind of glazing makes even the sunniest day look dark and gloomy. Thus, external overhangs, fins, etc. which are more discerning, are usually still the best shading devices. Tinted or reflective glazing is excellent, however, for blocking diffuse sky radiation in very humid regions, and for glare control (Lechner, 2001).

When daylighting is desired and solar heating is not, having the visible component of solar radiation pass through while heat radiation is blocked would be advantageous. Certain "specially selective" glazing systems can do that to a limited extent. Specially selective low-e-glazing transmits cooler daylight than other glazing materials, because it transmits a much higher ratio of visible-to-infrared radiation (Givoni, 1998).

In the near future, there might be even better glazing system than the "selective" types mentioned above. These are known as responsive glazing systems because they change in response to light, heat, and electricity.

Responsive glazing can be either the passive or the active kind. Passive glazing responds directly to environmental conditions, such as light level or temperature (photochromics or thermochromics, respectively). The active system can be controlled as needed and can include such devices as liquid crystal, dispersed particle, and electrochromics.

Photochromics: These materials change their transparency in response to light intensity. They are ideal for automatically controlling the quantity of daylight allowed into a building. The goal is to let in just enough light to eliminate the need for electric lighting, but not so much that the cooling load would increase.

Thermochromics: These materials change transparency in response to temperature. They are transparent when cold and reflective, white when hot. They can be used in skylights, where the loss of transparency on a hot day is not a problem as it would be in a view window. These materials could also be used to prevent passive systems from overheating in the summer

Liquid-Crystal Glazing: When electric power is applied, the transparent liquid crystals align and become translucent. Thus, liquid-crystal glazing has some application for shading, but its real potential is in privacy control.

Dispersed-Particle Glazing: Although similar to liquid-crystal glazing, this material is more promising for solar control because the applied power can change the transmittance of the material in a range between clear and dark states, thereby preserving the view.

Electrochromic Glazing: This is the most promising material because it can change transparency-not translucency-continuously over a wide range (about 10 percent to 70 percent) and can be easily controlled. Consequently, either a computer, a photocell, a thermostat, or the occupant can adjust the transparency as the local conditions require.

4.2.4 External Shading Devices

Blocking the sun before it reaches the building, particularly the glazed, but also the opaque surfaces (including the roof) and reflecting the solar radiation, is fundamental to the prevention of heat gain (Goulding, 1992). The appropriate choice from a wide range of fixed and movable shading systems will depend on location, orientation, building type and the overall cooling, heating and daylighting strategies adopted in the design phase of the building.

While shading systems must provide good solar protection in summer, they should not reduce solar gains in winter, obstruct natural lighting or impede natural ventilation. Well designed shading systems can actually enhance natural ventilation and daylighting. Shading systems can block the direct component of solar radiation but are usually not as effective in reducing the diffuse and reflected components.

4.3 Shading Devices

Once the window size has been established the most effective method of reducing solar heat gain is to prevent the transmission of shortwave radiation through the glass by external shading.

The effectiveness of a typical glazing and shading system may be measured in terms of the solar gain factor. This is the proportion of incident solar radiation transmitted by the window and shading device to the interior of an enclosure. The solar gain factor for an unglazed unshaded aperture is unit. This factor decreases as the shading system becomes more effective in reducing solar heat gain (Smith *et al*, 1982).

The requirements for daylight and ventilation may well conflict with the need to provide shading devices to control solar heat gain, reduce glare and prevent direct radiation falling upon the occupants of an enclosure. Traditional heavyweight building with small windows is unlikely to experience the solar overheating problems, which may occur in the excessively glazed lightweight modern office block.

4.3.1 Objective of Shading

Shading the glass affects the quantity of incident radiation and hence modifies both the heat flow to the interior and the indoor temperatures. It is useful to set out the purpose of shading in some detail (Steemers *et al*, 2002). They are mentioned as follows.

- To minimise the total solar energy entering a room and thereby reduce the average temperature of the room

- To prevent sunlight from falling directly onto occupants, resulting in an effective increase of temperature of between 3°c and 7°c
- To reduce the local illumination of surfaces that may present glare sources to the occupants
- To prevent the view of brightly lit outside surfaces, or clouds, or the sun itself

4.3.2 Types of Shading Devices

Shading devices are broadly classified into three categories based on its integration with the window (Goulding, 1992; Steemers *et al*, 2002; Lechner, 2001). They are classified again within these categories by their morphological characteristics and physical forms. The broad categories of shading devices are:

- Retractable or removable shading device
- Movable or adjustable shading device
- Fixed shading device

Retractable Shading Device:

Retractable means that these elements can be completely or partially removable from the window aperture (Steemers *et al*, 2002). It is important to note that shading devices of this type do not influence the availability of daylight in the room. That is, they will not influence switch-on time, because at times of low light availability they can be removed from the aperture. Clearly this property reconciles the conflict between allowing useful light in and keeping unwanted radiation out. If correctly operated, devices of this type will not lead to an increase in artificial lighting energy.

Movable Shading Devices

Movable shading is used externally or internally. Control can be either manual or power assisted and may be automated to respond to changing conditions, such as current radiation levels and daylighting or thermal requirements (Goulding, 1992). The configuration of operable shading devices can be changed, and therefore their performance can be much better than that of fixed devices. However, their position has to be adjusted, daily or seasonally, to the changing patterns of the sun's relative motion and the shading needs (Givoni, 1998). They usually need maintenance to keep them in good condition.

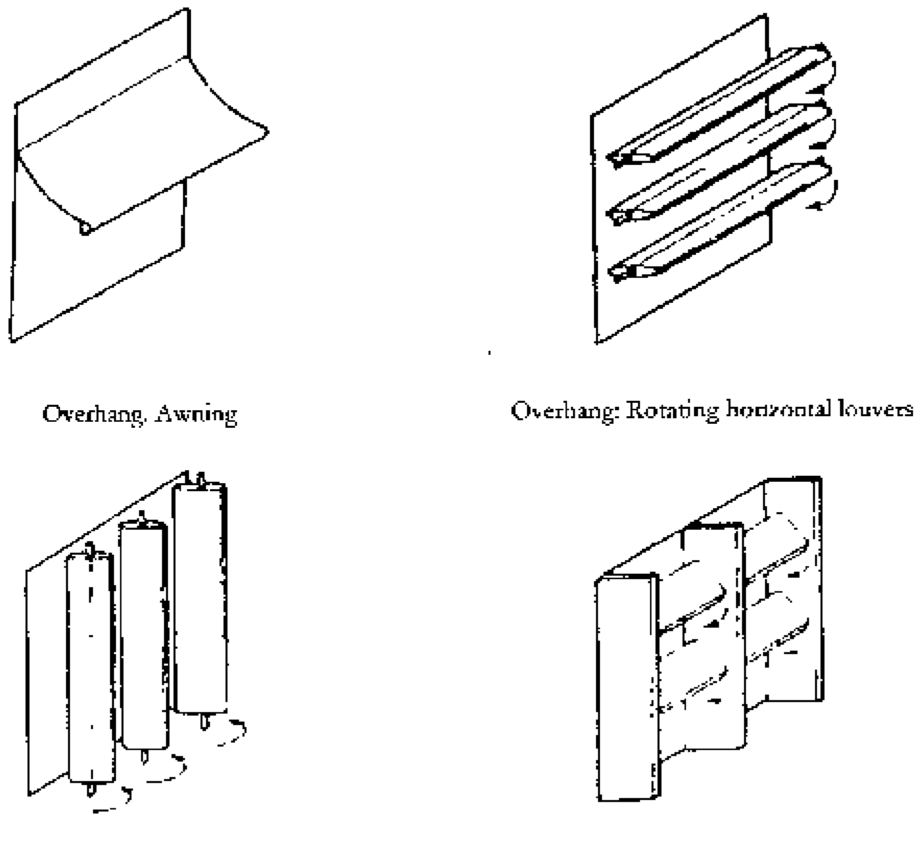


Figure 4.3: Some of movable shading devices *(Source. Lechner, 2001).*

The movement of shading devices can be very simple or very complex. An adjustment twice a year can be quite effective and yet simple. Late in spring, at the beginning of the overheated period, the shading devices would be manually extended. At the end of the overheated period in late fall, the device would be retracted for full solar exposure (Lechner, 2001).

There is a general conviction that since a building should be as low maintenance as possible, movable shading devices are unacceptable. The use of existing technology and careful detailing can produce trouble-free, low-maintenance movable shading devices.

Fixed Shading Devices

Fixed shading systems include structural elements, such as balconies and projecting fins or shelves and non-structural elements, such as canopies, blinds, louvers and screens. The orientation and shape of the opening to be shaded, relative to the position of the sun at different times of day and year, is critical to the design of fixed systems (Goulding, 1992). Each orientation will need to be examined separately, taking account of direct and diffuse or reflected components of the overall solar radiation throughout the day and year. Typically horizontal shading is used for south facades, whereas vertical or diagonal fins or louvers are often more efficient on the east or west facades in northern hemisphere.

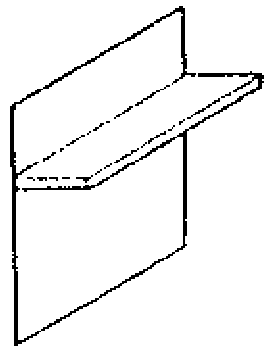
Fixed shading systems are most commonly used on the external facades where they can prevent direct radiation from reaching glazing or other openings and where heat absorbed by the shading system can be dissipated to the outside air. An obvious advantage of fixed shading is that it needs no handling by the occupants and is often maintenance free.

Fixed shading devices are of three types based on their physical forms (Koenigsberger *et al*, 1973; Givoni, 1998). They are horizontal shading device, vertical shading device and combination of the two (eggcrate). A brief discussion of these three types of fixed shading devices are presented below:

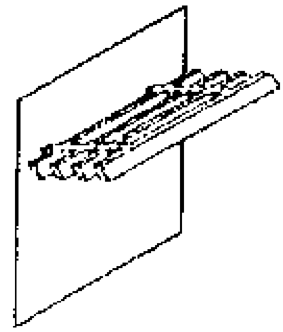
Vertical Shading Devices

Vertical devices consist of louver blades or projecting fins in a vertical position. Narrow blades with close spacing may give the same shadow angle as broader blades with wider spacing (Koenigsberger *et al*, 1973). Vertical fins are often presented as the shading devices of choice for east and west.

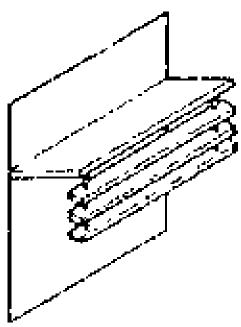
Vertical fins can be appropriate either when there is a desire to control the direction of view or when the view is not important. This type of device is most effective when the sun is at one side of the elevation, such as an eastern or western elevation. A vertical device to be effective when the sun is opposite to the wall considered, would have to give almost complete cover of the whole window.



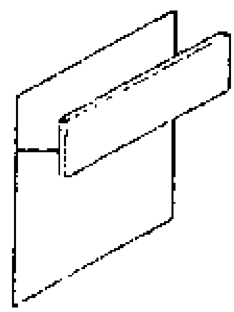
Overhang: Horizontal panel



Overhang: Louvers in horizontal plan

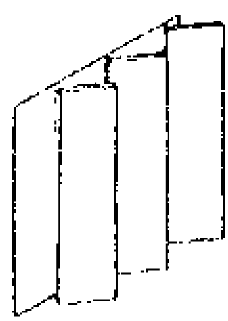


Overhang: Louvers in vertical plan

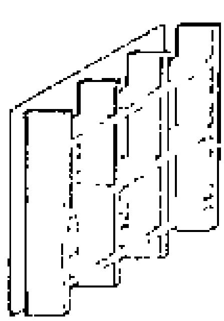


Overhang: Vertical panel

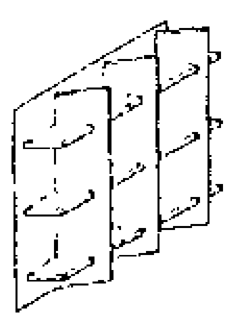
Vertical fin



Vertical fin slanted



Eggcrate



Eggcrate with slanted fins

Figure 4.4: Some of fixed shading devices *(Source: Lechner, 2001).*

Horizontal Shading Devices

The horizontal overhangs and its variations are the best choice for south facade. Because they are directionally selective, they can allow the low winter sun to enter while fully shading the high summer sun with minimum obstruction of the view.

Horizontal louvers have a number of advantages over solid overhangs. Horizontal louvers in a horizontal plane reduce structural loads by allowing wind to pass right through (Lechner, 2001). In the summer, they also minimize the collection of hot air next to the windows under the overhang. Horizontal louvers in a vertical plane are appropriate when the projecting distance from the wall must be limited. This could be important if a building is on or near the property line. Louvers can also be useful when the architecture calls for small-scale elements and a rich texture.

When designing an overhang for the south facade, one must remember that the sun comes from the southeast before noon and from the southwest after noon. Therefore, the sun will outflank an overhang the same width as a window. Narrow windows need either a very wide overhang or vertical fins in addition to the overhang. Wide strip windows are affected less by this problem.

Horizontal devices will be the most effective when the sun is opposite to the building face considered and at a high angle, such as for north and south facing walls (koenigsberger *et al*, 1973). In summer they can block the rays of the sun and in winter they can admit radiation from the sun's lower position. To exclude a low angle sun, this type of device would have to cover the window completely, permitting a view downwards only.

Egg-crate

Eggcrate shading devices are mainly for east and west windows in hot climates and for the additional southeast and southwest orientations in very hot climates (Lechner, 2001). An eggcrate is a combination of horizontal Overhangs (louvers) and vertical fins. By controlling sun penetration by both the altitude and azimuth angle of the sun, very effective shading of windows can be achieved. The Designer should first decide on the general appearance of the eggcrate system. As far as sun penetration is concerned, the scale of the eggcrate can be changed at any time as long as the ratio of height/depth and width/depth are kept constant.

4.4 Conclusion

Shading is a key strategy of achieving thermal comfort in the summer. Although shading of the whole building is beneficial, shading of the glazed areas is crucial. Heat gain is directly proportional to the area of glass exposed to solar radiation and therefore large glazed areas will permit a large and rapid heat gain. Existing heat-absorbing glasses can protect only 20% of the total incident radiation and reflective glazing prevents solar radiation up to 50%. Hence external shading devices can be a good answer to control the solar radiation. The most efficient solar control is provided by external shading devices, the design of which can only come from understanding the solar geometry. Direct radiation is dependent only on the altitude of the sun and geographical position. That's why; direct radiation can be controlled effectively by proper external shading devices.

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CHAPTER: FIVE

PERFORMANCE EVALUATION OF SHADING DEVICES

PERFORMANCE EVALUATION OF SHADING DEVICES

The performance of shading devices and its impact on solar heat gain through windows can precisely be evaluated by simulation study. Because in reality, due to the simultaneous influence of many different conditions, it is difficult to isolate the exclusive effect of one single aspect or the changes of it. Shadow simulation allows study of the effect of changes in one aspect, keeping other factors constant. The observations of simulated behaviour that occurs due to changing parameters allow the identification of elements, the reduction or introduction of which in the design contribute to solar heat gain. Another significant achievement of simulation study is that, it is possible to analyse the performance of shading devices for any period of the year simply by assigning simulation parameters (e.g. temperature, radiation, wind speed and direction, relative humidity and cloud cover).

In this chapter, nine tall office buildings from different commercial areas in the Dhaka city have been considered to evaluate performance of their shading devices, in terms of reducing solar heat gain through simulation study on the basis of set criteria. A dynamic computer simulation program named 'Ecotect' (version 5.20) has been used for this simulation study.

5.1 Selection of Shading Devices for Evaluation

Before making selection of shading devices, tall office buildings are identified on the basis of certain considerations to be discussed in the following section. These tall office buildings are located in different commercial areas in the Dhaka city, such as Motijheel, Dilkusha, Karwan bazaar, Panthapath, Banani, Mohakhali etc. After that, buildings were categorised considering the typology (based on geometry) of shading devices installed on their front façade. Sketches of window sections with shading device of these buildings were prepared with detail construction features, installation technique and geometric features. After analysing the sketches, nine shading devices were selected to evaluate performance in terms of reducing solar heat gain considering shading device typology and similarities in geometric features.

Tall Building Criteria

There is no fixed parameter of height to denote tall and high-rise building. According to the Council for Tall Buildings and Urban Habitat (CTBUH), the number of stories or its height does not strictly define a tall building. It also depends upon the context in which it stands. The Council for Tall Buildings and Urban Habitat (CTBUH) considers for instance, tall buildings as being buildings of ten storeys or more.

a) Walk up limit / provision for lift:
   - According to Building construction rules (2006), buildings of seven storied and above in height shall have provision for lift.
   - According to Bangladesh National Building Codes (1993), lifts shall be provided in buildings more than six storied or 20m in height.

b) Fire escape provision:
   - According to Fire Service and Civil Defence rules, buildings of seven storied and above in height shall have provision for Fire escape/ alternative staircase.

c) Structural analysis and design:
   - According to Wolfgang Shueller, buildings with height-to-width ratio above 5-7 are considered as high-rise structure.

In view of the above considerations, in the present context of Dhaka city, buildings above six storeys may be considered as tall buildings.

Selection of Shading Devices

Following the above criteria, eighty-four tall office buildings of Dhaka city were identified for investigation. Among them, forty buildings are situated at Motijheel and Dilkusha area; twenty-four buildings at Mohakhali, Gulshan Avenue and Banani Kemal Ataturk Avenue; fourteen buildings at Karwan Bazaar area and six buildings at Panthapath.

Among these buildings, twenty two buildings have horizontal shading devices, eleven buildings have vertical shading devices, twenty buildings have composite type (combination of horizontal and vertical) shading devices and thirty one buildings do not have shading devices on their front façade. Among these eighty-four tall office buildings, nine buildings were selected to evaluate performance of their shading devices. The list of buildings with location, height, orientation and type of shading device installed is presented below:

Table 5.1: List of the selected buildings and shading devices.

Sl No.	Identification Number	Location	Storey	Orientation	Shading Device
1	H01	Janata Bank Bhaban, Motijheel	23	East	Horizontal
2	H02	Global Insurance Ltd. Dilkusha	11	South	Horizontal
3	H03	Brac Center, Mohakhali	20	North	Horizontal
4	V01	Rupali Bank Ltd, Dilkusha	10	South	Vertical
5	V02	Ispahani Bhaban, Dilkusha	9	West	Vertical
6	V03	Bangladesh Samobye Bhaban, Motijheel	9	East	Vertical
7	C01	Krishi Bhaban, Dilkusha	11	South	Composite
8	C02	BCIC Bhaban, Dilkusha	22	South	Composite
9	C03	Meghna Life Insurance, Dilkusha	10	East	Composite

View of front facades of the selected building and sketches of window sections with shading devices of these buildings are presented below.

Figure 5.1(a): View of building H01.

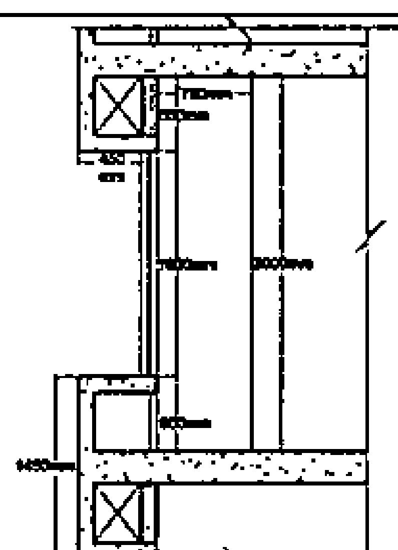


Figure 5.1(b): Window section of H01.

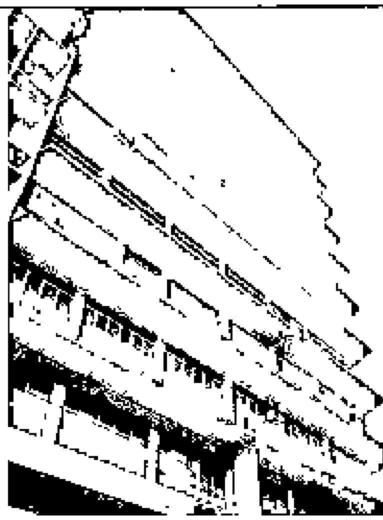


Figure 5.2(a): View of building H02.

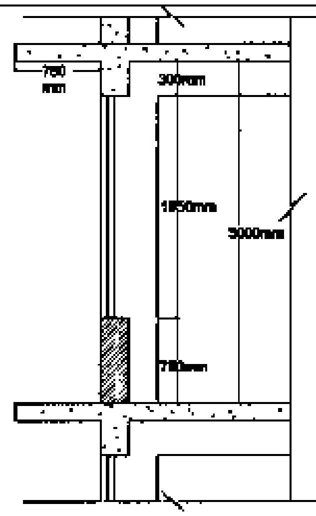


Figure 5.2(b): Window section of H02.

Figure 5.3(a): View of building H03.

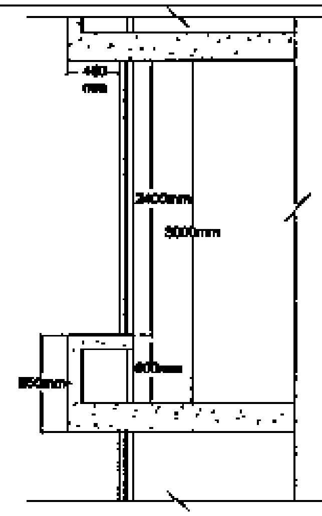


Figure 5.3(b): Window section of H03.

Figure 5.4(a): View of building V01.

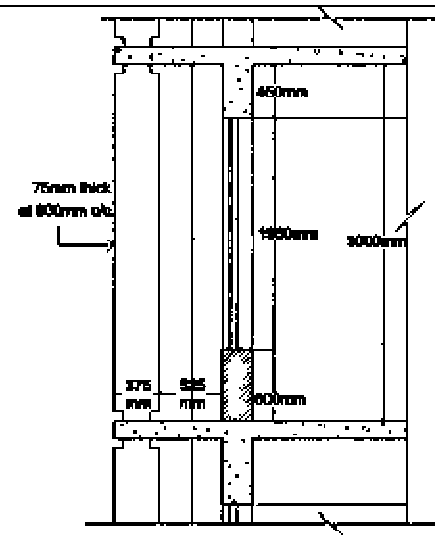


Figure 5.4(b): Window section of V01.

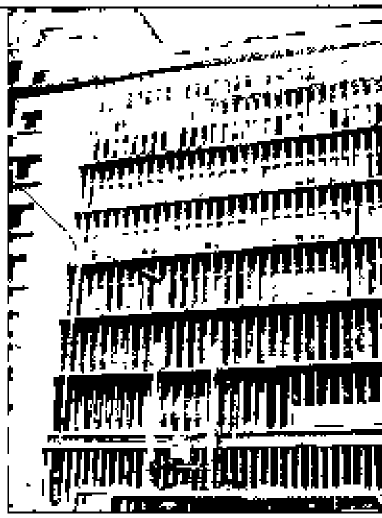


Figure 5.5(a): View of building V02.

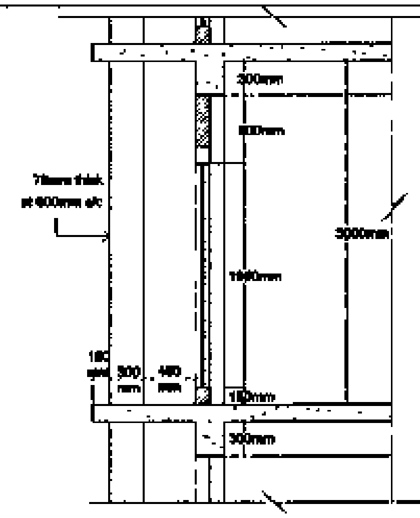


Figure 5.5(b): Window section of V02.

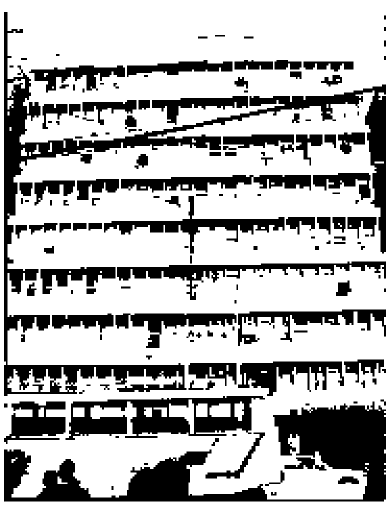


Figure 5.6(a): View of building V03.

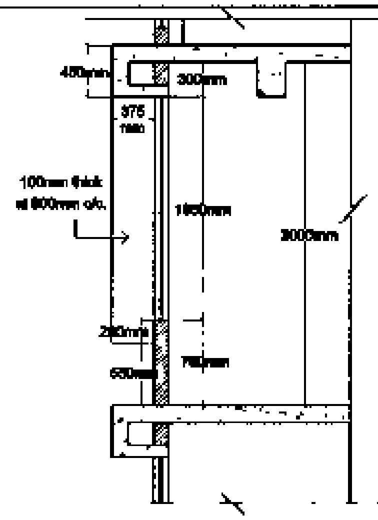


Figure 5.6(b): Window section of V03.

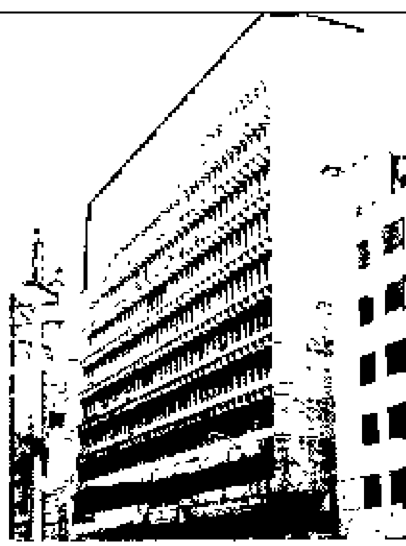


Figure 5.7(a): View of building C01.

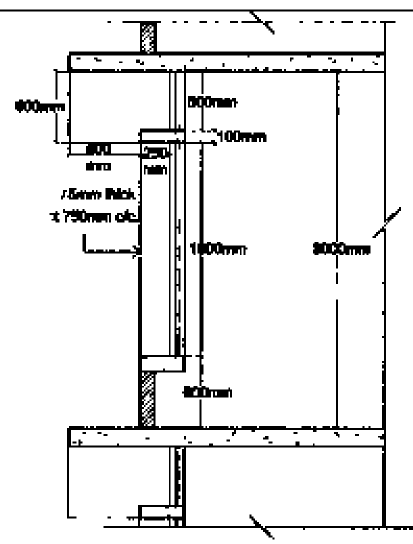


Figure 5.7(b): Window section of C01.

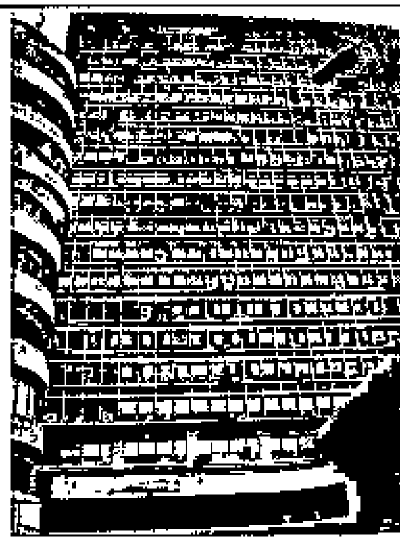


Figure 5.8(a): View of building C02.

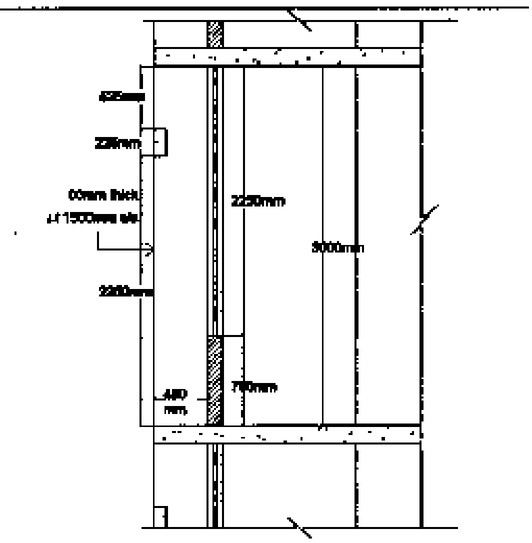


Figure 5.8(b): Window section of C02.

Figure 5.9(a): View of building C03.

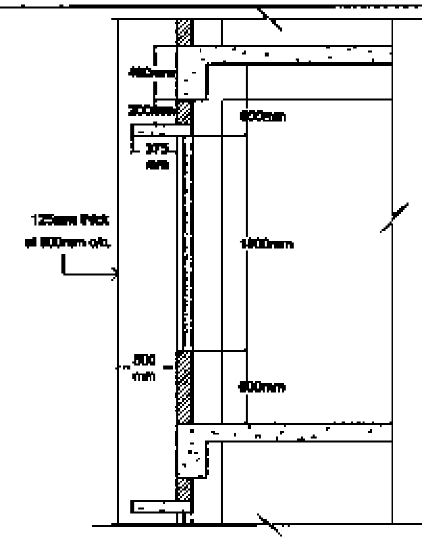


Figure 5.9(b): Window section of C03.

5.2 Performance Evaluation Process

Performance of the selected shading devices will be evaluated in terms of reducing solar heat gain through simulation study on the basis of set criteria to be discussed in the following section. Simulation is a powerful technique for solving a variety of problems. To simulate is to copy the behaviour of the phenomenon under study. It refers to some representation or model of a system that can be studied in order to understand the behaviour of the actual system itself and to make predictions about the future. It involves developing a model of a system and carrying out experiments on it. It helps analyzing the effect of phenomenon and their interaction on one another (Suri, 2005).

Evaluation process comprises the following steps:

- Setting criteria for performance evaluation
- Preparing climate database
- Setting simulation parameters
- Developing simulation model
- Analysing results of simulation

In order to evaluate the performance of shading devices in reducing solar heat gain, a base-case situation is established by studying the unshaded window (without shading device) during the critical shading period of the year at different orientations.

5.2.1 Criteria for Performance Evaluation

- The percentage of the shade area, given by various types of fixed shading devices (Givoni, 1969; Steemers *et al*, 2002). The percentage of the shade areas refers to portion of the window area, which is not exposed to the direct solar radiation. This also reflects the ability of a fixed shading device to protect the window area at critical time.
- Computation of the shading coefficient, which is the ratio of the heat entering the window-shading combination to that entering an unshaded window. Shading coefficient (C_{sh})can be expressed as below.

$$C_{sh} = \frac{\text{Heat entering through the window with shading device}}{\text{Heat entering through the window without shading device}}$$

Shading coefficients basically refer to the fraction of solar heat gain that passes through a transparent solar aperture compared to the amount of solar radiation incident upon it. The shading coefficient is expressed as a dimensionless number from 0 to 1. A high shading coefficient means high solar gain, while a low shading coefficient means low solar gain (Givoni, 1969; Givoni, 1998; Steemers *et al*, 2002; Lechner, 2001).

5.2.2 Simulation Program

Simulations regarding solar performance analysis are carried out using building analysis software 'ECOTECT v5.20'. It features a user-friendly 3D modelling interface fully integrated with a wide range of performance analysis and simulation functions. The visual nature of calculation feedback makes 'ECOTECT' unique. The process can be started with a detailed climatic analysis to calculate the potential effectiveness of various passive design techniques or to optimise the use of available solar, light and wind resources.

The original 'ECOTECT' software was written as a demonstration of some of the ideas presented in PhD thesis by Dr. Andrew Marsh at the School of Architecture and Fine Arts at The University of Western Australia. The software has undergone some major changes since then. Version 5.2 builds significantly on the functionality of previous versions introducing a range of new analysis functions and real-time hidden line and sketch visualization. It also refines some of the major algorithms, such as the thermal and daylight factor calculations.

ECOTECT provides a range of thermal and solar performance analysis options. At its core, is the Chartered Institute of Building Services Engineers (CIBSE) Admittance Method used to determine heat loads. The Admittance Method is widely used around the world and has been shown to be an extremely useful design-tool. This thermal algorithm is very flexible and has no restrictions on building geometry or the number of thermal zones that can be simultaneously analyzed. Most importantly, with only a few pre-calculations for shading and overshadowing, it is very quick method to calculate and can be used to display a wide range of very useful information.

Whilst in summary it is a simplified method, the Admittance Method encapsulates the effects of conductive heat flow through building fabric, infiltration and ventilation through openings, direct solar gains through transparent materials, indirect solar gains through opaque elements, internal heat gains from equipment, lights and people and the effects of inter-zonal heat flow.

Nicki Taylor validated ECOTECT as part of his research work for the degree of Bachelor of Engineering (Hons.) from Department of Environmental Engineering at University of Western Australia in 2002. He showed in his research that the mean error of the estimated results is less than 2%, indicating a reasonable degree of accuracy (Taylor, 2002).

5.2.3 Climate Database

The climate database stores files containing hourly weather data. The weather files supplied with Ecotect cover different regions of the world and each represents a typical year's weather for a particular region. The weather file is not provided with the software. But facilities are provided to allow creating own weather files and can be added to the climate database.

The weather file 'Ban_Dhaka.wea' has been prepared for the research purpose by using the Weather Tool, associated software of Ecotect. The Weather Tool is a visualization and analysis program for hourly climate data. The weather file consists of a group of parameters relating to the weather site and hourly values of seven weather variables (dry-bulb temperature, relative humidity, direct radiation, diffuse radiation, wind speed and direction and cloud cover). Hourly radiation data has been collected from Renewable Energy Research Centre of Dhaka University. Three hourly weather data regarding dry-bulb temperature, relative humidity, wind speed and direction and cloud cover has been collected from Climate Division, Bangladesh Meteorological Department Agargaon, Dhaka. Due to the simulation requirements, all three hourly data have been converted to hourly data by interpolation method. Hourly weather variables for Dhaka have been collected for the year 2005.

The site parameters of Dhaka for weather file are as follows:

Parameters	Details
Latitude (degrees North)	23°50' North
Longitude (degrees East)	90°20' East
Time Zone (hours ahead of GMT)	GMT +06.00

The combination of site parameters and hourly weather variables forms the weather file, with which the simulation program Ecotect is capable to analyse any climatic characteristics of the selected site.

5.2.4 Simulation Parameters

Before starting the simulations a set of parameters are set. These are described below. To investigate the results of the simulations, a specific day has been selected (from the weather database for a year) on the basis of some specific attributes to observe the results.

Considerations for Identifying the Simulation Day

For individual daily profile analysis, a day of the year has been selected in consideration of the typical characteristics of the given climate.

The test day is 21st of March (Day: 80). Outdoor air temperature range of this day is 24.5°C -35.4°C and sky condition is clear. From 0900-1700 hours the cloud cover is 1.1 out of 8.0 (13.8% coverage). This is a day with considerable high outdoor air temperature but not the extreme one and bears a common character regarding the climatic features specially of the hot-dry season. The average temperature of this day (29°C) is very close to the average temperature of the season (28.02°C). It has been observed that the sky condition in the given climate is clear for 67 percent of the whole pre-monsoon period (earlier shown in table 2.3) and the 'clear sky' condition prevail for the chosen day. This 'clear sky' condition of the chosen day is also important to investigate the impacts of solar radiation and this clear sky condition enhances the direct solar radiation to reach on building surfaces. Overcast sky condition impedes direct radiation to reach the building surfaces. Fixed shading device are effective to reduce heat gain from direct solar radiation. These are the reasons behind choosing a day with clear sky condition.

For a fixed shading device, the shading period is symmetrical about June 21 (Lechner, 2001). This is because the position of the sun cycles through the sky on a seasonal basis. Thus, the Sun will pass through the same path twice every year, the first time when going from winter to summer and the second time when traveling back to winter. Thus, any shading device will always shade between two dates. In the northern hemisphere, an optimized shading device for the 21st of March will actually shade from the 21st of March, right through June until the 21st of September. Thus the whole overheated period (hot-dry and warm-humid) is taken into account for simulation.

Considerations for Identifying the Time Period for Simulation

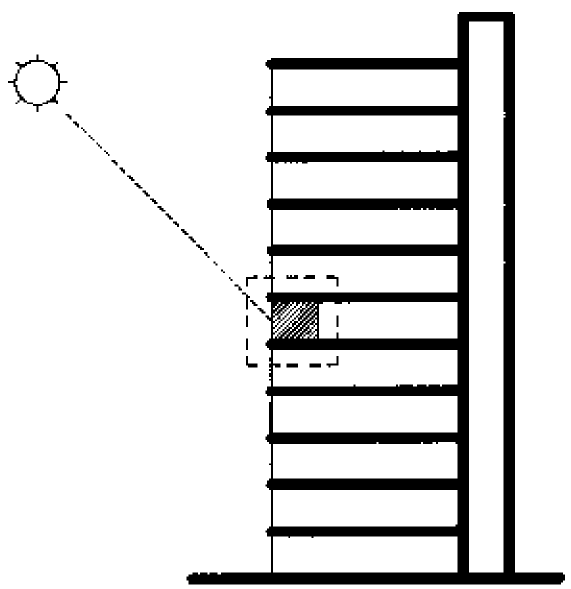
For simulation to investigate the performance of the shading devices, the time period is considered when the space is only considered to be used during office hours. In general, the office time is from 0900 to 1700 and this time period is taken as a critical time period for shading requirement.

5.2.5 Simulation Model

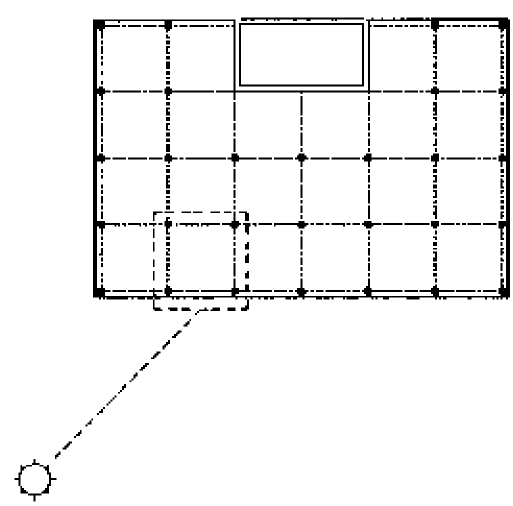
Following models have been developed for simulation that represent the selected shading devices. These models refer to the high-rise buildings selected with identical facades with a similar treated floor area with the shading device with single glazed clear glass. The room size for simulation model is 6000mm x 6000mm which is considered as located in an intermediate floor of a high-rise building. The room size is taken from the typical high-rise column grid. A fixed window width 5400mm has been considered with single glazed glass, as the window covers the whole span between two columns. Different shading devices are attached with it for simulation study. For the ease of calculation, a study plane at the level of the exterior surface of the window wall is considered.

In terms of shading analysis and solar heat gain, the simulations are done for the following options of models:

- The 'without shading' option - which refer to the high-rise models with identical facades with a similar treated floor area without the shading device but with clear glass;
- The 'with shading' option which refer to the high-rise models with shading as designed by the architect.



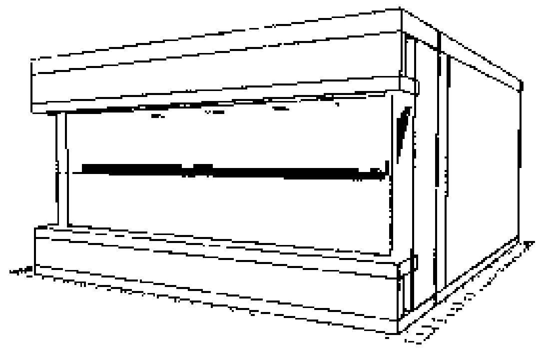
Section of typical high rise building



Typical floor plan of high rise building

Figure 5.10: Schematic drawings showing generation of simulation model from typical high rise building.

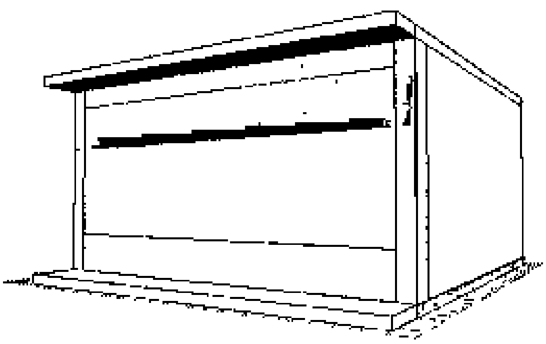
The simulations are done for the following models generated by 'Ecotect':



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 1800mm
- Overhang depth: 450mm

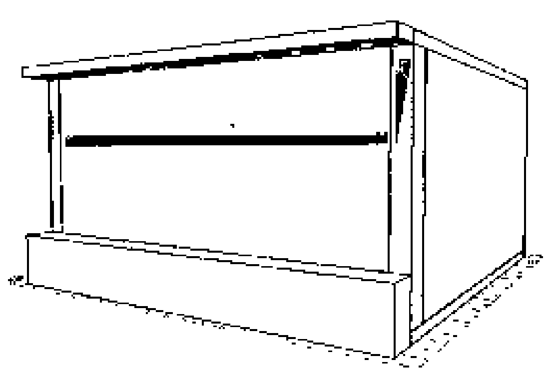
Figure 5.11: Simulation model of Shade H01.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 2100mm
- Overhang depth: 750mm

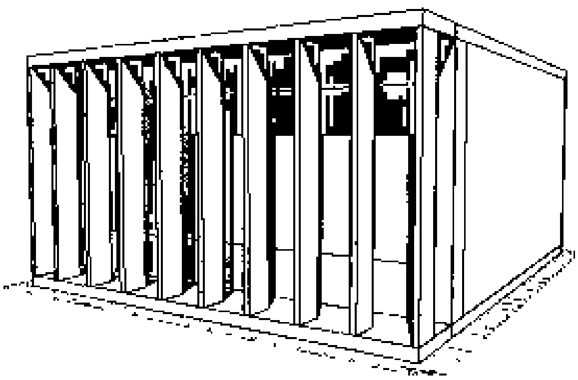
Figure 5.12: Simulation model of Shade H02.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 750mm, Width: 5400mm, Height: 2400mm
- Overhang depth: 450mm

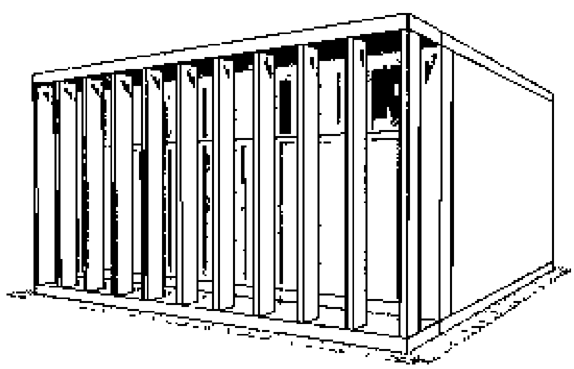
Figure 5.13: Simulation model of Shade H03.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 1950mm
- Vertical Fin: Depth: 375mm, Spacing: 600mm

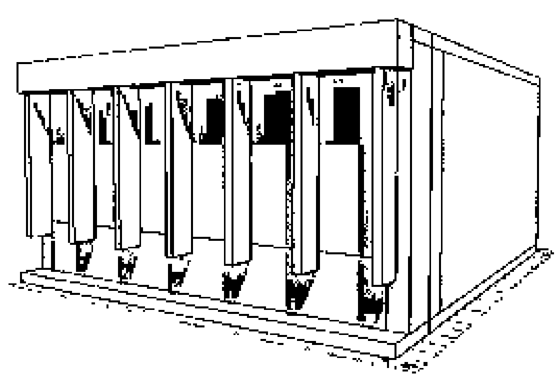
Figure 5.14: Simulation model of Shade V01.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 1950mm
- Vertical Fin: Depth: 300mm, Spacing: 600mm

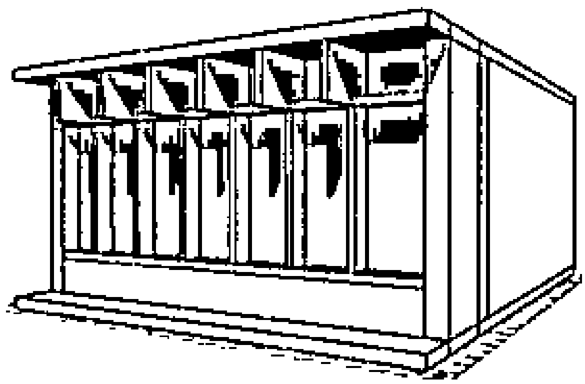
Figure 5.15: Simulation model of Shade V02.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 1950mm
- Vertical Fin: Depth: 450mm, Spacing: 600mm

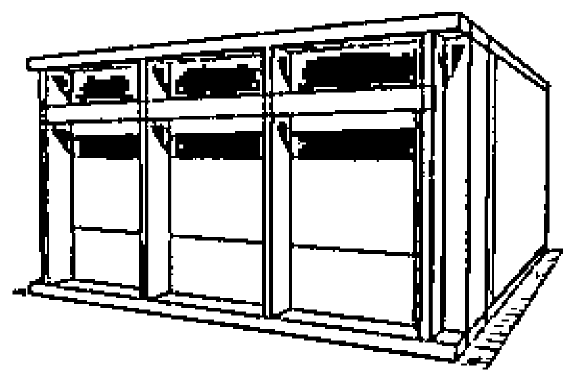
Figure 5.16: Simulation model of Shade V03.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 2400mm
- Vertical Fin: Depth: 300mm& 900mm, Spacing: 750mm
- Overhang depth: 300mm & 900mm

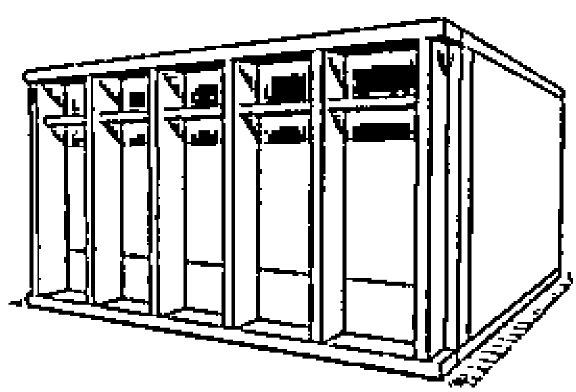
Figure 5.17: Simulation model of Shade C01.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 750mm, Width: 5400mm, Height: 2250mm
- Vertical Fin: Depth: 450mm, Spacing: 1500mm
- Overhang depth: 225mm

Figure 5.18: Simulation model of Shade C02.



Parameters:

- Office room dimension: 6000mm x 6000mm
- Floor height: 3000mm
- Window: Sill: 600mm, Width: 5400mm, Height: 1800mm
- Vertical Fin: Depth: 500mm, Spacing: 1050mm
- Overhang depth: 375mm

Figure 5.19: Simulation model of Shade C03.

5.3 Simulation Study for Performance Evaluation

Two studies about the performance of shading devices on solar radiation protection are carried out as under. The first study investigated the impact of orientation on the performance of shading devices while the second study compared the performance among the selected shading devices in different orientations on the basis of previously set criteria.

This study will help in identifying the effect of different parameters and interrelation among parameters in terms of solar shading aspect. This study will also assist to understand the influence of window orientation on the shading performance of shading devices.

5.3.1 Effect of Orientation on Shading Performance

The efficiency of the window shading is largely determined by the orientation of the window. When shading is not effective, solar radiation enters through the windows and heats up the building interior directly. Hence the indoor temperature will obviously be influenced by the orientation of the windows.

The quantitative effect of window orientation has been studied by simulation technique under different shading condition, which also reveal whether shading devices used are effective or not, according to orientation in order to cut direct sunlight penetration at critical times of the day. The results of the study are summarised in the following section.

5.3.1.1 Performance of Horizontal Shading Devices

The three models with selected horizontal shading devices were oriented in the three cardinal directions (East, West & South) and two oblique directions south-east and south-west. The results are given below with respect to individual cases.

Table 5.2 shows percentage of shaded area with respect to whole window area of Shade H01 at every 30-minute interval from sunrise to sunset. In the field investigation it was found that this shading device was attached mostly with an east-facing window. But through simulation, it is found that this shading device is not efficient at east orientation. It is capable to shade below 50% of the window area at east but up to 60% window area at south orientation. The performance at south is more consistent than that of other orientations. Figure 5.20 shows the shading performance of Shade H01 in different orientations and it expresses a consistent performance only in south orientation.

Table 5.2: Percentage of shaded area by Shade H01 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	22	28	35	50	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	21	27	31	38	45	59	*	*	*	*	*	*	*	*	*	*	*
South	52	54	53	56	56	55	60	53	56	57	54	55	52	50	48	42	38
Southwest	*	*	*	*	*	*	*	63	50	41	34	28	22	19	15	12	10
West	*	*	*	*	*	*	*	*	*	62	41	30	24	16	13	11	7

* Percentage of shaded area is not taken into account as the sun does not see the window.

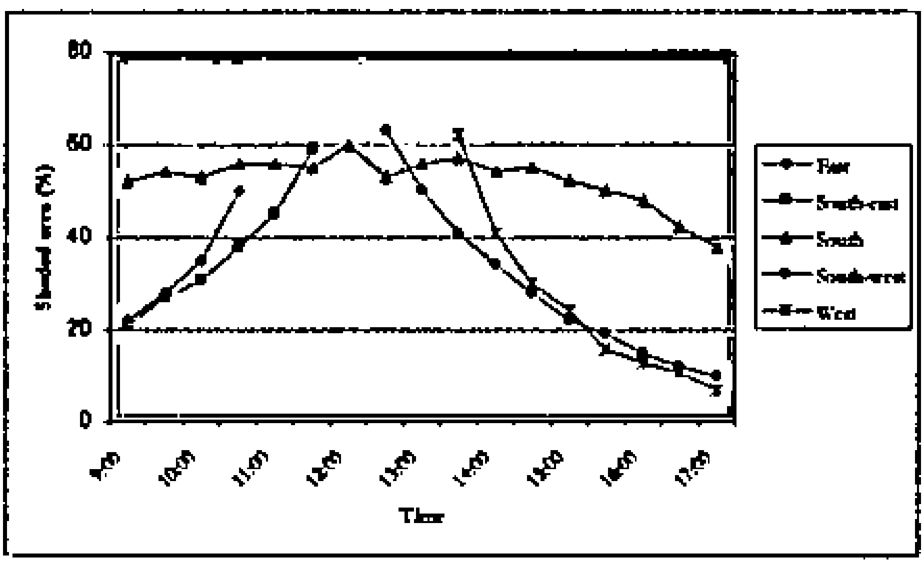


Figure 5.20: Percentage of shaded area by Shade H01 for 21st March at different orientations.[1]

In case of Shade H02, simulation results show that the device shades more window area at south orientation. In the field investigation it was found that this shading device was attached with a south facing window. As per simulation it is capable to shade up to 53% of window area at south orientation. The performance at south is more consistent than

[1] Corresponding values of percentage of shaded area prior to hours shown are not indicated as the sun does not see the window prior to the time range shown period.

that of other orientations. At south-west orientation it shades up to 56% of window area but the performance is not consistent. Table 5.3 and Figure 5.21 show the performance of Shade H02 at different orientations and it indicates a consistent performance only in south orientation.

Table 5.3: Percentage of shaded area by Shade H02 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	11	20	27	44	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	12	15	20	28	37	52	*	*	*	*	*	*	*	*	*	*	*
South	45	46	47	51	50	50	53	48	52	49	46	45	42	41	36	27	25
Southwest	*	*	*	*	*	*	*	56	44	33	23	17	13	8	4	0	0
West	*	*	*	*	*	*	*	*	*	54	30	21	12	6	3	0	0

* Percentage of shaded area is not taken into account as the sun does not see the window.

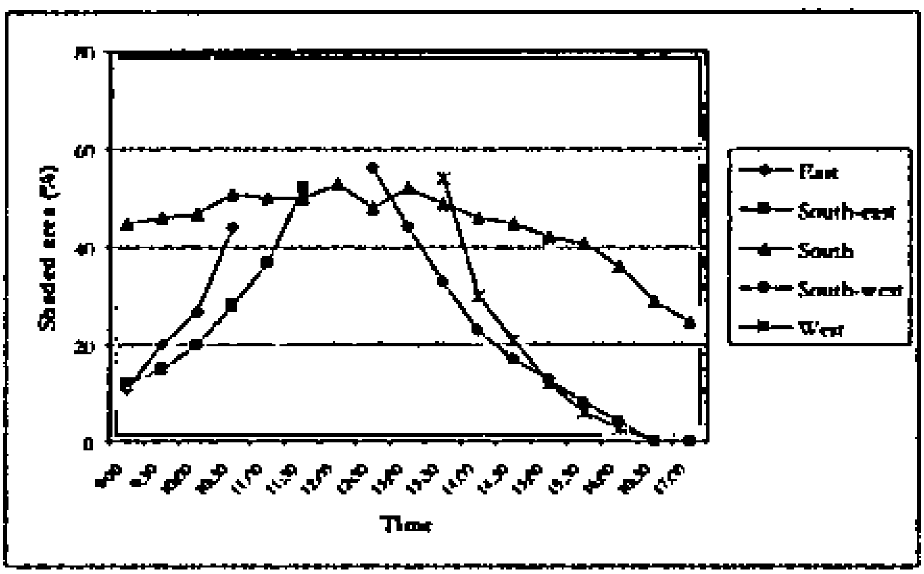


Figure 5.21: Percentage of shaded area by Shade H02 for 21st March at different orientations.[1 to 15]

Table 5.4 and Figure 5.22 show the performance of Shade H03 at different orientations and it expresses a comparatively better performance at south orientation than that for other orientations. It shades maximum 46% window area at south and more or less consistent for the whole day.

Table 5.4: Percentage of shaded area by Shade H03 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	11	20	31	38	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	17	22	21	33	34	44	*	*	*	*	*	*	*	*	*	*	*
South	39	41	45	42	41	44	46	40	44	39	36	43	39	38	38	30	28
Southwest	*	*	*	*	*	*	*	45	38	30	28	21	17	13	12	7	8
West	*	*	*	*	*	*	*	*	*	47	31	23	19	19	6	7	9

* Percentage of shaded area is not taken into account as the sun does not see the window.

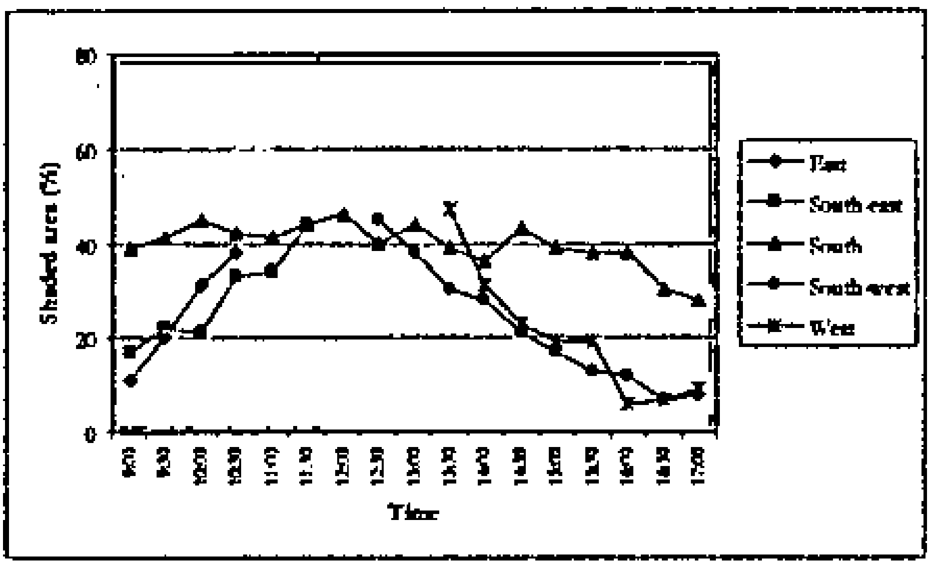


Figure 5.22: Percentage of shaded area by Shade H03 for 21st March at different orientations.

Findings

It has been observed from the results of the simulations that the performance of horizontal shading devices remains quite consistent at south orientation only. It works better when the sun is opposite to the window pane at a high altitude. This performance drops when the sun is in a lower altitude and oblique to the window pane. The horizontal overhang is not capable to protect the window when the sun azimuth and altitude are low. So from these analyses, need for modification is evident when the sun is at low azimuth and altitude.

5.3.1.2 Performance of Vertical Shading Devices

The three selected vertical shading devices were oriented in the three cardinal directions (East, West and South) and two oblique directions south-east and south-west to evaluate their performance at different orientations. The results are given below with respect to individual cases.

Table 5.5: Percentage of shaded area by Shade V01 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	47	53	78	87	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	46	50	50	53	75	91	*	*	*	*	*	*	*	*	*	*	*
South	81	87	89	94	91	83	81	88	88	87	88	85	85	78	69	57	36
Southwest	*	*	*	*	*	*	*	94	77	58	55	46	44	45	45	44	53
West	*	*	*	*	*	*	*	*	*	89	80	66	52	40	37	36	33

* Percentage of shaded area is not taken into account as the sun does not see the window.

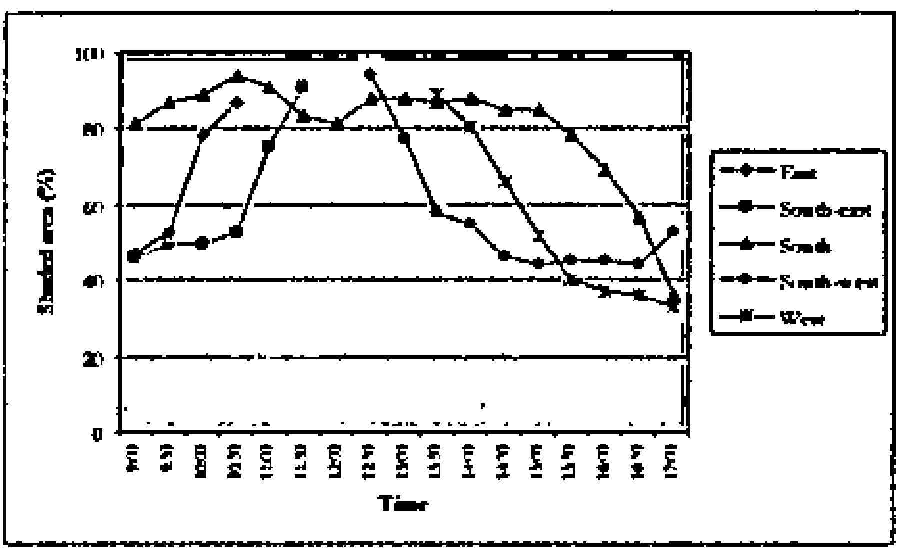


Figure 5.23: Percentage of shaded area by Shade V01 for 21st March at different orientations. [1(p 55)]

Table 5.5 shows percentage of shaded area with respect to whole window area of Shade V01 at every 30 minute interval from sunrise to sunset. In the field investigation it was found that this shading device was attached with a south facing window. But through simulation, it is found that this shading device is not only efficient at south orientation, it also works well at east and west. This shading device is capable to shade 60% of the window area on an average at east and west and up to 94% window area at south orientation. But one thing is clear that the large overhang that holds the vertical fins makes the whole shading device effective at south. Actually vertical fins do not have significant role in protection of window at south.

Table 5.6: Percentage of shaded area by Shade V02 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	40	49	66	82	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	44	36	43	46	94	90	*	*	*	*	*	*	*	*	*	*	*
South	76	83	87	83	71	75	68	65	72	71	76	86	83	73	64	53	21
Southwest	*	*	*	*	*	*	*	84	57	42	32	29	35	39	36	48	51
West	*	*	*	*	*	*	*	*	*	80	64	50	45	46	41	34	26

* Percentage of shaded area is not taken into account as the sun does not see the window

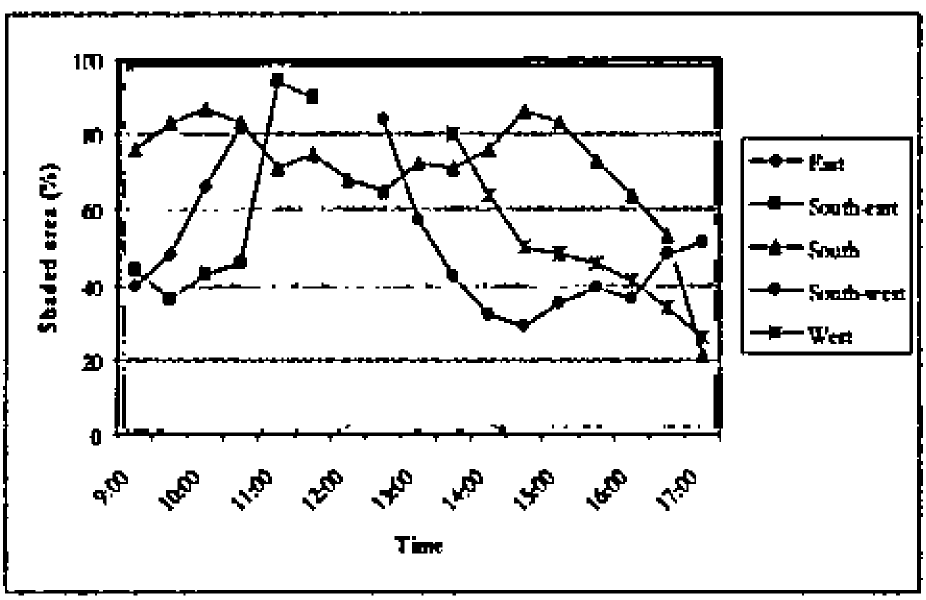


Figure 5.24: Percentage of shaded area by Shade V02 for 21st March at different orientations.[1 to 55]

In case of Shade V02, simulation results show that the device shades more window area at south orientation only when the sun is at an angle with the windowpane. That is when the sun is in southwest and southeast, this shading device is effective and capable to shade up to 87% of window area. In the field investigation it was found that this shading device was attached with a west-facing window. Through simulation it is found that this shading device is effective at west orientation and it also shades well at east and west. This shading device is capable to shade 52% of the window area on an average at east and west.

Table 5.7 shows percentage of shaded area with respect to whole window area of Shade V03. In the field investigation it was found that this shading device was attached with an east facing window. Through simulation, it is found that this shading device is efficient at south orientation; it also works well at south-east and south-west. This shading device is capable to shade 50% of the window area on an average at east and west. This shading device is effective in south façade only when the sun is at an angle with the window.

Table 5.7: Percentage of shaded area by Shade V03 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	38	42	53	58	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	43	32	30	34	49	61	*	*	*	*	*	*	*	*	*	*	*
South	100	96	82	66	75	56	51	63	66	73	72	92	100	100	100	100	100
Southwest	*	*	*	*	*	*	*	58	53	50	45	35	34	39	39	32	41
West	*	*	*	*	*	*	*	*	*	76	44	48	38	36	32	28	24

* Percentage of shaded area is not taken into account as the sun does not see the window.

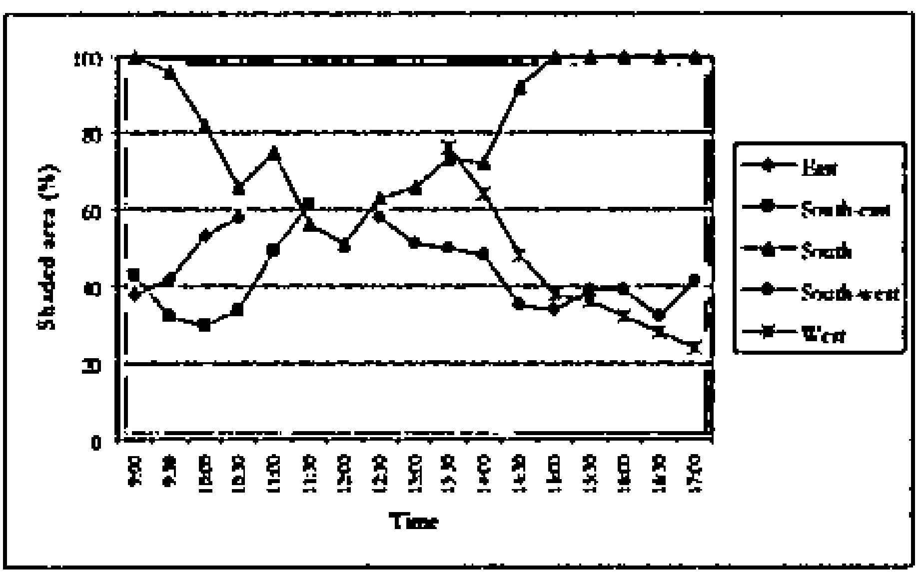


Figure 5.25: Percentage of shaded area by Shade V03 for 21st March at different orientations.

Findings

The investigation shows that vertical shading devices are effective on west and east façade. The simulation results show that all these three vertical shading devices are capable to shade above 50% of the window area on an average at east and west. Vertical shading devices are also capable to shade up to 94% window area at south orientation. But one thing has to be noticed that the large overhangs that holds the vertical fins makes the whole shading device effective at south. Actually vertical fins do not have significant role in shading of window at south. They work efficiently when the sun is at an angular position with the window. They are not effective when the sun's altitude is low and perpendicular with the façade. It has also to be noticed that vertical fins are not efficient at east and west orientation when the sun is just in front of the window. This phenomenon needs further investigation.

5.3.1.3 Performance of Composite Shading Devices

The three selected composite shading devices (combination of vertical fin and horizontal overhang) were oriented in the five directions - East, West, South, South-east and South-west and then simulated to investigate the influence of orientation on their shading performance. The results are given below with respect to individual cases.

Table 5.8: Percentage of shaded area by Shade C01 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	56	56	79	87	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	56	56	56	62	75	95	*	*	*	*	*	*	*	*	*	*	*
South	100	98	93	91	91	90	85	86	100	97	90	98	100	100	100	100	100
Southwest	*	*	*	*	*	*	*	96	84	69	58	59	54	53	57	65	57
West	*	*	*	*	*	*	*	*	*	94	82	76	60	55	48	40	25

* Percentage of shaded area is not taken into account as the sun does not see the window.

Table 5.8 shows percentage of shaded area with respect to whole window area of Shade C01 at every 30 minute interval from sunrise to sunset. In the field survey it was found that this shading device was attached with a south facing window. Through simulation, it is found that this shading device is not only efficient at south orientation; it also works well at south-east and south-west. This shading is capable to shade 60% of the window area on an average at south-east and south-west and up to 100% window area at south orientation.

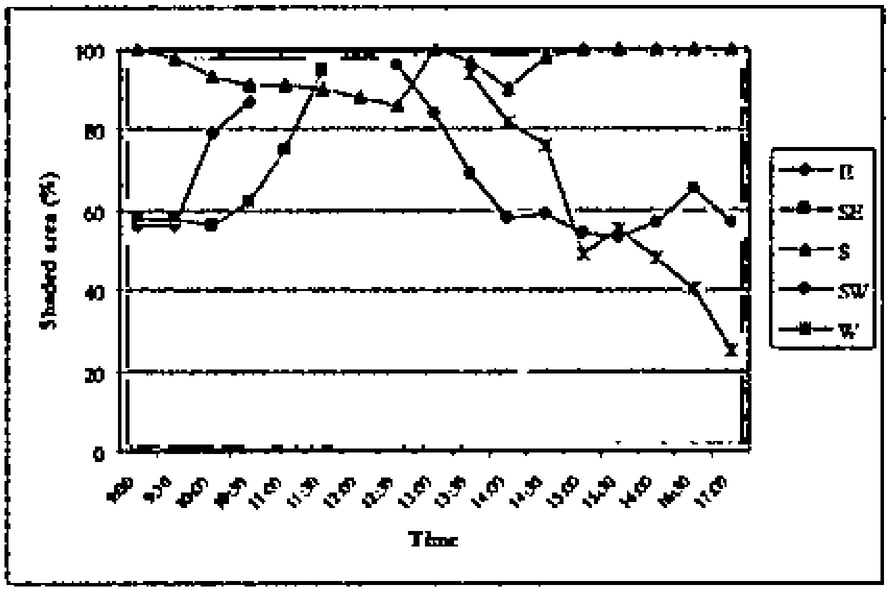


Figure 5.26: Percentage of shaded area by Shade C01 for 21st March at different orientations.[1 (p. 55)]

In case of Shade C02, simulation results show that the device works better at south orientation specially when the sun is in an angle with the window pane. That is when the sun is in south-west and south-east, this shading device is effective and capable to shade up to 100% window area. In the field survey it was found that this shading device was attached with a south facing window. But through simulation it is found that this shading device is also effective in east, south-east and south-west orientation.

Table 5.9: Percentage of shaded area by Shade C02 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	50	52	56	76	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	46	48	43	52	58	75	*	*	*	*	*	*	*	*	*	*	*
South	88	84	82	76	74	71	69	69	69	73	80	85	81	95	100	100	100
Southwest	*	*	*	*	*	*	*	83	63	56	49	46	46	48	41	41	49
West	*	*	*	*	*	*	*	*	*	80	62	50	49	43	39	31	21

* Percentage of shaded area is not taken into account as the sun does not see the window.

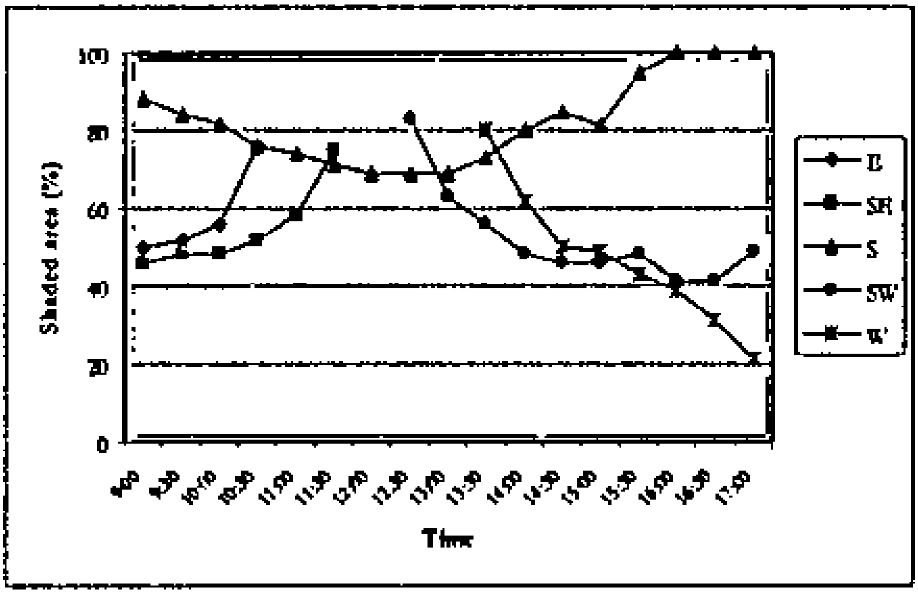


Figure 5.27: Percentage of shaded area by Shade C02 for 21st March at different orientations.[1 (p 33)]

Table 5.10 shows percentage of shaded area with respect to whole window area by Shade C03. In the field survey it was found that this shading device was attached with an east facing window. Through simulation, it is found that this shading device is effective at east and west orientation, but not consistent. The shading performance at south-east and south-west is more consistent than other orientations.

Table 5.10: Percentage of shaded area by Shade C03 for 21st March.

Orientation	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	35	44	54	77	*	*	*	*	*	*	*	*	*	*	*	*	*
Southeast	39	39	39	38	45	46	*	*	*	*	*	*	*	*	*	*	*
South	100	100	93	81	49	57	51	50	67	69	90	94	100	100	100	100	100
Southwest	*	*	*	*	*	*	*	67	51	43	35	38	39	47	51	41	50
West	*	*	*	*	*	*	*	*	*	76	58	62	52	37	33	31	21

* Percentage of shaded area is not taken into account as the sun does not see the window.

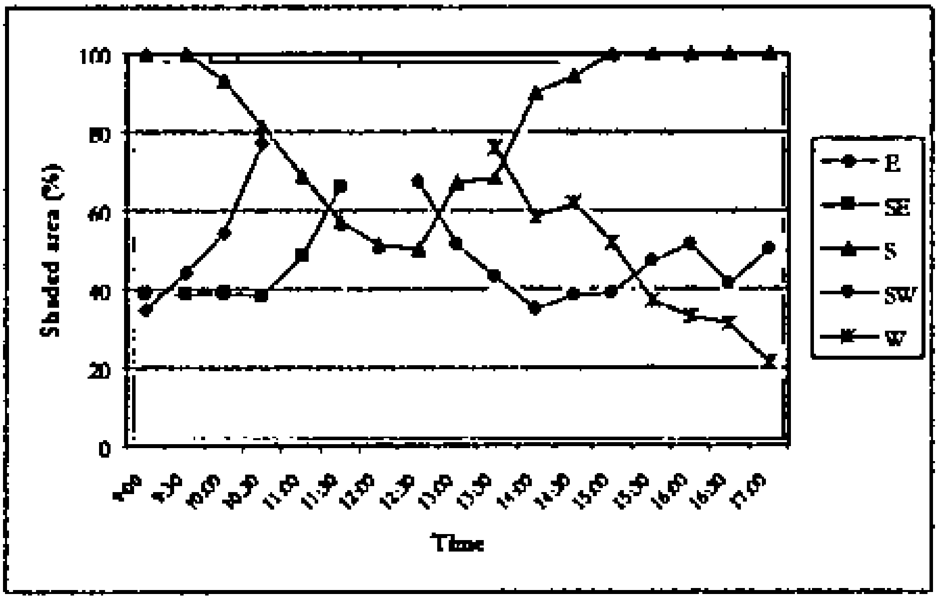


Figure 5.28: Percentage of shaded area by Shade C03 for 21st March at different orientations. [1 (b 35)]

Findings

The analysis shows that composite shading devices are effective in south, south-east and south-west orientation. They are effective both when sun is in perpendicular and angular position with the window pane. Horizontal overhangs of the composite shading are effective to protect the sun when it is at perpendicular position to the window. And vertical fins of the composite shading are effective to protect the sun when it is at an angular position to the window. But their performance in east and west orientation is not consistent.

5.3.2 Comparative Analysis of Shading Performance

To evaluate the shading performance on the basis of set criteria discussed earlier a comparative analysis among the selected shading devices has been summarised in the following section. This study will help in identifying the effect of different parameters and correlation among parameters.

5.3.2.1 Comparison among Horizontal Shading Devices

From above investigation on influence of orientation, it was observed that horizontal shading devices were effective on windows at south orientation than other orientations. At south orientation, all three shading devices were capable to shade maximum area of window pane at mid day. Simulation results show that among the three horizontal shading devices, Shade H01 can shade maximum 60% of the whole windowpane, Shade H02 can shade maximum 53% and Shade H03 can shade maximum 46% of the whole windowpane.

Table 5.11: Percentage of shaded area at different orientations by horizontal shading devices for 21st March.

Orientation	Shading	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	H01	22	28	35	50	*	*	*	*	*	*	*	*	*	*	*	*	*
	H02	11	20	27	44	*	*	*	*	*	*	*	*	*	*	*	*	*
	H03	11	20	31	39	*	*	*	*	*	*	*	*	*	*	*	*	*
South east	H01	21	27	31	38	45	50	*	*	*	*	*	*	*	*	*	*	*
	H02	12	15	20	28	37	52	*	*	*	*	*	*	*	*	*	*	*
	H03	17	22	21	33	34	44	*	*	*	*	*	*	*	*	*	*	*
South	H01	52	54	53	56	56	55	60	53	56	57	54	55	52	50	48	42	38
	H02	45	46	47	51	50	50	53	48	52	49	46	45	42	41	36	29	25
	H03	39	41	45	42	41	44	46	40	44	39	36	45	39	38	38	30	28
South west	H01	*	*	*	*	*	*	*	63	50	41	34	28	22	19	15	12	10
	H02	*	*	*	*	*	*	*	56	44	35	23	17	13	8	4	0	0
	H03	*	*	*	*	*	*	*	45	38	30	29	21	17	13	12	7	8
West	H01	*	*	*	*	*	*	*	*	*	62	41	30	24	16	11	11	7
	H02	*	*	*	*	*	*	*	*	*	54	30	21	12	4	3	0	0
	H03	*	*	*	*	*	*	*	*	*	47	31	23	19	19	6	7	9

* Percentage of shaded area is not taken into account as the sun does not see the window.

From table 5.11 it is observed that at east, south-east, west and south-west orientations all three shading devices are not effective. Sometimes these three shading devices can shade up to 63% of the window area but the efficiency drops frequently. Considering all these limitations, in comparison among these three horizontal shading devices, Shade

H01 is capable to shade better than other two shading devices at all five orientations. Shade H01 performs better in protecting solar radiation in comparison to other two shading devices.

Table 5.12 shows that at south orientation, Shade H01 can block 3411 watt solar radiation which is 54% of the total incident radiation (6314 watt). If it is compared with other two horizontal shading devices, it is found that Shade H02 can block 46% of the incident radiation and Shade H03 can block 41% of the incident radiation.

Table 5.12: Amount of direct solar radiation incident on windowpane at different orientations.

Orientation	Shade H01		Shade H02		Shade H03	
	Shaded in Watt	Unshaded in Watt	Shaded in Watt	Unshaded in Watt	Shaded in Watt	Unshaded in Watt
East	1885	3761	2153	3764	2126	3761
South	2903	6314	3439	6319	3766	6326
South-east	2420	5020	2759	5005	2856	5013
South-west	1693	3983	1960	3981	2085	3980
West	1138	2553	1318	2554	1421	2558

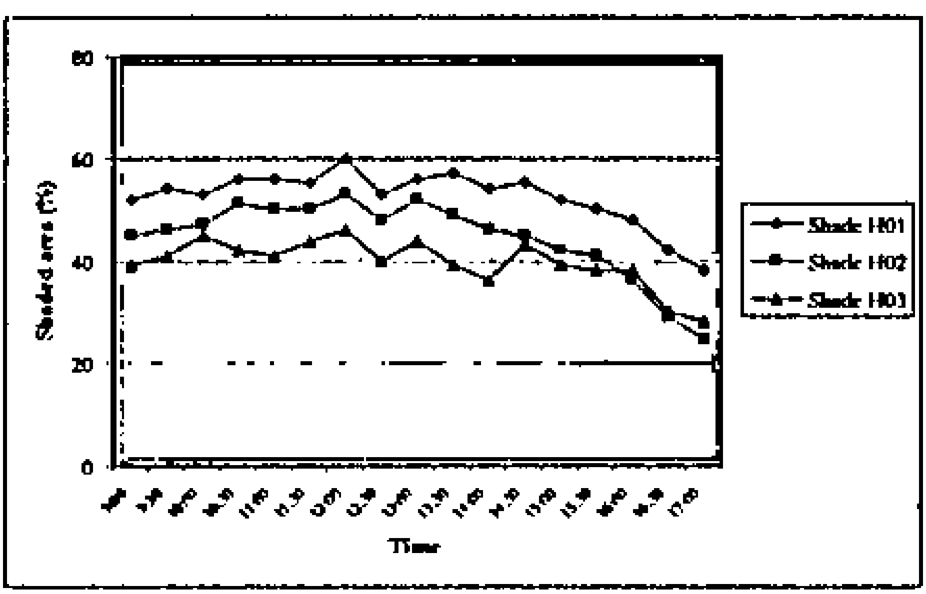


Figure 5.29: Comparison of percentage of shaded area at south orientation by horizontal shading devices for 21st March.

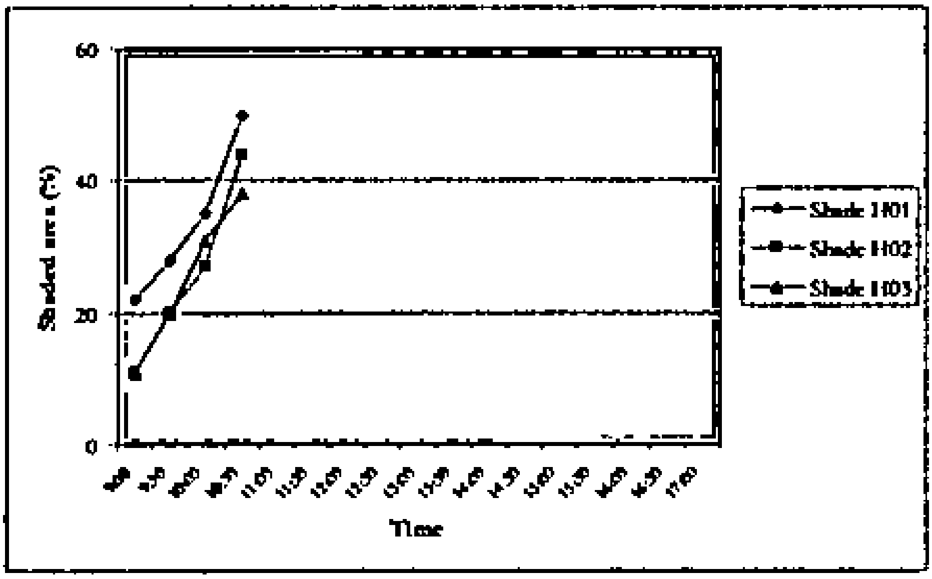


Figure 5.30: Comparison of percentage of shaded area at east orientation by horizontal shading devices for 21st March.[(p. 35)]

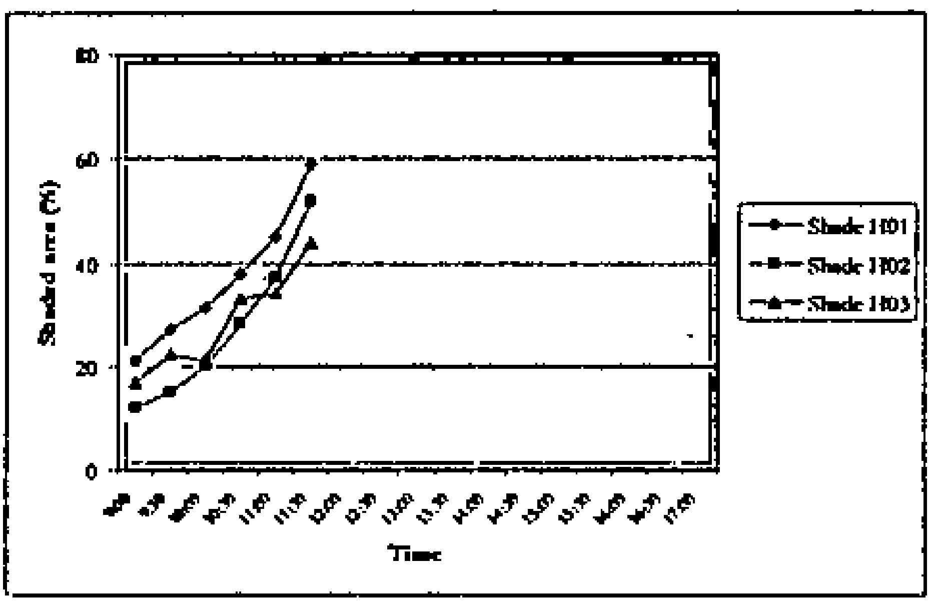


Figure 5.31: Comparison of percentage of shaded area at south-east orientation by horizontal shading devices for 21st March.[(p. 35)]

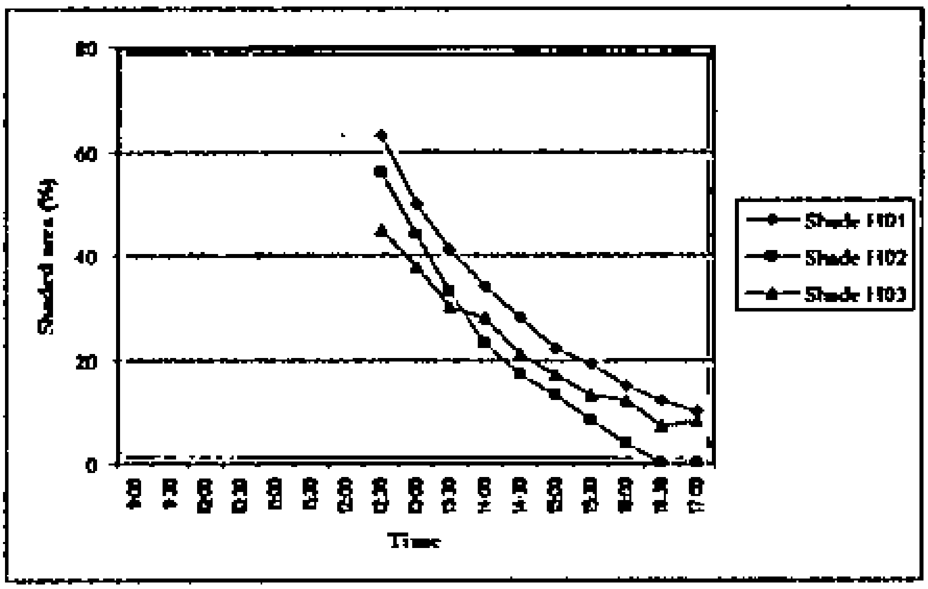


Figure 5.32: Comparison of percentage of shaded area at south-west orientation by horizontal shading devices for 21st March.[1 (p 15)]

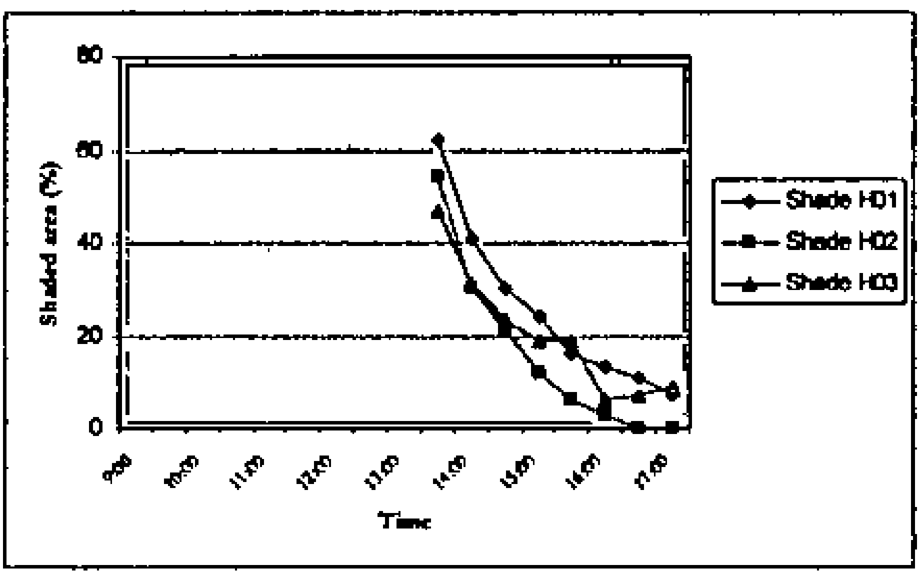


Figure 5.33: Comparison of percentage of shaded area at west orientation by horizontal shading devices for 21st March.[1 (p 15)]

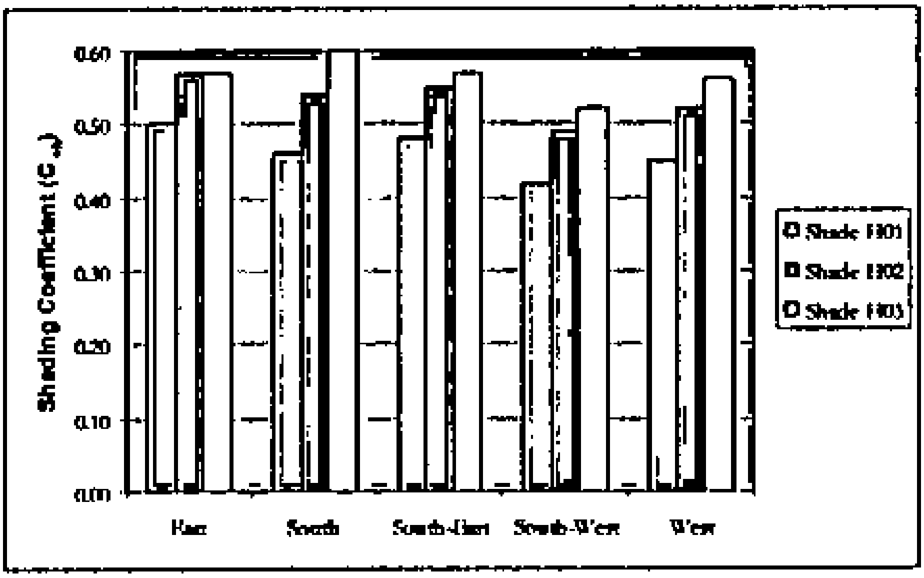


Figure 5.34: Comparison of shading coefficient of three horizontal shading devices at different orientations.

Although Shade H01 is more effective in comparison to Shade H02 and H03, the shading performance of Shade H01 is not up to the mark. It can not block almost 50% of the total incident radiation. This huge radiation enters through the unshaded part of the window pane into the space. So, horizontal projection of this Shade H01 is not enough to protect the window from the solar radiation properly.

Findings

The investigation shows that the horizontal shading device with larger overhang with respect to window height, shades more window area and reduces heat gain than other types. It indicates that projection depth of horizontal shading devices is the main determining factor for shading the window from direct solar radiation.

5.3.2.2 Comparison among Vertical Shading Devices

From aforesaid investigation on influence of orientation, it was also observed that Vertical shading devices were effective on windows at south-east and south-west orientation. So firstly, the performances of the vertical shading devices are evaluated with reference to their performance at these two orientations.

At south-east and south-west orientation, almost same character of performance of these vertical shading devices has been observed. All three shading devices are capable to shade maximum area of window pane at the time when the sun is just tilted to east or west from south. Simulation results show that among the three vertical shading devices, Shade H01 can shade 53% of the whole windowpane, Shade H02 can shade 45% and Shade H03 can shade 42% of the whole windowpane on an average.

From table 5.13 it is observed that at east, south, west orientations all three shading devices are not consistent in their performance. Sometimes these three shading devices can protect almost 90% of the window area but the efficiency drops frequently to 15%. Considering all these limitations, in comparison with these three vertical shading devices, Shade V01 is capable to shade better than other two shading devices at all five orientations. So Shade V01 gives better protection from solar radiation in comparison to other two shading devices.

Table 5.13: Percentage of shaded area at different orientations by vertical shading devices for 21st March.

Orientation	Shading	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	V01	47	51	78	87	95	*	*	*	*	*	*	*	*	*	*	*	*
	V02	40	48	66	82	94	*	*	*	*	*	*	*	*	*	*	*	*
	V03	38	42	53	58	80	*	*	*	*	*	*	*	*	*	*	*	*
South east	V01	46	50	50	53	75	91	*	*	*	*	*	*	*	*	*	*	*
	V02	44	36	43	46	94	90	*	*	*	*	*	*	*	*	*	*	*
	V03	43	32	30	34	49	41	*	*	*	*	*	*	*	*	*	*	*
South	V01	81	87	89	94	91	83	81	88	89	87	89	85	85	78	69	57	36
	V02	76	83	87	83	71	75	68	65	72	71	76	86	83	73	64	53	21
	V03	100	98	82	66	75	56	51	63	66	73	72	92	100	100	100	100	100
South west	V01	*	*	*	*	*	*	*	94	77	58	55	46	44	45	45	44	53
	V02	*	*	*	*	*	*	*	84	57	42	32	29	35	39	56	48	51
	V03	*	*	*	*	*	*	*	58	51	50	48	35	34	39	39	32	41
West	V01	*	*	*	*	*	*	*	*	*	89	80	66	42	40	27	16	13
	V02	*	*	*	*	*	*	*	*	*	80	64	50	40	36	31	24	16
	V03	*	*	*	*	*	*	*	*	*	76	64	49	38	36	22	18	14

* Percentage of shaded area is not taken into account as the sun does not see the window.

Table 5.14: Amount of direct solar radiation incident on window pane at different orientations.

Orientation	Shade V01		Shade V02		Shade V03	
	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded
	in Watt	in Watt	in Watt	in Watt	in Watt	in Watt
East	1248	3766	1461	3766	1443	3763
South	1102	6319	1783	6326	1336	6318
South-east	1490	5015	1962	5010	1998	5013
South-west	1022	3984	1465	4364	1492	4364
West	701	2556	906	2556	848	2556

Table 5.14 shows that at south-east and south-west orientation, Shade V01 can prevent almost 70% of the total incident radiation. If it is compared with the other two vertical shading devices, it is found that Shade V02 can resist 60-65% of the incident radiation and Shade V03 can prevent 60-65% of the incident radiation.

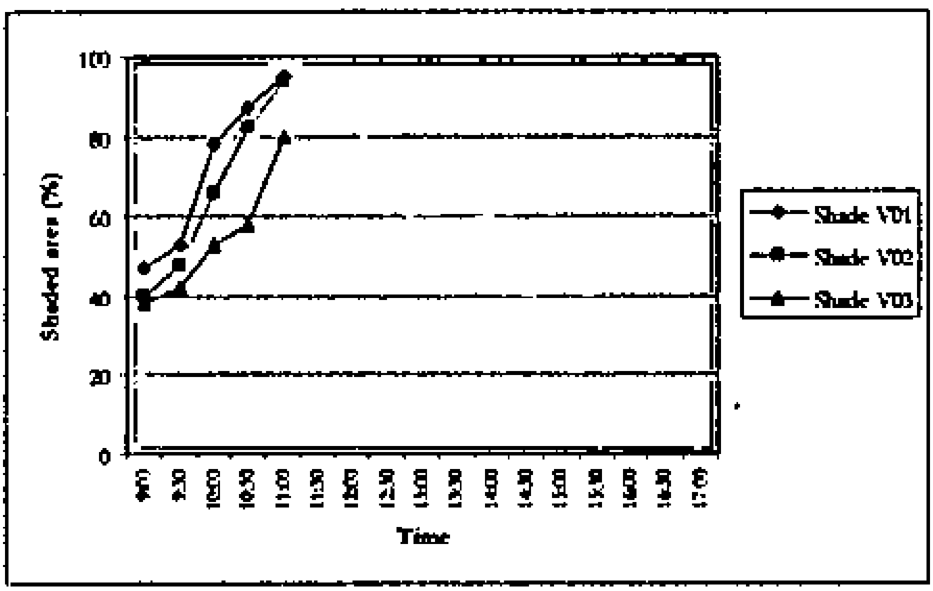


Figure 5.35: Comparison of percentage of shaded area at east orientation by vertical shading devices for 21st March.[4, 13]

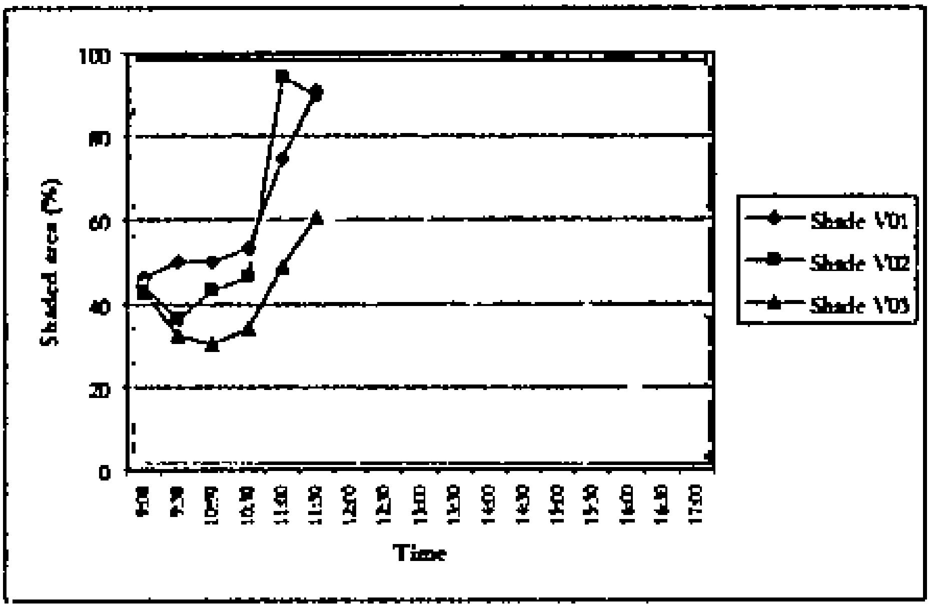


Figure 5.36: Comparison of percentage of shaded area at south-east orientation by vertical shading devices for 21st March.[10-55]

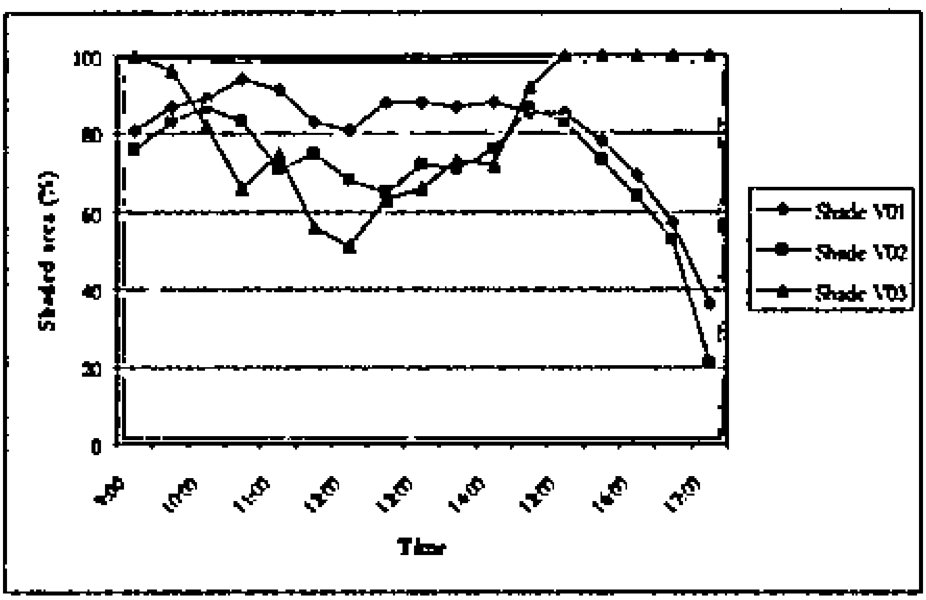


Figure 5.37: Comparison of percentage of shaded area at south orientation by vertical shading devices for 21st March.

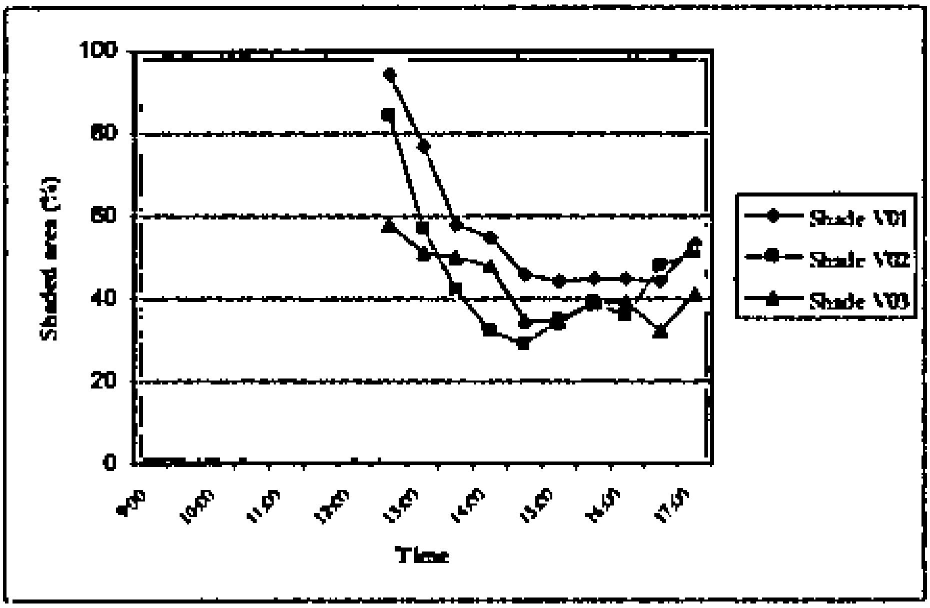


Figure 5.38: Comparison of percentage of shaded area at south-west orientation by vertical shading devices for 21st March.[1 (p. 35)]

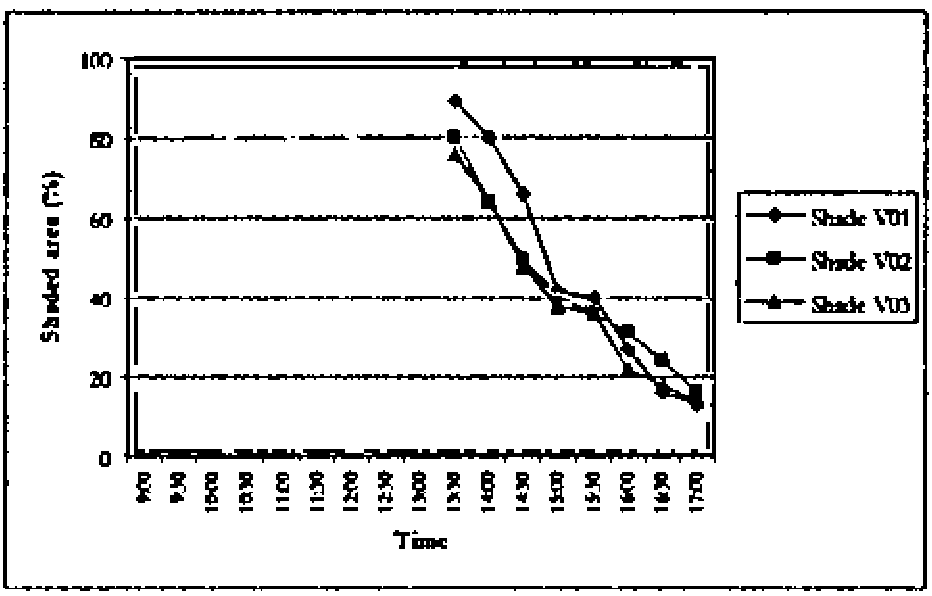


Figure 5.39: Comparison of percentage of shaded area at west orientation by vertical shading devices for 21st March.[1 (p. 35)]

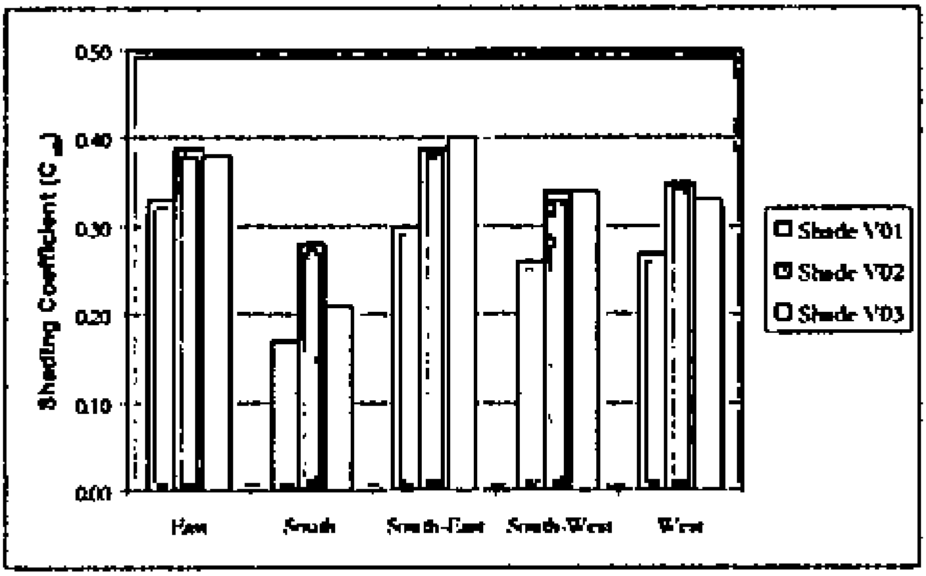


Figure 5.40: Comparison of shading coefficient of three vertical shading devices at different orientations.

Although Shade V01 is more effective in comparison to Shade V02 and V03, the performance of Shade V01 is not up to the mark. Actually it can not block 30% of the total incident radiation. This radiation enters through the unshaded part of the window pane into the space. So the depth, spacing and angle of the vertical fins of this Shade V01 are not enough to protect the window from the solar radiation properly.

Findings

The investigation shows that the vertical shading device with larger fin depth shades more than other selected vertical devices. It indicates the role of effective depth of shading devices (distance from window face to outer face of fins) including the gap between them on shading performance.

5.3.2.3 Comparison among Composite Shading Devices

From earlier investigation on influence of orientation, it was observed that composite shading devices were effective on windows at south, south-east and south-west orientation. So the performance of the composite shading devices is evaluated with reference to their performance at these three orientations.

At south-east and south-west orientation, the same character of performance of these composite shading devices has been observed. Simulation results show that among the three composite shading devices, Shade C01 can shade maximum 96% of the whole windowpane, Shade C02 can shade maximum 83% and Shade C03 can shade maximum 67% of the whole windowpane. The percentage of shaded window area decreases when sun moves to east or west from south. Table 5.16 shows that at south-east and south-west orientation, Shade C01 can block almost 80% of the total incident radiation. If it is compared with the other two composite shading devices, it is found that Shade C02 can block 65-70% of the incident radiation and Shade C03 can also block 60-65% of the incident radiation.

Table 5.15: Percentage of shaded area at different orientations by composite shading devices for 21st March.

Orientation	Shade	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
East	C01	56	56	79	87	*	*	*	*	*	*	*	*	*	*	*	*	*
	C02	50	52	56	76	*	*	*	*	*	*	*	*	*	*	*	*	*
	C03	35	44	54	77	*	*	*	*	*	*	*	*	*	*	*	*	*
South east	C01	58	58	56	62	73	95	*	*	*	*	*	*	*	*	*	*	*
	C02	46	48	49	52	58	75	*	*	*	*	*	*	*	*	*	*	*
	C03	39	39	39	38	48	66	*	*	*	*	*	*	*	*	*	*	*
South	C01	100	98	93	91	91	90	88	86	100	97	90	98	100	100	100	100	100
	C02	88	84	82	76	74	71	69	69	69	73	80	85	81	95	100	100	100
	C03	100	100	93	81	69	57	51	50	67	68	90	94	100	100	100	100	100
South west	C01	*	*	*	*	*	*	*	96	84	69	58	59	54	53	57	65	57
	C02	*	*	*	*	*	*	*	83	63	56	48	46	46	48	41	31	47
	C03	*	*	*	*	*	*	*	67	51	45	35	38	39	47	51	41	50
West	C01	*	*	*	*	*	*	*	*	*	94	82	76	60	55	48	40	25
	C02	*	*	*	*	*	*	*	*	*	80	62	59	49	43	39	31	21
	C03	*	*	*	*	*	*	*	*	*	76	58	62	52	37	35	31	21

* Percentage of shaded area is not taken into account as the sun does not see the window.

Table 5.16: Amount of direct solar radiation incident on window pane at different orientations.

Orientation	Shade C01		Shade C02		Shade C03	
	Shaded in Watt	Unshaded in Watt	Shaded in Watt	Unshaded in Watt	Shaded in Watt	Unshaded in Watt
East	960	3764	1255	3762	1342	3767
South	364	6324	1211	5843	1180	6319
South-east	1461	5015	1697	5008	1869	5025
South west	788	3986	1159	3985	1388	4089
West	531	2556	780	2558	801	2558

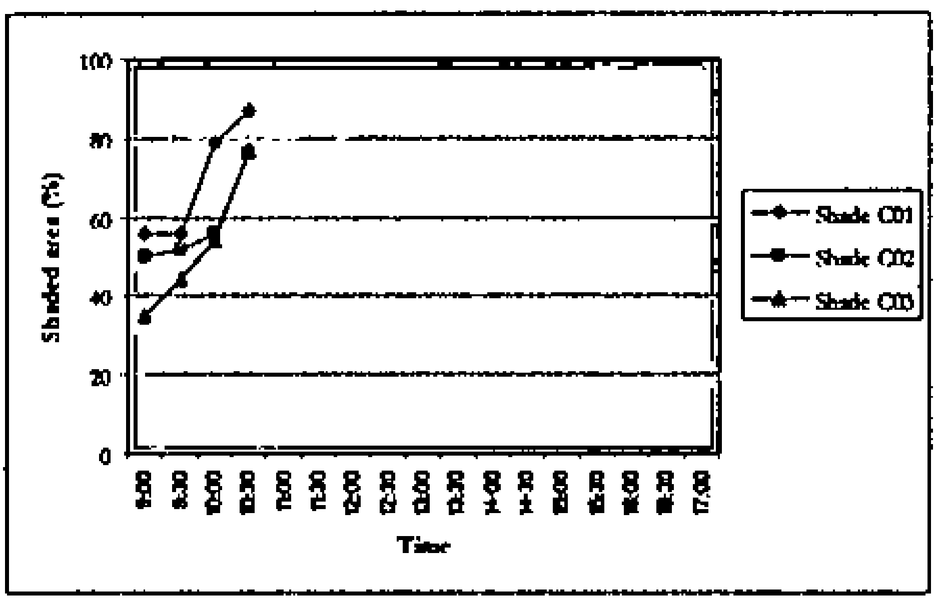


Figure 5.41: Comparison of percentage of shaded area at east orientation by composite shading devices for 21st March.[1 • 55]

The performance of composite shading devices is quite satisfactory at south orientation. They can shade up to 100% of window area. Although all three shading devices can shade up to 100% of window area, only Shade C01 is consistent in its performance throughout the day. It is clearly evident from figure 5.43. At south orientation, Shade C01 can block 5960 Watt, which is almost 95% of the incident radiation (6324 Watt).

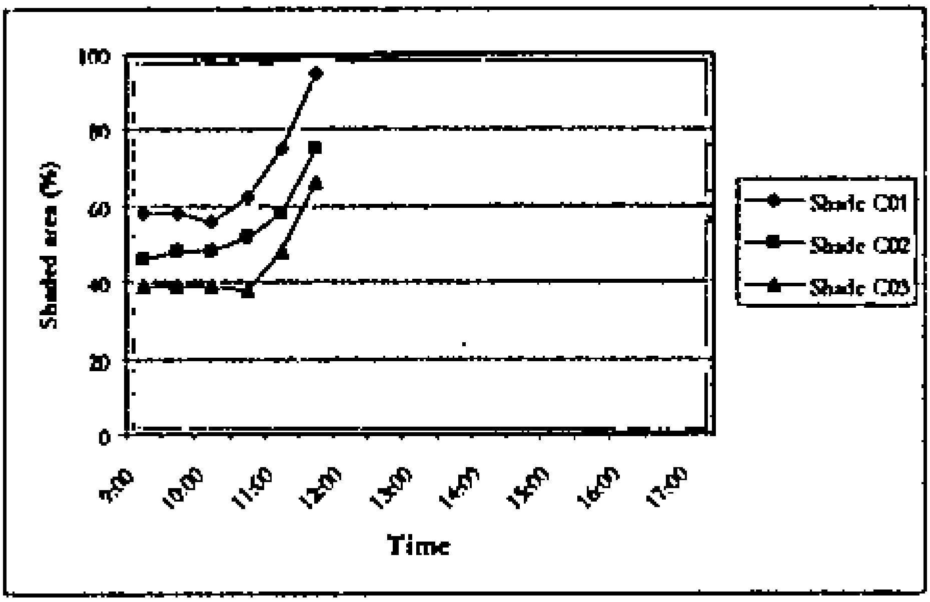


Figure 5.42: Comparison of percentage of shaded area at south-east orientation by composite shading devices for 21st March.

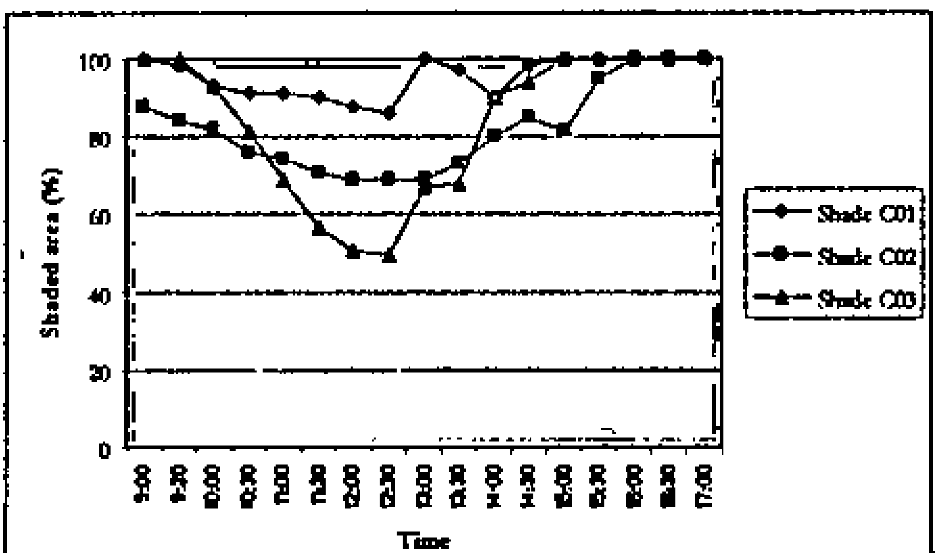


Figure 5.43: Comparison of percentage of shaded area at south orientation by composite shading devices for 21st March.

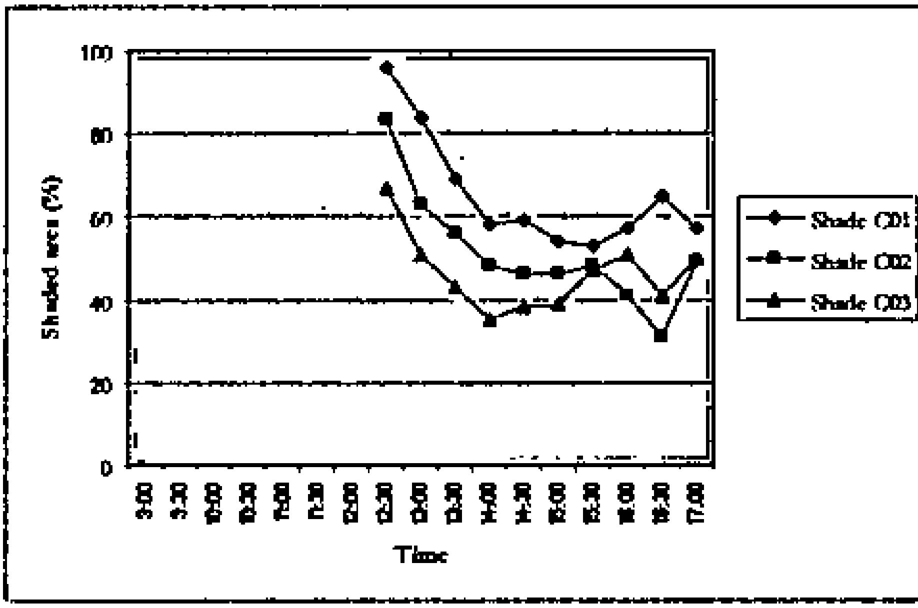


Figure 5.44: Comparison of percentage of shaded area at south-west orientation by composite shading devices for 21st March.[1 (p. 39)]

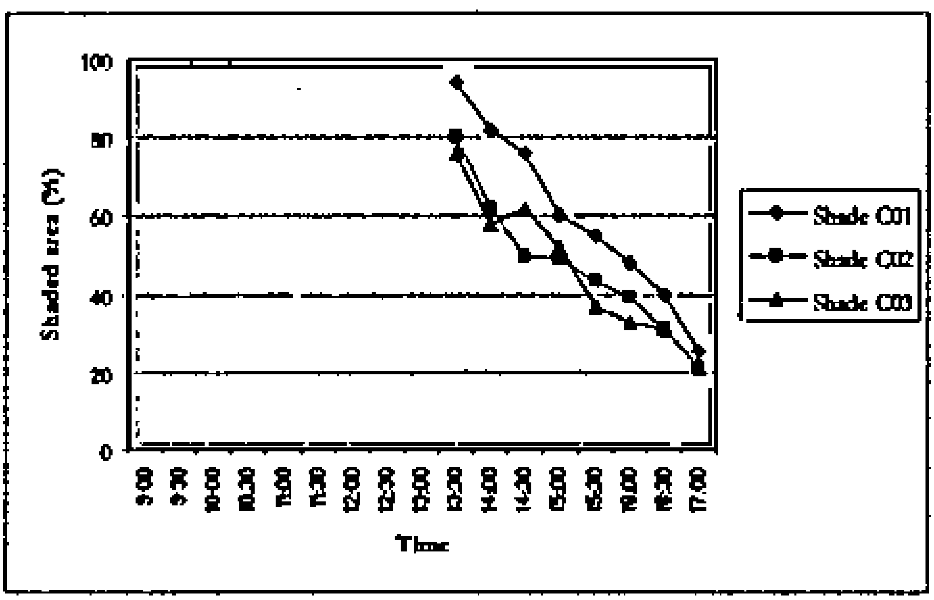


Figure 5.45: Comparison of percentage of shaded area at west orientation by composite shading devices for 21st March.[1 (p. 39)]

From table 5.15 it is observed that at east and west orientations all three shading devices are not consistent in their performance. Sometimes these three shading devices can protect almost 90% of the window area but the efficiency drops frequently to 15%. Considering all these limitations, in comparison among these three composite shading devices Shade C01 is able to shade better than other two shading devices at all five orientations. So Shade C01 performs better in protecting solar radiation with compared to other two shading devices.

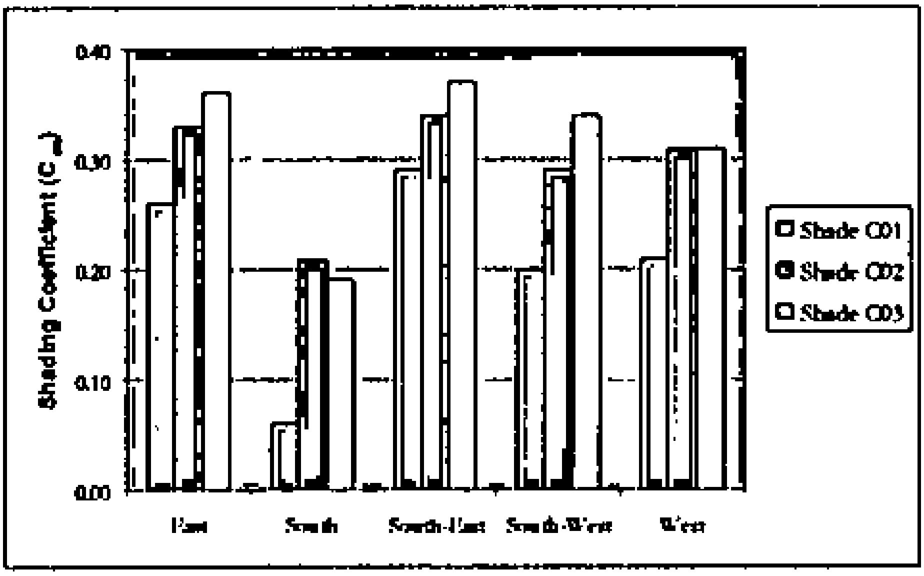


Figure 5.46: Comparison of shading coefficient of three composite shading devices at different orientations.

Although Shade C01 is more effective in comparison to shade C02 and C03, the performance of C01 is not upto the mark at south-east and south-west. It can not block almost 20%-30% of the total incident radiation. This radiation enters through the unshaded part of the window pane into the space. So the depth, spacing or angle of the vertical fins and horizontal overhang of this shade C01 can be modified to protect the window from the solar radiation properly.

Findings

The investigation shows that the composite shading devices are significantly efficient at south orientations. The shading device with larger overhang and fin-depth and smaller spacing between fins performs better than the others. It indicates the role of depth and spacing of fins and overhang on shading performance. With same depth and spacing of fins and overhang, shading devices are not as effective at south-east and south-west like south orientation. Here angle of fins may help to cut off the direct radiation at south-east and south-west.

5.4 Conclusion

The influences of orientations on performance of various shading devices are now clearly evident. It is also evident that horizontal overhangs are effective on facades facing south, vertical fins on windows at east and west orientation and composite shading devices are effective on windows at south-east and south-west. It has been also observed that vertical fins are not effective at east and west orientation when the sun is in east or west side.

After investigating the performance of commonly used shading devices it could be stated that the design of the shading devices are need to be explored for desired performance. The results of both the studies indicate that depth and spacing of overhangs and depth, spacing and angle of vertical fins has significant effect on shading performance. Modification of these parameters may make the shading devices effective in different orientations at the critical periods.

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CHAPTER: SIX

PARAMETRIC STUDY FOR OPTIMUM SHADING

PARAMETRIC STUDY FOR OPTIMUM SHADING

After investigating the selected commonly used shading devices, it is found that the performances of these selected shading devices are not consistent through out the critical period of the day. Heat gain is directly proportional to the area of glass exposed to solar radiation and, therefore, unshaded glazed areas permit a large and rapid heat gain. Solar heat gain can be controlled effectively by optimising shading. To achieve optimum shading, the design strategy of shading devices is needed to explore further.

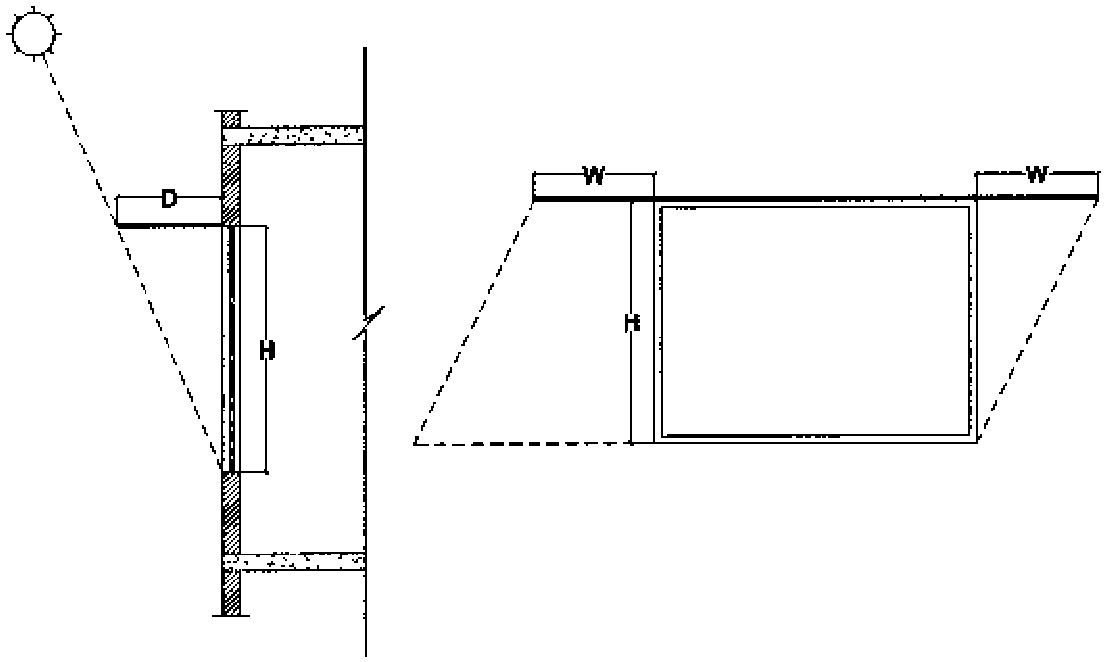
An investigation through parametric study to explore the strategies for optimum shading is presented in this chapter. Parametric study allows study of various specific alternatives with reference to performance of the model and choosing the best one. Series of parametric studies are performed where different parameters of shading devices are subjected to adjustment. Only one parameter is changed at a time in order to determine the relative influence of each. On the basis of the investigation and analysis that has been carried out in the previous chapter, some parameters have been chosen as variables to investigate through computer simulation for optimum shading. The simulation program 'Ecotect' (version 5.20) has been used for this parametric study.

6.1 Parameters for Optimum Shading Analysis

Before starting the parametric study, a set of parameters are considered as variables and some parameters are considered as constant. Variables and constants are considered separately for horizontal, vertical and composite shading devices. Variables that have been taken into consideration as different alternatives for simulations are given below:

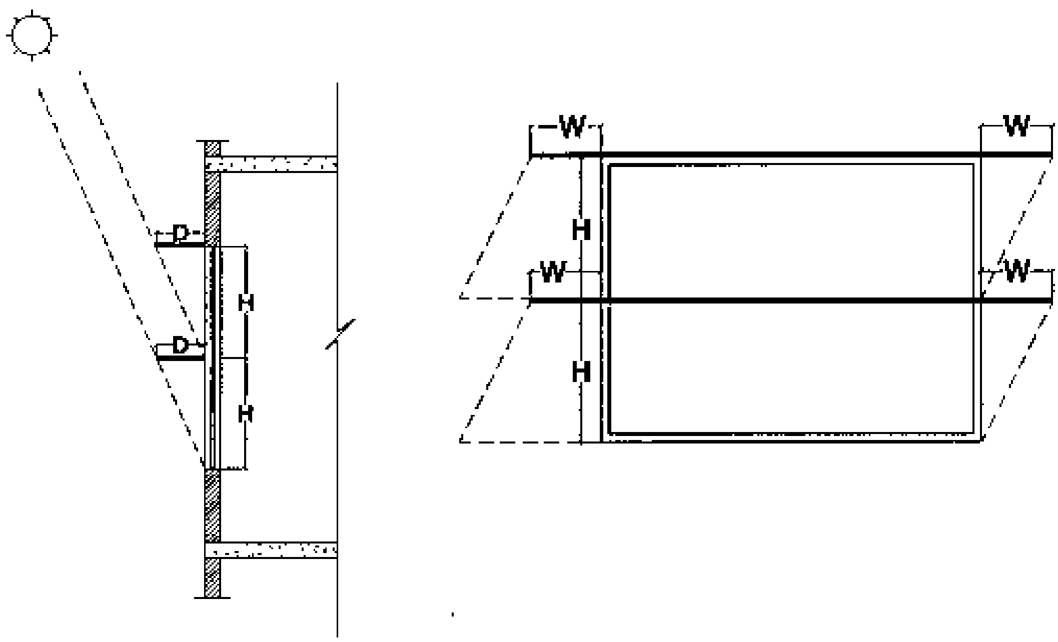
A. Cases with horizontal shading devices:

- Depth (D) of horizontal overhangs
- Side offset (W) of horizontal overhangs
- Minimizing the effective height (H)



Section Elevation

Figure 6.1: Schematic diagrams showing parameters of horizontal shading device.



Section Elevation

Figure 6.2: Schematic diagrams showing parameters of horizontal shading device.

B. Cases with vertical shading devices:

- Depth (D) and spacing (S) of vertical fins
- Horizontal angle of vertical fins (θ)
- Extension (X) of vertical fins above window

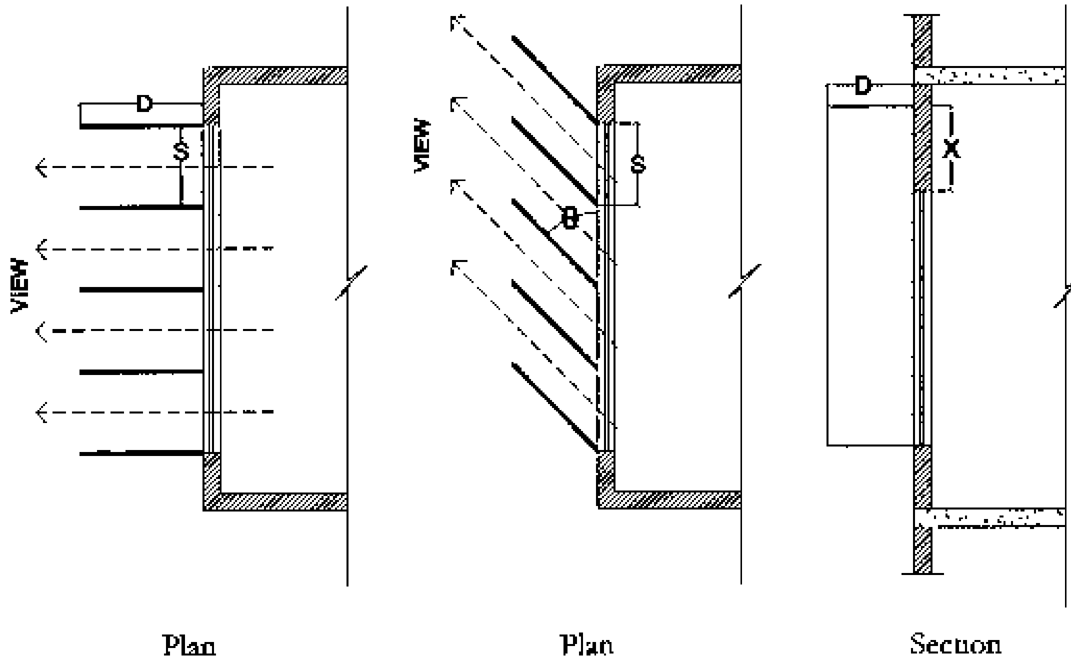


Figure 6.3: Schematic diagrams showing different parameters of vertical shading device.

C. Cases with composite shading devices:

- Depth (d) and spacing (h) of horizontal overhangs
- Depth (d') and spacing (w) of vertical fins
- Horizontal angle of vertical fins (Ø)

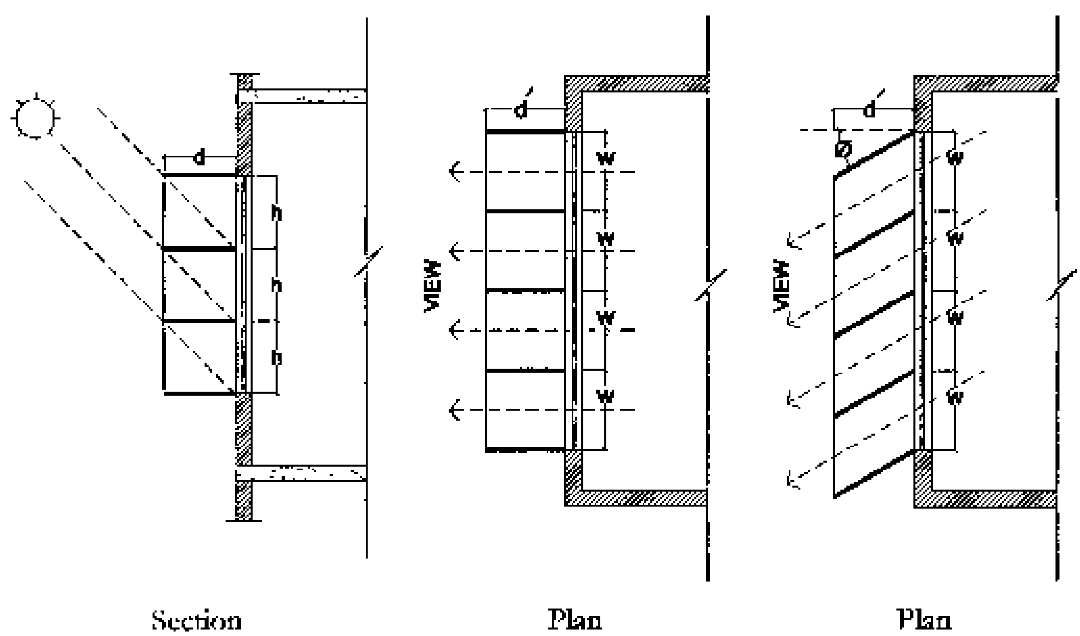


Figure 6.4: Schematic diagrams showing different parameters of composite shading device.

6.2 Simulation Day and Time for the Parametric Study

The considered day for simulation is 21^{st} of March (Day: 80). The time period is considered from 0900 to 1700. The considerations behind selecting the day and time period were mentioned earlier.

6.3 Parametric Modelling

Models have been developed for the parametric study by 'Ecotect'. The following aspects have been considered for the parametric models:

- The room size for simulation model is 6000mm x 6000mm, which is considered as located in an intermediate floor of a high-rise building. The room size is taken from the typical high-rise column grid.
- A fixed window size (5400mm x 2400mm) has been considered with single glazed clear glass for the parametric study. The window width is determined by the column span as it is assumed that the window covers the whole span between two columns. The maximum window height found in the field survey is taken as the height of the window for the parametric study. Different shading devices are attached with it for simulation study.
- For ease of calculation, thickness of the shade has not been taken into account and a study plane at the level of the exterior surface of the window wall has been considered.

In order to evaluate the shading performance of shading devices in reducing solar heat gain a base case situation is established by studying the unshaded window (without shading device) during the critical shading period of the year at different orientations.

6.4 Parametric Studies for Horizontal Shading Devices

From case studies and literature reviews it has been observed that horizontal shading devices are effective at south orientation. Through parametric study an attempt has been made to find out the size of the horizontal overhang for optimum shading at south orientation only. Three parameters (overhang depth, side offset of horizontal overhangs and minimizing the effective height) are considered as variables for this parametric study.

Only one parameter is changed at a time in order to determine the effect of each parameter on the shading performance. The parametric study is started with a certain value of parameters and then an increase in value of parameters has been considered to assess the impact of parameter on the shading performance. In all the cases, the shading performance is increased to a certain level with the increase in value of parameters. After that, the shading performance is not increased any more with the increase in value of parameters. This value of parameter is considered as optimum value for maximum shading. The results of this study are summarised in the following sections.

6.4.1 Effect of Depth of Horizontal Overhangs

The parametric study is started for horizontal shading devices of varying depth, started from 750mm up to 1350mm from the exterior surface of the wall, over the window (model shown in figure 6.5). In each step impact of 150mm increment has been studied.

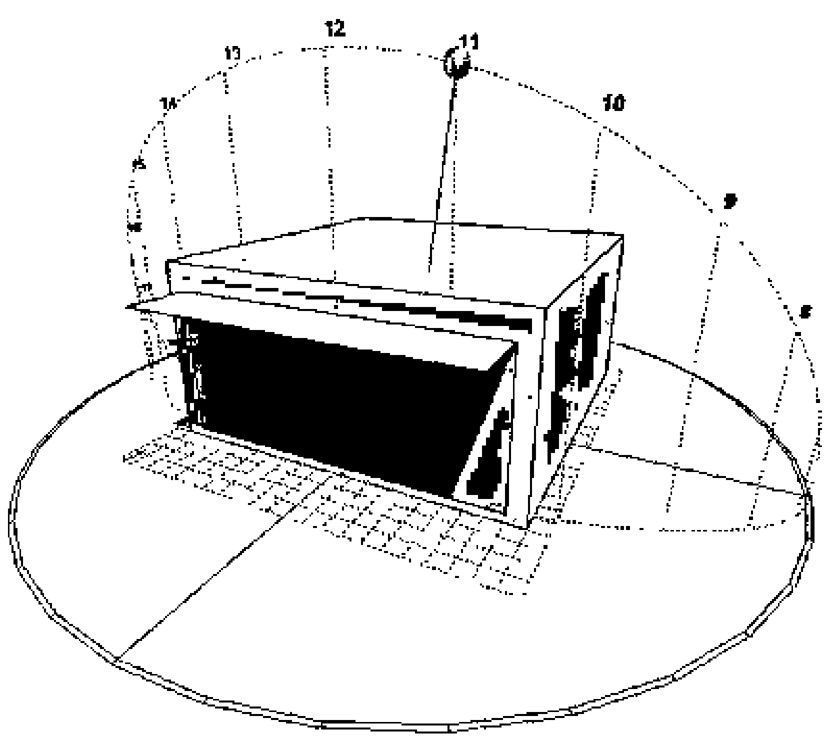


Figure 6.5: View of the model with horizontal overhang (1050mm depth) used for parametric study for 21st March (Ecotect output).

The percentage of shaded area of the window varies for different depths of overhang. Table 6.1 shows percentage of shaded areas for different overhang depth. The percentage of shaded area is increased with the increase of shading depth up to some extent. For 750mm depth, it shades maximum 74% of the window area and for 900mm depth it can shade maximum 88% of the window area. For 1050mm depth, it shades maximum 100% of the window area and after that the percentage of shaded area is not increased with the increase of shading depth. But although for 1050mm depth, it shades maximum 100% of the window area, the percentage of shaded area is decreased along as time passes before and after mid day (shown in figure 6.6).

Table 6.1: Percentage of shaded area by horizontal overhangs with different depth for 21st March.

Depth	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
In mm	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
750	57	58	63	65	67	67	74	67	68	66	63	61	60	53	50	40	31
900	66	68	75	77	79	83	88	80	83	79	74	69	64	60	56	43	29
1050	73	78	83	87	92	96	100	94	94	90	84	79	75	66	59	43	31
1200	74	80	85	90	92	95	99	96	94	92	87	82	77	69	60	45	29
1350	74	81	84	89	92	96	99	97	94	91	85	82	74	70	60	42	29

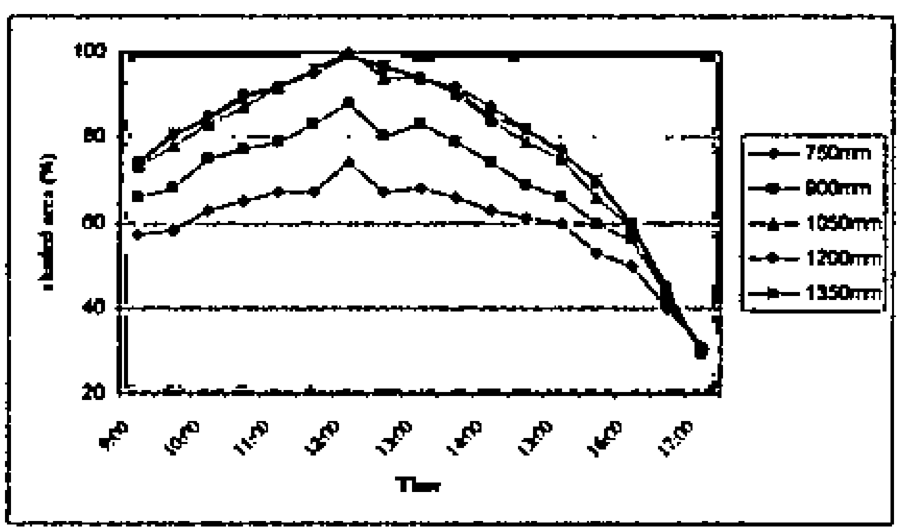


Figure 6.6: Percentage of shaded area by horizontal overhangs with different depth for 21st March.

From table 6.2, it is evident that more energy is saved with the increase of shading depth, which is not always applicable e.g. energy saving performance of 1050mm device is same to 1200mm and 1350mm device. Highest percentage (81%) of energy is saved by the devices having 1050mm to 1350mm depth, while the lowest was presented by 30inches device, which was only 61%.

Table 6.2: Shading coefficient by horizontal overhangs with different depth for 21st March.

No.	Shading depth in mm	With shade in Watt	Without shade in Watt	Shading Coefficient
1	750	2463	6327	0.39
2	900	1673	6327	0.26
3	1050	1202	6327	0.19
4	1200	1185	6327	0.19
5	1350	1179	6327	0.19

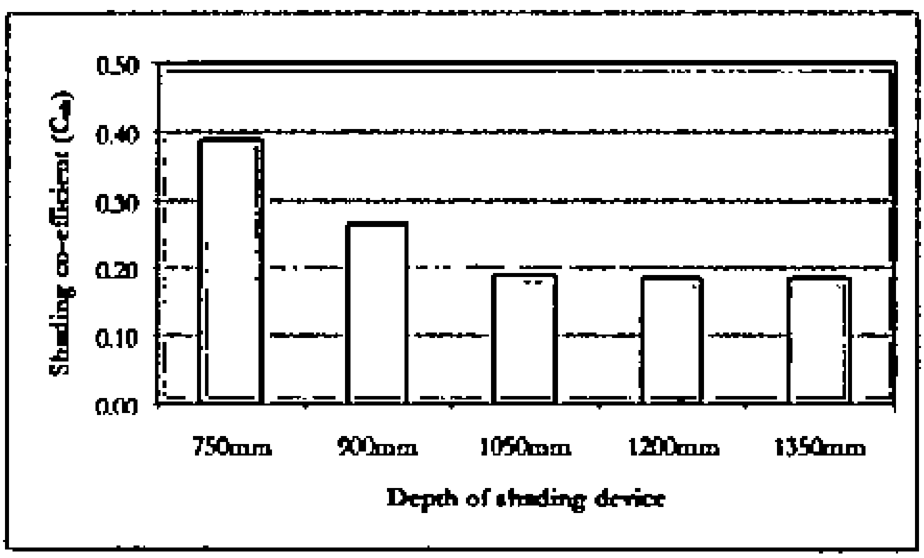


Figure 6.7: Shading coefficient by horizontal overhangs with different depth for 21st March.

From figure 6.7, it has been observed that the ratio of total energy received between shaded and unshaded situation is lowest for 1050mm to 1350mm depth of shading device, while it is highest for 750mm depth. The 1050mm device shows lowest shading coefficient 0.19, which is equal to that of 1200mm and 1350mm device. For 1050mm depth the shading device reaches the lowest shading coefficient and after that it goes same for 1050mm and 1350mm depth. The lower the shading coefficient is better against solar radiation gain.

Findings:

For 1050mm depth, horizontal overhang shades maximum window area and shows lowest shading coefficient. So, for 2400mm window height, optimum depth of overhang for maximum shading is 1050mm which is 7/16 of window height.

6.4.2 Effect of Side Offset of Horizontal Overhangs

From the above investigation, it has been observed that horizontal shading device with 1050mm depth can provide maximum shading. After that, further increase in depth has no significant improvement to increase shading area. To improve the performance of 1050mm depth device at morning and afternoon, the effect of side offset of horizontal overhangs from window edge is studied. The parametric study is started for horizontal shading devices with varying side offset, started from 300mm up to 1200mm (model shown in figure 6.8). In each step 300mm increment has been considered.

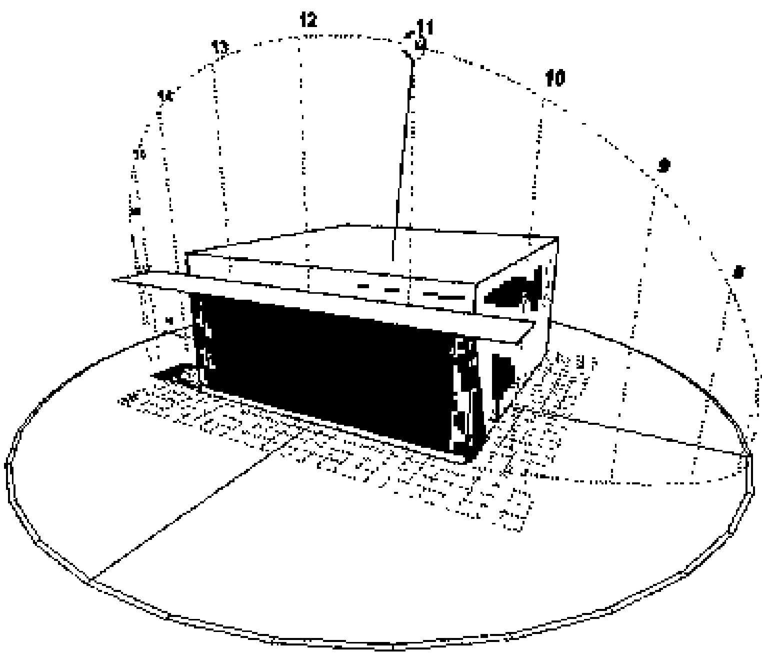


Figure 6.8: View of the model with horizontal overhang (1050mm depth) with 1200mm side offset used for parametric study for 21st March (Ecotect output).

The percentage of shaded area of the window varies for different side offset of overhang. Table 6.3 below shows percentage of shaded areas for different side offset. The percentage of shaded area is increased with the increase of side offset. For 1200mm depth, it shades 91% of the window area at 9 am, which is 18% higher than that of without side offset of 1050mm device. For 1050mm depth, it shades 84% of the window area and after that, the percentage of shaded area is decreased as time passes (shown in figure 6.9). At 5pm it can shade 44% of the window area, which is 13% higher than that of without side offset of 1050mm device.

Table 6.3: Percentage of shaded area by horizontal overhangs (1050mm depth) with different side offset from window edge for 21st March.

Side Offset	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
in mm	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0	73	78	83	87	92	96	100	94	94	90	84	79	75	66	59	43	31
300	78	83	89	93	94	100	100	96	99	96	88	84	80	73	65	48	33
600	82	89	93	97	98	99	100	96	100	98	92	89	84	77	70	53	36
900	89	90	96	98	98	100	97	98	100	100	95	94	88	81	73	56	41
1200	91	92	98	98	98	100	100	100	100	100	95	95	92	84	76	62	44

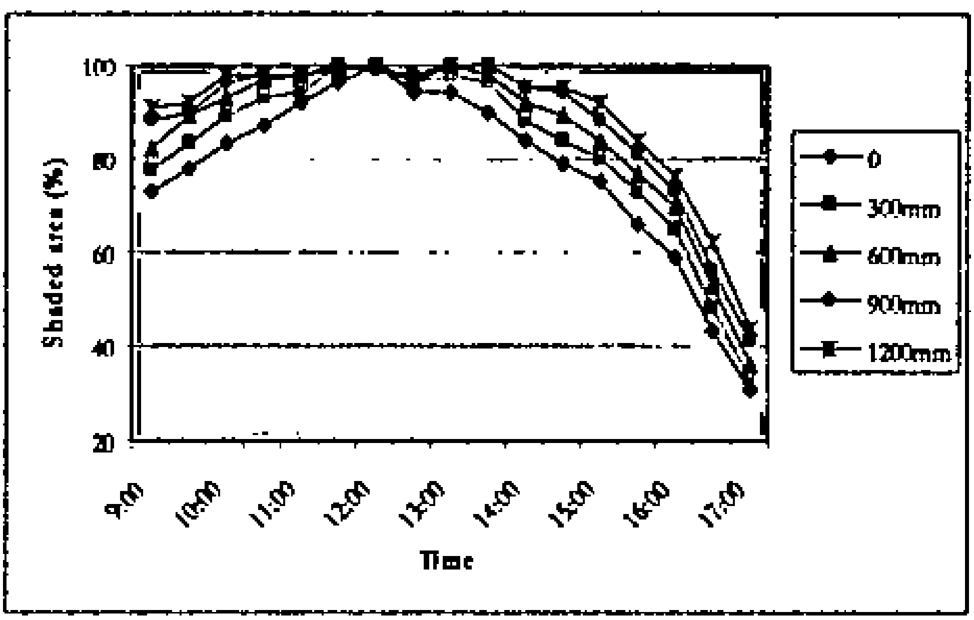


Figure 6.9: Percentage of shaded area by horizontal overhangs with different side offset from window edge for 21st March.

Findings:

For 1200mm side offset from window edge, horizontal overhang shades maximum window area. So, for 2400mm window height, optimum side offset of overhang for maximum shading is 1200mm which is 1/2 of window height. 900mm side offset may also be used.

6.4.2 Effect of Minimizing the Effective Height of the Window

From the above investigation it has been observed that horizontal shading device with 1050mm depth with 1200mm side offset from window edge can provide maximum shading.

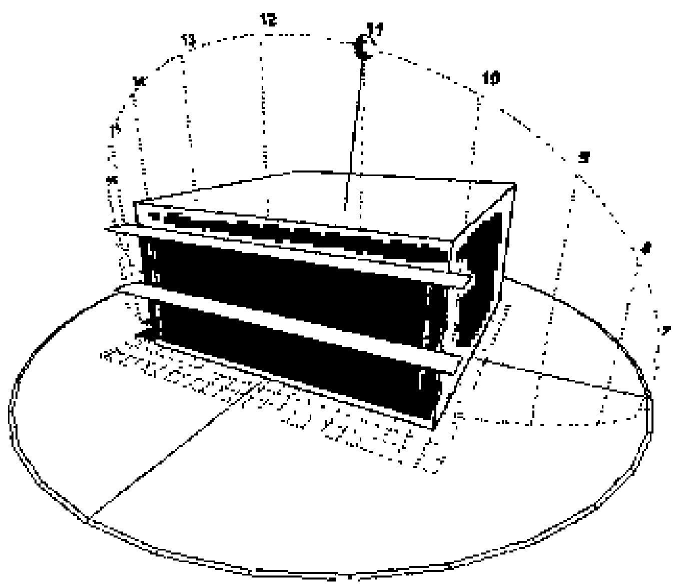


Figure 6.10: View of the model with horizontal overhangs (525mm depth) with 600mm side offset used for parametric study for 21st March (Ecotect output).

After that, to investigate the impact of the effective height of the window on the shading performance of the devices, two options have been studied. At first option, two overhangs are considered, one at lintel level and another at mid pane of the window. The depth of both of the overhangs is 525mm, which is half of the previous depth (1050mm) with 600mm side offset from window edge (model shown in figure 6.10). At second option, four overhangs are considered, one at lintel level and the other three are distributed evenly at 600mm intervals. The depth of both the overhangs is 262mm inches, which is half of the previous depth (525mm) with 300mm side offset from window edge (model shown in figure 6.11).

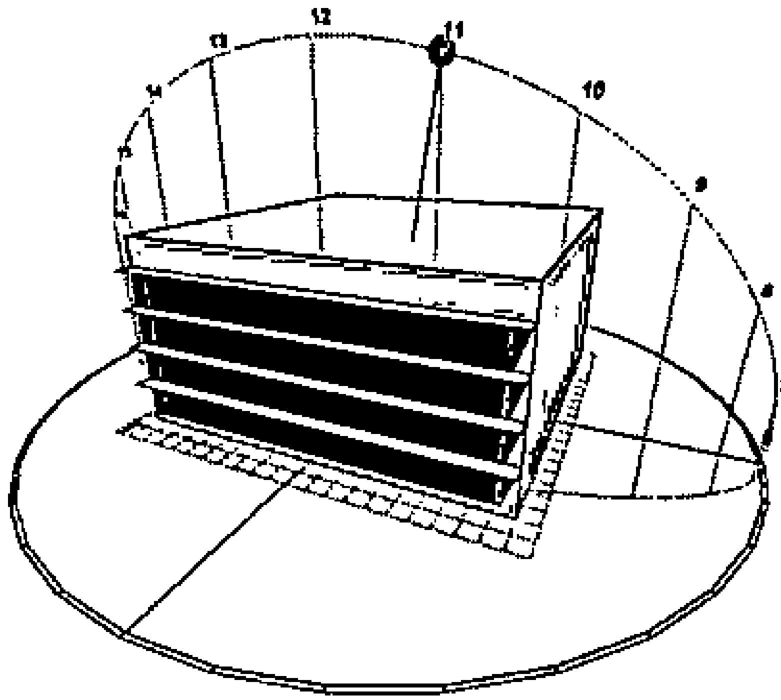


Figure 6.11: View of the model with horizontal overhangs (262mm depth) with 300mm side offset used for parametric study for 21st March (Ecotect output).

Table 6.4: Percentage of shaded area by horizontal overhangs with different effective heights of the window for 21st March.

Depth in mm	09:00 (%)	09:30 (%)	10:00 (%)	10:30 (%)	11:00 (%)	11:30 (%)	12:00 (%)	12:30 (%)	13:00 (%)	13:30 (%)	14:00 (%)	14:30 (%)	15:00 (%)	15:30 (%)	16:00 (%)	16:30 (%)	17:00 (%)
1050	91	92	98	98	98	100	100	97	100	100	95	95	92	84	76	62	44
525	95	96	99	99	99	97	100	97	100	99	94	97	93	89	84	72	67
262	98	98	99	100	100	97	100	100	100	100	99	99	98	96	91	85	82

The percentage of shaded area of the window increases with minimizing the effective height of the window. Table 6.4 shows percentage of shaded areas for different options. For first option, it shades 95% of the window area at 9 am and 67% of the window area at 5 pm while for second option, it shades 98% of the window area at 9 am and 82% of the window area at 5 pm. At 5pm the percentage of shaded area for second option is 15% higher than that of for first option.

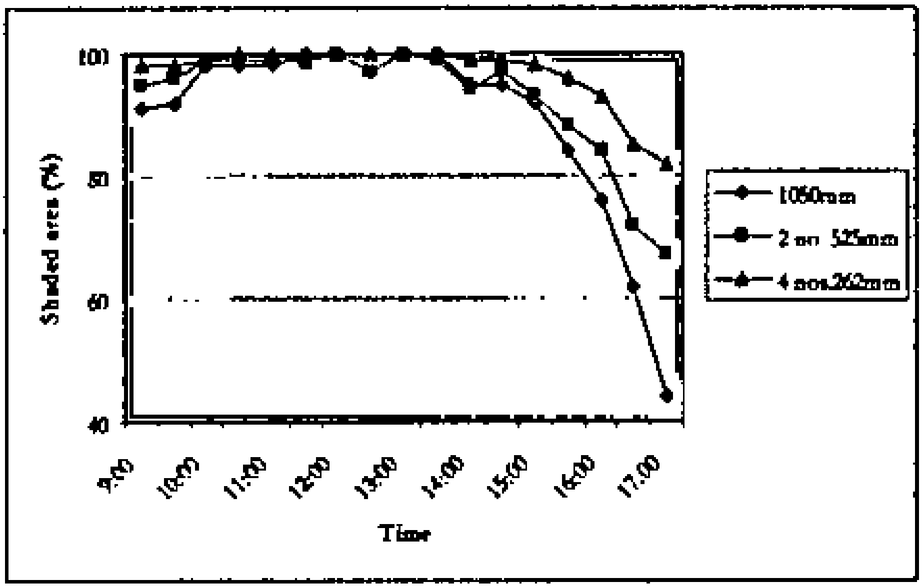


Figure 6.12: Percentage of shaded area by horizontal overhang with different effective heights of window for 21st March.

From table 6.5 it is evident that more energy is saved with minimizing the effective height of the window. Highest percentage (95%) of energy is saved by second option which is 4% higher than that of first option. The ratio total energy received between shaded and unshaded situation is lowest for second option. In the second option the lowest shading co-efficient is 0.05. The lower the shading co-efficient is better against solar radiation gain.

Table 6.5: Shading coefficient by horizontal overhangs with different depth at different height for 21st March.

No	Effective height of the window in mm	With shade in Watt	Without shade in Watt	Shading Coefficient
1	2400	714	6327	0.11
2	1200	582	6327	0.09
3	600	339	6327	0.05

Findings:

Minimizing effective height of window is beneficial to improve the performance of shading device further. This could be done by using several overhangs on the window pane instead of one large overhang.

6.5 Parametric Studies for Vertical Shading Devices

From case studies and literature reviews it has been observed that vertical shading devices are effective at west and east orientation. Through parametric study an attempt has been made to find out the size and geometry of the vertical fins for optimum shading at east and west orientation only. Parametric study is done for optimum shading at west orientation. As sun path is symmetrical about 12 pm, same solution will be applicable for east orientation. Three parameters (depth and spacing of vertical fins and angle of vertical fins) are considered as variables for this parametric study. The results of this study are summarised in the following sections.

6.5.1 Effect of Depth and Spacing of Vertical Fins

The parametric study has been started for vertical shading devices of varying depth, from 600mm to 1200mm from the exterior surface of the wall, over the window (model shown in figure 6.13) while the spacing between the fins is considered as constant. In each step impact of 300mm increment has been observed.

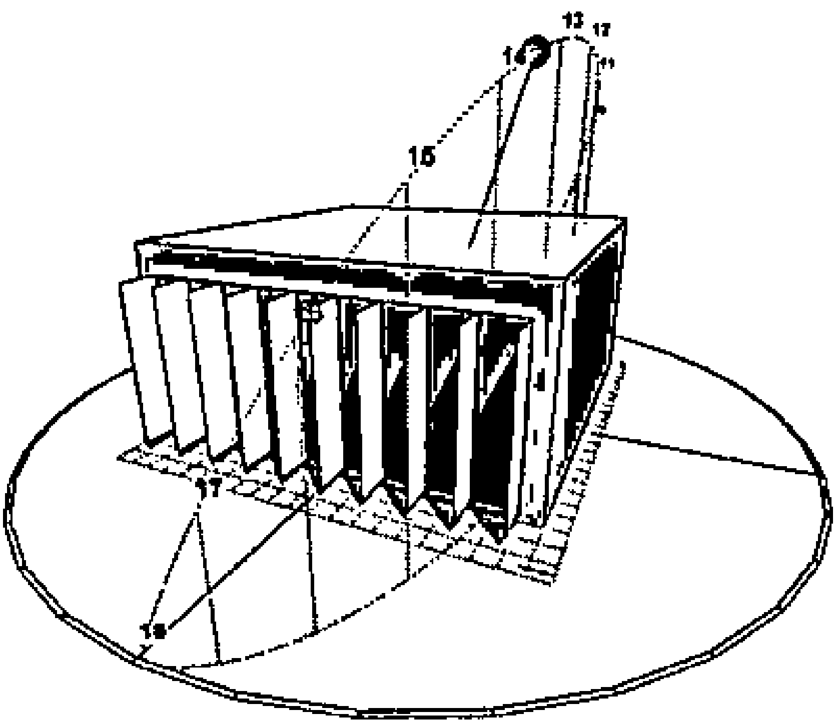


Figure 6.13: View of the model with vertical fins (600mm depth at 600mm interval) used for parametric study for 21st March (Ecotect output).

Table 6.6: Percentage of shaded area by vertical fins with different depth for 21st March

Depth	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
in mm	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
600	*	*	*	*	*	*	*	*	*	70	61	44	37	33	22	21	9
900	*	*	*	*	*	*	*	*	*	70	72	64	51	46	32	27	14
1200	*	*	*	*	*	*	*	*	*	71	72	70	63	58	48	36	24

* Percentage of shaded area is not taken into account as the sun does not see the window.

The percentage of shaded area of the window varies for different depths of fins. Table 6.6 shows percentage of shaded areas for different fin-depth. The percentage of shaded area is increased with the increase of shading depth but not very significantly. For 600mm depth, the device shades maximum 70% of the window area and for 900mm depth it can also shade maximum 70% of the window area and for 1200mm depth it can shade maximum 71% of the window area. For 600mm, 900mm, and 1200mm depth, the minimum percentage of shaded area is 9%, 14% and 24% respectively. So, only increasing of depth of fins is not effective to shade the window from solar radiation.

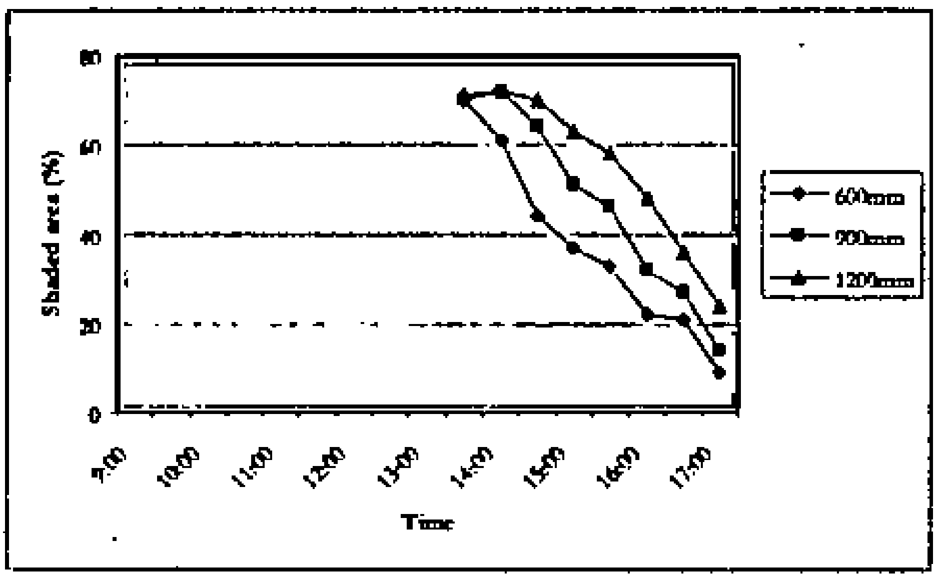


Figure 6.14 Percentage of shaded area by vertical fins with different depth for 21st March.[1]

[1] Corresponding values of percentage of shaded area prior to hours shown are not indicated as the sun does not see the window prior to the time range shown period.

Findings:

The percentage of shaded area is increased with the increase of shading depth but not very significantly. So, only increasing of depth of fins is not effective to shade the window from solar radiation.

6.5.2 Effect of Angle of Vertical Fins

From the above investigation it has been observed that for vertical shading only increasing of depth of fins is not effective to protect the window from solar radiation. After that the increase in depth of fins is not further effective to increase shading area. To improve the performance of vertical devices, the effect of different angle of vertical fins with window surface is studied. The parametric study is done for 600mm, 900mm and 1200mm deep vertical fins with 30° and 45° angles with the line perpendicular to the window surface (model shown in figure 6.15, 6.16).

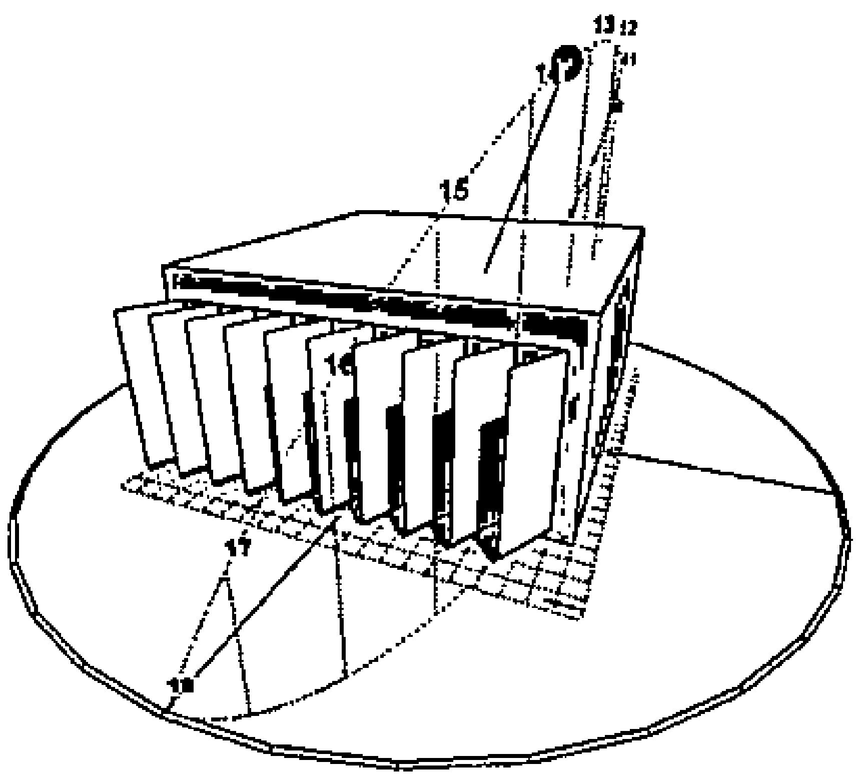


Figure 6.15: View of the model with vertical fins (900mm depth 30° slanted) used for parametric study for 21st March (Ecotect output).

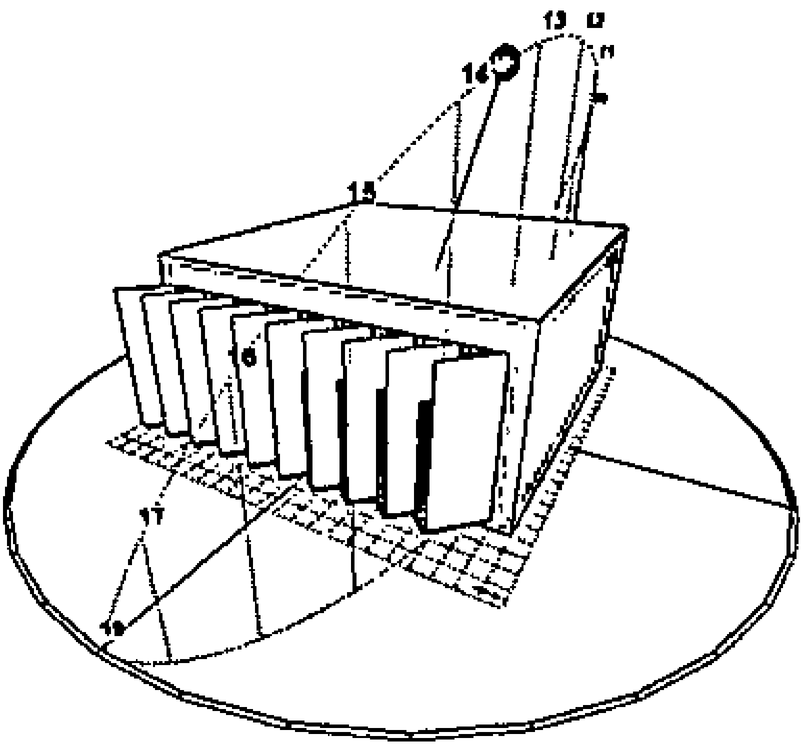


Figure 6.16: View of the model with vertical fins (900mm depth 45° slanted) used for parametric study for 21st March (Ecotect output).

Table 6.7: Percentage of shaded area by vertical shading devices with different depth and angle for 21st March.

Depth in mm	Angle	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
600	30°	*	*	*	*	*	*	*	*	*	80	83	84	77	73	70	64	56
600	45°	*	*	*	*	*	*	*	*	*	86	87	89	91	86	85	82	73
900	30°	*	*	*	*	*	*	*	*	*	80	83	85	87	88	91	91	87
900	45°	*	*	*	*	*	*	*	*	*	84	89	90	93	92	94	97	97
1200	30°	*	*	*	*	*	*	*	*	*	80	83	85	87	88	91	91	95
1200	45°	*	*	*	*	*	*	*	*	*	86	87	89	91	90	94	93	96

* Percentage of shaded area is not taken into account as the sun does not see the window.

The percentage of shaded area of the window varies for different depths of fins with different angle. With changing the angle from perpendicular to the window surface the percentage of shaded area of the window is increased significantly. Table 6.7 shows percentage of shaded areas for different fin-depth with different angles. The highest performance is seen by vertical fins, 900mm depth with 45° angle. For 900mm depth with 45° angle vertical fins, it shades maximum 97% of the window area and after that the percentage of shaded area is not increased with the increase of shading depth. The performance of 900mm depth with 30° angle vertical fins is very close to that of 900mm depth with 45° angle vertical fins.

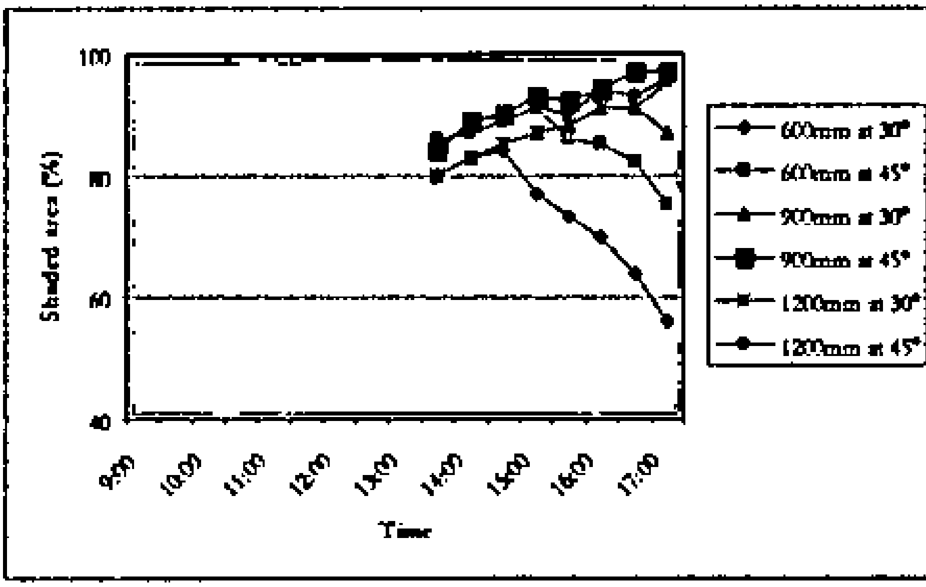


Figure 6.17: Percentage of shaded area by vertical shading devices with different depth and angle for 21st March. [6.9]

Table 6.8: Shading coefficient by vertical shading devices with different depth and angle for 21st March.

No.	Depth in mm	Angle	With shade in Watt	Without shade in Watt	Shading coefficient
1	600	30°	564	2558	0.22
2	600	45°	384	2558	0.15
3	900	30°	444	2558	0.17
4	900	45°	346	2558	0.14
5	1200	30°	439	2558	0.17
6	1200	45°	347	2558	0.14

From table 6.8, it is evident that more energy is saved with the increase of shading depth, which is not always applicable e.g. energy saving performance of 900mm depth with 45°

angle vertical fins is same to that of 1200mm depth with 45° angle vertical fins. Highest percentage (86%) of energy is saved by the devices having 900mm depth with 45° angle vertical fins, while the lowest is presented by 600mm depth with 30° angle vertical fins, which is only 78%.

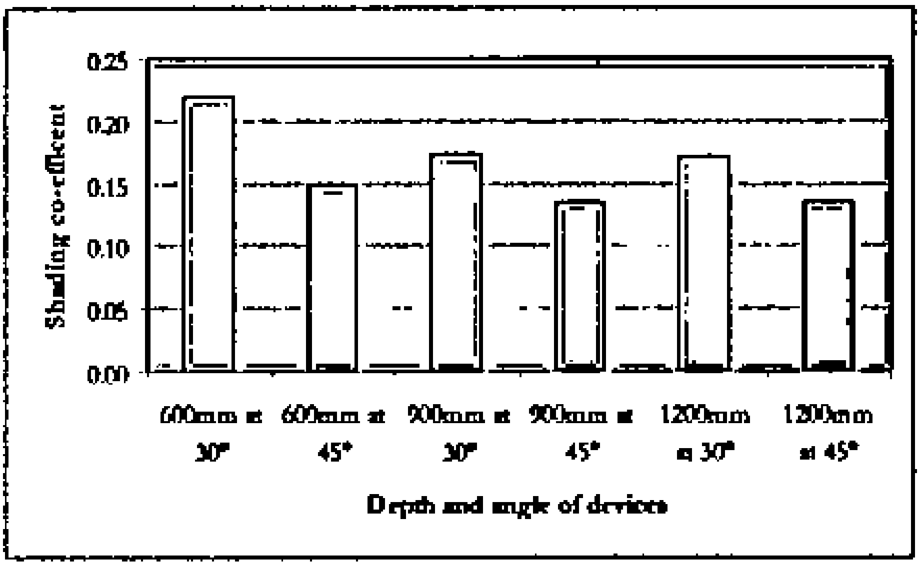


Figure 6.18 Shading coefficient by vertical shading devices with different depth and angle for 21st March.

Findings:

For 900mm depth, vertical fin at 45° angle with the line perpendicular to the window surface, shades maximum window area and shows lowest shading coefficient. So, for 600mm spacing, optimum depth of fins for maximum shading is 900mm which is 3/2 of spacing between fins.

6.5.3 Effect of Extending of Vertical Fins above Window

From the above investigation it has been observed that for vertical shading increasing of depth and angle of fins is effective to protect the window from solar radiation. After that the increase in depth and angle of fins is not further effective to increase shaded area. To improve further the performance of vertical devices, the effect of extending of vertical fins above window is studied for 900mm depth with 45° angle vertical fins. The parametric study is started for vertical shading devices with varying extension of vertical fins above window, started from 150mm to 600mm (model shown in figure 6.19). In each step 150mm increment has been considered.

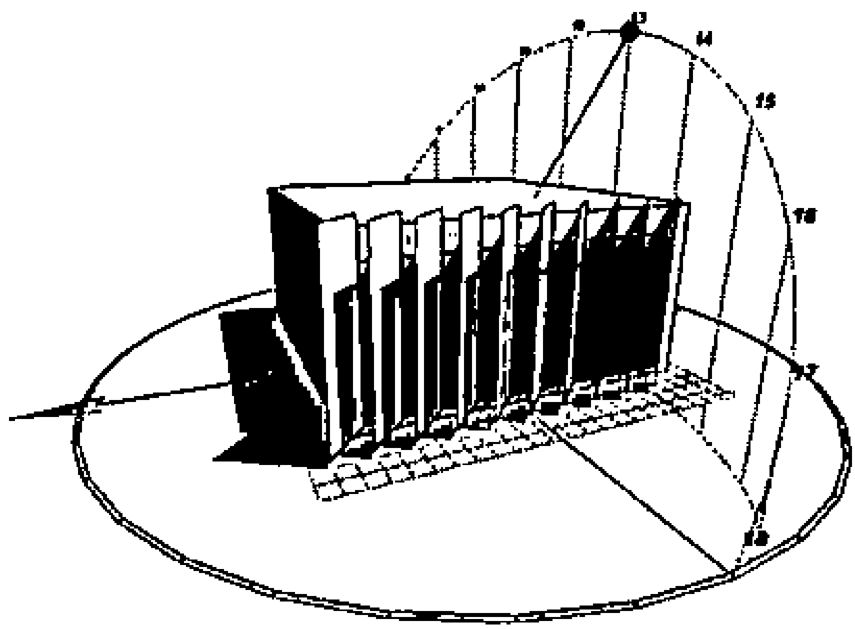


Figure 6.19: View of the model with vertical fins with 600mm extension above window used for parametric study for 21st March (Ecotect output).

The percentage of shaded area of the window varies for different extension of vertical fins above window. Table 6.9 shows percentage of shaded areas for different extension of vertical fins above window. The highest performance is seen by vertical fins with 600mm extension above window, which shades constantly 100% of the window area.

Table 6.9: Percentage of shaded area by vertical fins with varying extension of vertical fins above window for 21st March.

Depth	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
in mm	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
150	*	*	*	*	*	*	*	*	*	90	93	94	96	97	98	99	100
300	*	*	*	*	*	*	*	*	*	95	98	98	99	100	100	100	100
450	*	*	*	*	*	*	*	*	*	98	100	100	100	100	100	100	100
600	*	*	*	*	*	*	*	*	*	100	100	100	100	100	100	100	100

* Percentage of shaded area is not taken into account as the sun does not see the window.

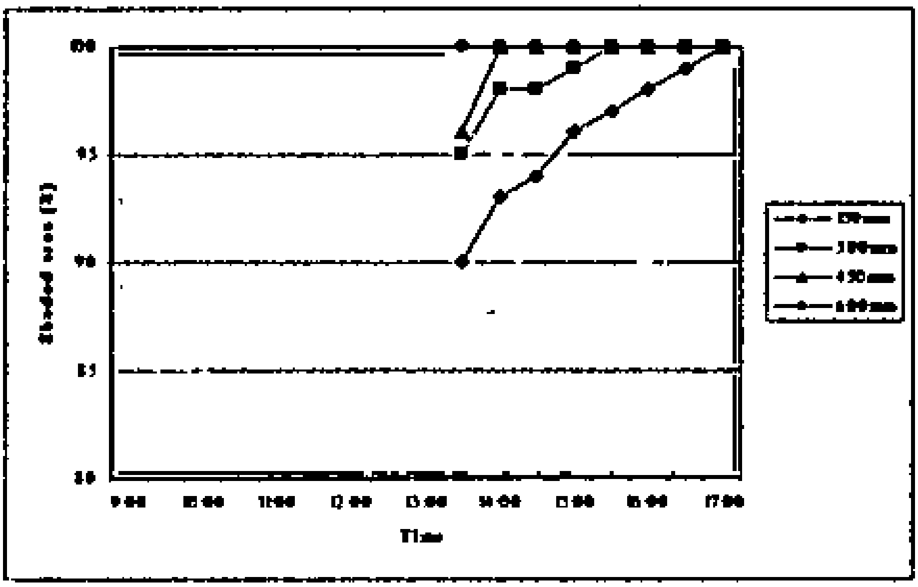


Figure 6.20: Percentage of shaded area by vertical fins with varying extension of vertical fins above window for 21st March.[169]

From table 6.10 below, it is evident that more energy is saved with different extension of vertical fins above window. Highest percentage (99%) of energy is saved by the devices having 900mm depth and 45° angle vertical fins with 600mm extension above window.

Table 6.10: Shading coefficient by vertical fins with varying extension of vertical fins above window for 21st March.

No.	Extension in mm	With shade in Watt	Without shade in Watt	Shading Coefficient
1	150	218	2558	0.09
2	300	132	2558	0.05
3	450	67	2558	0.03
4	600	32	2558	0.01

Findings:

For 600mm extension above window, vertical fin shades maximum window area and shows lowest shading coefficient. So, for 600mm spacing, optimum extension of vertical fin above window for maximum shading is 600mm, which is equal to the spacing between fins.

6.6 Parametric Studies for Composite Shading Devices

Case studies and literature reviews so far done, reveal that composite shading devices are effective at south-east and south-west orientation. Through this parametric study an attempt has been made to find out the size and geometry of the horizontal overhangs and the vertical fins for optimum shading at south-east and south-west orientation only. Parametric study is done for optimum shading at south-west orientation. As sun path is symmetrical about 12 pm, the same solution will be applicable for south-east orientation also. Two parameters (depth and spacing of horizontal overhang and vertical fins and angle of vertical fins) are considered as variables for this parametric study. The results of this study are summarised in the following sections.

6.6.1 Effect of Depth and Spacing of Horizontal Overhangs & Vertical Fins

The parametric study has been done for composite shading devices of varying spacing of horizontal overhangs and vertical fins, while the depth of the fins and overhangs is considered as constant. As composite shading devices are combination of horizontal overhangs and vertical fins, spacings of both devices have impact on the shading performance of composite shading devices.

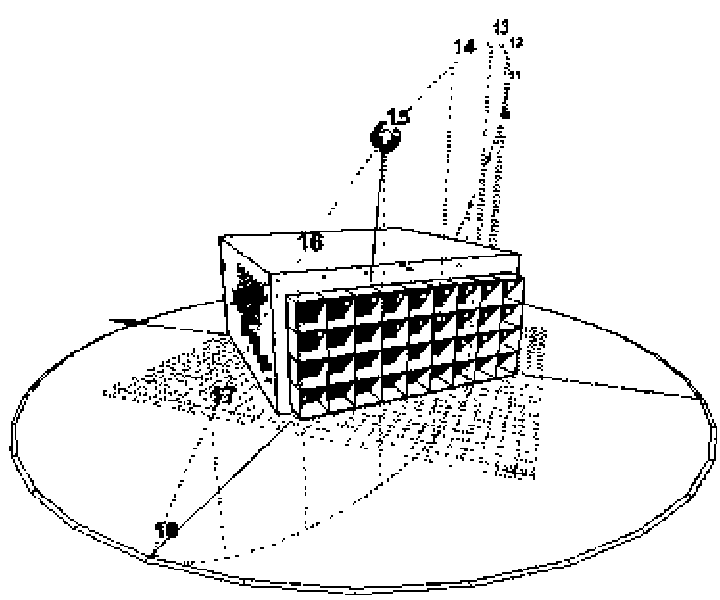


Figure 6.21: View of the model with composite shading device used for parametric study for 21st March (Ecotect output).

Two options have been studied. At first option, spacing of vertical fins is considered as constant along with the depth of horizontal overhangs and vertical fins; only spacing of horizontal overhangs is a variable. The parametric study is done for 600mm and 1200mm spacing of horizontal overhangs. At second option, spacing of horizontal overhangs is considered as constant along with the depth of horizontal overhangs and vertical fins, only spacing of vertical fins is a variable. The parametric study is done for 600mm and 1200mm spacing of vertical fins (model shown in figure 6.21). In both cases, depth of horizontal overhangs and vertical fins is 600mm.

Table 6.11: Percentage of shaded area by composite shading devices with different spacing for 21st March.

Spacing in mm	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
600 x 1200	*	*	*	*	*	*	*	100	100	82	72	67	68	66	70	76	79
600 x 600	*	*	*	*	*	*	*	100	100	100	100	100	95	87	85	82	85
1200 x 600	*	*	*	*	*	*	*	100	99	100	99	100	95	82	77	64	60
1200 x 1200	*	*	*	*	*	*	*	100	100	82	69	61	56	55	50	49	47

* Percentage of shaded area is not taken into account as the sun does not see the window.

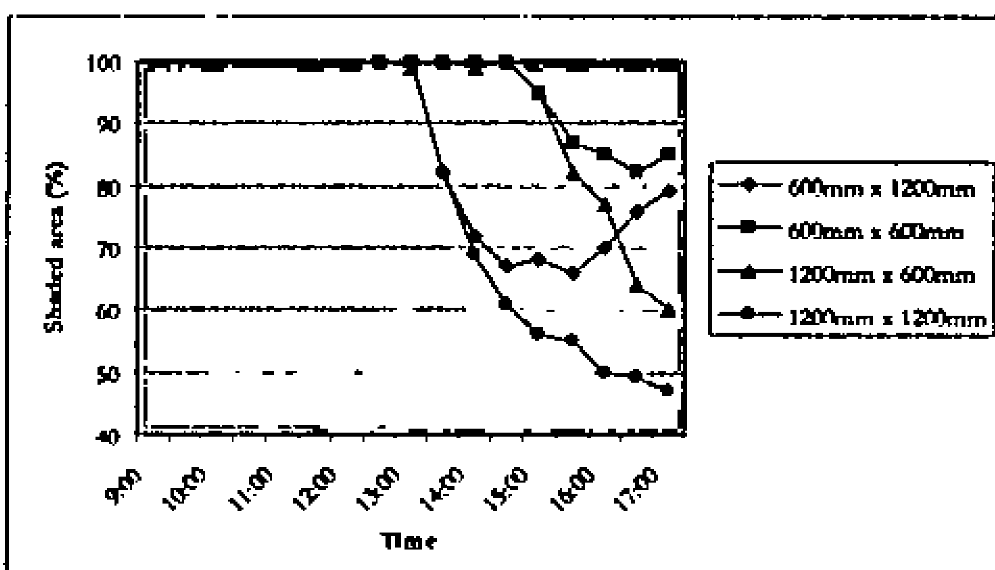


Figure 6.22: Percentage of shaded area by composite shading devices with different spacing for 21st March.[69]

The percentage of shaded area of the window varies for different spacing of fins and overhangs. Table 6.11 shows percentage of shaded areas for different spacing of fins and overhangs. The percentage of shaded area is increased with the decrease of spacing of fins and overhangs. The highest performance is seen by 600mm spacing vertical fins with 600mm spacing horizontal overhangs. For 600mm spacing vertical fins with 600mm spacing horizontal overhangs, it shades from 79 to 100% of the window area at different time of the day. The performance of other alternatives is not consistent (shown in figure 6.22).

Findings:

For 600mm depth of fins and overhangs at 600mm interval, composite shading devices shade maximum window area and shows lowest shading coefficient. So, at 600mm interval, optimum depth of vertical fins and overhangs for maximum shading is 600mm, which is equal to the spacing between fins and overhangs respectively.

6.6.2 Effect of Angle of Vertical Fins

From the above investigation it has been observed that for composite shading only increasing of spacing of fins and overhangs is not effective to protect the window from solar radiation throughout the day. To improve the performance of composite shading devices, the effect of different angle of vertical fins with window surface is studied in the following section. The parametric study is done for 600mm spacing horizontal overhang and 600mm spacing vertical fins with 30° and 45° angles with the line perpendicular to the window surface (model shown in figure 6.23).

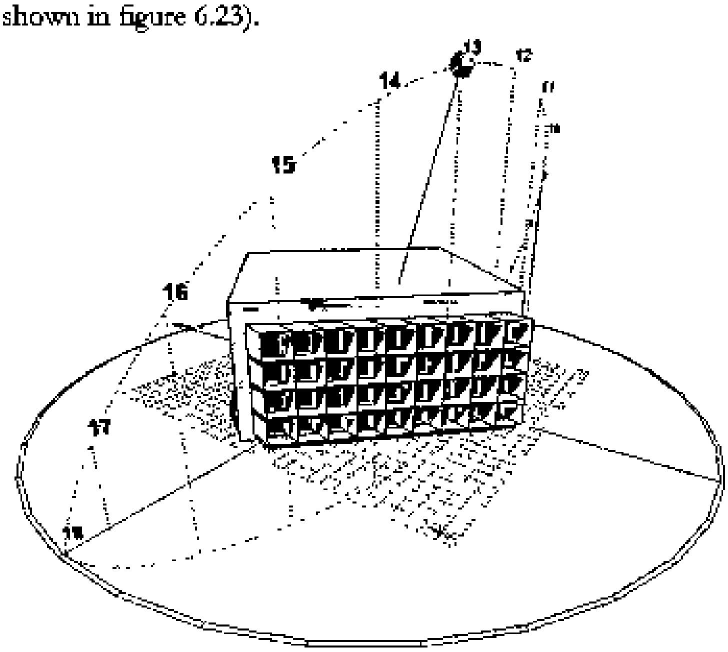


Figure 6.23: View of the model with composite shading device with slanted fins used for parametric study for 21st March.

The percentage of shaded area of the window varies for vertical fins of composite shading device with different angle. With changing the angle from perpendicular to the window surface the percentage of shaded area of the window is increased significantly. Table 6.12 shows percentage of shaded areas for vertical fins with different angles. For 600mm spacing horizontal overhangs with 600mm spacing vertical fins with 30° angle, it shades maximum 100% of the window area. The performance of 600mm spacing horizontal overhangs with 600mm spacing vertical fins with 45° angle is almost same to that of 600mm spacing horizontal overhangs with 600mm spacing vertical fins with 30° angle (shown in figure 6.24).

Table 6.12: Percentage of shaded area by composite shading devices with different angle for 21st March.

Angle	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0°	*	*	*	*	*	*	*	100	100	100	100	100	95	87	85	82	85
30°	*	*	*	*	*	*	*	100	100	99	100	98	97	97	100	100	99
45°	*	*	*	*	*	*	*	100	100	99	99	98	99	99	100	100	99

* Percentage of shaded area is not taken into account as the sun does not see the window.

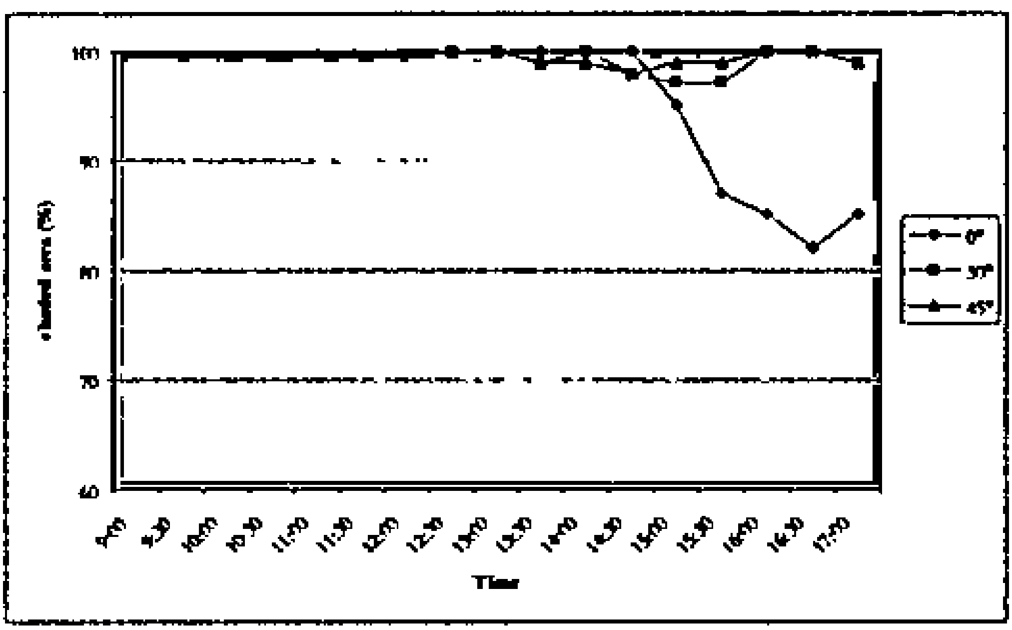


Figure 6.24: Percentage of shaded area by composite shading devices with different angle for 21st March. [illegible]

Following Table 6.13 shows that, energy saving performance of 600mm spacing horizontal overhangs with 600mm spacing vertical fins with 30° angle is very close to that of 600mm spacing horizontal overhangs with 600mm spacing vertical fins with 45° angle. Highest percentage (99%) of energy is saved by the devices having 600mm spacing horizontal overhangs with 600mm spacing vertical fins with 45° angle.

Table 6.13: Shading coefficient by composite shading devices with different angle for 21st March.

No.	Angle	With shade in Watt	Without shade in watt	Shading Coefficient
1	0°	84	4015	0.02
2	30°	36	4015	0.01
3	45°	27	4015	0.01

Findings:

For 600mm depth of fins and overhangs at 600mm interval, composite shading device at 45° angle with the line perpendicular to the window surface shades maximum window area and shows lowest shading coefficient.

6.7 Conclusion

Based on the observation made in the parametric studies, it can be stated that with the help of some simple strategies and modifications of shading devices, the optimum solution concerning solar heat gain issues within tall office buildings can be achieved for considerable period of office hours at five critical orientations for periods requiring shading. By providing a better protection against solar heat gain, the energy consumption to dissipate that heat could be reduced.

CHAPTER: SEVEN

GUIDELINES FOR DESIGN OPTIMIZATION OF SHADING DEVICES

GUIDELINES FOR DESIGN OPTIMIZATION OF SHADING DEVICES

Shading is the major consideration to reduce solar heat gain in overheated periods. Shading of a window offers the first line of defence against heat gains from solar radiation. External shading device is the most efficient solar control as it cuts off solar radiation before reaching the window. The design of shading devices can primarily come from understanding the solar geometry. The efficiency of the window shading devices is largely determined by the orientation of the window. Every orientation of the window requires appropriate shading strategy.

In the previous sections, the theoretical basis and the results of the simulation studies were discussed. Based on the set criteria nine selected shading devices were evaluated through simulation. The evaluation of these selected shading devices in terms of solar control helped in identifying the factors that affect in reducing solar heat gain. To explore the strategies for optimum shading, a parametric study was pursued through series of simulations. The observations of the simulated behaviour that occurs due to changing parameters allow the identification of geometric elements, the reduction or introduction of which in the design contribute to reduce solar heat gain. The following sections present recommendations and guidelines.

7.1 Proposed Guidelines for Efficient Shading System

In view of all the investigations and on the basis of findings outlined above, a set of guidelines has been drawn for efficient shading to reduce solar heat gain. Investigations showed that different types of shading devices were appropriate for different orientations. The following recommendations are made for different orientations and for different types of shading devices. The recommendations and guidelines are particularly applicable for tall office buildings of Dhaka city (longitudes: 90°23' East and latitudes: 23°46' North).

7.1.1 Guidelines for Horizontal Shading Device

- It has been found from the investigation that horizontal shading devices were efficient at south orientation only. Hence horizontal shading devices are appropriate to protect the windows from solar heat gain at south orientation. It works efficiently from 10 am to 2 pm when the sun is opposite to the window pane and at a high altitude.

- The depth of the overhang depends on the window height and is independent of the window width. The performance of horizontal shading device increases with the increase of depth of the overhang. After a certain depth, the performance does not increase significantly with the increase of shading depth. The important factor is the ratio between depth of the overhang and height of the window.
- For optimum shading, the ratio between depth of overhang and height of the window is

D= 7/16 x H

Where, D= depth of overhang

H= Height of window

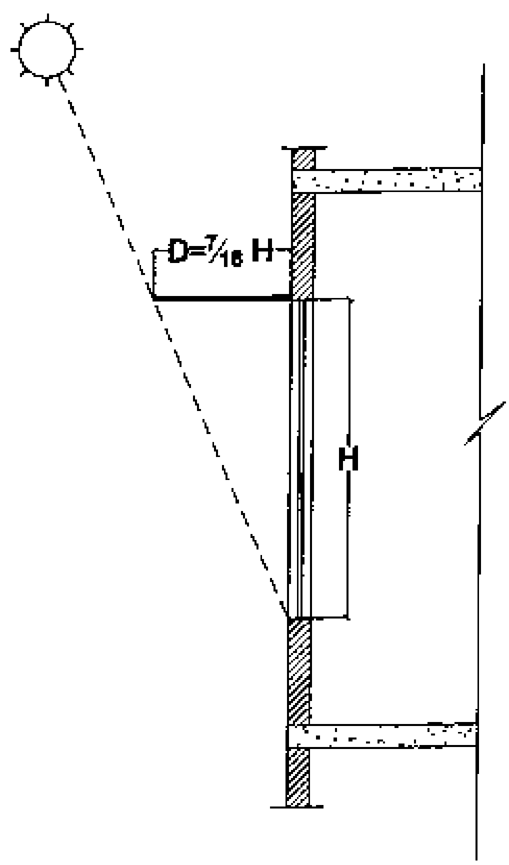


Figure 7.1: Schematic diagram showing parameters of horizontal shading device.

- When designing an overhang for the south facade, one must remember that the sun travels from the southeast before noon and to the southwest after noon. Therefore, the sun will outflank an overhang with the same width as window-width. Windows need wider overhang offset from the window edge (figure 7.2). The side offset from window edge also depends on the height of the window.
- The ratio between the side offset from window edge of overhang and height of the window is

  W= H/2

  Where, W= side offset from window edge

  H= Height of window

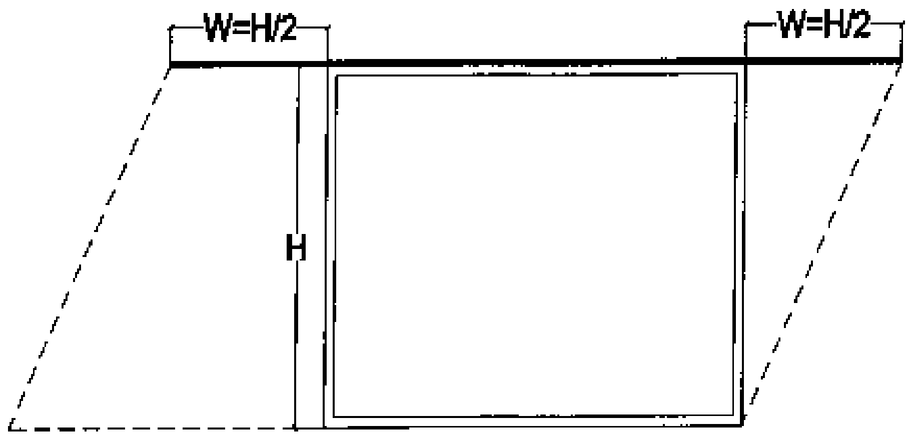


Figure 7.2: Schematic diagram showing parameters of horizontal shading device.

- For large height of windows, minimizing effective height of window is beneficial to improve the performance of shading device further. This could be done by using several overhangs on the window pane instead of one large overhang (figure 7.3). Installing several overhangs on the window pane is also appropriate when the projecting distance from the wall is limited for structural or other reasons. This could be important if a building is on or near the property line or there are certain restrictions by building regulations. As far as sun penetration is concerned, the scale of the overhangs can be changed at any time as long as the ratio of D/H and W/H are kept constant.

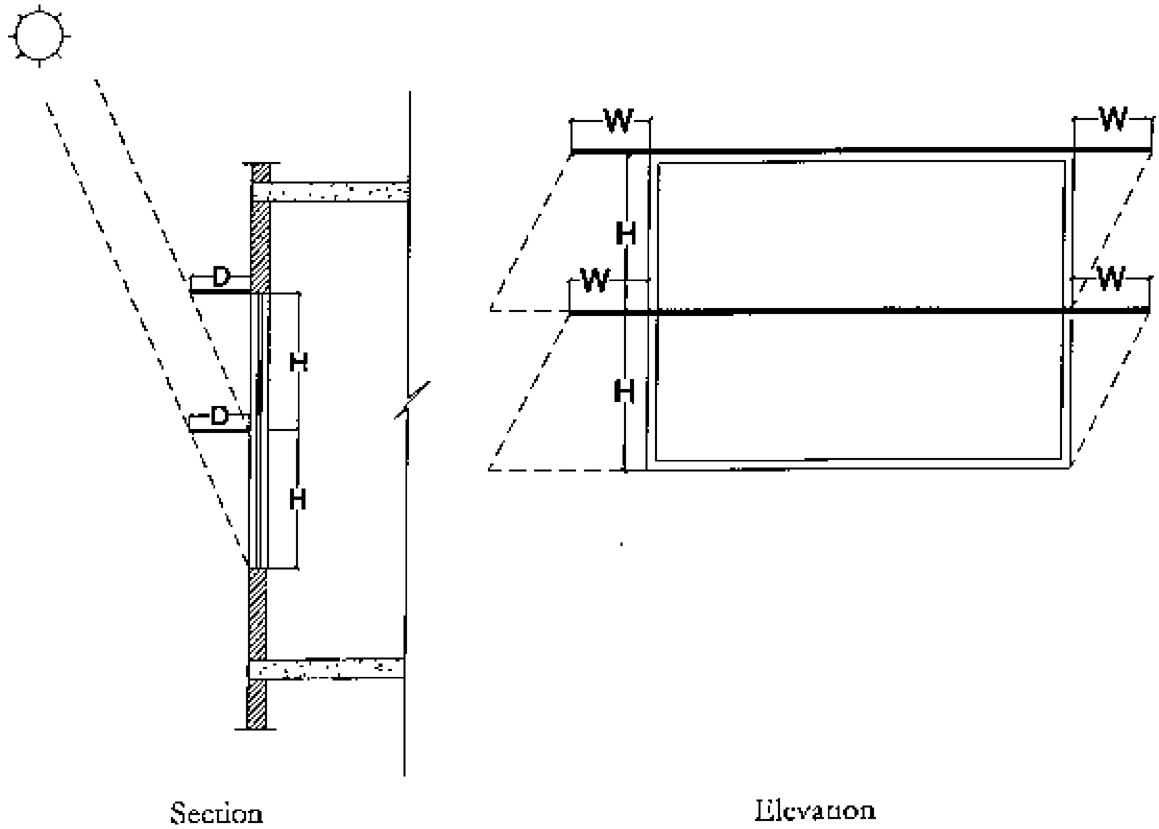


Figure 7.3: Schematic diagrams showing parameters of horizontal shading device.

7.1.2 Guidelines for Vertical Shading Device

- It has been found from the investigation that vertical shading devices were efficient at east and west orientation only. Hence vertical shading devices are appropriate to protect the windows from solar heat gain at east and west orientation. It works efficiently with the sun at a low altitude.
- The depth and spacing of vertical fins is independent of window height and width. The performance of vertical shading devices increases with the increase of depth of vertical fins and with the decrease of spacing between vertical fins. After achieving certain depth, the performance does not increase with the increase of shading depth. The depth of vertical fin depends on the spacing between vertical fins and vice versa. The important factor is the ratio between the depth of vertical fin and the spacing between vertical fins.

- For optimum shading, the ratio between the depth and the spacing of vertical fin is

  D=1.5x S

  Where, D= depth of vertical fin

  S= spacing of the vertical fin

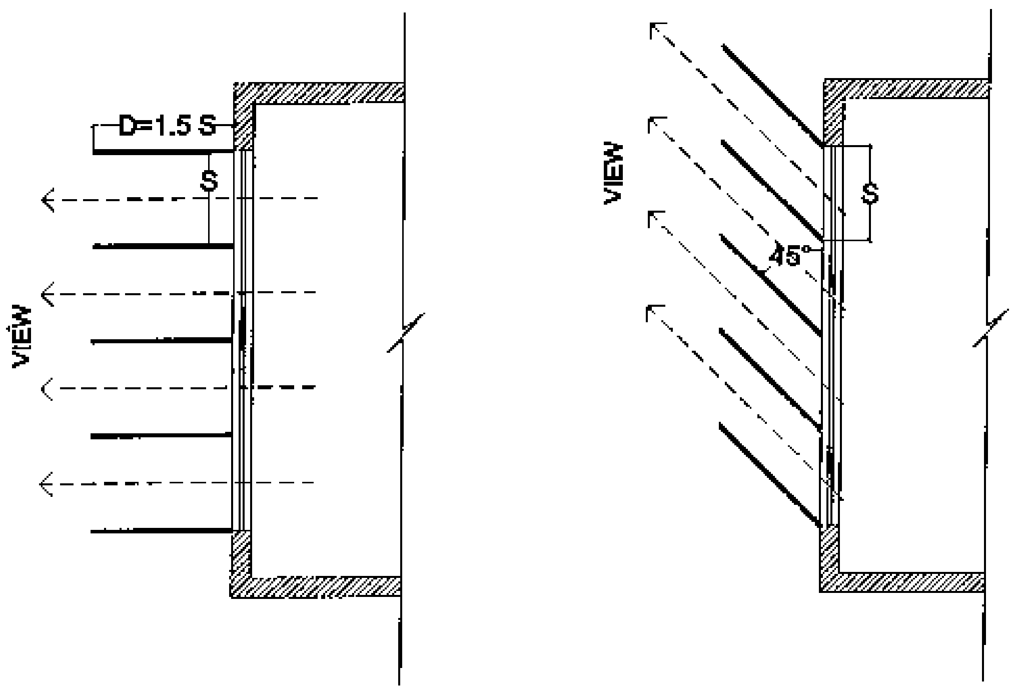


Figure 7.4: Schematic diagrams showing different parameters of vertical shading device.

- This type of device is most effective when the sun is at one side of the elevation. A vertical device to be effective when the sun is opposite to the window considered would have to give almost complete cover of the whole window. With changing the angle from perpendicular to the window surface to clock-wise direction, the performance of vertical fin increases significantly. Vertical fins at 45° angle with the line perpendicular to the window surface are most effective. This type of vertical slanted fin can be appropriate either when there is a desire to control the direction of view or when the view is not important.
- When designing a vertical fin for west facade, one must remember that the sun travels relative to earth from the southwest. Therefore, the sun will outflank a vertical fin with the same height as a window-height. Windows need higher vertical fin extending over the window edge. The extension over the top edge of window depends on spacing between vertical fins.

- The ratio between extension of fins over the window edge and the spacing between vertical fins is

  X=S

  Where, X= extension of fin over the window edge

  S= spacing between vertical fins

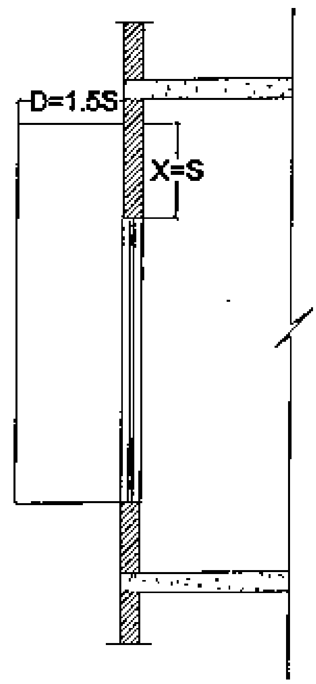


Figure 7.5: Schematic diagram showing different parameters of vertical shading device.

7.1.3 Guidelines for Composite Shading Device

- The investigation showed that the composite shading devices were efficient at south-east and south-west orientation. By controlling sun penetration by both the altitude and azimuth angle of the sun, very effective shading of windows can be achieved.
- The depth and spacing of vertical fins and horizontal overhang of composite shading device is independent of the window height and width. The performance of composite shading devices increase with the increase of depth and with the decrease of spacing between vertical fins and horizontal overhangs of composite shading device. The depth of vertical fin and horizontal overhang depend respectively on the spacing between vertical fins and horizontal overhangs and vice versa. The important factor is the ratio between the depth and the spacing between vertical fins and horizontal overhangs.

- For optimum shading, the ratio between the depth and the spacing of the vertical fins of composite shading device is

  w=d

  Where, d= depth of vertical fin

  w= spacing between vertical fins

  And the ratio between depth and spacing of horizontal overhangs of composite shading device is

  h=d

  Where, d= depth of horizontal overhang

  h= spacing between horizontal overhangs

  It means that depth of vertical fins and depth of horizontal overhangs has to be equal.

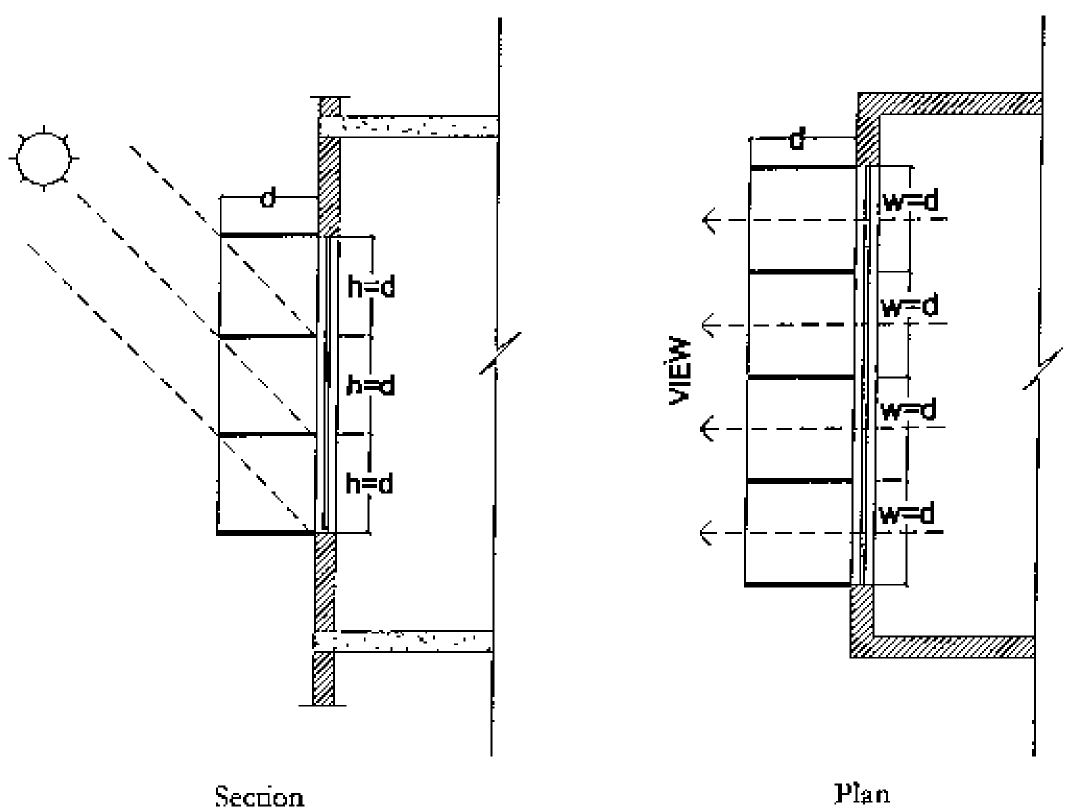


Figure 7.6: Schematic diagrams showing different parameters of composite shading device.

- With changing angle of vertical fin from perpendicular to the window surface to anti-clock-wise direction, the performance of composite shading device increases. Vertical fin at 30° angles with the line perpendicular to the window surface are most effective.

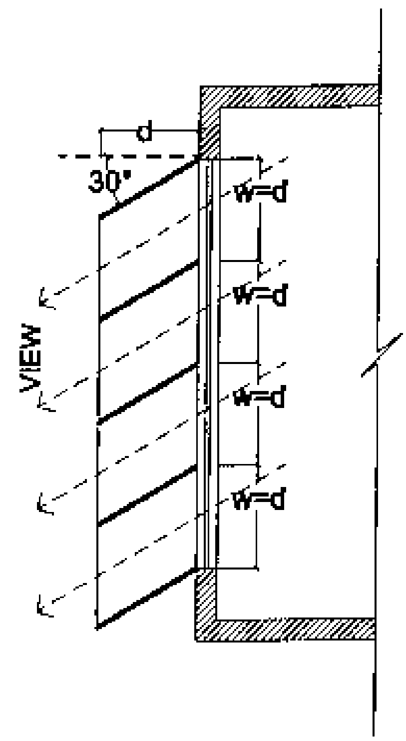


Figure 7.7: Schematic diagram showing different parameters of composite shading device.

- The Designer should first decide on the general appearance of the composite system. As far as sun penetration is concerned, the scale of the composite shading device can be changed at any time as long as the ratio of h/d and w/d are kept constant.

7.2 Conclusion

This work was an attempt to explore design strategies of efficient shading devices in tropical urban climatic context with a focus to reduce solar heat gain in overheated periods. To achieve the objectives, through investigations a set of strategies has been drawn that could help to design an efficient shading device in place of commonly practised ones in Dhaka. This work may also instigate designers design efficient shading devices with a reference to climate issues.

At present the necessity to reduce the energy consumption in the buildings is an important issue in Bangladesh. The design strategies of efficient shading devices that have emerged as a direct outcome of this study are important in producing energy efficient design solutions. It may be extremely useful to have such strategies in mind during the pre-design and design stages of buildings, as passive solutions allow buildings to responsive with environment, thereby reducing energy consumption.

7.3 Suggestions for Future Research

Some of the most important areas that need to be explored further are summarized below:

- More research needed to assess the impact of shading devices on daylight and ventilation through the window.
- Performance of shading devices can be evaluated in reducing heat gain for diffused solar radiation.
- Performance evaluation can be done with various thickness of shading devices with different types of materials. The use of shading materials and methods of installation with regards to their thermal properties need to be investigated for detailed recommendation for their uses.
- Possibility of mechanized movable shading device can be explored. The cost effectiveness of fixed shading device with comparison to movable shading device can be done considering maintenance and construction cost.
- Combination of shading devices (interior and exterior), movable shading devices and shading devices combined with special (solar-protective, low-e) glazing should be studied.
- 'Dhaka Metropolis Building Construction Rule 2006' can be examined considering solar shading in buildings.
- Impact of shading optimization on building energy consumption may be studied in view of energy saving potentials.

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APPENDICES

APPENDIX A: Hourly Dry Bulb Temperature (°C)

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month: January

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time															
0:00	12.5	13.0	15.4	18.4	15.2	16.4	16.6	16.2	15.2	13.8	15.9	13.6	13.8	14.2	14.2
1:00	14.4	14.9	16.7	19.1	16.7	17.1	17.4	16.9	15.4	15.1	16.5	14.7	14.5	14.9	15.1
2:00	16.3	16.7	18.0	19.8	18.1	17.9	18.1	17.5	15.7	16.4	17.2	15.9	15.2	15.7	16.1
3:00	18.2	18.6	19.3	20.5	19.6	18.6	18.9	18.2	15.9	17.7	17.8	17.0	15.9	16.4	17.0
4:00	20.3	20.6	21.3	21.8	21.2	20.5	20.6	19.8	17.9	19.5	18.1	18.5	17.5	18.3	18.7
5:00	22.4	22.7	23.2	23.2	22.8	22.5	22.3	21.5	20.0	21.4	18.4	20.1	19.1	20.2	20.3
6:00	24.5	24.7	25.2	24.5	24.4	24.4	24.0	23.1	22.0	23.2	18.7	21.6	20.7	22.1	22.0
7:00	25.0	25.1	25.7	24.6	24.9	24.7	24.5	23.6	22.5	23.7	18.1	22.1	21.1	22.4	22.5
8:00	25.5	25.6	26.3	24.8	25.3	25.1	24.9	24.0	22.9	24.1	17.4	22.7	21.6	22.7	23.1
9:00	26.0	26.0	26.8	24.9	25.8	25.4	25.4	24.5	23.4	24.6	16.8	23.2	22.0	23.0	23.6
10:00	24.7	24.3	25.3	24.1	24.7	24.4	24.3	23.4	22.3	22.8	16.5	22.3	21.2	22.1	22.6
11:00	23.5	22.6	23.7	23.3	23.5	23.4	23.2	22.3	21.1	21.0	16.1	21.5	20.4	21.1	21.5
12:00	22.2	20.9	22.2	22.5	22.4	22.4	22.1	21.2	20.0	19.2	15.8	20.6	19.6	20.2	20.5
13:00	20.5	20.1	21.6	21.5	21.7	21.7	21.4	20.5	19.2	18.3	15.8	19.9	19.0	19.6	19.6
14:00	18.7	19.2	21.0	20.4	20.9	20.9	20.8	19.9	18.4	17.4	15.7	19.3	18.3	19.1	18.6
15:00	17.0	18.4	20.4	19.4	20.2	20.2	20.1	19.2	17.6	16.5	15.7	18.6	17.7	18.5	17.7
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17:00	15.7	17.7	20.5	18.9	19.4	19.3	19.0	18.4	16.5	16.5	15.4	17.7	17.2	16.6	17.1
18:00	15.0	17.3	20.6	18.6	19.0	18.8	18.4	18.0	15.9	16.5	15.2	17.2	17.0	15.6	16.8
19:00	14.1	18.0	19.3	18.2	18.4	18.3	17.9	16.5	16.0	15.9	15.3	16.6	16.3	15.6	15.9
20:00	13.3	18.7	17.9	17.8	17.8	17.7	17.5	14.9	16.1	15.2	15.5	16.0	15.7	15.5	14.9
21:00	12.4	19.4	16.6	17.4	17.2	17.2	17.0	13.4	16.2	14.6	15.6	15.4	15.0	15.5	14.0
22:00	14.4	18.3	15.2	16.1	16.1	15.9	17.0	14.9	16.7	15.9	16.0	16.3	16.9	17.5	16.2
23:00	16.4	17.3	13.8	14.8	15.0	14.7	17.0	16.5	17.3	17.1	16.5	17.1	18.9	19.6	18.4

Day	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																
0:00	13.0	12.8	14.9	17.0	14.6	12.3	13.2	12.4	13.4	15.0	15.0	12.6	13.1	17.5	17.0	16.8
1:00	14.6	14.6	16.1	17.3	15.5	14.1	13.7	14.1	14.6	15.5	16.2	14.8	15.3	17.9	18.0	17.9
2:00	16.2	16.4	17.4	17.7	16.3	15.8	14.1	15.7	15.8	15.9	17.3	17.0	17.6	18.4	19.0	18.9
3:00	17.8	18.2	18.6	18.0	17.2	17.6	14.6	17.4	17.0	16.4	18.5	19.2	19.8	18.8	20.0	20.0
4:00	20.0	20.3	20.3	19.7	18.3	19.1	16.2	18.6	18.7	18.4	19.7	20.7	21.1	19.7	21.9	22.3
5:00	22.3	22.4	22.1	21.3	19.5	20.5	17.8	19.8	20.3	20.4	20.8	22.2	22.4	20.7	23.9	24.7
6:00	24.5	24.5	23.8	23.0	20.6	22.0	19.4	21.0	22.0	22.4	22.0	23.7	23.7	21.6	25.8	27.0
7:00	24.7	25.0	23.9	23.3	21.5	22.0	20.2	20.9	22.3	22.7	22.6	23.9	23.7	22.5	25.9	27.4
8:00	25.0	25.6	23.9	23.7	22.3	22.0	20.9	20.9	22.5	23.1	23.2	24.0	23.7	23.3	26.1	27.8
9:00	25.2	26.1	24.0	24.0	23.2	22.0	21.7	20.8	22.8	23.4	23.8	24.2	23.7	24.2	26.2	28.2
10:00	23.8	24.2	23.2	23.4	22.3	20.6	20.7	20.2	22.1	22.4	23.0	23.4	23.1	23.4	24.9	27.0
11:00	22.4	22.3	22.4	22.8	21.3	19.2	19.7	19.6	21.3	21.4	22.2	22.6	22.4	22.6	23.7	25.8
12:00	21.0	20.4	21.6	22.2	20.4	17.8	18.7	19.0	20.6	20.4	21.4	21.8	21.8	21.8	22.4	24.6
13:00	19.8	19.5	20.9	21.5	19.2	17.4	17.4	18.3	20.0	19.7	20.5	20.3	21.3	21.1	21.7	23.7
14:00	18.6	18.5	20.2	20.7	17.9	16.9	16.1	17.7	19.4	19.1	19.6	18.7	20.7	20.5	21.1	22.9
15:00	17.4	17.6	19.5	20.0	16.7	16.5	14.8	17.0	18.8	18.4	18.7	17.2	20.2	19.8	20.4	22.0
16:00	16.7	17.1	19.2	19.4	16.5	16.2	14.4	16.9	18.5	17.9	17.9	17.5	19.7	19.3	19.9	21.3
17:00	16.1	16.5	18.8	18.8	16.4	15.9	13.9	16.7	18.1	17.5	17.2	17.9	19.3	18.7	19.3	20.7
18:00	15.4	16.0	18.5	18.2	16.2	15.6	13.5	16.6	17.8	17.0	16.4	18.2	18.8	18.2	18.8	20.0
19:00	15.4	16.5	17.6	16.3	15.5	14.7	14.4	16.6	17.2	16.5	16.6	18.1	18.4	18.2	18.7	20.0
20:00	15.4	17.1	16.7	14.5	14.7	13.9	15.3	16.5	16.6	16.1	16.8	18.1	17.9	18.2	18.6	20.0
21:00	15.4	17.6	15.8	12.6	14.0	13.0	16.2	16.5	16.0	15.6	17.0	18.0	17.5	18.2	18.5	20.0
22:00	17.8	19.6	18.7	16.3	16.7	16.6	17.8	17.6	17.4	16.7	17.9	18.3	17.2	12.1	12.3	13.3
23:00	20.1	21.7	21.5	20.1	19.5	20.2	19.4	18.8	18.8	17.8	18.7	18.5	16.9	6.1	6.2	6.7

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: February

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0:00	18.4	16.2	12.4	13.5	13.9	13.4	17.0	18.0	17.8	18.4	16.9	18.0	20.8	21.6	20.6	22.5	23.7	24.4	23.8	22.2	23.8	21.0	19.9	20.2	18.9	19.6	18.8	16.6
1:00	18.9	16.9	13.9	14.5	15.2	15.6	18.3	19.6	19.4	20.5	18.9	19.7	21.9	22.5	21.6	23.2	24.3	24.7	24.1	22.9	24.6	22.2	21.0	21.1	19.0	20.7	20.9	19.1
2:00	19.3	17.7	15.5	15.5	16.6	17.8	19.7	21.2	21.0	22.1	21.0	21.5	23.1	23.3	22.6	23.9	25.0	25.1	24.4	23.5	25.4	23.5	22.1	21.9	21.0	21.9	22.9	21.5
3:00	19.8	18.4	17.0	16.5	17.9	20.0	21.0	22.8	22.6	24.0	23.0	23.2	24.2	24.2	23.6	24.6	25.6	25.4	24.7	24.2	26.2	24.7	23.2	22.8	22.0	23.0	25.0	24.0
4:00	20.9	19.7	18.2	18.3	19.9	21.8	22.9	24.5	24.3	25.0	24.3	24.9	26.1	25.6	25.2	25.7	26.7	26.7	25.6	25.3	27.7	25.6	24.7	24.1	23.4	24.8	26.4	26.2
5:00	22.1	21.1	19.3	20.2	22.0	23.6	24.7	26.1	25.9	26.0	25.5	26.7	28.1	27.0	26.9	26.9	27.9	27.9	26.4	26.4	29.1	26.4	26.3	25.5	24.9	26.6	27.9	28.4
6:00	23.2	22.4	20.5	22.0	24.0	25.4	26.6	27.9	27.6	27.0	26.8	28.4	30.0	28.4	28.5	28.0	29.0	29.2	27.3	27.5	30.6	27.3	27.8	26.8	26.3	28.4	29.3	30.6
7:00	22.8	22.9	20.9	22.7	24.6	26.0	27.5	28.2	28.1	27.4	27.2	29.1	30.7	28.9	29.3	28.7	29.8	29.8	28.2	28.3	30.9	27.5	28.5	27.3	27.1	29.0	29.5	30.7
8:00	22.4	23.5	21.4	23.5	25.1	26.7	28.5	28.6	28.5	27.9	27.6	29.9	31.3	29.3	30.0	29.3	30.6	30.4	29.0	29.0	31.3	27.6	29.3	27.7	28.0	29.5	29.8	30.7
9:00	22.0	24.0	21.8	24.2	25.7	27.3	29.4	29.0	29.0	28.3	28.0	30.6	32.0	29.8	30.8	30.0	31.4	31.0	29.9	29.8	31.6	27.8	30.0	28.2	28.8	30.1	30.0	30.8
10:00	21.7	22.9	21.1	23.4	24.7	26.1	28.3	27.8	28.1	27.5	27.3	29.6	30.7	28.7	29.9	29.6	30.5	30.3	29.3	29.7	30.8	27.3	29.0	27.3	27.9	29.2	29.1	29.9
11:00	21.3	21.9	20.3	22.6	23.6	24.8	27.1	26.7	27.1	26.8	26.7	28.6	29.5	27.6	28.9	29.2	29.6	29.5	28.8	29.5	30.0	26.9	27.9	26.3	27.1	28.4	28.3	29.1
12:00	21.0	20.8	19.6	21.8	22.6	23.6	26.0	25.5	26.2	26.0	26.0	27.6	28.2	26.5	28.0	28.8	28.7	28.8	28.2	29.4	29.2	26.4	26.9	25.4	26.2	27.5	27.4	28.2
13:00	20.2	20.2	18.8	20.9	20.5	22.5	25.0	24.5	25.3	24.8	24.5	26.7	27.4	25.7	26.9	27.9	27.9	27.9	27.5	28.3	28.6	25.5	25.5	24.4	25.3	25.9	26.4	26.7
14:00	19.4	19.6	18.1	19.9	18.3	21.5	24.0	23.4	24.5	23.6	22.9	25.8	26.6	25.0	25.9	27.1	27.0	27.1	26.8	27.2	28.1	24.7	24.0	23.4	24.5	24.4	25.4	25.3
15:00	18.6	19.0	17.3	19.0	16.2	20.4	23.0	22.4	23.6	22.4	21.4	24.9	25.8	24.2	24.8	26.2	26.2	26.2	26.1	26.1	27.5	23.8	22.6	22.4	23.6	22.8	24.4	23.8
16:00	18.3	18.5	17.0	18.3	15.6	19.9	22.2	21.6	22.9	21.4	21.3	24.4	25.4	23.5	24.0	25.7	25.7	25.6	24.8	25.9	26.6	23.2	22.1	21.8	23.1	21.7	23.1	22.7
17:00	18.1	17.9	16.7	17.5	15.0	19.5	21.4	20.8	22.3	20.4	21.3	24.0	24.9	22.7	23.2	25.1	25.3	25.1	23.6	25.8	25.8	22.6	21.7	21.3	22.7	20.7	21.8	21.7
18:00	17.8	17.4	16.4	16.8	14.4	19.0	20.6	20.0	21.6	19.4	21.2	23.5	24.5	22.0	22.4	24.6	24.8	24.5	22.3	25.6	24.9	22.0	21.2	20.7	22.2	19.6	20.5	20.6
19:00	17.5	16.6	15.6	16.3	14.1	18.6	20.0	19.5	20.9	19.3	20.8	23.1	24.0	21.3	22.4	24.5	24.7	24.4	22.4	25.1	23.7	21.7	20.8	20.5	21.4	19.4	19.6	20.2
20:00	17.3	15.8	14.8	15.7	13.9	18.2	19.4	19.0	20.1	19.1	20.4	22.8	23.5	20.7	22.3	24.3	24.7	24.3	22.5	24.5	22.6	21.5	20.4	20.2	20.6	19.2	18.7	19.8
21:00	17.0	15.0	14.0	15.2	13.6	17.8	18.8	18.5	19.4	19.0	20.0	22.4	23.0	20.0	22.3	24.2	24.6	24.2	22.6	24.0	21.4	21.2	20.0	20.0	19.8	19.0	17.8	19.4
22:00	18.3	17.3	17.2	17.3	17.2	20.0	20.6	20.8	20.7	20.5	21.6	22.2	22.4	20.5	22.0	23.9	24.1	24.1	22.7	23.8	22.4	22.8	20.8	20.2	20.1	20.5	19.9	21.4
23:00	19.7	19.7	20.5	19.3	20.9	22.3	22.4	23.1	22.1	22.0	23.1	22.0	21.8	23.1	21.7	23.5	23.5	24.1	22.9	23.6	23.5	24.4	21.7	20.4	20.5	21.9	22.1	23.3

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: March

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	21.0	22.0	23.7	21.4	24.5	24.5	24.2	25.4	23.4	23.5	24.7	21.8	21.2	21.6	21.4	23.2	23.0	24.0	23.0	23.4	24.5	26.0	22.5	20.6	20.8	23.4	24.2	25.3	25.4	25.0	19.7
1:00	22.3	23.2	24.5	23.5	25.4	25.7	25.1	25.9	24.3	24.5	24.7	22.3	22.9	23.3	22.7	24.2	24.2	25.4	23.3	25.1	25.5	26.7	23.1	21.1	22.0	24.5	25.1	26.0	26.1	25.7	20.5
2:00	23.7	24.3	25.4	25.7	26.3	26.8	25.9	26.3	25.3	25.5	24.8	22.9	24.5	25.0	24.1	25.2	25.4	26.8	23.5	26.7	26.6	27.5	23.8	21.7	23.2	25.6	26.1	26.7	26.9	26.5	21.2
3:00	25.0	25.5	26.2	27.8	27.2	28.0	26.8	26.8	26.2	26.5	24.8	23.4	26.2	26.7	25.4	26.2	26.6	28.2	23.8	28.4	27.6	28.2	24.4	22.2	24.4	26.7	27.0	27.4	27.6	27.2	22.0
4:00	27.0	27.8	28.4	29.6	28.7	29.4	28.2	27.8	27.7	28.3	26.4	23.7	27.7	28.4	27.0	27.7	27.9	27.7	26.0	29.3	29.2	30.1	23.6	22.3	25.4	27.4	28.1	28.5	28.5	28.3	22.4
5:00	29.0	30.1	30.6	31.4	30.2	30.7	29.6	28.8	29.1	30.2	28.0	23.9	29.2	30.1	28.6	29.1	29.2	27.1	28.2	30.3	30.9	31.9	22.8	22.3	26.5	28.2	29.3	29.7	29.3	29.3	22.9
6:00	31.0	32.4	32.8	33.2	31.7	32.1	31.0	29.8	30.6	32.0	29.6	24.2	30.7	31.8	30.2	30.6	30.5	26.6	30.4	31.2	32.5	33.8	22.0	22.4	27.5	28.9	30.4	30.8	30.2	30.4	23.3
7:00	31.5	32.9	33.3	33.9	32.2	32.8	31.7	30.9	31.2	32.8	29.5	24.6	30.9	32.1	30.9	31.3	31.3	27.9	30.8	32.1	33.5	33.8	22.7	22.9	28.1	29.7	31.0	31.5	31.0	30.9	24.9
8:00	32.1	33.4	33.9	34.5	32.7	33.5	32.5	31.9	31.8	33.6	29.4	25.1	31.0	32.3	31.5	31.9	32.0	29.2	31.2	32.9	34.4	33.8	23.3	23.5	28.8	30.4	31.6	32.1	31.7	31.3	26.6
9:00	32.6	33.9	34.4	35.2	33.2	34.2	33.2	33.0	32.4	34.4	29.3	25.5	31.2	32.6	32.2	32.6	32.8	30.5	31.6	33.8	35.4	33.8	24.0	24.0	29.4	31.2	32.2	32.8	32.5	31.8	28.2
10:00	31.7	32.8	33.3	34.3	32.6	33.3	32.3	32.0	31.8	33.5	28.6	25.1	30.5	31.2	31.5	31.8	31.9	29.3	31.1	33.3	34.1	32.9	22.6	23.3	28.8	30.7	31.6	32.2	31.7	28.9	27.7
11:00	30.7	31.7	32.1	33.3	32.0	32.3	31.3	31.0	31.2	32.7	27.8	24.6	29.7	29.8	30.7	31.0	31.1	28.2	30.7	32.7	32.7	31.9	21.2	22.7	28.2	30.3	31.0	31.6	30.8	25.9	27.1
12:00	29.8	30.6	31.0	32.4	31.4	31.4	30.4	30.0	30.6	31.8	27.1	24.2	29.0	28.4	30.0	30.2	30.2	27.0	30.2	32.2	31.4	31.0	19.8	22.0	27.6	29.8	30.4	31.0	30.0	23.0	26.6
13:00	28.8	29.5	30.3	31.0	30.7	30.5	29.5	29.2	29.6	30.7	26.2	23.9	28.2	28.1	29.0	29.5	29.5	26.7	29.8	31.1	30.6	28.7	20.3	21.8	26.3	28.6	28.7	29.8	29.2	22.1	26.0
14:00	27.8	28.5	29.7	29.6	29.9	29.7	28.5	28.4	28.7	29.5	25.3	23.5	27.5	27.9	28.1	28.9	28.9	26.3	29.4	30.1	29.8	26.3	20.9	21.5	25.1	27.4	27.1	28.7	28.5	21.1	25.4
15:00	26.8	27.4	29.0	28.2	29.2	28.8	27.6	27.6	27.7	28.4	24.4	23.2	26.7	27.6	27.1	28.2	28.2	26.0	29.0	29.0	29.0	24.0	21.4	21.3	23.8	26.2	25.4	27.5	27.7	30.2	24.8
16:00	26.2	26.7	28.3	27.5	28.6	27.9	27.1	27.3	27.3	28.0	24.1	22.9	25.9	26.1	26.5	27.7	27.7	25.7	28.3	28.1	28.3	24.1	21.3	21.1	23.3	25.7	25.1	27.1	26.8	20.6	24.7
17:00	25.6	25.9	27.5	26.9	28.0	27.1	26.7	27.1	27.0	27.6	23.7	22.7	25.2	24.5	25.8	27.1	27.1	25.3	27.6	27.3	27.5	24.3	21.3	21.0	22.9	25.3	24.9	26.6	25.9	21.0	24.7
18:00	25.0	25.2	26.8	26.2	27.4	26.2	26.2	26.8	26.6	27.2	23.4	22.4	24.4	23.0	25.2	26.6	26.6	25.0	26.9	26.4	26.8	24.4	21.2	20.8	22.4	24.8	24.6	26.2	25.0	21.4	24.6
19:00	24.3	24.9	25.7	25.8	26.9	26.0	26.0	26.0	26.1	26.7	23.1	22.3	23.9	22.5	24.4	26.0	26.3	24.7	26.2	26.1	26.4	24.1	21.1	20.9	22.5	24.7	24.5	26.0	24.7	21.2	24.3
20:00	23.7	24.7	24.5	25.4	26.5	25.7	25.8	25.2	25.5	26.1	22.7	22.1	23.5	22.0	23.6	25.4	25.9	24.3	25.5	25.8	25.9	23.9	20.9	20.9	22.5	24.6	24.3	25.8	24.3	21.0	23.9
21:00	23.0	24.4	23.4	25.0	26.0	25.5	25.6	24.4	25.0	25.6	22.4	22.0	23.0	21.5	22.8	24.8	25.6	24.0	24.8	25.5	25.5	23.6	20.8	21.0	22.6	24.5	24.2	25.6	24.0	20.8	23.6
22:00	23.0	23.8	23.5	23.4	24.9	25.4	25.4	25.0	25.3	25.9	23.5	21.5	22.9	22.9	23.9	25.4	26.1	24.3	25.7	26.6	24.8	24.8	22.9	21.5	22.7	24.8	24.1	25.4	23.4	21.3	15.7
23:00	23.0	23.2	23.7	21.8	23.9	25.3	25.2	25.7	25.7	26.3	24.5	24.9	22.9	24.2	24.9	25.9	26.7	24.6	26.7	27.7	24.0	26.0	24.9	22.1	22.9	25.1	24.1	25.2	22.8	21.7	7.9

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: April

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
0.00	23.0	22.6	23.8	20.2	22.8	25.2	25.0	26.3	26.0	26.6	25.6	26.4	22.8	25.6	26.0	26.5	27.2	24.9	27.6	28.8	23.3	27.2	27.0	22.6	23.0	25.4	24.0	25.0	22.2	22.2
1.00	24.3	24.7	25.9	22.1	24.6	26.3	25.9	27.2	26.8	27.5	26.4	26.8	24.9	26.7	27.2	27.1	28.1	26.7	28.5	29.5	26.1	28.2	28.0	25.0	24.9	26.8	25.9	26.5	23.6	23.9
2.00	25.7	26.9	27.9	24.1	26.3	27.3	26.9	28.1	27.5	28.3	27.2	27.2	26.9	27.9	28.4	27.8	29.1	28.4	29.4	30.3	29.0	29.2	29.0	27.4	26.7	28.2	27.9	28.1	25.0	25.7
3.00	27.0	29.0	30.0	26.0	28.1	28.4	27.8	29.0	28.3	29.2	28.0	27.6	29.0	29.0	29.6	28.4	30.0	30.2	30.3	31.0	31.8	30.2	30.0	29.8	28.6	29.6	29.8	29.6	26.4	27.4
4.00	28.1	30.3	31.2	27.7	29.1	29.5	29.1	29.9	29.5	30.4	29.3	29.2	30.1	30.3	30.6	29.9	31.2	31.3	31.6	32.0	32.7	31.6	30.8	30.8	29.6	30.7	30.9	31.1	28.1	28.5
5.00	29.2	31.7	32.4	29.3	30.0	30.5	30.3	30.9	30.8	31.6	30.5	30.9	31.3	31.7	31.5	31.5	32.5	32.4	32.9	33.0	33.7	33.0	31.7	31.8	30.6	31.8	32.1	32.5	29.9	29.5
6.00	30.3	33.0	33.6	31.0	31.0	31.6	31.6	31.8	32.0	32.8	31.8	32.5	32.4	33.0	32.5	33.0	33.7	33.5	34.2	34.0	34.6	34.4	32.5	32.8	31.6	32.9	33.2	34.0	31.6	30.6
7.00	30.5	33.2	33.8	31.5	31.3	32.1	32.1	32.4	32.7	33.3	32.4	32.9	33.1	33.6	33.4	33.3	34.0	34.1	34.6	34.4	34.6	34.9	33.1	33.2	32.1	33.3	33.2	34.5	30.3	31.1
8.00	30.8	33.3	34.0	32.0	31.7	32.7	32.5	33.1	33.3	33.8	33.0	33.2	33.9	34.1	34.2	33.7	34.3	34.7	35.0	34.7	34.6	35.3	33.6	33.6	32.7	33.6	33.1	34.9	29.1	31.7
9.00	31.0	33.5	34.2	32.5	32.0	33.2	33.0	33.7	34.0	34.3	33.6	33.6	34.6	34.7	35.1	34.0	34.6	35.3	35.4	35.1	34.6	35.8	34.2	34.0	33.2	34.0	33.1	35.4	27.8	32.2
10.00	30.8	32.7	33.4	31.9	31.6	32.6	32.5	33.0	33.3	32.2	32.0	33.0	33.7	34.0	34.7	33.2	33.7	34.7	34.7	34.4	34.5	35.1	33.7	33.5	32.9	30.5	32.3	33.3	26.2	31.5
11.00	30.5	31.8	32.6	31.2	31.2	32.0	32.1	32.3	32.5	30.1	30.4	32.3	32.9	33.3	34.2	32.4	32.9	34.2	33.9	33.8	34.5	34.3	33.1	33.1	32.7	27.1	31.4	31.1	24.6	30.7
12.00	30.3	31.0	31.8	30.6	30.8	31.4	31.6	31.6	31.8	28.0	28.8	31.7	32.0	32.6	33.8	31.6	32.0	33.6	33.2	33.1	34.4	33.6	32.6	32.6	32.4	23.6	30.6	29.0	23.0	30.0
13.00	28.9	29.9	29.1	29.5	30.1	30.7	30.7	30.7	30.5	27.5	28.1	30.3	31.2	31.8	32.6	30.9	31.3	32.8	32.7	32.3	33.5	32.7	32.0	31.9	29.8	24.2	28.7	27.7	23.1	28.7
14.00	27.6	28.9	26.3	28.5	29.3	30.1	29.9	29.9	29.3	26.9	27.3	29.0	30.4	31.0	31.4	30.2	30.7	32.0	32.1	31.4	32.6	31.7	31.5	31.3	27.1	24.9	26.7	26.3	23.2	27.3
15.00	26.2	27.8	23.6	27.4	28.6	29.4	29.0	29.0	28.0	26.4	26.6	27.6	29.6	31.2	30.2	29.5	31.0	31.2	31.6	30.6	31.7	30.8	30.9	30.6	24.5	25.5	24.8	25.0	23.3	26.0
16.00	25.7	27.7	23.3	26.7	28.2	28.6	28.1	28.3	27.8	26.3	26.4	27.1	29.0	29.7	29.5	28.9	29.4	30.6	31.1	28.7	31.1	30.4	30.2	30.0	24.9	25.3	24.8	25.0	23.5	24.5
17.00	25.2	27.5	22.9	25.9	27.8	27.8	27.3	27.7	27.6	26.1	26.2	26.7	28.4	29.2	28.9	28.4	28.8	29.9	30.5	26.9	30.6	29.9	29.5	29.3	25.2	25.2	24.8	25.0	23.7	23.1
18.00	24.7	27.4	22.6	25.2	27.4	27.0	26.4	27.0	27.4	26.0	26.0	26.2	27.8	28.7	28.2	27.8	28.2	29.3	30.0	25.0	30.0	29.5	28.8	28.7	25.6	25.0	24.8	25.0	23.9	21.6
19.00	24.3	26.7	21.9	24.8	27.0	26.7	26.3	26.8	27.2	26.0	25.9	25.3	27.5	28.4	27.8	27.7	26.5	28.9	29.7	24.8	29.3	29.0	28.2	28.1	25.5	24.9	24.7	24.7	23.6	21.6
20.00	23.8	26.1	21.3	24.4	26.6	26.3	26.2	26.7	27.1	26.0	25.9	24.5	27.1	28.1	27.4	27.5	24.7	28.4	29.5	24.6	28.7	28.5	27.6	27.4	25.5	24.7	24.7	24.3	23.3	21.6
21.00	23.4	25.4	20.6	24.0	26.2	26.0	26.1	26.5	26.9	26.0	25.8	23.6	26.8	27.8	27.0	27.4	23.0	28.0	29.2	24.4	28.0	28.0	27.0	26.8	25.4	24.6	24.6	24.0	23.0	21.6
22.00	22.8	24.7	21.7	24.6	25.3	24.9	25.2	26.1	28.3	26.7	26.3	25.3	26.2	26.4	26.6	27.3	23.4	25.9	28.8	24.0	26.8	28.0	26.3	26.8	26.0	25.9	25.1	25.7	24.9	23.8
23.00	22.2	24.1	22.9	25.2	24.5	23.7	24.3	25.6	29.8	27.5	26.9	27.1	25.6	24.9	26.3	27.3	23.8	23.9	28.4	23.7	25.6	28.0	25.7	26.8	26.7	27.3	25.7	27.3	26.7	26.0

Hourly Dry Bulb Temperature (°C)

Source. Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month: May

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	21.6	23.4	24.0	25.8	23.6	22.6	23.4	25.2	31.2	28.2	27.4	28.8	25.0	23.5	25.9	27.2	24.2	21.8	28.0	23.3	24.4	28.0	25.0	26.8	27.3	28.6	26.2	29.0	28.6	28.2	28.4
1:00	23.6	25.3	25.6	26.3	25.8	24.1	25.1	24.6	29.5	29.1	28.5	28.7	26.7	25.3	25.9	28.6	25.5	23.4	28.8	24.7	24.9	26.2	26.2	27.9	27.9	29.3	27.8	29.8	29.5	29.1	29.6
2:00	25.6	27.1	27.2	26.7	28.0	25.5	26.9	23.9	27.7	29.9	29.5	28.5	28.3	27.2	26.0	30.1	26.9	25.0	29.6	26.1	25.5	24.4	27.4	28.9	28.4	30.1	29.4	30.5	30.3	29.9	30.8
3:00	27.6	29.0	28.8	27.2	30.2	27.0	28.6	23.3	26.0	30.8	30.6	28.4	30.0	29.0	26.0	31.5	28.2	26.6	30.4	27.5	26.0	22.6	28.6	30.0	29.0	30.8	31.0	31.3	31.2	30.8	32.0
4:00	28.9	29.7	29.9	27.3	27.1	28.0	29.6	25.1	26.7	31.8	31.7	29.9	31.3	30.3	27.0	32.3	28.8	28.2	31.0	28.6	27.3	22.8	28.2	29.4	30.3	31.8	32.2	32.1	32.0	31.9	32.8
5:00	30.1	30.5	30.9	27.3	24.1	29.0	30.6	26.8	27.3	32.8	32.9	31.4	32.5	31.7	28.0	33.0	29.4	29.7	31.6	29.7	28.7	23.0	27.8	28.8	31.7	32.8	33.4	32.8	32.8	32.9	33.6
6:00	31.4	31.2	32.0	27.4	21.0	30.0	31.6	28.6	28.0	33.8	34.0	32.9	33.8	33.0	29.0	33.8	30.0	31.3	32.2	30.8	30.0	23.2	27.4	28.2	33.0	33.8	34.6	33.6	33.6	34.0	34.4
7:00	31.6	31.5	32.4	27.6	24.2	30.4	31.9	29.2	29.1	34.5	34.7	33.5	34.2	33.7	29.7	34.3	30.7	32.1	29.8	29.3	30.6	24.5	28.0	28.7	33.7	34.2	34.8	34.2	34.1	34.3	34.5
8:00	31.8	31.7	32.8	27.7	27.4	30.8	32.3	29.8	30.1	35.1	35.5	34.0	34.6	34.3	30.3	34.7	31.3	33.0	27.4	27.9	31.2	25.7	28.7	29.2	34.3	34.6	35.0	34.7	34.5	34.7	34.7
9:00	32.0	32.0	33.2	27.9	30.6	31.2	32.6	30.4	31.2	35.8	36.2	34.6	35.0	35.0	31.0	35.2	32.0	33.8	25.0	26.4	31.8	27.0	29.3	29.7	35.0	35.0	35.2	35.3	35.0	35.0	34.8
10:00	29.7	31.1	32.5	28.0	28.5	30.7	31.9	29.5	31.3	33.9	35.7	31.1	34.4	34.3	30.3	34.7	28.4	33.3	25.1	26.1	30.5	27.0	29.1	29.7	34.1	34.4	34.5	34.9	34.5	34.7	34.5
11:00	27.5	30.1	31.9	28.1	26.5	30.1	31.3	28.7	31.3	31.9	35.1	27.5	33.8	33.7	29.7	34.3	24.8	32.9	25.1	25.7	29.3	27.0	28.8	29.6	33.3	33.9	33.9	34.4	33.9	34.5	34.1
12:00	25.2	29.2	31.2	28.2	24.4	29.6	30.6	27.8	31.4	30.0	34.6	24.0	33.2	33.0	29.0	33.8	21.2	32.4	25.2	25.4	28.0	27.0	28.6	29.6	32.4	33.3	33.2	34.0	33.4	34.2	33.8
13:00	25.0	28.6	29.5	27.7	24.5	29.0	29.9	27.0	30.7	29.1	33.3	23.7	29.4	31.5	28.5	32.9	21.7	31.6	25.0	25.3	27.9	26.7	28.4	29.1	31.9	32.5	32.3	33.0	32.9	33.4	33.1
14:00	24.7	28.1	27.7	27.1	24.6	28.3	29.1	26.2	30.1	28.1	32.1	23.5	25.5	30.1	27.9	32.1	22.3	30.8	24.7	25.1	27.8	26.3	28.1	28.5	31.3	31.6	31.5	32.0	32.4	32.7	32.5
15:00	24.5	27.5	26.0	26.6	24.7	27.7	28.4	25.4	29.4	27.2	30.8	23.2	21.7	28.6	27.4	31.2	22.8	30.0	24.5	25.0	27.7	26.0	27.9	28.0	30.8	30.8	30.6	31.0	31.9	31.9	31.8
16:00	24.0	27.3	26.2	26.3	24.6	27.1	27.8	25.6	28.9	27.1	30.4	24.0	22.5	28.5	27.1	30.5	22.9	29.7	24.3	25.1	27.9	25.9	27.8	27.9	30.4	30.3	30.1	30.5	31.3	31.4	31.3
17:00	23.5	27.0	26.4	26.1	24.5	26.4	27.3	25.8	28.5	26.9	29.9	24.8	23.2	28.3	26.7	29.7	22.9	29.5	24.0	25.3	28.0	25.7	27.7	27.9	30.0	29.9	29.7	29.9	30.6	30.8	30.7
18:00	23.0	26.8	26.6	25.8	24.4	25.8	26.7	26.0	28.0	26.8	29.5	25.6	24.0	28.2	26.4	29.0	23.0	29.2	23.8	25.4	28.2	25.6	27.6	27.8	29.6	29.4	29.2	29.4	30.0	30.3	30.2
19:00	23.0	26.4	26.4	24.8	23.9	25.4	26.4	25.9	28.0	26.9	29.3	25.7	24.0	27.3	26.7	26.7	22.8	28.9	23.6	25.3	28.2	25.5	27.5	27.8	29.2	28.5	29.1	29.2	29.7	29.7	30.0
20:00	23.0	25.9	26.2	23.8	23.3	24.9	26.1	25.7	28.0	26.9	29.2	25.7	24.0	26.5	26.9	24.3	22.6	28.5	23.5	25.1	28.2	25.4	27.5	27.8	28.8	27.7	29.1	29.0	29.3	29.2	29.7
21:00	23.0	25.5	26.0	22.8	22.8	24.5	25.8	25.6	28.0	27.0	29.0	25.8	24.0	25.6	27.2	22.0	22.4	28.2	23.3	25.0	28.2	25.3	27.4	27.8	28.4	26.8	29.0	28.8	29.0	28.6	29.5
22:00	24.9	26.8	27.1	23.5	24.0	25.0	26.6	25.9	28.5	27.6	29.0	26.7	25.9	26.2	27.1	24.4	24.1	28.5	25.2	26.3	28.4	26.4	27.7	27.8	27.9	26.9	28.0	27.7	28.0	27.9	19.7
23:00	26.9	28.2	28.3	24.3	25.2	25.5	27.4	26.1	29.0	28.2	29.0	27.6	27.7	26.9	27.1	26.8	25.7	28.9	27.1	27.5	28.6	27.5	27.9	27.8	27.5	27.1	27.0	26.5	27.0	27.1	9.8

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: June

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0:00	28.8	29.5	29.4	25.0	26.4	26.0	28.2	26.4	29.5	28.8	29.0	28.5	29.6	27.5	27.0
1:00	29.9	30.3	30.1	26.3	27.8	27.7	29.4	28.0	30.6	29.9	29.8	29.3	30.4	28.8	26.5
2:00	30.9	31.2	30.9	27.7	29.1	29.4	30.6	29.6	31.7	30.9	30.6	30.0	31.2	30.1	26.1
3:00	32.0	32.0	31.6	29.0	30.5	31.1	31.8	31.2	32.8	32.0	31.4	30.8	32.0	31.4	25.6
4:00	32.7	32.9	32.6	30.2	31.3	31.5	32.2	31.9	33.7	33.1	32.5	31.9	31.0	32.1	26.4
5:00	33.5	33.7	33.7	31.3	32.2	31.9	32.6	32.5	34.6	34.1	33.5	33.1	30.0	32.9	27.2
6:00	34.2	34.6	34.7	32.5	33.0	32.3	33.0	33.2	35.5	35.2	34.6	34.2	29.0	33.6	28.0
7:00	34.5	35.2	34.9	32.7	33.8	33.1	33.9	33.8	34.8	35.3	34.6	34.5	29.3	33.5	29.2
8:00	34.9	35.8	35.1	32.8	34.6	34.0	34.7	34.4	34.1	35.5	34.6	34.7	29.7	33.5	30.3
9:00	35.2	36.4	35.3	33.0	35.4	34.8	35.6	35.0	33.4	35.6	34.6	35.0	30.0	33.4	31.5
10:00	34.6	35.6	34.8	32.5	31.2	34.3	35.2	34.7	32.6	35.1	33.7	34.4	29.6	30.6	31.4
11:00	34.0	34.8	34.4	31.9	27.0	33.9	34.7	34.5	31.7	34.5	32.9	33.9	29.2	27.8	31.3
12:00	33.4	34.0	33.9	31.4	22.8	33.4	34.3	34.2	30.9	34.0	32.0	33.3	28.8	25.0	31.2
13:00	32.7	33.1	33.2	30.8	23.6	32.5	31.1	33.5	30.5	31.9	31.3	32.5	28.5	25.2	30.9
14:00	31.9	32.3	32.4	30.3	24.4	31.5	27.9	32.7	30.0	29.9	30.5	31.8	28.2	25.5	30.5
15:00	31.2	31.4	31.7	29.7	25.2	30.6	24.7	32.0	29.6	27.8	29.8	31.0	27.9	25.7	30.2
16:00	30.7	30.9	31.1	28.6	25.2	30.4	25.2	31.5	29.7	28.3	29.6	30.7	27.7	25.9	30.0
17:00	30.3	30.5	30.6	27.5	25.2	30.2	25.7	31.1	29.7	28.9	29.4	30.3	27.4	26.1	29.8
18:00	29.8	30.0	30.0	26.4	25.2	30.0	26.2	30.6	29.8	29.4	29.2	30.0	27.2	26.3	29.6
19:00	29.7	29.8	29.3	26.3	25.4	29.6	26.1	30.4	29.5	29.1	29.0	29.9	27.1	26.4	29.4
20:00	29.7	29.6	28.7	26.3	25.6	29.2	26.1	30.2	29.3	28.9	28.8	29.9	26.9	26.4	29.2
21:00	29.6	29.4	28.0	26.2	25.8	28.8	26.0	30.0	29.0	28.6	28.6	29.8	26.8	26.5	29.0
22:00	28.6	28.2	26.9	26.1	25.9	27.8	26.4	29.2	28.5	28.3	27.8	29.0	27.1	26.1	27.6
23:00	27.5	27.0	25.8	26.1	26.1	26.9	26.8	28.4	28.1	27.9	27.1	28.3	27.3	25.8	26.2

Day / Time	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0:00	29.2	27.4	29.2	29.0	28.8	28.8	28.6	28.2	27.8	27.0	27.2	26.0	25.4	26.0	26.4
1:00	29.9	28.5	30.2	29.8	29.7	29.5	29.4	28.7	28.9	27.8	27.8	26.7	25.5	26.5	26.7
2:00	30.5	29.5	31.1	30.7	30.5	30.3	30.2	29.3	29.9	28.5	28.4	27.5	25.7	26.9	27.1
3:00	31.2	30.6	32.1	31.5	31.4	31.0	31.0	29.8	31.0	29.3	29.0	28.2	25.8	27.4	27.4
4:00	29.6	31.3	32.9	32.0	32.1	31.8	30.3	29.5	31.3	29.2	30.0	28.5	26.0	27.3	27.9
5:00	28.0	32.1	33.6	32.5	32.7	32.7	29.5	29.3	31.7	29.1	31.0	28.8	26.1	27.1	28.5
6:00	26.4	32.8	34.4	33.0	33.4	33.5	28.8	29.0	32.0	29.0	32.0	29.1	26.3	27.0	29.0
7:00	26.8	33.0	34.6	33.1	33.7	33.9	28.4	29.3	30.0	29.0	31.3	28.7	26.2	27.1	28.5
8:00	27.2	33.3	34.9	33.3	33.9	34.2	27.9	29.5	27.9	28.9	30.7	28.4	26.1	27.3	27.9
9:00	27.6	33.5	35.1	33.4	34.2	34.6	27.5	29.8	25.9	28.9	30.0	28.0	26.0	27.4	27.4
10:00	27.5	33.1	34.4	32.9	33.7	33.4	28.1	29.7	26.3	29.2	29.9	27.7	26.4	27.5	27.4
11:00	27.5	32.7	33.7	32.3	33.1	32.2	28.8	29.5	26.8	29.5	29.9	27.5	26.9	27.5	27.3
12:00	27.4	32.5	33.0	31.8	32.6	31.0	29.4	29.4	27.2	29.8	29.8	27.2	27.3	27.6	27.3
13:00	27.5	31.7	32.3	31.2	32.0	30.9	29.1	29.0	27.1	29.1	29.5	26.9	27.1	27.3	27.1
14:00	27.5	31.2	31.7	30.6	31.4	30.7	28.9	28.7	27.1	28.5	29.1	26.6	26.8	27.1	27.0
15:00	27.6	30.6	31.0	30.0	30.8	30.6	28.6	28.3	27.0	27.8	28.8	26.3	26.6	26.8	26.8
16:00	27.6	30.4	30.8	29.8	30.5	30.3	28.5	28.2	27.0	27.7	28.5	26.3	26.4	26.7	26.7
17:00	27.5	30.2	30.5	29.6	30.1	29.9	28.3	28.1	27.0	27.6	28.1	26.2	26.2	26.7	26.7
18:00	27.5	30.0	30.3	29.4	29.8	29.6	28.2	28.0	27.0	27.5	27.8	26.2	26.0	26.6	26.6
19:00	27.5	29.9	30.0	29.2	29.5	29.4	28.2	27.9	26.9	27.4	27.6	26.1	25.9	26.4	26.5
20:00	27.5	29.7	29.7	29.0	29.3	29.1	28.2	27.9	26.7	27.3	27.4	25.9	25.7	26.2	26.5
21:00	27.5	29.6	29.4	28.8	29.0	28.9	28.2	27.8	26.6	27.2	27.2	25.8	25.6	26.0	26.4
22:00	27.1	28.6	28.8	28.5	28.6	28.1	27.6	27.7	26.8	27.2	27.5	26.4	26.1	26.5	26.7
23:00	26.8	27.6	28.2	28.3	28.1	27.2	27.0	27.6	27.0	27.3	27.7	27.0	26.7	27.1	26.9

Hourly Dry Bulb Temperature (°C)

Source. Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month. July

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0.00	26.5	25.8	24.7	26.0	26.2	25.9	27.2	27.6	27.6	27.6	26.3	27.5	27.6	25.4	24.8	26.4	26.6	27.6	28.0	27.7	26.4	26.4	27.5	27.2	27.3	28.0	27.6	27.2	27.6	27.2	28.0
1.00	27.3	26.2	24.8	26.2	25.8	27.1	28.0	28.5	28.0	27.7	26.8	28.0	27.5	25.5	25.0	27.0	27.6	28.1	28.7	28.4	27.7	26.4	27.9	27.8	28.4	28.9	27.5	27.8	28.3	28.1	28.9
2.00	28.1	26.6	24.9	26.3	25.4	28.3	28.8	29.5	28.4	27.9	27.2	28.5	27.3	25.5	25.2	27.6	28.6	28.5	29.5	29.1	29.1	26.5	28.3	28.4	29.5	29.7	27.5	28.4	29.0	28.9	29.7
3.00	28.9	27.0	25.0	26.5	25.0	29.5	29.6	30.4	28.8	28.0	27.7	29.0	27.2	25.6	25.4	28.2	29.6	29.0	30.2	29.8	30.4	26.5	28.7	29.0	30.6	30.6	27.4	29.0	29.7	29.8	30.6
4.00	27.9	27.3	25.1	26.8	25.7	30.4	30.4	31.0	29.7	28.4	27.3	29.9	27.2	25.9	25.4	28.9	30.3	29.5	30.8	30.5	30.5	27.7	29.6	30.1	31.2	30.7	28.4	29.7	30.4	30.7	31.1
5.00	27.0	27.5	25.2	27.1	26.3	31.3	31.2	31.6	30.7	28.8	27.0	30.9	27.2	26.3	25.5	29.7	31.1	30.0	31.4	31.3	30.5	28.8	30.6	31.1	31.8	30.7	29.4	30.5	31.0	31.6	31.5
6.00	26.0	27.8	25.3	27.4	27.0	32.2	32.0	32.2	31.6	29.2	26.6	31.8	27.2	26.6	25.5	30.4	31.8	30.5	32.0	32.0	30.6	30.0	31.5	32.2	32.4	30.8	30.4	31.2	31.7	32.5	32.0
7.00	26.7	27.7	25.6	27.0	27.7	32.3	32.1	32.2	30.7	29.3	27.2	31.3	26.7	27.0	25.8	30.6	32.3	31.0	32.1	31.2	31.1	30.4	31.4	32.5	32.3	30.9	31.3	31.5	32.3	31.7	32.1
8.00	27.3	27.5	26.0	26.7	28.3	32.5	32.3	32.2	29.7	29.3	27.9	30.7	26.3	27.4	26.0	30.8	32.9	31.5	32.3	30.3	31.5	30.8	31.3	32.7	32.3	31.1	32.3	31.7	32.8	30.8	32.1
9.00	28.0	27.4	26.3	26.3	29.0	32.6	32.4	32.2	28.8	29.4	28.5	30.2	25.8	27.8	26.3	31.0	33.3	32.0	32.4	29.5	32.0	31.2	31.2	33.0	32.2	31.2	33.2	32.0	33.4	30.0	32.2
10.00	28.1	27.2	26.5	26.8	28.8	32.5	32.6	31.7	29.2	29.6	28.5	29.9	25.9	27.5	26.4	30.9	32.5	32.0	32.2	28.7	31.8	30.9	31.2	32.6	32.0	30.9	32.1	31.7	32.0	30.2	32.1
11.00	28.1	27.0	26.6	27.4	28.7	32.3	32.8	31.3	29.6	29.8	28.4	29.5	25.9	27.1	26.4	30.8	31.8	32.0	32.0	28.0	31.6	30.5	31.2	32.2	31.8	30.7	31.1	31.5	30.6	30.4	32.1
12.00	28.2	26.8	26.8	27.9	28.5	32.2	33.0	30.8	30.0	30.0	28.4	29.2	26.0	26.8	26.5	30.7	31.0	32.0	31.8	27.2	31.4	30.2	31.2	31.8	31.6	30.4	31.0	31.2	29.2	30.6	32.0
13.00	27.7	26.7	26.4	27.7	28.0	31.5	31.8	30.3	29.6	29.5	28.3	29.1	26.1	26.7	26.3	29.7	30.3	31.2	31.1	27.3	30.8	29.8	30.7	31.1	30.9	30.0	29.7	30.8	29.2	30.1	31.3
14.00	27.3	26.7	26.0	27.4	27.6	30.8	30.6	29.7	29.2	29.1	28.1	28.9	26.1	26.5	26.2	28.8	29.7	30.3	30.5	27.5	30.3	29.4	30.3	30.5	30.1	29.6	29.5	30.4	29.1	29.7	30.7
15.00	26.8	26.6	25.6	27.2	27.1	30.1	29.4	29.2	28.8	28.6	28.0	28.8	26.2	26.4	26.0	27.8	29.0	29.5	29.8	27.6	29.7	29.0	29.8	29.8	29.4	29.2	29.2	30.0	29.1	29.2	30.0
16.00	26.7	26.6	25.5	27.1	26.7	29.7	29.3	29.0	28.6	28.5	28.0	28.7	26.1	26.3	26.0	27.6	28.9	29.2	28.4	27.4	29.4	28.8	29.5	28.9	29.3	29.1	29.1	29.6	29.0	29.0	29.7
17.00	26.5	26.6	25.5	26.9	26.4	29.4	29.1	28.8	28.4	28.3	28.0	28.5	26.1	26.3	26.0	27.4	28.7	28.8	27.0	27.2	29.1	28.7	29.1	28.1	29.3	28.9	28.9	29.2	28.9	28.8	29.3
18.00	26.4	26.6	25.4	26.8	26.0	29.0	29.0	28.6	28.2	28.2	28.0	28.4	26.0	26.2	26.0	27.2	28.6	28.5	25.6	27.0	28.8	28.5	28.8	27.2	29.2	28.8	28.8	28.8	28.8	28.6	29.0
19.00	26.5	26.4	25.5	26.7	25.9	28.5	28.5	28.3	28.0	28.1	27.9	28.3	25.9	26.0	26.0	27.1	28.4	28.4	25.7	26.9	27.7	28.3	28.4	27.0	28.9	28.5	28.4	28.6	28.5	28.5	28.7
20.00	26.3	26.1	25.7	26.7	25.9	27.9	27.9	28.1	27.8	27.9	27.9	28.1	25.9	25.8	26.0	26.9	28.2	28.3	25.9	26.7	26.5	28.2	27.9	26.8	28.7	28.1	28.0	28.4	28.3	28.4	28.5
21.00	26.6	25.9	25.8	26.6	25.8	27.4	27.4	27.8	27.6	27.8	27.8	28.0	25.8	25.6	26.0	26.8	28.0	28.2	26.0	26.6	25.4	28.0	27.5	26.6	28.4	27.8	27.6	28.2	28.0	28.3	28.2
22.00	27.1	27.0	26.1	26.8	26.3	27.3	27.4	27.7	27.2	27.5	27.3	27.7	26.5	26.5	26.5	26.8	27.7	27.8	26.3	26.9	25.9	27.6	27.7	26.8	27.7	27.5	27.5	27.8	28.1	28.2	28.3
23.00	27.7	28.2	26.5	27.0	26.7	27.1	27.4	27.7	26.9	27.3	26.9	27.3	27.1	27.4	26.9	26.8	27.5	27.4	26.7	27.1	26.3	27.1	28.0	27.0	26.9	27.3	27.5	27.4	28.3	28.1	28.5

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: August

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0:00	28.2	29.3	26.8	27.2	27.2	27.0	27.4	27.6	26.5	27.0	26.4	27.0	27.8	28.3	27.4	26.8	27.2	27.0	27.0	27.4	26.8	26.7	28.2	27.2	26.2	27.0	27.4	27.0	28.4	28.0	28.6
1:00	29.0	29.1	27.6	27.6	27.8	27.5	27.9	28.2	26.8	27.0	26.6	26.8	28.4	28.7	27.9	27.2	28.1	27.2	27.5	28.2	27.3	27.1	28.6	27.7	26.6	27.7	28.2	27.7	29.4	29.0	29.5
2:00	29.7	28.8	28.4	28.0	28.4	28.0	28.5	28.9	27.1	27.0	26.8	26.7	29.0	29.1	28.3	27.6	28.9	27.3	28.1	28.9	27.7	27.6	29.1	28.3	27.1	28.3	29.0	28.3	30.4	30.0	30.3
3:00	30.5	28.6	29.2	28.4	29.0	28.5	29.0	29.5	27.4	27.0	27.0	26.5	29.6	29.5	28.8	28.0	29.8	27.5	28.6	29.7	28.2	28.0	29.5	28.8	27.5	29.0	29.8	29.0	31.4	31.0	31.2
4:00	31.4	29.9	29.7	28.9	29.9	29.0	29.0	29.7	27.3	27.5	27.7	27.4	30.2	30.0	29.5	29.2	30.2	28.0	28.5	30.1	28.8	28.9	29.8	29.0	27.9	29.8	30.1	30.0	31.7	31.7	29.9
5:00	32.3	31.1	30.2	29.5	30.7	29.5	30.7	29.8	27.3	27.9	28.5	28.3	30.8	30.4	30.1	30.3	30.6	28.5	28.3	30.6	29.4	29.9	30.1	29.2	28.2	30.7	30.4	31.0	31.9	32.3	28.7
6:00	33.2	32.4	30.7	30.0	31.6	30.0	31.6	30.0	27.2	28.4	29.2	29.2	31.4	30.9	30.8	31.5	31.0	29.0	28.2	31.0	30.0	30.8	30.4	29.4	28.6	31.5	30.7	32.0	32.2	33.0	27.4
7:00	33.4	32.8	31.1	30.3	31.3	29.9	31.8	29.0	28.3	28.9	29.7	30.1	31.7	30.9	30.8	30.5	31.4	29.5	28.8	29.7	29.5	29.8	30.9	29.5	29.0	31.8	30.1	32.4	32.2	33.0	28.5
8:00	33.5	33.3	31.4	30.5	31.1	29.7	32.0	28.0	29.5	29.3	30.2	30.9	32.1	31.0	30.8	29.6	31.8	30.1	29.4	28.3	29.0	28.8	31.3	29.7	29.4	32.0	29.6	32.7	32.2	33.0	29.7
9:00	33.7	33.7	31.8	30.8	30.8	29.6	32.2	27.0	30.6	29.8	30.7	31.8	32.4	31.0	30.8	28.6	32.2	30.6	30.0	27.0	28.5	27.8	31.8	29.8	29.8	32.3	29.0	33.1	32.2	33.0	30.8
10:00	33.4	32.7	31.3	29.6	29.9	29.4	31.5	27.7	30.2	29.7	30.7	31.1	32.3	30.7	30.7	29.1	32.0	30.7	30.0	27.3	28.2	28.3	30.9	29.5	29.6	31.0	29.1	32.6	31.9	32.5	30.7
11:00	33.0	31.7	30.7	28.4	29.0	29.2	30.9	28.3	29.9	29.7	30.8	30.3	32.3	30.3	30.7	29.6	31.8	30.7	30.0	27.7	27.9	28.7	29.9	29.1	29.4	29.6	29.1	32.1	31.7	32.1	30.6
12:00	32.7	30.7	30.2	27.2	28.1	29.0	30.2	29.0	29.5	29.6	30.8	29.6	32.2	30.0	30.6	30.1	31.6	30.8	30.0	28.0	27.6	29.2	29.0	28.8	29.2	28.3	29.2	31.6	31.4	31.6	30.5
13:00	32.1	30.4	29.8	27.4	28.2	28.7	29.6	28.8	29.2	29.0	30.0	29.4	31.3	29.6	29.9	29.8	31.0	30.3	29.7	27.9	27.6	28.7	28.8	27.7	28.7	28.1	28.7	31.0	30.9	31.1	30.1
14:00	31.6	30.0	29.4	27.6	28.3	28.4	29.0	28.7	28.9	28.3	29.3	29.2	30.7	29.3	29.3	29.5	30.3	29.7	29.3	27.7	27.5	28.2	28.6	26.5	28.2	28.0	28.1	30.4	30.5	30.5	29.8
15:00	31.0	29.7	29.0	27.8	28.4	28.1	28.4	28.5	28.6	27.7	28.5	29.0	30.0	28.9	28.6	29.2	29.7	29.2	29.0	27.6	27.5	27.7	28.4	25.4	27.7	27.8	27.6	29.8	30.0	30.0	29.4
16:00	30.7	29.5	28.6	27.8	28.3	28.0	28.4	28.5	28.5	27.7	28.3	28.9	29.8	28.6	28.4	28.9	29.5	29.1	28.7	27.5	27.5	27.8	28.3	25.5	27.5	27.7	27.5	29.5	29.7	29.9	29.5
17:00	30.3	29.2	28.2	27.8	28.1	27.9	28.3	28.4	28.3	27.8	28.2	28.7	29.6	28.3	28.2	28.7	29.2	28.9	28.3	27.5	27.4	28.0	28.1	25.7	27.4	27.7	27.4	29.3	29.5	29.7	29.5
18:00	30.0	29.0	27.8	27.8	28.0	27.8	28.3	28.4	28.2	27.8	28.0	28.6	29.4	28.0	28.0	28.4	29.0	28.8	28.0	27.4	27.4	28.1	28.0	25.8	27.2	27.6	27.3	29.0	29.2	29.6	29.6
19:00	29.9	28.7	27.7	27.7	27.7	27.7	28.1	28.1	28.1	27.5	27.7	28.5	29.3	28.0	27.6	28.1	28.7	28.5	27.9	27.3	27.3	28.1	27.8	25.9	27.1	27.5	27.3	28.9	29.0	29.4	29.3
20:00	29.7	28.3	27.6	27.5	27.3	27.5	28.0	27.8	28.1	27.3	27.3	28.4	29.1	28.0	27.2	27.7	28.3	28.3	27.7	27.1	27.1	28.0	27.7	25.9	27.1	27.5	27.2	28.7	28.8	29.2	29.1
21:00	29.6	28.0	27.5	27.4	27.0	27.4	27.8	27.5	28.0	27.0	27.0	28.3	29.0	28.0	26.8	27.4	28.0	28.0	27.6	27.0	27.0	28.0	27.5	26.0	27.0	27.4	27.2	28.6	28.6	29.0	28.8
22:00	29.0	28.0	27.6	27.6	27.0	27.1	27.8	27.1	27.5	26.1	26.7	27.9	28.3	27.5	26.7	27.4	27.7	28.1	27.7	26.3	26.7	27.5	27.2	25.5	27.1	26.8	27.2	27.8	27.7	28.4	19.2
23:00	28.4	28.0	27.7	27.8	27.0	26.7	27.7	26.6	26.9	25.1	26.5	27.6	27.5	26.9	26.5	27.4	27.3	28.1	27.7	25.7	26.3	27.1	26.9	25.1	27.1	26.1	27.2	27.0	26.9	27.8	9.6

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: September

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0:00	27.8	28.0	27.8	28.0	27.0	26.4	27.7	26.2	26.4	24.2	26.2	27.2	26.8	26.4	26.4
1:00	29.0	28.9	28.5	28.8	28.1	28.1	29.0	26.9	27.2	25.4	26.9	28.4	27.3	27.4	27.8
2:00	30.3	29.8	29.2	29.6	29.3	29.7	30.3	27.5	28.0	26.6	27.6	29.6	27.9	28.5	29.2
3:00	31.5	30.7	29.9	30.4	30.4	31.4	31.6	28.2	28.8	27.8	28.3	30.8	28.4	29.5	30.6
4:00	31.1	31.7	30.6	31.0	28.7	32.0	29.2	29.3	29.4	28.9	29.0	31.3	29.8	30.5	31.7
5:00	30.6	32.8	31.3	31.7	27.1	32.6	26.9	30.5	30.1	30.1	29.8	31.7	31.2	31.6	32.9
6:00	30.2	33.8	32.0	32.3	25.4	33.2	24.5	31.6	30.7	31.2	30.5	32.2	32.6	32.6	34.0
7:00	29.4	33.1	31.9	31.8	25.8	33.8	24.8	32.1	31.3	31.5	31.0	32.4	32.5	32.4	34.2
8:00	28.6	32.5	31.9	31.4	26.1	34.4	25.0	32.5	31.9	31.9	31.6	32.5	32.3	32.3	34.4
9:00	27.8	31.8	31.8	30.9	26.5	35.0	25.3	33.0	32.5	32.2	32.1	32.7	32.2	32.1	34.6
10:00	28.4	31.5	31.5	30.6	26.9	33.3	25.7	32.4	31.9	31.7	31.8	31.7	30.2	31.3	33.9
11:00	29.0	31.3	31.3	30.3	27.3	31.7	26.1	31.8	31.4	31.3	31.4	30.7	28.2	30.6	33.3
12:00	29.6	31.0	31.0	30.0	27.7	30.0	26.5	31.2	30.6	30.8	31.1	29.7	26.2	29.8	32.6
13:00	29.1	30.4	30.5	29.7	27.3	29.8	26.4	30.9	30.3	29.5	30.5	29.2	26.5	29.5	32.1
14:00	28.5	29.8	30.0	29.3	27.0	29.7	26.3	30.5	29.7	28.3	29.8	28.8	26.9	29.1	31.7
15:00	28.0	29.2	29.5	29.0	26.6	29.3	26.2	30.2	29.2	27.0	29.2	28.3	27.2	28.8	31.2
16:00	28.1	29.0	29.3	29.0	26.5	29.2	26.1	28.6	28.9	27.0	28.4	28.1	27.5	28.3	30.8
17:00	28.1	28.8	29.0	29.0	26.3	28.9	26.1	27.0	28.5	27.0	27.6	27.8	27.9	27.9	30.4
18:00	28.2	28.6	28.8	29.0	26.2	28.6	26.0	25.4	28.2	27.0	26.8	27.6	28.2	27.4	30.0
19:00	28.1	28.4	28.7	28.5	26.2	28.4	26.1	25.6	28.1	26.7	26.7	27.4	27.9	27.3	29.0
20:00	28.1	28.2	28.5	28.1	26.2	28.2	26.1	25.8	28.1	26.3	26.7	27.2	27.7	27.1	28.0
21:00	28.0	28.0	28.4	27.6	26.2	28.0	26.2	26.0	28.0	26.0	26.6	27.0	27.4	27.0	27.0
22:00	27.1	26.8	27.5	26.8	26.2	26.6	25.7	26.1	27.2	26.0	26.4	26.7	27.1	26.8	26.4
23:00	26.3	25.6	26.7	26.0	26.2	25.1	25.3	26.3	26.4	26.0	26.2	26.4	26.7	26.7	25.7

Day / Time	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0:00	27.4	27.0	28.2	27.8	25.0	26.0	26.6	26.6	24.6	27.2	25.5	27.2	26.2	26.0	27.2
1:00	28.8	28.0	29.1	29.2	26.3	26.9	27.7	27.5	25.1	27.9	26.6	28.5	27.7	26.5	27.9
2:00	30.2	29.0	30.1	30.6	27.5	27.7	28.7	28.4	25.5	28.5	27.6	29.7	29.1	27.1	28.7
3:00	31.6	30.0	31.0	32.0	28.8	28.6	29.8	29.3	26.0	29.2	28.7	31.0	30.6	27.6	29.4
4:00	32.5	30.6	31.7	32.7	28.5	29.4	30.1	29.7	27.2	29.8	29.6	31.4	31.5	27.7	29.9
5:00	33.3	31.2	32.3	33.3	28.1	30.2	30.5	30.2	28.4	30.4	30.6	31.8	32.3	27.8	30.5
6:00	34.2	31.8	33.0	34.0	27.8	31.0	30.8	30.6	29.6	31.0	31.5	32.2	33.2	27.9	31.0
7:00	34.1	32.0	32.9	33.6	26.9	31.3	29.4	30.4	29.9	30.6	31.8	32.3	31.6	28.3	28.9
8:00	34.3	32.2	32.9	33.2	25.9	31.7	28.0	30.2	30.3	30.2	32.1	32.5	30.1	28.6	26.7
9:00	34.0	32.4	32.8	32.8	25.0	32.0	26.6	30.0	30.6	29.8	32.4	32.6	28.5	29.0	24.6
10:00	33.3	32.0	32.2	32.5	24.9	30.8	26.5	29.2	30.2	29.5	31.6	31.4	28.7	29.1	24.8
11:00	32.7	31.5	31.7	32.3	24.9	29.7	26.5	28.5	29.8	29.1	30.8	30.3	28.8	29.1	24.9
12:00	32.0	31.1	31.1	32.0	24.8	28.5	26.4	27.7	29.4	28.8	30.0	29.1	29.0	29.2	25.1
13:00	31.7	30.9	30.5	31.6	25.1	28.3	26.3	27.8	28.8	28.5	29.5	29.0	28.9	29.0	25.2
14:00	31.5	30.6	30.0	31.2	25.4	28.0	26.3	27.9	28.3	28.3	29.1	28.8	28.9	28.7	25.3
15:00	31.2	30.4	29.4	30.8	25.7	27.8	26.2	28.0	27.7	28.0	28.6	28.7	28.8	28.5	25.4
16:00	30.2	30.2	29.2	30.0	25.9	27.6	26.3	27.8	27.3	27.8	28.4	28.6	28.3	28.3	25.4
17:00	29.2	30.0	29.0	29.2	26.0	27.4	26.1	27.5	27.0	27.6	28.2	28.5	27.7	28.2	25.5
18:00	28.2	29.8	28.8	28.4	26.2	27.2	26.0	27.3	26.6	27.4	28.0	28.4	27.2	28.0	25.5
19:00	28.0	29.5	28.7	28.3	26.2	27.1	26.0	27.4	26.7	26.7	27.9	27.9	27.1	27.9	25.5
20:00	27.8	29.3	28.5	28.1	26.2	27.0	26.0	27.4	26.9	25.9	27.7	27.5	27.1	27.7	25.4
21:00	27.6	29.0	28.4	28.0	26.2	26.9	26.0	27.5	27.0	25.2	27.6	27.0	27.0	27.6	25.4
22:00	27.3	28.1	27.6	26.6	25.3	26.0	25.3	26.0	25.4	24.4	26.1	26.3	26.6	26.6	25.1
23:00	27.1	27.2	26.7	25.2	24.3	25.2	24.5	24.5	23.8	23.5	24.7	25.7	26.2	25.7	24.7

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: October

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	25.2	24.4	25.8	25.2	26.2	23.7	24.8	26.4	25.6	26.0	26.0	26.1	26.4	26.5	25.1	26.8	26.3	25.9	23.8	23.4	24.3	23.8	23.0	22.2	22.7	23.2	25.0	25.8	24.7	24.4	23.6
1:00	25.2	24.6	26.8	25.9	27.1	25.3	26.5	27.6	27.1	27.8	27.7	27.2	27.7	28.1	27.2	27.9	26.9	26.6	24.4	23.5	24.9	24.7	22.5	23.1	24.2	24.5	25.8	26.4	26.3	25.7	25.1
2:00	25.2	24.8	27.7	26.5	28.1	26.8	28.3	28.7	28.5	29.7	29.4	28.2	28.9	29.7	29.4	28.9	27.6	27.3	24.9	23.6	25.6	25.5	21.9	23.9	25.7	25.9	26.5	26.9	27.9	27.1	26.7
3:00	25.2	25.0	28.7	27.2	29.0	28.4	30.0	29.9	30.0	31.5	31.1	29.3	30.2	31.3	31.5	30.0	28.2	28.0	25.5	23.7	26.2	26.4	21.4	24.8	27.2	27.2	27.3	27.5	29.5	28.4	28.2
4:00	25.2	25.5	28.6	27.5	28.9	29.1	30.6	30.1	30.8	31.9	30.5	30.3	31.1	32.2	32.1	30.9	29.2	28.0	26.4	23.9	25.9	26.3	21.5	25.1	28.1	28.3	28.3	27.9	29.9	29.2	29.2
5:00	25.2	25.9	28.5	27.9	28.9	29.7	31.2	30.2	31.6	32.3	29.8	31.2	32.1	33.1	32.8	31.7	30.2	28.0	27.4	24.2	25.5	26.2	21.7	25.5	28.9	29.5	29.4	28.2	30.3	30.0	30.3
6:00	25.2	26.4	28.4	28.2	28.8	30.4	31.8	30.4	32.4	32.7	29.2	32.2	33.0	34.0	33.4	32.6	31.2	28.0	28.3	24.4	25.2	26.1	21.8	25.8	29.8	30.6	30.4	28.6	30.7	30.8	31.3
7:00	25.3	26.5	28.4	28.7	29.8	30.8	31.5	29.7	32.8	32.9	29.0	32.4	32.3	34.1	33.6	31.8	29.1	26.5	28.4	24.4	25.0	25.5	21.5	26.0	30.0	30.7	30.8	28.9	30.9	31.0	31.3
8:00	25.5	26.7	28.4	29.2	30.0	31.1	31.3	29.0	33.1	33.2	28.8	32.5	31.5	34.1	33.9	31.0	27.1	25.1	28.6	24.3	24.9	25.0	21.3	26.2	30.1	30.9	31.2	29.2	31.1	31.2	31.2
9:00	25.6	26.8	28.4	29.7	31.9	31.5	31.0	28.3	33.5	33.4	28.6	32.7	30.8	34.2	34.1	30.2	25.0	23.6	28.7	24.3	24.7	24.4	21.0	26.4	30.3	31.0	31.6	29.5	31.3	31.4	31.2
10:00	25.4	26.7	28.0	29.2	30.5	30.6	30.7	27.7	32.4	32.1	28.3	32.1	30.3	33.1	33.0	29.2	25.0	23.6	28.4	24.1	24.5	24.3	21.1	25.9	29.5	30.3	30.7	28.9	30.4	30.5	29.4
11:00	25.3	26.5	27.6	28.6	28.8	29.7	30.3	27.2	31.4	30.7	28.1	31.4	29.9	32.1	31.9	28.2	25.0	23.6	28.1	24.0	24.3	24.3	21.3	25.5	28.8	29.5	29.7	28.2	29.4	29.7	27.6
12:00	25.1	26.4	27.2	28.1	27.2	28.8	30.0	26.6	30.3	29.4	27.8	30.8	29.4	31.0	30.8	27.2	25.0	23.6	27.8	23.8	24.1	24.2	21.4	25.0	28.0	28.8	28.8	27.6	28.5	28.8	25.8
13:00	25.2	26.3	27.0	27.9	26.8	28.0	29.3	26.3	29.7	28.9	27.7	29.9	29.0	30.5	30.2	26.9	25.2	23.7	27.3	23.8	24.2	24.2	21.5	24.5	27.6	28.3	28.4	27.1	27.7	28.2	25.8
14:00	25.3	26.1	26.7	27.8	26.4	27.2	28.7	26.1	29.0	28.3	27.5	28.9	28.6	29.9	29.6	26.5	25.5	23.9	26.7	23.9	24.3	24.2	21.7	23.9	27.2	27.9	28.0	26.7	27.0	27.6	25.7
15:00	25.4	26.0	26.5	27.6	26.0	26.4	28.0	25.8	28.4	27.8	27.4	28.0	28.2	29.4	29.0	26.2	25.7	24.0	26.2	23.9	24.4	24.2	21.8	23.4	26.8	27.4	27.6	26.2	26.2	27.0	25.7
16:00	25.1	26.0	26.4	27.3	25.5	26.1	27.7	25.7	27.9	27.5	27.1	27.7	28.1	29.0	28.6	26.0	25.7	24.1	26.0	23.9	24.3	24.0	21.8	23.3	26.3	26.7	27.4	26.3	26.5	26.6	24.6
17:00	24.9	26.0	26.3	27.1	25.1	25.7	27.3	25.5	27.5	27.3	26.8	27.5	27.9	28.6	28.2	25.8	25.7	24.3	25.8	23.9	24.1	23.7	21.8	23.3	25.9	25.9	27.2	26.3	26.7	26.1	23.5
18:00	24.6	26.0	26.2	26.8	24.6	25.4	27.0	25.4	27.0	27.0	26.5	27.2	27.8	28.2	27.8	25.6	25.7	24.4	25.6	23.9	24.0	23.5	21.8	23.2	25.4	25.2	27.0	26.4	27.0	25.7	22.4
19:00	24.6	26.0	26.1	26.7	24.4	25.3	26.9	25.2	26.7	26.8	26.4	27.1	27.5	27.8	27.5	25.6	25.7	24.3	25.3	23.9	24.0	23.4	21.8	23.1	24.8	25.2	26.7	26.2	26.5	24.9	22.4
20:00	24.6	26.0	25.9	26.5	24.2	25.3	26.7	25.0	26.5	26.7	26.3	26.9	27.3	27.4	27.1	25.5	25.8	24.3	25.1	23.8	24.0	23.3	21.8	22.9	24.2	25.2	26.3	26.0	26.1	24.0	22.4
21:00	24.6	26.0	25.8	26.4	24.0	25.2	26.6	24.8	26.2	26.5	26.2	26.8	27.0	27.0	26.8	25.5	25.8	24.2	24.8	23.8	24.0	23.2	21.8	22.8	23.6	25.2	26.0	25.8	25.6	23.2	22.4
22:00	23.7	24.5	24.9	24.9	23.2	24.1	24.9	24.0	25.7	25.8	24.9	24.9	23.9	24.2	24.2	23.6	23.8	22.9	21.9	21.8	22.6	21.9	20.9	21.6	21.9	23.2	23.4	23.4	23.3	21.0	14.9
23:00	22.9	22.9	23.9	23.3	22.4	23.1	23.3	23.2	25.1	25.1	23.5	23.1	20.9	21.4	21.5	21.7	21.8	21.5	19.1	19.8	21.2	20.5	19.9	20.3	20.2	21.2	20.8	21.1	20.9	18.8	7.5

Hourly Dry Bulb Temperature (°C)

Source, Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: November

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
0:00	22.0	21.4	23.0	21.8	21.6	22.0	21.6	22.4	24.6	24.4	22.2	21.2	17.8	18.6	18.9	19.8	19.8	20.2	16.2	17.8	19.8	19.2	19.0	19.1	18.5	19.2	18.2	18.7	18.6	16.6
1:00	23.8	23.2	24.2	22.9	23.1	23.3	23.1	23.5	25.6	24.7	23.5	22.6	19.9	23.0	21.1	21.9	22.0	21.5	18.7	19.5	21.1	21.0	20.9	20.5	19.7	19.4	18.8	19.9	19.9	18.7
2:00	25.6	25.0	25.4	24.1	24.5	24.7	24.5	24.7	26.6	24.9	24.9	24.0	21.9	23.4	23.4	23.9	24.3	22.7	21.1	21.3	22.5	22.8	22.9	21.8	21.0	19.5	19.4	21.0	21.2	20.7
3:00	27.4	26.8	26.6	25.2	26.0	26.0	26.0	25.8	27.6	25.2	26.2	25.4	24.0	25.8	25.6	26.0	26.5	24.0	23.6	23.0	23.8	24.6	24.8	23.2	22.2	19.7	20.0	22.2	22.5	22.8
4:00	28.1	27.7	27.7	26.6	27.2	27.0	27.1	26.5	28.3	26.6	27.1	26.3	25.2	26.3	26.3	27.0	27.5	25.4	24.7	24.1	24.5	24.9	25.8	24.3	23.4	20.9	21.6	23.6	23.7	24.0
5:00	28.7	28.7	28.9	28.0	28.3	28.0	28.3	27.3	29.0	28.0	28.0	27.3	26.3	26.9	27.1	28.0	28.4	26.9	25.9	25.3	25.1	25.1	26.8	25.5	24.6	22.0	23.2	25.0	24.8	25.2
6:00	29.4	29.6	30.0	29.4	29.5	29.0	29.4	28.0	29.7	29.4	28.9	28.2	27.5	27.4	27.8	29.0	29.4	28.3	27.0	26.4	25.8	25.4	27.8	26.6	25.8	23.2	24.8	26.4	26.0	26.4
7:00	29.1	29.9	30.1	29.9	29.9	29.4	29.6	28.3	29.8	29.5	29.3	28.4	27.7	27.5	27.7	28.9	29.4	28.5	27.1	26.8	26.3	26.3	27.5	26.9	26.1	24.1	25.5	26.9	26.6	26.7
8:00	28.9	30.1	30.3	30.5	30.2	29.8	29.8	28.6	29.9	29.7	29.7	28.6	27.9	27.7	27.7	28.9	29.5	28.6	27.3	27.2	26.7	27.1	27.1	27.1	26.5	24.9	26.1	27.5	27.2	26.9
9:00	28.6	30.4	30.4	31.0	30.6	30.2	30.0	28.9	30.0	29.8	30.1	28.8	28.1	27.8	27.6	28.8	29.5	28.8	27.4	27.6	27.2	28.0	26.8	27.4	26.8	25.8	26.8	28.0	27.8	27.2
10:00	27.7	29.4	29.3	29.7	29.2	29.1	28.9	28.3	29.3	28.9	29.1	27.7	26.5	26.5	26.3	27.4	27.9	26.9	25.9	26.4	25.7	26.9	25.6	25.8	25.9	24.9	25.2	26.2	26.5	25.5
11:00	26.9	28.5	28.1	28.3	27.9	28.1	27.9	27.6	28.5	27.9	28.2	26.7	25.0	25.3	24.9	26.0	26.2	25.1	24.5	25.1	24.3	25.9	24.4	24.2	24.9	24.1	23.6	24.4	25.1	23.9
12:00	26.0	27.5	27.0	27.0	26.5	27.0	26.8	27.0	27.8	27.0	27.2	25.6	23.4	24.0	23.6	24.6	24.6	23.2	23.0	23.9	22.8	24.8	23.2	22.6	24.0	23.2	22.0	22.6	23.8	22.2
13:00	25.7	26.8	26.3	26.4	26.0	26.3	25.6	26.5	26.8	26.4	26.5	25.1	22.5	23.2	23.1	23.9	23.9	22.3	22.9	23.1	22.1	23.7	22.9	22.5	23.0	22.3	21.5	22.5	23.3	21.3
14:00	25.3	26.1	25.7	25.8	25.5	25.7	24.5	26.3	25.8	25.8	25.7	24.5	21.5	22.4	22.7	23.1	23.1	21.4	22.9	22.4	21.4	22.5	22.5	22.3	22.0	21.3	20.9	22.5	22.7	20.3
15:00	25.0	25.4	25.0	25.2	25.0	25.0	23.3	25.6	24.8	25.2	25.0	24.0	20.6	21.6	22.2	22.4	22.4	20.5	22.8	21.6	20.7	21.4	22.2	22.2	21.0	20.4	20.4	22.4	22.2	19.4
16:00	24.4	24.9	24.6	24.8	24.4	24.1	23.3	25.5	24.7	25.1	24.5	22.6	20.1	21.3	21.9	22.1	21.8	19.7	22.5	21.5	20.8	20.9	21.7	21.5	20.6	20.1	20.6	21.8	21.6	18.9
17:00	23.8	24.5	24.2	24.4	23.8	23.1	23.4	25.3	24.5	25.1	24.0	21.3	19.7	21.0	21.7	21.7	21.1	18.8	22.1	21.3	20.9	20.5	21.1	20.9	20.2	19.7	20.8	21.1	21.1	18.4
18:00	23.2	24.0	23.8	24.0	23.2	22.2	23.4	25.2	24.4	25.0	23.5	19.9	19.2	20.7	21.4	21.4	20.5	18.0	21.8	21.2	21.0	20.0	20.6	20.2	19.8	19.4	21.0	20.5	20.5	17.9
19:00	22.9	23.8	23.2	23.7	22.9	22.1	23.2	25.1	24.4	24.7	23.1	19.4	19.1	20.4	21.2	21.3	20.5	17.7	20.8	21.1	20.5	19.8	20.3	20.0	19.7	19.1	20.7	20.1	20.1	17.7
20:00	22.6	23.7	22.6	23.3	22.7	22.1	23.0	25.1	24.4	24.3	22.6	18.9	18.9	20.0	21.0	21.1	20.4	17.3	19.8	20.9	19.9	19.7	20.0	19.7	19.7	18.9	20.3	19.6	19.6	17.6
21:00	22.3	23.5	22.0	23.0	22.4	22.0	22.8	25.0	24.4	24.0	22.2	18.4	18.8	19.7	20.8	21.0	20.4	17.0	18.8	20.8	19.4	19.5	19.7	19.5	19.6	18.6	20.0	19.2	19.2	17.4
22:00	20.3	21.1	20.3	21.7	20.7	20.1	20.9	21.7	21.1	20.7	19.5	17.6	18.1	18.4	18.7	19.4	19.0	17.8	18.3	19.1	18.1	19.7	19.7	18.6	18.6	17.7	18.2	17.4	17.2	15.9
23:00	18.4	18.8	18.7	20.5	19.1	18.3	18.9	18.3	17.7	17.5	16.9	16.8	17.3	17.2	16.5	17.8	17.6	18.5	17.7	17.3	16.7	20.0	19.7	17.6	17.7	16.9	16.4	15.6	15.2	14.3

Hourly Dry Bulb Temperature (°C)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month, December

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.00	16.4	16.4	17.0	19.2	17.4	16.4	17.0	15.0	14.4	14.2	14.2	16.0	16.6	15.9	14.4	16.2
1.00	18.7	18.8	18.7	20.5	18.0	17.6	18.2	17.3	16.9	16.5	16.5	17.7	17.6	17.1	16.4	18.4
2.00	21.1	21.2	20.5	21.7	18.6	18.8	19.5	19.7	19.5	18.9	18.9	19.3	18.6	18.2	18.4	20.6
3.00	23.4	23.6	22.2	23.0	19.2	20.0	20.7	22.0	22.0	21.2	21.2	21.0	19.6	19.4	20.4	22.8
4.00	24.4	24.5	23.9	24.0	21.1	21.8	22.5	23.4	23.4	22.8	22.7	22.6	21.5	21.4	22.6	24.4
5.00	25.4	25.5	25.5	24.9	22.9	23.7	24.2	24.9	24.9	24.3	24.1	24.2	23.4	23.3	24.8	26.1
6.00	26.4	26.4	27.2	25.9	24.8	25.5	26.0	26.3	26.3	25.9	25.6	25.8	25.3	25.3	27.0	27.7
7.00	26.6	26.7	27.5	25.8	25.3	25.8	26.2	26.4	26.4	26.2	25.9	26.1	25.6	25.5	27.5	27.9
8.00	26.9	27.0	27.9	25.7	25.8	26.2	26.3	26.5	26.5	26.5	26.3	26.4	25.9	25.8	27.9	28.2
9.00	27.1	27.3	28.2	25.6	26.3	26.5	26.5	26.6	26.6	26.8	26.6	26.7	26.2	26.0	28.4	28.4
10.00	25.3	26.0	26.9	25.0	25.0	24.8	24.5	24.8	24.5	24.7	24.5	25.5	25.0	24.1	26.5	26.7
11.00	23.6	24.8	25.7	24.3	23.7	23.1	22.5	22.9	22.3	22.7	22.3	24.2	23.8	22.1	24.5	24.9
12.00	21.8	23.5	24.4	23.7	22.4	21.4	20.5	21.1	20.2	20.6	20.2	23.0	22.6	20.2	22.6	23.2
13.00	21.2	22.6	23.8	23.1	21.7	21.4	19.9	20.1	19.7	19.7	19.3	21.9	22.0	20.2	22.4	22.2
14.00	20.6	21.6	23.2	22.6	21.1	21.4	19.4	19.2	19.1	18.9	18.5	20.7	21.3	20.1	22.2	21.3
15.00	20.0	20.7	22.6	22.0	20.4	21.4	18.8	18.2	18.6	18.0	17.6	19.6	20.7	20.1	22.0	20.3
16.00	19.4	20.7	21.8	21.5	20.0	20.7	18.6	17.7	18.0	17.9	17.1	19.1	20.0	18.9	21.5	19.7
17.00	18.8	20.7	21.0	20.9	19.6	19.9	17.3	17.3	17.4	17.7	16.7	18.5	19.4	17.8	21.1	19.2
18.00	18.2	20.7	20.2	20.4	19.2	19.2	16.5	16.8	16.8	17.6	16.2	18.0	18.7	16.6	20.6	18.6
19.00	17.8	20.1	19.5	19.9	18.8	18.9	16.3	16.9	16.5	17.4	15.8	17.7	18.3	16.4	19.5	18.0
20.00	17.4	19.6	18.7	19.5	18.4	18.7	16.2	16.9	16.1	17.2	15.4	17.3	17.8	16.2	18.3	17.4
21.00	17.0	19.0	18.0	19.0	18.0	18.4	16.0	17.0	15.8	17.0	15.0	17.0	17.4	16.0	17.2	16.8
22.00	11.3	12.7	12.0	12.7	12.0	12.3	10.7	11.3	10.5	11.3	10.0	11.3	11.6	10.7	11.5	11.2
23.00	5.7	6.3	6.0	6.3	6.0	6.1	5.3	5.7	5.3	5.7	5.0	5.7	5.8	5.3	5.7	5.6

Day / Time	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0.00	16.2	19.3	17.2	15.6	15.4	20.2	19.7	16.7	16.7	16.0	14.6	13.8	13.2	12.8	15.4
1.00	17.4	20.2	18.8	17.8	17.5	20.7	20.5	18.2	17.9	16.7	16.2	15.9	15.1	14.8	17.1
2.00	18.6	21.0	20.4	19.9	19.5	21.1	21.2	19.7	19.0	17.3	17.8	17.9	17.1	16.9	18.7
3.00	19.8	21.9	22.0	22.1	21.6	21.6	22.0	21.2	20.2	18.0	19.4	20.0	19.0	18.9	20.4
4.00	21.7	23.4	23.3	23.4	23.3	22.1	22.9	22.5	21.5	19.9	20.9	22.0	20.9	20.9	21.7
5.00	23.5	24.8	24.7	24.7	24.9	22.7	23.9	23.8	22.9	21.7	22.3	24.0	22.7	23.0	22.9
6.00	25.4	26.3	26.0	26.0	26.6	23.2	24.8	25.1	24.2	23.6	23.8	26.0	24.6	25.0	24.2
7.00	25.9	26.4	26.6	26.4	27.3	23.0	25.3	25.5	25.2	24.1	24.4	26.2	24.9	25.0	24.8
8.00	26.3	26.5	27.2	26.8	27.9	22.7	25.7	25.8	26.2	24.5	25.1	26.5	25.3	25.0	25.4
9.00	26.8	26.6	27.8	27.2	28.6	22.5	26.2	26.2	27.2	25.0	25.7	26.7	25.6	25.0	26.0
10.00	25.7	25.9	25.8	25.5	27.3	22.2	25.1	24.9	25.9	24.0	24.4	25.2	23.6	23.8	24.7
11.00	24.7	25.2	23.8	23.7	26.1	21.9	23.9	23.7	24.5	23.0	23.1	23.7	21.7	22.7	23.3
12.00	23.6	24.5	21.8	22.0	24.8	21.6	22.8	22.4	23.2	22.0	21.8	22.2	19.7	21.5	22.0
13.00	23.4	23.6	21.3	21.0	23.6	21.3	22.0	21.3	22.2	21.6	21.1	21.5	18.8	20.7	21.4
14.00	23.2	22.6	20.8	20.0	22.3	21.0	21.3	20.1	21.1	21.3	20.3	20.7	17.9	19.8	20.9
15.00	23.0	21.7	20.3	19.0	21.1	20.7	20.5	19.0	20.1	20.9	19.6	20.0	17.0	19.0	20.3
16.00	22.6	21.5	19.5	18.7	20.9	20.6	19.7	19.3	19.7	20.0	19.0	19.5	16.4	18.9	19.7
17.00	22.3	21.2	18.6	18.5	20.8	20.5	18.9	19.5	19.2	19.1	18.4	18.9	15.9	18.7	19.1
18.00	21.9	21.0	17.8	18.2	20.6	20.4	18.1	19.8	18.8	18.2	17.8	18.4	15.3	18.6	18.5
19.00	21.6	19.9	17.5	17.8	20.7	20.2	18.0	19.4	18.3	17.5	16.4	17.5	14.8	17.9	17.9
20.00	21.3	18.7	17.3	17.4	20.9	20.0	17.9	19.0	17.9	16.7	15.0	16.5	14.3	17.1	17.2
21.00	21.0	17.6	17.0	17.0	21.0	19.8	17.8	18.6	17.4	16.0	13.6	15.6	13.8	16.4	16.6
22.00	14.0	11.7	11.3	11.3	14.0	13.2	11.9	12.4	11.6	10.7	9.1	10.4	9.2	10.9	11.1
23.00	7.0	5.9	5.7	5.7	7.0	6.6	5.9	6.2	5.8	5.3	4.5	5.2	4.6	5.5	5.5

APPENDIX B: Hourly Direct Solar Radiation in Watt/m^2

Hourly Direct Solar Radiation in Watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month: January

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00	14	12	4	1	7	15	16	14	15	14	1	4	8	14	11	12	13	15	16	18	21	23	25	28	30	32	32	32	2	4	5
8:00	62	22	52	5	48	85	92	97	83	85	16	49	81	79	56	78	79	79	80	91	102	113	123	134	145	153	129	122	5	7	5
9:00	165	34	119	13	132	166	178	194	210	188	6	79	152	171	54	197	154	110	67	107	146	186	226	265	305	312	223	167	8	17	22
10:00	290	88	195	28	218	244	254	245	347	307	2	399	215	300	142	285	204	122	40	96	152	208	264	320	375	378	223	158	113	89	53
11:00	379	89	197	123	278	206	313	331	388	370	1	457	248	366	204	327	260	192	125	178	231	284	337	390	443	339	371	114	96	75	56
12:00	388	97	167	88	357	229	265	384	373	408	1	436	179	340	335	280	214	149	83	145	208	270	332	395	457	429	368	164	152	135	125
13:00	353	175	172	21	325	199	264	374	346	334	1	365	233	333	300	272	225	177	130	181	232	282	333	384	435	402	347	44	32	28	26
14:00	241	152	106	34	294	146	212	253	233	250	1	285	98	236	191	186	168	150	132	163	194	226	257	288	320	331	171	101	72	53	32
15:00	124	62	33	17	165	108	108	136	113	124	0	173	56	121	117	116	111	105	100	118	137	155	174	192	210	174	66	24	23	16	10
16:00	26	13	6	3	46	25	28	24	27	28	0	43	17	26	21	27	28	30	31	37	43	49	55	61	67	57	37	2	1	4	4
17:00	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	2	2	2	2	2	1	1	1	1	2	0	1	2	1
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year: 2005 Month February

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Time																												
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	1	0	1	0	1	1	0	0	0	1	0	0	1	2	2	0	1	1	1	1	1	1	2	1	2	2	2	2
7:00	11	22	24	36	24	7	12	27	27	26	30	28	28	83	84	2	3	4	7	16	24	33	42	36	68	72	58	44
8:00	37	121	135	155	126	44	69	119	122	128	151	20	86	255	240	5	10	18	16	34	52	70	101	130	215	245	234	224
9:00	17	305	269	301	272	61	164	120	250	236	280	325	144	416	415	76	71	37	3	16	30	43	289	163	366	412	500	409
10:00	8	446	356	391	323	216	273	311	288	361	406	439	231	527	556	188	189	99	10	22	35	47	432	250	489	506	606	573
11:00	34	520	383	480	434	330	344	447	343	393	471	518	331	566	632	162	189	117	44	61	78	95	536	319	564	626	689	664
12:00	101	538	420	520	506	356	367	391	365	506	473	516	505	523	615	398	208	111	13	49	86	122	601	290	574	646	713	709
13:00	6	535	398	509	489	186	319	313	305	463	474	466	477	478	558	431	326	294	262	248	234	219	563	376	530	538	634	588
14:00	11	407	293	371	376	146	242	242	241	307	334	380	374	372	424	397	334	328	323	237	152	66	435	312	412	491	509	478
15:00	1	216	175	251	234	130	120	126	136	201	206	255	238	243	264	149	225	222	220	155	90	25	250	207	274	355	313	330
16:00	1	101	56	87	83	37	43	32	54	67	105	95	96	104	98	83	87	88	89	65	42	19	65	84	120	129	137	140
17:00	0	5	3	5	5	2	2	4	3	6	6	7	7	8	7	7	3	5	7	5	4	2	8	9	14	13	12	16
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Hourly Direct Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month: March

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	3	3	0	4	2	1	2	1	2	3	2	1	2	7	3	2	5	1	2	3	8	1	6	1	17	2	5	2	3	7	10
7:00	65	62	3	75	42	37	26	4	14	25	14	3	74	108	71	64	58	12	34	57	91	6	56	2	77	11	86	6	22	31	50
8:00	220	219	153	224	145	130	65	5	130	255	129	4	269	229	204	180	155	112	166	219	215	73	36	4	56	34	196	88	91	5	76
9:00	399	410	378	385	301	321	118	17	302	438	221	4	486	425	311	282	253	21	408	195	230	163	49	4	68	133	250	97	85	11	131
10:00	526	544	556	524	432	459	218	73	402	519	35	3	604	502	380	494	305	21	356	240	516	265	20	19	286	303	302	336	82	211	323
11:00	577	605	652	620	474	535	410	101	499	495	57	8	701	532	479	479	478	29	206	261	611	110	58	7	635	584	391	298	251	296	327
12:00	563	594	669	621	429	414	400	367	525	507	27	28	677	533	525	512	495	143	293	447	620	171	66	6	493	623	416	267	92	348	253
13:00	527	509	607	536	400	415	461	303	517	565	20	16	596	302	482	459	360	70	148	493	582	391	1	65	570	593	434	268	273	173	141
14:00	429	364	461	402	302	313	376	281	413	372	108	3	368	235	367	364	344	227	49	431	449	298	9	45	530	200	296	268	240	176	209
15:00	321	216	307	266	180	187	219	129	243	171	77	1	226	101	237	263	232	36	52	274	243	67	1	1	352	186	234	178	123	68	119
16:00	132	79	127	116	73	64	54	46	68	74	19	0	76	2	93	115	91	32	37	119	63	68	1	1	173	42	90	60	3	9	38
17:00	11	7	14	15	7	4	8	1	9	6	1	1	11	0	9	7	14	10	5	16	8	0	2	3	17	18	12	14	3	0	5
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year 2005 Month: April

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1
6:00	14	17	17	20	17	19	2	4	5	30	2	3	12	11	10	9	5	23	5	1	28	24	18	12	6	18	2	9	16	42
7:00	70	89	123	126	90	119	14	68	9	97	11	6	88	69	51	32	25	117	56	8	141	59	74	89	104	105	13	72	132	223
8:00	146	217	283	333	237	146	103	177	6	48	96	31	282	233	185	137	126	243	104	60	285	82	92	102	112	185	128	190	251	284
9:00	252	373	484	511	324	156	287	250	225	291	267	213	463	469	475	482	371	348	317	163	442	118	122	125	129	348	386	196	143	271
10:00	434	546	548	628	302	353	370	269	239	403	212	145	583	514	444	375	333	452	371	51	476	346	215	237	405	337	504	382	302	50
11:00	358	388	564	650	494	554	510	423	101	316	315	392	624	593	562	531	257	343	428	235	509	368	226	503	496	432	463	252	329	287
12:00	157	61	598	574	550	456	624	469	436	365	375	482	593	547	501	455	92	249	407	541	604	486	369	410	480	225	491	401	404	454
13:00	109	78	377	440	504	517	596	376	421	401	220	455	554	512	470	428	148	304	460	390	571	441	312	409	435	375	503	410	83	222
14:00	242	275	134	518	384	347	507	276	410	254	204	351	401	343	284	225	210	272	334	287	471	345	219	229	218	323	4	184	1	385
15:00	170	221	161	359	216	268	332	295	303	232	217	217	243	206	169	132	180	174	168	94	302	252	202	180	128	1	117	154	0	334
16:00	66	95	65	164	102	127	131	90	149	100	94	83	106	81	56	30	45	31	16	48	114	118	122	52	24	5	125	109	2	160
17:00	9	14	1	27	15	20	24	22	27	2	1	9	14	12	10	8	6	2	2	6	16	19	22	9	0	8	19	19	2	50
18:00	0	0	0	0	0	1	1	0	0	4	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0

Hourly Direct Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year 2005 Month May

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	1	1	2	1	1	1	1	1	0	0	0	1	2	1	1	1	1	1	0	2	2	1	1	0	0	1	0	0	1	1	1
6 00	46	18	74	16	15	11	6	2	3	6	5	34	31	24	17	10	29	16	3	38	29	21	12	3	1	25	49	7	17	27	21
7:00	199	55	224	30	23	16	9	2	5	44	7	28	152	122	93	63	117	66	15	181	144	108	71	34	69	95	122	89	85	81	81
8 00	388	177	386	12	107	203	299	4	5	66	124	170	287	219	151	84	262	204	11	355	270	185	101	16	55	164	273	151	212	273	234
9:00	518	376	516	34	428	432	435	146	15	277	206	419	397	298	200	101	139	105	106	495	372	249	126	3	45	202	359	256	288	320	532
10:00	524	222	586	34	1	207	412	492	15	334	208	500	469	439	408	377	278	203	155	526	358	189	20	200	151	319	412	497	419	497	634
11:00	239	22	496	377	129	319	509	460	103	336	295	534	513	492	470	449	482	58	49	518	361	203	45	480	179	367	513	566	348	431	691
12:00	254	13	523	402	439	536	634	389	96	500	329	438	437	436	435	434	506	182	248	342	293	245	196	464	147	166	410	362	455	531	647
13:00	403	57	601	280	403	481	559	396	399	464	305	443	419	396	373	350	114	148	1	261	261	262	262	89	273	167	345	306	412	475	499
14 00	349	84	501	54	298	376	454	324	262	278	382	381	359	337	315	293	308	139	326	101	145	188	232	175	402	235	213	414	434	431	340
15 00	13	5	209	277	15	163	311	186	163	9	262	298	284	270	256	242	4	56	292	253	213	174	135	136	255	238	90	222	283	269	265
16:00	2	2	133	140	2	69	136	93	57	134	125	152	144	136	128	121	12	69	1	14	28	41	55	49	142	86	81	134	183	146	153
17 00	2	1	8	22	19	15	12	7	9	23	22	14	15	17	18	19	15	8	0	7	14	20	27	5	27	15	23	25	49	43	36
18.00	1	0	0	0	2	4	5	0	0	1	1	-2	-2	-1	0	0	0	0	0	0	1	1	9	0	0	0	1	0	1	1	1

Year 2005 Month: June

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	1	1	1	1	1	1	3	1	1	4	1	0	1	1	2	1	0	0	1	1	1	1	2	1	1	1	1	1	0	0
6:00	14	19	20	22	23	10	64	10	32	48	16	20	17	14	16	19	11	13	15	22	29	18	11	17	14	10	8	6	4	13
7-00	80	31	97	76	56	132	116	32	128	155	40	33	34	35	11	36	38	42	47	40	33	40	24	96	62	28	27	25	24	23
8 00	194	104	184	210	237	257	91	140	132	262	75	34	54	74	6	25	54	82	111	101	92	129	75	123	98	73	58	42	27	11
9 00	304	182	358	411	465	319	140	357	249	327	124	144	164	320	10	15	26	38	49	116	184	110	13	264	174	84	47	10	14	18
10.00	414	317	564	530	496	334	47	229	249	287	162	202	117	276	17	10	28	45	63	199	335	141	17	264	147	31	38	9	13	51
11:00	407	401	589	454	312	533	51	352	445	185	272	340	151	105	31	11	259	506	144	524	400	93	45	336	280	225	48	12	21	26
12:00	347	401	585	360	373	557	283	171	524	39	211	180	215	378	32	14	237	460	204	377	259	26	70	55	40	25	56	11	24	52
13.00	334	467	553	335	168	627	433	240	308	131	138	167	197	129	37	8	202	396	267	319	267	167	66	76	84	92	45	5	23	20
14:00	320	322	321	125	268	317	380	299	387	81	197	165	133	167	107	3	174	344	265	277	376	212	47	37	27	258	41	8	15	14
15.00	212	268	205	62	122	342	37	155	176	15	132	80	28	44	28	6	99	191	117	253	172	100	27	55	82	94	33	12	13	12
16:00	119	166	70	33	21	155	119	99	132	26	107	60	13	1	29	7	45	84	105	125	13	19	16	16	16	142	22	9	10	15
17.00	29	49	23	1	19	38	27	38	32	12	18	9	0	2	11	4	19	34	25	16	9	12	9	8	8	20	5	4	14	5
18 00	2	2	1	0	1	2	0	2	2	2	14	7	0	0	2	0	1	2	1	0	1	2	2	3	3	2	1	1	4	1

Hourly Direct Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year 2005 Month: July

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
5:00	0	0	0	3	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	1	0
6:00	9	5	0	19	10	2	7	11	7	5	2	2	2	2	2	2	2	2	2	8	9	8	7	6	69	35	19	3	57	24	30
7:00	16	8	1	73	38	2	9	15	4	4	3	3	4	4	5	5	5	6	6	37	51	51	52	53	223	214	134	55	174	43	42
8:00	8	4	1	6	202	397	593	51	52	54	65	59	53	47	41	35	29	23	17	45	117	97	76	56	416	336	226	117	237	288	177
9.00	41	64	1	1	38	75	189	341	35	5	26	47	53	58	64	69	75	80	79	26	23	168	313	457	602	63	152	241	180	110	8
10.00	34	18	0	12	5	455	216	422	154	11	18	25	1	2	7	12	17	22	66	255	10	34	58	332	607	334	62	333	128	242	279
11 00	18	10	1	12	7	511	232	164	407	38	38	35	33	30	27	25	22	22	344	229	21	76	132	423	714	25	113	104	70	112	205
12:00	44	35	4	23	17	188	578	523	57	14	11	8	5	2	16	30	44	58	262	177	32	101	169	316	463	416	369	25	186	164	239
13:00	42	64	4	7	25	287	486	224	0	27	24	20	16	12	4	7	11	15	29	126	161	179	197	284	371	307	242	322	468	99	258
14:00	10	7	8	2	161	146	235	150	95	14	42	70	98	126	4	111	218	325	197	7	366	212	58	164	270	162	463	469	510	100	148
15:00	12	13	5	16	13	374	295	182	213	11	39	67	95	123	3	143	283	423	330	5	281	157	32	106	181	145	194	234	313	199	154
16.00	9	3	7	17	4	263	300	156	19	42	39	37	34	32	1	77	152	227	90	0	46	101	156	96	35	13	249	56	6	105	108
17:00	3	1	5	7	3	95	117	11	19	8	6	4	2	1	1	21	42	63	55	0	4	15	26	6	4	5	40	3	40	23	46
18.00	0	0	1	6	1	6	8	1	1	0	0	0	0	1	1	1	1	1	0	0	0	1	1	1	2	0	4	1	2	1	1

Year 2005 Month: August

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
5:00	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	16	3	2	11	3	2	8	1	1	0	0	0	0	1	2	15	28	1	1	1	1	1	0	2	2	4	3	2	1	3	5
7:00	22	2	12	19	14	7	10	80	41	1	2	2	3	3	56	118	181	1	8	6	4	2	3	8	3	24	28	31	35	38	41
8:00	91	4	14	24	18	15	17	12	6	1	1	2	3	4	20	53	86	6	5	5	5	4	10	10	7	34	64	93	123	152	160
9.00	26	44	301	143	25	78	26	18	9	1	19	37	55	6	102	197	111	4	4	11	19	6	11	6	9	108	121	134	97	69	111
10 00	316	353	89	106	72	158	30	21	12	2	38	73	109	8	32	323	164	5	37	32	26	3	9	15	10	128	199	270	67	42	158
11:00	299	392	56	45	164	72	75	51	27	3	73	144	215	267	284	354	376	10	20	160	300	63	11	13	7	141	229	318	51	111	6
12 00	313	388	23	41	191	72	57	45	34	23	11	35	59	116	132	86	215	16	444	234	24	87	45	7	12	135	243	352	2	182	6
13 00	417	576	346	173	129	59	29	23	16	10	17	22	26	180	4	59	342	1	102	60	18	12	123	9	10	262	367	272	9	162	378
14 00	197	246	241	82	8	44	172	119	67	15	77	101	126	103	59	15	283	363	118	61	4	16	13	10	17	246	371	295	52	116	119
15 00	110	65	231	142	3	22	110	83	56	29	171	165	159	57	49	41	333	356	65	41	16	179	10	16	13	295	354	213	71	6	150
16:00	111	18	94	8	5	33	36	25	14	1	221	156	91	37	96	156	93	204	14	9	3	101	10	31	28	2	45	87	94	26	14
17:00	68	1	3	2	3	5	1	1	1	1	58	40	21	3	25	47	26	29	20	22	24	4	3	0	3	0	6	12	12	2	0
18:00	2	0	1	1	1	0	1	1	0	0	3	2	1	0	0	0	0	0	1	2	3	0	0	0	0	1	2	3	0	1	0

Hourly Direct Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month September

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	0	0	0	0	1	0	0	0	0	0	16	5	0	8	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
6:00	24	9	16	22	29	35	12	1	0	1	0	14	0	5	0	5	1	64	20	2	7	6	1	3	4	6	7	8	10	11
7:00	96	102	108	113	119	124	43	26	10	5	15	182	1	28	100	172	37	213	153	4	9	14	3	9	14	18	23	27	32	36
8:00	63	87	160	233	305	378	203	116	29	137	80	520	18	68	151	234	56	289	171	9	105	102	30	20	10	18	33	48	62	77
9 00	241	261	344	426	509	591	264	327	47	31	252	625	101	293	426	345	29	523	453	16	342	184	37	24	12	293	242	191	140	89
10:00	93	70	47	24	2	692	5	12	20	24	268	548	216	178	566	372	147	429	228	10	415	77	165	94	24	348	247	224	202	179
11.00	2	2	2	2	2	658	1	312	86	314	161	610	400	25	574	571	136	478	168	3	251	173	54	36	19	324	184	134	83	33
12:00	1	2	2	3	4	627	0	264	541	93	488	659	391	43	480	722	4	393	330	2	112	238	7	14	22	136	32	65	99	133
13 00	1	3	4	5	3	172	1	363	398	94	503	303	138	60	291	586	301	418	467	2	464	300	203	107	10	28	100	92	83	75
14:00	2	4	5	7	7	124	1	344	371	140	469	126	121	181	318	382	24	277	412	1	228	5	9	13	17	2	122	88	55	22
15:00	4	3	3	3	8	6	3	282	121	271	162	95	23	63	192	276	25	368	260	1	28	1	5	8	11	11	11	11	11	11
16:00	7	6	5	4	5	4	4	99	5	34	190	128	4	3	59	149	28	171	126	1	82	1	2	3	4	4	5	5	6	6
17.00	4	3	2	2	3	0	2	3	1	14	22	16	1	1	5	13	0	19	11	0	1	0	0	0	1	6	6	6	6	6
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Year: 2005 Month. October

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	8	4	1	4	7	10	13	16	19	18	17	16	15	14	13	12	11	10	9	8	60	40	20	0	22	7	1	0	5	10	14
7:00	31	26	21	30	39	48	57	66	75	73	71	68	66	64	62	54	46	37	29	21	4	5	5	5	128	126	15	0	26	52	78
8 00	93	110	126	142	157	173	188	204	219	215	211	207	202	198	194	166	138	111	83	55	10	8	6	4	373	176	65	90	115	140	164
9 00	88	86	85	159	232	306	379	453	527	444	439	434	428	423	417	261	196	131	67	2	3	18	10	1	286	346	25	63	101	139	177
10 00	1	4	169	239	309	378	448	518	588	194	245	295	345	396	446	233	175	117	58	0	0	2	3	269	335	86	157	172	186	201	215
11:00	1	2	41	100	160	219	278	337	396	127	187	247	308	368	428	232	174	116	58	0	2	0	0	199	397	101	701	599	498	396	294
12:00	69	5	1	26	52	77	102	128	127	337	345	352	359	366	373	0	39	77	116	1	1	1	3	3	331	54	628	525	422	320	217
13.00	51	27	3	52	100	149	197	246	394	370	340	310	280	250	220	1	29	57	85	1	1	0	1	2	32	167	482	401	321	240	159
14.00	24	25	27	23	19	15	12	8	186	71	133	196	258	320	382	0	8	17	26	1	1	0	2	21	252	134	316	317	319	321	322
15:00	9	7	4	8	12	16	20	24	151	94	115	136	157	178	199	18	14	11	7	0	1	0	0	116	36	98	143	151	159	167	174
16 00	4	2	0	4	8	12	16	20	36	17	24	32	40	48	56	35	23	12	0	0	1	1	2	15	9	6	23	25	27	29	31
17 00	4	1	3	1	6	7	9	10	1	0	0	0	0	0	0	1	2	2	3	0	0	1	1	1	0	1	0	0	0	0	0
18 00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Hourly Direct Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month: November

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	19	16	24	36	40	29	26	23	20	17	17	17	17	17	17	17	13	10	6	2	8	5	2	2	1	3	5	7	14	12
7:00	104	82	140	181	169	168	154	140	126	112	112	112	112	112	112	112	94	75	56	38	33	29	24	27	21	38	56	74	134	117
8:00	189	278	312	356	391	356	339	321	304	286	286	286	286	286	286	286	245	204	163	122	101	81	60	77	81	130	179	228	287	226
9:00	215	447	488	524	573	553	528	503	477	452	452	452	452	452	452	452	399	346	293	146	90	34	133	146	196	246	296	346	421	404
10 00	230	569	607	636	660	654	630	605	581	556	556	556	556	556	556	556	434	312	190	195	123	52	179	167	271	374	478	464	543	498
11:00	193	652	655	695	692	673	633	594	554	515	515	515	515	515	515	515	420	325	231	179	108	38	223	137	257	377	497	486	601	380
12:00	114	553	600	652	581	428	388	349	310	271	229	186	144	102	59	271	260	249	237	147	121	96	463	108	248	387	527	404	506	325
13:00	78	421	520	516	495	454	424	395	365	335	307	279	251	223	195	335	278	221	164	142	166	191	114	25	164	303	442	278	381	331
14:00	24	280	312	344	346	312	256	200	144	88	98	108	118	129	139	126	113	101	88	96	102	108	71	58	134	210	286	210	211	209
15:00	3	119	133	147	157	210	166	121	77	33	33	34	34	34	35	34	34	33	33	36	32	28	18	19	55	91	126	99	96	83
16.00	1	17	17	24	26	22	17	12	7	2	4	5	7	8	10	8	6	4	2	4	4	3	2	2	5	8	11	8	10	8
17 00	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0
18 00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year: 2005 Month: December

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	4	7	9	11	13	15	17	19	17	14	12	10	7	5	5	5	2	0	0	0	0	0	0	1	1	1	1	2	1	1	0
7 00	35	73	86	98	110	122	135	147	138	128	119	110	101	91	56	106	4	3	3	4	5	5	14	24	33	42	52	61	29	24	19
8:00	163	192	204	215	227	238	250	261	257	253	248	244	239	235	218	241	23	16	38	61	83	106	119	132	145	159	172	185	94	83	72
9:00	272	333	335	338	341	343	346	348	354	360	365	371	377	383	423	303	26	142	167	192	216	241	253	265	278	290	302	314	185	178	172
10.00	377	407	411	416	420	425	429	434	434	433	433	433	432	432	472	413	62	110	158	206	254	303	320	337	355	372	389	407	263	272	281
11 00	460	345	352	360	368	375	383	391	397	404	411	418	424	431	412	329	15	95	174	254	334	413	402	391	379	368	356	345	226	277	328
12:00	426	350	312	274	236	198	160	122	177	233	289	344	400	455	296	284	28	82	136	190	245	299	307	316	324	333	341	350	260	303	345
13:00	314	280	270	260	250	240	230	220	237	255	272	289	306	323	278	182	90	106	122	138	155	171	189	207	225	243	261	280	298	316	335
14 00	166	234	215	195	176	156	137	117	132	146	161	176	191	205	126	161	48	92	136	180	224	268	263	257	251	246	240	234	236	238	239
15 00	74	126	110	95	79	64	48	32	41	49	57	65	73	82	47	96	11	42	73	104	135	166	160	153	146	139	133	126	125	125	124
16.00	7	15	13	11	10	8	6	4	5	5	6	6	7	8	4	10	2	20	39	58	76	95	81	68	55	41	28	15	18	20	23
17:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	12	18	24	30	25	20	15	10	5	0	0	0	0
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C: Hourly Diffuse Solar Radiation in Watt/m^2

Hourly Diffuse Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year 2005 Month, January

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	4	3	4	3	3	3	3	4	3	3	3	4	4	3	5	5	5	5	5	5	5	5	4	4	4	4	5	4	5	5	4
7:00	50	45	32	36	54	55	55	54	54	55	25	42	58	55	81	57	56	56	55	55	55	55	54	54	54	54	63	64	57	54	53
8:00	112	99	126	103	130	129	127	126	129	127	135	137	139	134	150	129	130	132	133	130	128	125	122	120	117	112	134	159	150	152	152
9:00	166	95	181	164	194	190	184	183	185	185	136	172	207	195	247	187	195	203	211	202	192	183	173	164	154	149	194	247	230	244	257
10.00	193	168	241	222	240	226	223	229	202	210	110	206	269	219	269	217	244	271	299	289	279	269	259	249	239	212	260	309	291	269	244
11:00	200	183	251	262	256	256	246	240	226	224	107	216	310	236	330	244	289	333	378	356	335	313	292	270	249	288	320	331	334	339	343
12:00	198	176	249	297	235	268	274	221	232	221	74	224	306	252	257	259	293	326	360	340	320	300	280	260	240	256	317	347	365	387	401
13:00	184	220	240	237	211	270	243	202	220	214	60	215	290	222	229	260	282	305	327	307	287	266	246	226	206	228	271	336	303	262	217
14:00	152	186	193	223	157	209	191	180	195	178	62	177	208	193	206	212	233	253	274	259	245	231	216	202	188	199	287	282	268	243	219
15:00	108	122	107	138	120	134	136	134	140	126	48	129	138	140	144	153	174	195	216	203	190	177	165	152	139	153	200	164	142	124	105
16:00	51	50	43	57	60	61	62	64	67	61	47	69	73	69	64	61	63	64	66	69	72	75	78	81	83	86	111	50	53	57	62
17:00	4	1	2	4	5	5	5	6	7	5	8	11	7	7	5	4	4	5	5	7	9	11	13	15	18	15	16	5	6	7	8
18.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year 2005 Month, February

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Time																												
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	4	5	6	6	6	7	6	7	6	7	10	10	10	10	10	4	7	9	10	11	13	14	14	13	16	18	16	15
7:00	61	71	74	74	73	71	68	67	70	74	75	85	94	67	64	65	67	69	72	77	83	88	91	84	84	84	79	74
8:00	168	144	158	149	153	156	163	159	144	140	143	155	167	112	108	119	147	151	168	169	170	171	173	169	141	130	127	124
9:00	278	174	220	198	205	223	235	237	191	192	196	192	224	145	133	281	294	216	139	207	275	343	201	262	185	161	158	148
10:00	226	195	280	244	256	278	286	248	239	240	230	209	284	173	147	360	381	334	286	339	393	446	218	309	213	185	162	155
11:00	347	221	323	252	260	290	302	232	287	274	256	214	301	206	156	364	347	380	414	432	450	468	212	322	228	198	167	160
12:00	429	226	306	235	235	286	303	255	301	247	258	218	216	234	167	310	382	355	329	378	427	475	191	336	233	200	170	149
13.00	183	177	277	205	198	293	296	285	275	226	226	206	192	231	164	270	334	357	380	395	410	424	170	292	218	194	169	167
14:00	198	175	247	192	178	281	283	252	221	217	217	180	169	213	159	240	234	251	269	301	332	364	159	238	199	175	153	149
15:00	84	168	184	146	141	206	179	171	163	163	173	140	139	166	138	187	186	193	200	218	236	253	151	176	154	146	136	119
16:00	65	94	106	92	90	95	105	76	98	98	140	93	88	103	93	108	112	115	118	134	149	165	117	110	100	98	96	87
17:00	10	20	21	21	22	18	18	23	21	25	25	26	23	28	25	26	23	26	30	33	35	38	36	32	32	32	33	31
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Hourly Diffuse Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year 2005 Month: March

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	16	19	10	17	18	18	22	10	21	31	32	33	25	20	21	20	43	31	31	32	40	29	50	15	42	29	45	29	49	49	50
7:00	88	90	84	80	101	100	115	61	86	112	84	55	109	100	103	115	126	139	123	106	127	120	140	35	136	117	145	124	134	137	133
8:00	135	147	201	132	193	193	212	96	116	136	122	109	151	161	161	191	222	284	239	194	204	252	188	102	239	159	241	257	243	202	194
9:00	162	167	191	161	220	203	306	200	273	165	144	122	164	205	214	265	315	289	271	330	318	305	280	113	226	280	332	312	317	268	250
10:00	176	182	172	175	239	217	376	319	300	213	384	70	173	294	257	269	352	236	303	350	259	372	279	312	286	360	370	364	324	447	389
11:00	207	198	164	178	266	233	386	311	302	267	430	216	175	277	266	314	338	296	340	383	238	363	270	176	310	314	351	417	439	464	409
12:00	220	208	162	180	294	316	337	340	289	250	363	351	192	245	252	327	341	401	416	337	243	397	259	199	312	249	367	405	425	449	399
13:00	198	214	162	180	266	271	276	340	252	183	273	274	200	278	243	293	406	277	345	273	217	349	34	352	222	240	337	367	424	392	350
14:00	178	205	164	166	237	220	228	269	213	200	339	81	239	294	221	260	320	383	242	229	198	313	128	282	183	210	297	315	333	333	317
15:00	133	168	136	135	184	169	181	194	178	196	248	35	192	179	175	198	208	265	199	181	178	215	69	27	155	244	233	237	240	244	237
16:00	97	104	97	91	108	102	127	125	121	122	136	36	133	70	161	111	134	177	132	121	109	140	27	29	100	133	134	112	74	101	112
17:00	32	28	32	28	30	28	45	30	40	41	37	25	54	12	55	34	45	47	48	39	42	16	28	39	46	59	46	50	46	6	19
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year 2005 Month: April

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	0	0	0	0	3	3	2	2	4	3	1	4	6	6	5	5	5	7	6	3	9	10	8	6	5	9	7	10	13	12
6:00	50	51	53	55	55	60	62	55	71	67	54	55	70	69	68	67	67	77	66	23	75	85	75	66	57	83	67	80	93	81
7:00	128	124	122	129	149	142	159	170	155	161	163	101	152	147	143	138	136	166	206	140	147	187	186	185	184	182	169	178	186	143
8:00	187	179	174	164	209	252	233	253	144	210	237	205	208	220	232	244	250	238	286	267	196	299	287	275	263	283	253	259	265	245
9:00	233	215	208	188	288	266	316	309	340	322	311	377	238	283	328	372	283	301	343	371	223	332	357	382	406	315	293	424	399	388
10:00	332	275	237	198	341	293	336	307	414	366	360	359	257	297	338	379	293	321	349	427	272	326	379	397	410	395	308	395	417	506
11:00	353	298	238	214	360	308	332	330	409	391	457	402	266	296	326	356	405	381	358	389	290	354	419	370	344	372	408	453	417	464
12:00	349	299	256	287	318	323	272	355	437	382	426	340	269	299	329	359	413	395	377	301	255	329	403	391	341	387	361	396	412	401
13:00	308	267	281	285	288	299	227	334	386	318	361	296	253	281	310	338	376	354	331	320	233	308	383	365	321	354	285	335	264	393
14:00	301	285	254	167	239	254	184	284	259	298	292	266	229	270	310	350	374	328	283	278	205	248	292	317	306	282	75	311	21	270
15:00	229	222	220	141	195	208	157	226	186	205	242	213	190	214	239	263	243	243	242	189	173	202	231	263	241	34	183	236	7	173
16:00	123	135	120	104	123	129	121	139	138	146	144	139	131	137	143	149	149	139	129	160	124	138	153	165	102	23	149	159	0	130
17:00	31	44	32	44	46	49	53	51	56	14	34	52	51	55	59	63	61	36	43	43	51	51	51	64	6	110	69	67	0	71
18:00	0	0	0	0	0	0	0	1	2	0	6	0	0	1	3	4	2	1	0	2	0	2	4	5	9	14	3	6	0	0

Hourly Diffuse Solar Radiation in watt/m^2

Source. Renewable Energy Research Centre, Dhaka University

Year 2005 Month: May

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	16	15	18	17	18	17	15	14	11	14	18	22	21	18	15	12	9	12	16	24	20	16	13	9	15	0	22	9	17	24	25
6:00	86	103	85	99	60	61	62	63	69	76	95	110	96	85	74	63	109	89	69	108	94	79	65	51	23	69	116	74	90	107	108
7:00	155	199	141	219	171	123	74	26	109	193	145	159	178	181	185	188	205	195	184	175	179	183	187	191	232	215	198	237	222	207	210
8:00	181	308	191	182	207	232	257	92	118	290	287	277	210	202	194	186	281	418	170	218	208	198	188	179	213	252	291	288	280	271	285
9:00	214	308	251	301	30	149	268	374	260	366	379	304	217	184	151	117	246	418	418	250	209	167	126	84	248	286	324	303	306	309	249
10:00	295	349	281	104	54	219	384	387	227	406	418	333	343	354	364	375	430	460	447	313	296	279	262	391	391	438	364	298	388	339	243
11:00	337	254	319	343	491	429	367	397	446	423	422	353	365	377	389	401	378	493	288	389	343	297	251	397	399	413	350	315	434	305	255
12:00	391	233	292	415	476	391	306	445	295	383	391	407	402	397	392	387	376	528	404	429	480	530	581	401	339	399	380	344	384	286	274
13:00	323	309	283	297	398	351	303	402	405	334	346	351	356	361	366	371	430	463	36	359	393	426	460	450	376	364	355	313	340	258	322
14:00	285	306	243	218	306	284	262	326	345	294	278	301	302	304	305	307	323	345	306	240	290	340	390	381	294	319	299	262	266	265	290
15:00	129	159	207	226	231	218	205	258	263	116	213	228	235	241	247	253	81	250	203	238	273	309	344	289	235	256	244	214	215	198	234
16:00	59	70	139	138	98	126	154	158	170	251	150	169	169	170	170	170	0	186	36	89	143	196	250	169	173	159	181	151	138	163	153
17:00	20	28	57	57	60	63	66	65	70	145	73	53	59	64	69	74	0	73	4	44	85	125	166	78	84	86	76	78	75	84	77
18:00	2	2	3	4	3	2	0	3	3	24	21	32	26	19	13	7	6	5	9	9	10	10	80	4	9	9	9	9	12	11	11

Year 2005 Month: June

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	25	26	26	21	16	17	29	50	21	45	19	39	34	29	34	25	13	15	17	15	12	24	18	27	20	13	12	10	9	17
6:00	108	80	103	110	117	78	105	91	103	124	90	131	119	107	95	121	79	90	102	101	101	110	64	92	92	92	71	49	28	112
7:00	213	150	198	219	239	266	203	197	228	187	210	205	205	205	111	198	202	209	217	216	216	203	136	203	188	172	175	178	181	183
8:00	299	270	254	278	302	308	293	304	301	268	273	222	278	333	44	169	219	269	319	317	315	314	300	293	243	192	168	143	119	94
9:00	353	335	321	293	266	338	350	329	332	326	327	386	308	459	71	102	170	238	306	335	364	273	113	330	305	281	193	104	125	145
10:00	373	405	295	331	366	435	287	397	321	378	401	405	295	468	118	82	175	268	361	375	390	255	107	453	324	196	277	81	167	341
11:00	434	396	332	424	398	321	240	424	345	352	493	409	347	446	215	88	252	416	434	401	430	306	278	425	374	324	331	102	180	216
12:00	437	377	312	458	414	296	366	456	326	218	432	402	367	458	201	116	258	399	399	433	352	195	391	312	232	152	328	98	183	344
13:00	373	317	300	425	352	244	339	441	299	341	285	303	322	344	244	68	213	358	420	436	343	371	399	343	287	231	337	47	162	158
14:00	315	298	309	363	357	206	283	339	296	268	299	318	336	375	307	26	171	316	360	331	323	326	328	274	220	399	297	69	106	109
15:00	266	230	246	271	289	180	197	228	215	123	237	208	179	235	172	51	161	271	303	249	250	228	206	232	258	233	249	101	88	91
16:00	167	149	171	156	106	143	157	169	169	141	208	146	83	5	153	51	111	170	164	158	106	148	113	109	105	198	123	75	74	105
17:00	78	72	78	17	45	74	85	96	80	69	75	40	5	0	68	30	67	104	98	92	66	88	69	65	61	103	39	34	94	41
18:00	10	9	9	4	7	10	5	15	12	0	9	5	2	1	12	5	11	17	14	10	10	16	11	19	27	12	8	11	22	9

Hourly Diffuse Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month: July

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	19	10	2	0	7	14	9	19	8	5	13	13	12	12	11	10	10	9	9	13	17	16	15	13	14	17	15	13	19	13	9
6:00	76	41	6	1	37	74	88	102	88	64	40	44	49	53	57	61	66	70	74	112	123	115	106	98	67	102	87	72	90	100	95
7:00	127	71	15	2	35	68	105	141	120	118	116	122	127	133	139	144	150	156	162	193	258	243	228	212	119	144	169	194	150	189	133
8:00	69	43	18	190	227	264	301	240	279	282	288	286	283	281	278	276	274	271	269	281	260	259	259	259	138	207	234	260	210	221	211
9:00	280	415	27	214	271	328	269	290	337	133	253	373	383	393	403	413	423	433	437	328	322	281	240	199	158	308	286	263	337	355	182
10.00	280	219	12	393	173	363	284	350	415	268	274	279	82	88	154	221	287	353	420	467	254	353	452	370	288	360	432	300	288	419	401
11:00	258	300	47	369	223	317	330	322	351	370	372	375	379	382	385	389	392	393	473	465	337	398	458	337	215	382	387	392	353	315	333
12:00	419	494	112	460	376	328	317	332	437	411	340	268	196	125	217	309	401	493	471	487	400	411	422	344	267	290	314	395	316	284	297
13:00	352	547	117	140	427	304	282	291	218	326	316	306	296	286	175	244	312	380	363	327	446	396	347	321	294	284	274	208	273	275	274
14:00	134	158	256	75	406	273	285	266	360	219	279	340	401	461	177	257	338	418	382	166	363	303	243	271	299	374	213	245	224	319	298
15:00	178	265	150	286	208	128	198	216	271	199	229	259	289	319	152	156	160	163	307	92	297	231	165	219	273	306	252	208	243	260	236
16:00	100	94	120	151	121	93	115	175	102	135	154	173	191	210	106	112	119	125	178	18	227	186	145	178	211	154	167	211	91	182	148
17:00	39	38	65	81	76	71	59	79	80	48	55	62	69	75	80	82	84	85	58	7	79	87	96	46	78	95	60	48	102	93	86
18-00	8	7	14	0	19	23	16	16	12	12	1	2	3	4	4	5	6	7	5	0	7	11	15	11	11	3	21	7	15	6	10

Year: 2005 Month: August

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	10	11	10	3	13	1	13	6	3	0	2	4	4	4	5	7	10	0	4	4	3	2	4	3	6	11	10	9	8	7	6
6:00	78	60	36	80	75	36	108	50	30	10	20	31	21	12	58	64	69	13	41	35	29	24	31	33	38	90	75	61	47	56	64
7:00	82	32	143	136	190	121	123	194	111	28	40	52	64	76	145	171	197	43	117	97	77	57	90	102	66	215	206	198	189	181	176
8:00	171	132	155	179	212	229	230	247	133	18	40	61	82	103	166	193	220	145	137	127	118	109	211	154	118	244	254	264	275	285	293
9:00	251	321	322	345	285	221	306	211	117	22	113	204	295	156	335	463	278	134	125	230	335	189	204	104	161	326	385	444	361	415	372
10:00	384	367	398	274	361	564	475	337	200	62	173	284	395	203	284	446	314	183	297	366	434	444	234	243	238	363	410	458	390	394	419
11:00	350	367	398	311	428	528	390	280	171	61	187	313	439	383	437	465	178	279	225	376	526	368	283	206	171	360	404	449	244	476	125
12 00	309	322	257	329	438	399	501	462	423	384	345	335	325	379	240	378	415	289	460	346	233	497	452	101	289	387	414	440	74	497	177
13:00	272	271	352	395	417	520	349	299	250	201	381	312	243	389	211	374	254	107	265	308	331	223	535	120	286	410	400	390	157	431	382
14 00	278	257	270	252	133	294	395	328	261	194	422	411	400	313	243	173	338	301	379	298	217	264	231	134	318	339	336	334	271	274	356
15 00	212	189	238	181	62	233	238	251	264	276	357	340	322	292	243	194	253	164	287	239	191	300	153	190	234	208	221	235	189	153	327
16 00	114	108	180	120	90	218	136	118	101	84	184	229	273	168	150	132	188	127	183	136	88	190	144	170	199	34	96	157	155	153	104
17 00	78	28	62	45	52	74	33	29	24	22	127	108	90	71	67	62	90	62	145	109	73	33	45	23	57	14	36	59	52	36	15
18.00	14	0	7	11	11	7	0	2	4	2	37	26	15	3	4	4	4	3	2	1	0	2	1	0	1	0	0	0	0	0	0

Hourly Diffuse Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month: September

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	8	9	7	4	2	8	4	7	3	1	0	0	10	0	6	5	6	12	7	1	4	5	3	0	0	0	0	0	0	0
6:00	79	65	66	67	68	69	110	40	53	20	106	82	45	63	36	78	38	81	79	33	94	112	44	43	50	58	65	72	80	87
7:00	178	170	160	149	139	128	176	167	158	155	153	138	109	202	194	185	198	138	136	96	203	213	133	144	148	151	155	159	162	166
8:00	203	198	183	169	154	140	253	244	236	336	296	83	278	342	304	267	333	197	239	186	353	346	275	281	287	293	312	332	351	370
9:00	341	330	282	235	187	140	362	273	339	386	410	110	443	373	258	277	395	166	207	286	366	274	328	309	290	483	496	508	521	533
10:00	307	236	164	93	21	146	87	245	404	462	381	177	498	327	271	295	413	310	398	179	321	215	426	398	370	355	445	459	474	488
11:00	81	73	65	58	50	210	19	457	413	491	445	134	328	277	275	277	428	289	388	66	404	445	239	280	321	416	444	454	463	473
12:00	39	61	83	104	126	265	25	353	291	480	312	101	311	298	303	219	420	277	375	41	330	357	173	249	324	374	333	376	419	462
13:00	22	81	140	199	90	267	40	314	326	363	210	251	401	274	313	214	7	256	344	58	387	400	332	264	196	286	306	363	421	479
14:00	57	112	166	220	172	317	60	242	264	215	185	191	300	277	301	213	339	202	261	39	356	86	148	210	272	139	324	330	336	342
15:00	117	122	127	133	136	142	81	145	192	140	143	167	167	135	193	151	222	75	168	31	181	81	115	149	184	191	206	221	236	251
16:00	125	115	104	94	88	42	80	91	105	101	131	146	32	61	117	88	98	49	86	24	100	55	65	75	85	93	102	111	120	129
17:00	47	44	43	38	41	13	31	15	18	42	85	51	6	11	24	24	12	17	25	5	13	18	18	18	17	16	21	27	32	37
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year 2005 Month: October

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	84	81	78	75	72	69	66	63	60	55	51	46	42	37	33	26	20	13	7	0	1	14	27	40	58	41	32	37	38	40	42
7:00	168	169	171	163	154	146	138	130	122	118	115	111	108	104	101	81	61	41	21	0	161	158	156	153	132	130	146	61	76	91	107
8:00	340	310	280	267	253	240	227	213	200	199	198	198	197	196	195	156	117	79	40	1	242	221	201	181	119	222	215	211	206	202	198
9:00	467	401	334	314	293	272	251	231	210	303	284	265	246	227	208	265	233	201	168	136	250	358	263	169	315	242	299	295	291	287	283
10:00	74	156	388	360	332	303	275	247	218	288	280	271	262	254	245	275	229	183	137	91	145	248	190	194	197	314	404	390	377	363	350
11:00	62	198	259	271	283	294	306	317	329	204	220	236	252	268	284	363	291	219	146	74	67	211	174	236	298	298	164	205	246	288	329
12:00	398	335	45	87	129	171	213	255	374	241	254	268	282	296	309	150	253	356	459	86	121	155	136	193	331	254	145	188	230	272	314
13:00	349	220	90	141	193	244	295	346	261	229	241	254	266	278	290	78	176	274	372	110	82	55	107	205	191	264	142	173	203	233	264
14:00	335	328	321	279	236	194	152	109	203	160	158	156	154	152	149	78	135	192	250	77	64	51	53	204	229	262	123	126	130	133	137
15:00	201	151	101	117	132	148	164	180	145	126	121	116	112	107	102	114	126	138	150	30	63	98	38	128	113	145	87	89	90	91	93
16:00	89	48	45	54	63	72	81	90	64	47	48	48	48	49	49	95	80	65	49	9	41	73	20	44	53	54	30	32	33	35	37
17:00	24	11	11	10	10	10	10	9	4	7	6	6	5	5	4	3	2	1	0	1	2	3	4	0	0	1	0	0	0	0	0
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Hourly Diffuse Solar Radiation in watt/m^2

Source: Renewable Energy Research Centre, Dhaka University

Year: 2005 Month: November

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	43	40	38	39	34	37	35	33	31	29	29	29	29	29	29	29	29	30	30	30	0	18	36	20	23	24	24	25	26	20
7:00	122	118	99	85	70	80	79	78	77	76	76	76	76	76	76	76	82	88	94	100	108	116	125	90	104	98	92	85	71	64
8:00	193	149	136	112	91	98	100	102	105	107	107	107	107	107	107	107	121	135	149	163	163	163	163	159	177	162	146	131	101	106
9:00	279	174	152	134	101	102	109	115	122	129	129	129	129	129	129	129	159	190	221	210	171	132	254	214	203	192	181	170	125	125
10:00	336	173	162	142	119	113	124	134	144	155	155	155	155	155	155	155	182	210	238	263	239	216	313	249	236	223	210	181	136	163
11:00	370	159	165	139	145	133	149	165	182	198	198	198	198	198	198	198	231	263	296	293	284	275	348	278	255	233	210	195	132	247
12:00	357	168	160	135	160	202	200	198	196	194	197	200	203	206	209	194	217	240	264	271	286	300	9	248	225	201	177	205	156	216
13:00	294	162	152	127	125	187	186	185	185	184	190	197	203	209	215	184	202	221	239	251	263	276	230	189	171	153	135	201	158	167
14:00	203	138	126	113	99	155	159	164	169	174	163	152	141	130	120	133	147	160	174	175	190	206	199	160	142	124	106	139	148	139
15:00	100	99	93	87	77	122	116	110	104	98	95	91	88	85	81	85	90	94	98	112	112	113	85	83	80	76	73	78	99	92
16:00	34	37	40	35	31	31	31	30	30	30	30	30	29	29	29	29	29	30	30	30	31	32	19	19	20	22	24	21	31	24
17:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year: 2005 Month: December

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	25	28	23	18	14	9	5	0	2	5	7	10	12	15	14	14	13	11	8	5	3	0	2	4	6	8	10	11	11	9	6
7:00	76	83	72	60	49	37	25	14	22	30	38	46	54	63	61	55	81	70	56	42	28	14	22	31	40	48	57	66	74	66	58
8:00	118	119	108	98	87	76	66	55	61	67	74	80	86	92	88	76	172	149	126	102	79	55	63	71	79	88	96	104	131	125	118
9:00	166	141	130	119	109	98	87	76	82	87	93	99	105	111	84	122	249	206	173	141	108	76	85	95	104	113	123	132	182	176	171
10:00	195	157	151	145	139	133	127	122	125	128	131	134	137	140	117	142	301	265	229	193	157	122	127	133	139	145	151	157	208	203	198
11:00	189	189	181	173	165	157	150	142	145	148	150	153	156	159	171	204	260	236	213	189	166	142	150	157	165	173	181	189	224	216	208
12:00	179	181	190	199	208	216	225	234	218	203	187	172	156	140	234	213	328	309	290	271	253	234	225	216	208	199	190	181	240	226	212
13:00	164	175	176	178	180	182	183	185	180	175	170	164	159	154	185	220	315	289	263	237	211	185	183	182	180	178	176	175	177	179	182
14:00	147	129	131	132	133	134	136	137	135	133	131	129	127	125	137	168	206	192	178	164	151	137	136	134	133	132	131	129	135	141	146
15:00	92	85	85	86	86	87	87	88	87	86	85	84	84	83	88	92	109	105	100	96	92	88	87	87	86	86	85	85	90	96	102
16:00	24	34	32	31	30	28	27	25	25	25	25	25	21	24	25	31	28	27	27	26	26	25	27	28	30	31	32	34	38	42	47
17:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX D: Hourly Relative Humidity (%)

Hourly Relative Humidity (%)

Source. Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month. January

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	97	97	95	96	97	85	80	74	76	81	89	95	93	87	81	88	97	90	89	91	84	85	97	95	89	84	96	93	91	87	85
1:00	91	95	91	91	91	77	75	70	76	73	85	88	89	84	75	80	92	84	88	84	74	84	89	90	87	79	84	84	86	81	80
2.00	84	93	87	85	85	70	70	65	76	66	82	81	85	82	68	71	88	79	88	78	63	83	82	86	85	74	71	74	81	75	74
3:00	78	91	83	80	79	62	65	61	76	58	78	74	81	79	62	63	83	73	87	71	53	82	74	81	83	69	59	63	76	69	69
4:00	66	77	73	70	72	59	61	55	65	51	78	68	74	69	55	56	69	64	76	66	46	74	67	72	71	64	54	60	70	61	59
5:00	55	63	63	60	64	57	57	50	54	43	78	62	68	59	49	50	54	55	66	62	38	66	59	62	60	59	49	54	65	53	48
6:00	43	49	53	50	57	54	53	44	43	36	78	56	61	49	42	43	40	46	55	57	31	58	52	53	48	54	44	49	59	45	38
7:00	41	46	52	51	51	52	50	42	39	34	81	53	58	47	40	41	40	47	54	52	30	57	51	51	46	50	43	46	56	42	36
8:00	38	44	50	52	46	49	46	39	36	32	84	49	56	45	39	38	40	48	52	46	29	55	51	49	45	47	41	42	54	39	35
9.00	36	41	49	53	40	47	43	37	32	30	87	46	53	43	37	36	40	49	51	41	28	54	50	47	43	43	40	39	51	36	33
10:00	41	51	57	59	42	52	48	43	39	40	88	50	58	48	42	44	50	55	55	45	36	58	54	50	48	46	44	44	56	43	40
11.00	46	60	65	65	44	57	52	49	45	49	90	54	63	54	46	53	59	60	58	48	43	63	58	54	54	49	47	50	60	49	48
12:00	51	70	73	71	46	62	57	55	52	59	91	58	68	59	51	61	69	66	62	52	51	67	62	57	59	52	51	55	65	56	55
13:00	60	74	76	74	50	66	60	55	54	65	91	62	71	60	56	68	74	70	67	61	52	75	67	61	62	57	59	60	69	61	56
14:00	69	77	79	78	53	70	63	54	56	70	90	65	75	60	61	74	78	75	73	71	52	83	73	64	66	62	68	64	72	67	58
15:00	78	81	82	81	57	74	66	54	58	76	90	69	78	61	66	81	83	79	78	80	53	91	78	68	69	67	76	69	76	72	59
16:00	82	84	81	83	59	76	66	55	61	77	90	71	78	66	67	85	84	81	78	75	56	92	80	68	72	70	73	74	78	77	63
17:00	85	86	81	84	62	77	67	56	63	77	91	72	78	72	67	89	86	83	77	70	58	93	81	69	75	74	70	79	79	81	66
18:00	89	89	80	86	64	79	67	57	66	78	91	74	78	77	68	93	87	85	77	65	61	94	83	69	78	77	67	84	81	86	70
19:00	90	90	83	88	69	79	70	58	71	80	92	78	80	79	69	94	89	85	80	73	66	94	83	72	80	79	72	86	82	87	73
20:00	91	90	87	90	75	80	73	59	76	83	94	81	82	80	71	94	92	86	83	82	71	94	83	75	81	80	77	87	84	88	75
21:00	92	91	90	92	80	80	76	60	81	85	95	85	84	82	72	95	94	86	86	90	76	94	83	78	83	82	82	89	85	89	78
22:00	61	61	60	61	53	53	51	40	54	57	63	57	56	55	48	63	63	57	57	60	51	63	55	52	55	55	55	59	57	59	52
23:00	31	30	30	31	27	27	25	30	27	28	32	28	28	27	24	32	31	29	29	30	25	31	28	26	28	27	27	30	28	30	26

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: February

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Time																												
0:00	71	97	96	88	88	79	89	83	85	87	91	89	85	48	69	89	90	84	89	91	57	74	77	78	59	74	79	78
1:00	69	90	87	83	83	71	86	75	76	77	84	80	78	45	63	86	87	80	86	89	56	73	70	75	57	68	67	70
2:00	67	83	79	78	77	64	82	67	68	68	77	71	71	41	58	83	84	76	84	88	55	72	62	72	56	63	55	63
3:00	65	76	70	73	72	56	79	59	59	58	70	62	64	38	52	80	81	72	81	86	54	71	55	69	54	57	43	55
4:00	60	70	64	64	63	49	72	52	53	54	62	56	53	32	44	74	75	67	78	80	48	61	49	63	49	45	37	46
5:00	56	64	59	55	55	43	66	45	47	49	53	50	41	26	35	69	68	62	74	75	43	51	42	58	45	33	32	37
6:00	51	58	53	46	46	36	59	38	41	45	45	44	30	20	27	63	62	57	71	69	37	41	36	52	40	31	26	28
7:00	55	53	50	43	41	36	51	35	43	43	43	40	28	19	26	60	57	55	65	65	37	40	35	47	38	22	25	26
8:00	58	47	47	40	36	35	43	32	45	40	42	35	26	18	25	57	52	52	60	62	38	38	33	43	37	24	24	23
9:00	62	42	44	37	31	35	35	29	47	38	40	31	24	17	24	54	47	50	54	58	38	37	32	38	35	25	23	21
10:00	65	46	49	40	34	42	44	34	49	39	43	36	30	21	27	56	52	53	57	59	42	40	34	39	36	27	24	25
11:00	68	49	53	43	36	49	52	39	51	40	45	40	35	25	31	59	57	57	60	61	46	44	36	39	36	28	25	29
12:00	71	53	58	46	39	56	61	44	53	41	48	45	41	29	34	61	62	60	63	62	50	47	38	40	37	30	26	33
13:00	76	58	62	50	49	60	64	50	56	48	56	48	44	31	45	67	68	64	66	69	52	51	48	44	42	37	30	40
14:00	80	62	67	55	59	63	66	56	60	55	65	50	46	34	56	73	73	69	70	75	53	54	57	47	47	44	34	46
15:00	85	67	71	59	69	67	69	62	63	62	73	53	49	36	67	79	79	73	73	82	55	58	67	51	52	51	38	53
16:00	86	70	72	65	74	70	72	65	66	69	72	56	50	41	71	82	81	77	73	83	57	59	69	52	55	56	46	58
17:00	87	73	74	70	79	72	76	67	70	73	72	60	52	45	75	86	84	81	73	85	59	61	71	53	58	62	53	64
18:00	88	76	75	76	84	75	79	70	73	79	71	63	53	50	79	89	86	85	73	86	61	62	73	54	61	67	61	69
19:00	89	79	77	78	85	77	79	73	78	79	73	68	55	55	79	89	86	85	77	88	64	65	75	54	65	68	67	71
20:00	90	83	80	80	87	78	79	76	82	79	76	74	57	60	80	89	86	86	81	89	67	68	77	54	68	69	72	74
21:00	91	86	82	82	88	80	79	79	67	79	78	79	59	65	80	89	86	86	85	91	70	71	79	54	72	70	78	76
22:00	61	57	55	55	59	53	53	53	58	53	52	53	39	43	53	59	57	57	57	61	47	47	53	36	48	47	52	51
23:00	30	29	27	27	29	27	26	26	29	26	26	26	20	22	27	30	29	29	28	30	23	24	26	18	24	23	26	25

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month: March

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	67	76	92	83	91	92	93	89	89	87	91	92	85	80	60	79	92	87	89	81	87	87	80	92	94	85	87	91	86	91	98
1.00	64	74	87	74	86	84	88	86	79	82	83	88	78	70	55	76	87	81	86	76	83	82	80	90	89	82	83	86	83	88	96
2:00	61	72	82	65	80	77	83	84	68	76	75	85	71	60	51	74	83	75	82	72	78	77	80	87	83	79	80	83	80	86	93
3:00	58	70	77	56	75	69	78	81	58	71	67	81	64	50	46	71	78	69	79	67	74	72	80	85	78	76	76	79	77	83	91
4:00	49	58	61	48	69	59	71	73	50	60	60	78	57	43	41	64	70	70	72	63	66	64	80	83	72	71	70	72	72	76	91
5:00	41	45	44	40	62	49	63	66	43	50	53	76	50	35	37	58	62	72	66	60	59	56	80	82	66	67	65	66	67	69	90
6:00	32	33	28	32	56	39	56	58	35	39	46	73	43	28	32	51	54	73	59	56	51	48	80	80	60	62	59	59	62	62	90
7.00	29	31	25	30	53	35	50	50	32	34	46	69	41	29	32	49	48	67	58	53	46	48	76	80	57	56	57	57	59	59	84
8:00	25	30	21	28	51	30	45	42	30	30	46	66	40	30	32	47	43	62	58	49	42	48	72	80	53	51	55	55	55	57	77
9.00	22	28	18	26	48	26	39	31	27	25	46	62	38	31	32	45	37	56	57	46	37	48	68	80	50	45	53	53	52	54	71
10:00	26	32	23	27	51	35	46	40	31	30	53	63	42	31	33	45	41	61	59	48	45	52	77	84	53	43	56	54	57	69	74
11.00	31	36	28	29	53	44	52	46	36	35	60	63	46	31	34	46	45	66	61	50	53	57	87	87	56	41	59	55	62	83	76
12:00	35	40	33	30	56	53	59	52	40	40	67	64	50	31	35	46	49	71	63	52	61	61	96	91	59	39	62	56	67	98	79
13:00	38	43	33	46	60	56	64	59	43	49	73	68	54	33	39	50	50	72	64	58	65	60	92	91	61	47	64	62	71	97	82
14:00	41	46	34	61	64	59	70	65	45	57	78	72	59	34	44	54	52	72	66	64	69	59	87	91	62	56	67	69	75	97	85
15:00	44	49	34	77	68	62	75	72	48	66	84	76	63	36	48	58	53	73	67	70	73	58	83	91	64	64	69	75	79	96	88
16:00	45	54	38	80	72	63	78	72	50	69	84	77	65	43	53	61	57	76	71	72	76	59	84	92	67	69	75	78	83	94	90
17:00	47	60	41	83	75	65	81	73	52	72	84	78	66	50	57	64	60	79	76	75	80	60	84	93	70	75	80	82	87	92	91
18.00	48	65	45	86	79	66	84	73	54	75	84	79	68	57	62	67	64	82	80	77	83	61	85	94	73	80	86	85	91	90	93
19:00	50	74	52	87	81	70	83	77	59	78	87	79	69	58	68	71	69	84	81	77	84	63	87	93	78	82	86	85	92	92	92
20:00	53	82	59	88	83	74	83	80	63	81	89	80	69	60	73	74	73	86	81	78	86	64	88	93	82	83	87	86	92	93	92
21:00	55	91	66	89	85	78	82	84	68	84	92	80	70	61	79	78	78	88	82	78	87	66	90	92	87	85	87	86	93	95	91
22:00	37	61	44	59	57	52	55	56	45	56	61	53	47	41	53	52	52	59	55	52	58	44	60	61	58	57	58	57	62	63	61
23:00	18	30	22	30	28	26	27	28	23	28	31	27	23	20	26	26	26	29	27	26	29	22	30	31	29	28	29	29	31	32	30

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: April

Day / Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0:00	94	87	84	86	86	91	89	84	91	90	92	91	93	93	91	87	90	79	89	77	66	81	87	84	87	77	87	77	85	85
1:00	90	80	77	76	81	87	85	80	87	86	88	86	74	87	85	84	85	77	84	74	57	79	81	76	75	73	82	76	79	76
2:00	87	74	70	66	77	82	81	75	83	83	83	81	55	82	78	81	80	75	79	72	49	77	75	68	62	70	78	76	72	67
3:00	83	67	63	56	72	78	77	71	79	79	79	76	36	76	72	78	75	73	74	69	40	75	69	60	50	66	73	75	66	58
4:00	77	61	56	52	67	69	69	64	73	73	72	66	36	67	67	70	69	68	66	65	39	63	64	58	52	65	69	70	65	54
5:00	71	55	48	47	61	61	62	58	68	68	65	55	37	58	62	63	62	63	58	62	39	55	60	57	53	65	66	65	64	49
6:00	65	49	41	43	56	52	54	51	62	62	58	45	37	49	57	55	56	58	50	58	38	45	55	55	55	64	62	60	63	45
7:00	63	46	38	41	54	51	51	51	58	60	57	39	34	46	52	55	55	55	48	54	38	44	54	53	55	61	61	53	60	44
8:00	62	42	36	39	53	50	48	50	54	57	57	34	30	42	47	56	55	52	47	49	38	42	52	51	54	59	59	47	58	44
9:00	60	39	33	37	51	49	45	50	50	55	56	28	27	39	42	56	54	49	45	45	38	41	51	49	54	56	57	40	55	43
10:00	59	46	38	39	52	51	48	51	54	62	60	28	31	43	44	60	58	52	48	48	39	45	53	53	57	66	55	48	62	46
11:00	59	54	42	41	52	52	52	52	58	70	64	29	36	46	46	63	63	55	52	52	40	48	54	56	60	76	52	56	69	49
12:00	58	61	47	43	53	54	55	53	62	77	68	29	40	50	48	67	67	58	55	55	41	52	56	60	63	86	50	64	76	52
13:00	63	64	51	49	54	59	59	58	66	78	72	40	43	54	56	70	71	61	58	60	43	57	59	63	68	82	56	68	75	58
14:00	68	68	56	56	54	63	62	63	71	78	75	51	46	58	65	73	74	65	62	66	45	62	62	66	74	78	63	73	74	64
15:00	73	71	60	62	55	68	66	68	75	79	79	62	49	62	73	76	78	68	65	71	47	67	65	69	79	74	69	77	73	70
16:00	78	68	67	65	62	72	71	72	78	80	83	62	51	65	76	78	80	71	67	69	52	68	69	72	78	75	71	77	71	75
17:00	84	65	73	69	68	75	76	77	80	81	86	63	53	68	80	79	83	73	69	67	57	70	72	74	77	76	72	77	69	80
18:00	89	62	80	72	75	79	81	81	83	82	90	63	55	71	83	81	85	76	71	65	62	71	76	77	76	77	74	77	67	85
19:00	87	66	83	74	78	81	82	82	84	85	90	71	62	72	84	83	82	79	73	63	67	74	79	79	76	78	75	76	68	85
20:00	84	70	87	76	81	83	83	84	86	87	91	78	68	74	86	86	80	82	74	62	71	77	82	81	77	80	75	74	70	85
21:00	82	74	90	78	84	85	84	85	87	90	91	86	75	75	87	88	77	85	76	60	76	80	85	83	77	81	76	73	71	85
22:00	55	49	60	52	56	57	56	57	58	60	61	57	50	50	58	59	51	57	51	40	51	53	57	55	51	54	51	49	47	57
23:00	27	25	30	26	28	28	28	28	29	30	30	29	25	25	29	29	26	28	25	20	25	27	28	28	26	27	25	24	24	28

Hourly Relative Humidity (%)

Source Bangladesh Meteorological Department, Climate Divison, Agargaon, Dhaka

Year 2005 Month, May

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0.00	88	81	84	86	68	93	74	89	68	93	92	92	85	80	85	90	91	92	92	88	81	88	88	95	92	91	87	87	86	90	89
1.00	77	73	76	85	61	83	67	89	73	88	88	84	82	77	85	85	83	87	88	83	79	90	86	91	89	87	83	83	82	85	83
2.00	67	66	68	84	54	74	61	90	77	82	84	77	80	74	85	79	74	81	83	77	76	92	84	88	86	82	78	79	77	79	78
3:00	56	58	60	83	47	64	54	90	82	77	80	69	77	71	85	74	66	76	79	72	74	94	82	84	83	78	74	75	73	74	72
4.00	54	57	56	84	61	59	51	84	82	72	74	67	72	65	79	69	67	74	76	68	72	95	82	81	77	74	68	70	69	67	66
5:00	52	57	53	86	76	55	47	77	83	68	67	64	67	60	74	65	68	71	73	63	71	95	81	78	71	70	62	65	64	60	59
6:00	50	56	49	87	90	50	44	71	83	63	61	62	62	54	68	60	69	69	70	59	69	96	81	75	65	66	56	60	60	53	53
7:00	50	55	47	82	76	49	45	69	78	60	55	60	60	56	66	58	66	66	78	61	69	86	79	73	63	64	57	58	58	53	54
8:00	51	54	46	77	61	48	45	67	73	56	50	58	57	57	65	55	63	64	85	64	70	77	78	72	61	63	58	55	57	53	55
9:00	51	53	44	72	47	47	46	65	68	53	44	56	55	59	63	53	60	61	93	66	70	67	76	70	59	61	59	53	55	53	56
10:00	54	56	47	71	55	49	49	67	68	50	47	63	58	60	67	56	73	63	88	70	74	72	79	66	64	66	61	55	57	54	58
11.00	58	58	50	70	63	50	51	70	68	47	49	69	62	62	72	58	85	65	82	73	79	78	83	63	69	70	62	58	60	56	61
12:00	61	61	53	69	71	52	54	72	68	44	52	76	65	63	76	61	98	67	77	77	83	83	86	59	74	75	64	60	62	57	63
13:00	65	64	59	72	74	56	58	77	71	53	58	80	74	67	70	65	94	72	80	77	84	83	86	64	76	77	67	65	63	61	66
14:00	70	68	65	75	78	61	63	83	74	61	63	85	82	70	65	69	91	77	84	76	86	82	86	70	78	79	70	70	65	65	70
15:00	74	71	71	78	81	65	67	88	77	70	69	89	91	74	59	73	87	82	87	76	87	82	86	75	80	81	73	75	66	69	73
16:00	78	72	73	78	92	68	71	90	80	71	75	84	86	77	63	75	88	82	87	77	87	85	87	78	82	83	77	78	69	72	76
17.00	81	74	76	79	83	70	74	91	82	72	80	79	81	80	67	78	90	83	86	78	87	87	88	82	84	86	82	82	73	74	78
18:00	85	75	78	79	84	73	78	93	85	73	86	74	76	83	71	80	91	83	86	79	87	90	89	85	86	88	86	85	76	77	81
19:00	85	76	79	77	89	73	80	93	87	76	87	74	74	83	77	84	91	84	86	80	88	91	89	86	88	88	86	85	78	80	82
20:00	85	77	81	76	93	73	83	93	88	78	89	74	72	83	82	87	91	85	85	81	88	92	90	87	91	88	86	86	81	84	82
21:00	85	78	82	74	98	73	85	93	90	81	90	74	70	83	88	91	91	86	85	82	89	93	90	88	93	88	86	86	83	87	83
22:00	57	52	55	49	65	49	57	62	60	54	60	49	47	55	59	61	61	57	57	55	59	62	60	59	62	59	57	57	55	58	55
23:00	28	26	27	25	33	24	28	31	30	27	30	25	23	28	29	30	30	29	28	27	30	31	30	29	31	29	29	29	28	29	28

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: June

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
0:00	87	88	89	88	84	90	87	90	90	90	92	83	89	92	92	92	92	92	76	86	87	89	90	93	92	92	91	96	93	94
1:00	81	85	84	80	78	84	82	85	85	84	88	81	85	85	90	88	89	87	75	81	84	84	88	87	88	89	86	96	90	92
2:00	76	83	78	73	72	77	78	79	79	78	84	79	81	78	88	84	86	81	75	76	80	80	86	81	84	86	82	95	86	90
3:00	70	80	73	65	66	71	73	74	74	72	80	77	77	71	86	80	83	76	74	71	77	75	84	73	80	83	77	95	83	88
4:00	67	74	68	62	64	67	70	72	69	67	73	72	80	71	84	84	79	72	74	68	72	79	83	73	80	78	78	95	85	86
5:00	65	67	63	60	62	64	68	70	63	63	66	68	83	70	82	87	76	69	74	66	68	83	81	72	80	74	79	94	88	83
6:00	62	61	58	57	60	60	65	68	58	58	59	63	86	70	80	91	72	65	74	63	63	87	80	70	80	69	80	94	90	81
7:00	61	60	57	60	58	56	59	66	61	57	60	62	78	69	79	91	70	63	72	62	61	90	80	77	78	73	82	95	90	83
8:00	60	58	56	64	55	51	52	65	64	57	60	60	70	69	78	90	69	60	69	62	60	93	79	85	77	78	83	95	90	86
9:00	59	57	55	67	53	47	46	63	67	56	61	59	62	68	77	90	67	58	67	61	58	96	79	92	75	82	85	96	90	88
10:00	61	60	57	68	68	50	50	61	67	57	65	62	68	78	78	90	70	63	70	65	61	91	79	90	75	80	86	94	89	88
11:00	63	62	60	70	83	53	54	59	66	57	69	64	74	88	79	90	73	67	72	70	64	85	80	89	75	78	86	91	88	87
12:00	65	65	62	71	98	56	58	57	66	58	73	67	80	98	80	90	76	72	75	74	67	80	80	87	75	76	87	89	87	87
13:00	69	69	66	67	97	62	68	61	69	68	74	71	80	97	82	90	78	76	74	76	70	82	82	87	78	77	89	89	87	87
14:00	73	74	70	62	97	67	78	66	73	77	75	74	81	97	85	89	81	80	73	77	74	84	85	88	82	79	90	90	88	88
15:00	77	78	74	58	96	73	88	70	76	87	76	78	81	96	87	89	83	84	72	79	77	86	87	88	85	80	92	90	88	88
16:00	80	81	77	65	95	75	89	74	76	85	77	80	83	95	88	87	84	85	73	80	80	87	88	89	86	81	93	92	88	89
17:00	82	83	81	72	94	77	89	77	73	82	78	82	85	93	88	85	86	85	73	81	83	88	88	91	86	82	94	93	88	91
18:00	85	86	84	79	93	79	90	81	75	80	79	84	87	92	89	83	87	86	74	82	86	89	89	92	87	83	95	95	88	92
19:00	86	87	85	82	92	81	90	83	78	82	80	85	87	92	90	84	88	87	76	83	87	89	89	92	88	84	95	95	89	92
20:00	86	88	86	85	92	84	90	84	82	85	82	85	88	91	91	86	88	87	77	85	89	90	90	93	88	86	95	95	90	92
21:00	87	89	87	88	91	86	90	86	85	87	83	86	88	91	92	87	89	88	79	86	90	90	90	93	89	87	95	95	91	92
22:00	58	59	58	59	61	57	60	57	57	58	55	57	59	61	61	58	59	59	53	57	60	60	60	62	59	58	63	63	61	61
23:00	29	30	29	29	30	29	30	29	28	29	28	29	29	30	31	29	30	29	26	29	30	30	30	31	30	29	32	32	30	31

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: July

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	92	97	99	93	93	96	88	87	87	87	93	89	90	95	96	93	95	90	90	94	90	93	96	92	81	78	85	89	81	87	87
1:00	89	95	99	92	95	90	84	82	84	86	91	87	91	96	96	90	89	87	86	90	83	93	94	88	76	74	87	84	77	81	82
2:00	85	92	98	91	96	85	80	76	82	86	90	85	93	96	95	88	84	85	82	85	76	92	92	84	70	69	88	79	74	75	76
3:00	82	90	98	90	98	79	76	71	79	85	88	83	94	97	95	85	78	82	78	81	69	92	90	80	65	65	90	74	70	69	71
4:00	86	89	98	89	95	74	73	69	75	83	90	78	94	94	94	80	74	79	73	77	70	87	83	73	63	66	84	71	68	67	69
5:00	90	88	98	89	91	68	69	67	71	81	93	74	95	90	94	76	69	75	71	74	72	83	76	67	62	67	78	68	65	65	68
6:00	94	87	98	88	88	63	66	65	67	79	95	69	95	87	93	71	65	72	68	70	73	78	69	60	60	68	72	65	63	63	66
7:00	90	87	96	90	84	63	65	64	72	79	91	72	96	85	92	70	63	69	67	74	70	76	69	60	61	67	67	65	61	67	66
8:00	87	88	94	93	81	64	63	64	77	80	87	75	96	82	90	69	62	66	67	78	66	75	69	61	61	67	62	65	59	72	65
9:00	83	88	92	95	77	64	62	63	82	80	83	78	97	90	89	68	60	63	66	82	63	73	69	61	62	66	57	65	57	76	65
10:00	84	89	88	92	79	64	61	64	80	78	83	79	97	80	89	70	63	64	67	85	65	74	69	62	62	66	63	66	64	75	64
11:00	84	91	85	88	81	63	61	66	77	77	82	79	96	81	89	73	66	65	68	87	67	75	69	62	62	67	69	67	71	75	64
12:00	85	92	81	85	83	63	60	67	75	75	82	80	96	81	89	75	69	66	69	90	69	76	69	63	62	67	75	68	78	74	63
13:00	88	93	86	86	85	68	64	69	77	77	84	82	96	82	89	77	73	69	71	90	73	80	71	67	67	69	76	69	78	75	68
14:00	92	95	90	86	87	72	67	72	78	80	87	84	95	84	90	79	76	72	74	89	77	83	74	72	71	72	78	70	79	76	73
15:00	95	96	95	87	89	77	71	74	80	82	89	86	95	85	90	81	80	75	76	89	81	87	76	76	76	74	79	71	79	77	78
16:00	94	96	95	88	90	78	73	75	80	84	90	86	95	86	90	84	81	78	83	91	84	87	77	82	76	75	79	74	79	79	79
17:00	94	96	95	88	92	79	75	76	80	85	91	87	95	86	91	87	82	82	90	93	86	88	79	89	77	76	79	76	80	81	81
18:00	93	96	95	89	93	80	77	77	80	87	92	87	95	87	91	90	83	85	97	95	89	88	80	95	77	77	79	79	80	83	82
19:00	93	97	94	89	94	83	78	79	82	87	92	87	96	88	92	91	85	86	97	93	90	89	84	94	77	79	82	79	81	83	84
20:00	93	97	93	90	94	87	80	80	83	88	92	87	96	89	92	92	86	86	96	92	91	91	88	93	78	81	84	80	82	83	85
21:00	93	98	92	90	95	90	81	82	85	88	92	87	97	90	93	93	88	87	96	90	92	92	92	92	78	83	87	80	83	83	87
22:00	62	65	61	60	63	60	51	55	57	59	61	58	65	60	62	62	59	58	64	60	61	61	61	61	52	55	58	53	55	55	58
23:00	31	33	31	30	32	30	27	27	28	29	31	29	32	30	31	31	29	29	32	30	31	31	31	31	26	28	29	27	28	28	29

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: August

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	87	87	88	90	90	92	88	92	92	95	95	96	95	95	88	93	92	95	93	88	92	94	90	93	91	93	92	92	90	92	92
1:00	83	86	84	88	87	91	87	88	94	95	95	93	91	94	86	92	86	94	89	84	91	93	88	91	89	90	87	88	83	87	87
2:00	78	86	80	85	83	89	87	83	95	95	95	90	88	92	83	91	81	94	85	90	90	93	86	89	88	86	81	84	76	82	83
3:00	74	85	76	83	80	88	86	79	97	95	95	87	84	91	81	90	75	93	81	76	89	92	84	87	86	83	76	80	69	77	78
4:00	69	78	73	80	77	85	81	79	97	93	91	84	82	88	79	82	72	91	82	73	84	97	82	85	85	79	75	75	68	74	80
5:00	65	70	70	78	73	81	77	80	96	92	87	82	79	85	78	74	70	88	82	71	80	82	81	84	84	74	74	71	68	70	82
6:00	60	63	67	75	70	78	72	80	96	90	83	79	77	82	76	66	67	86	83	68	75	77	79	82	83	70	73	66	67	67	84
7:00	58	62	67	73	72	77	70	86	89	87	78	76	75	78	75	73	67	83	81	76	77	82	77	79	82	68	78	64	67	66	82
8:00	57	62	67	71	73	77	69	91	82	84	74	72	73	75	75	80	67	81	78	84	79	87	75	75	80	67	82	63	67	64	79
9:00	55	61	67	69	75	76	67	97	75	81	69	69	71	71	74	87	67	78	76	92	81	92	73	72	79	65	87	61	67	63	77
10:00	58	65	68	77	80	77	71	94	77	81	71	75	71	73	73	83	68	76	76	90	81	88	76	75	80	71	85	64	69	66	76
11:00	61	68	68	85	84	79	75	92	79	82	72	80	72	74	72	80	68	73	75	87	86	84	78	79	82	76	82	67	70	69	76
12:00	64	72	69	93	89	80	79	89	81	82	74	86	72	76	71	76	69	71	75	85	89	80	81	82	83	82	90	70	72	72	75
13:00	67	72	71	92	89	82	83	90	85	86	79	86	75	78	74	77	71	74	76	86	90	83	84	87	83	84	82	74	75	75	80
14:00	70	73	73	90	89	85	86	90	88	90	84	87	78	81	77	77	74	77	76	88	91	86	86	91	83	87	84	78	77	79	84
15:00	73	73	75	89	89	87	90	91	92	94	89	87	81	83	80	78	76	80	77	89	92	89	89	96	83	89	86	82	80	82	89
16:00	75	74	79	89	90	87	91	92	92	94	90	89	83	84	81	80	79	82	79	89	91	90	89	96	85	89	87	83	83	84	88
17:00	77	75	83	89	91	88	91	92	92	95	91	90	85	86	82	83	82	85	81	90	89	90	90	95	88	90	88	85	86	87	88
18:00	79	76	87	89	92	88	92	93	92	95	92	92	87	87	83	85	85	87	83	90	88	91	90	95	90	90	89	86	89	89	87
19:00	81	83	88	89	93	88	91	93	92	95	93	92	87	87	86	87	84	87	84	90	89	91	91	93	91	91	89	88	89	89	89
20:00	82	85	88	88	93	88	91	92	93	95	94	93	88	87	90	88	83	88	86	90	91	90	91	92	92	91	90	89	89	90	90
21:00	84	90	89	88	94	88	90	92	93	95	95	93	88	87	93	90	82	88	87	90	92	90	92	90	93	92	90	91	89	90	92
22:00	56	60	59	59	63	59	60	61	62	63	63	62	59	58	62	60	55	59	58	60	61	60	61	60	62	61	60	61	59	60	61
23:00	28	30	30	29	31	29	30	31	31	32	32	31	29	29	31	30	27	29	29	30	31	30	31	30	31	31	30	30	30	30	31

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: September

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Time																														
0:00	97	95	90	90	93	97	92	98	97	94	93	83	83	90	95	79	83	77	87	96	95	93	95	93	96	96	97	85	96	88
1:00	90	89	86	84	88	87	86	92	93	90	89	77	80	85	88	78	80	73	80	94	90	87	91	95	93	90	90	82	92	85
2:00	83	83	83	79	84	78	80	87	88	87	85	72	78	79	80	78	78	68	73	91	85	81	87	96	89	84	84	78	89	83
3:00	76	77	79	73	79	68	74	81	84	83	81	66	75	74	73	77	75	64	66	89	80	75	83	98	86	78	77	75	85	80
4:00	77	72	75	71	83	65	82	77	81	77	78	64	60	70	69	72	72	62	64	89	76	73	81	93	82	76	74	71	86	76
5:00	77	68	70	68	87	62	90	74	79	70	74	62	63	66	65	66	69	61	63	90	73	71	79	89	79	73	72	68	88	71
6:00	78	63	66	66	91	59	98	70	76	64	71	60	57	62	61	61	66	59	61	90	69	69	77	84	75	71	69	64	89	67
7:00	82	67	65	68	91	57	98	67	73	63	67	60	60	62	60	60	65	58	63	92	68	76	78	84	78	68	69	70	85	77
8:00	85	70	63	71	91	54	98	65	69	63	64	60	62	63	59	59	64	56	65	94	66	83	78	84	81	66	60	77	81	86
9:00	89	74	62	73	91	52	98	62	66	62	60	60	65	63	58	58	63	55	67	96	65	90	79	84	84	63	69	83	77	96
10:00	86	75	64	74	90	59	98	66	67	64	62	65	75	68	62	61	66	59	67	96	68	89	84	85	86	68	77	85	78	96
11:00	82	76	66	74	88	66	97	70	68	67	64	69	85	74	65	63	68	62	67	95	72	87	90	85	88	74	85	86	78	97
12:00	79	77	68	75	87	73	97	74	69	69	66	74	95	79	69	66	71	66	67	95	75	86	95	86	90	79	93	88	79	97
13:00	83	79	72	77	89	75	96	77	73	77	71	75	91	80	72	68	74	69	71	96	77	88	95	89	90	83	93	88	81	97
14:00	88	81	75	80	90	76	96	79	76	85	75	75	87	81	74	69	76	73	74	96	80	89	94	91	89	88	93	89	83	96
15:00	92	83	79	82	92	78	95	82	80	93	80	76	83	82	77	71	79	76	78	97	82	91	94	94	89	92	93	89	85	96
16:00	92	85	81	82	93	81	95	87	82	93	84	78	84	86	80	74	79	77	84	96	84	91	94	95	90	92	93	89	86	96
17:00	93	88	84	83	94	84	96	91	83	93	88	79	86	89	83	77	79	78	91	96	85	91	94	96	91	93	92	88	88	96
18:00	93	90	86	83	95	87	96	96	85	93	92	81	87	93	86	80	79	79	97	95	87	91	94	97	92	93	92	88	89	96
19:00	94	90	86	84	95	88	96	96	87	94	92	82	89	93	87	80	79	81	97	95	88	91	94	97	93	94	92	89	89	96
20:00	94	89	87	85	95	89	95	97	88	94	92	82	90	93	89	81	80	82	96	94	88	91	93	96	93	94	92	91	90	96
21:00	95	89	87	86	95	90	95	97	90	95	92	83	92	93	90	81	80	84	96	94	89	91	93	96	94	95	92	92	90	96
22:00	63	59	58	57	63	60	63	65	60	63	61	55	61	62	60	54	53	56	64	63	59	61	62	64	63	63	61	61	60	64
23:00	32	30	29	29	32	30	32	32	30	32	31	28	31	31	30	27	27	28	32	31	30	30	31	32	31	32	31	31	30	32

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: October

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	96	93	91	93	95	96	95	95	95	97	93	89	90	95	95	88	90	97	87	94	90	94	98	98	95	93	82	82	90	86	81
1:00	96	93	87	90	89	91	86	90	86	87	83	85	82	84	81	84	87	94	85	94	87	91	97	93	88	86	79	81	82	79	71
2:00	96	93	84	86	83	85	78	84	78	76	73	82	73	72	68	79	84	92	84	95	85	89	97	87	82	80	75	80	75	73	62
3:00	96	93	80	83	77	80	69	79	69	66	63	78	65	61	54	75	81	80	82	95	82	86	96	82	75	73	72	79	67	66	52
4:00	96	93	80	82	79	74	65	76	63	63	64	74	61	57	53	69	76	83	79	95	85	83	95	81	71	70	68	77	64	61	46
5:00	96	90	81	81	80	67	62	74	58	60	64	69	58	53	51	63	72	77	75	94	88	81	95	80	67	66	65	76	62	56	40
6:00	96	88	81	80	82	61	58	71	52	57	65	65	54	49	50	57	67	71	72	94	91	78	94	79	63	63	61	74	59	51	34
7:00	95	89	81	77	76	60	61	73	52	55	66	63	54	49	46	60	77	76	72	94	91	83	94	78	63	61	57	73	58	49	34
8:00	94	89	81	74	71	59	64	74	51	54	66	62	55	50	41	63	86	82	73	95	91	88	94	78	62	60	53	72	58	48	34
9:00	93	90	81	71	65	58	67	76	51	52	67	60	55	50	37	66	96	87	73	95	91	93	94	77	62	58	49	71	57	46	34
10:00	93	89	81	74	70	60	69	78	57	57	69	63	59	53	45	74	96	88	74	95	91	93	95	81	66	61	56	75	64	53	44
11:00	92	89	81	76	76	62	70	79	64	62	70	66	63	56	53	82	96	90	76	96	92	94	95	84	69	64	63	79	71	60	53
12:00	92	88	81	79	81	64	72	81	70	67	72	69	67	59	61	90	96	91	77	96	92	94	96	88	73	67	70	83	78	67	63
13:00	93	89	84	80	81	71	77	85	74	72	74	72	72	63	64	90	96	90	80	95	92	94	96	90	76	66	71	85	82	71	61
14:00	94	89	86	82	81	79	82	89	79	78	76	74	76	66	74	91	96	89	82	95	93	95	96	91	80	66	72	88	86	75	58
15:00	95	90	89	83	81	86	87	93	83	83	78	77	81	70	81	91	96	88	85	94	93	95	96	93	83	65	73	90	90	79	56
16:00	95	90	89	85	85	89	89	94	86	85	80	78	83	73	82	92	96	89	85	94	93	96	96	94	83	71	74	90	86	77	64
17:00	96	91	90	88	88	91	90	94	89	88	82	78	84	77	84	92	97	91	86	94	94	97	97	95	84	76	75	90	82	74	71
18:00	96	91	90	90	92	94	92	95	92	90	84	79	86	80	85	93	97	92	86	94	94	98	97	96	84	82	76	90	78	72	79
19:00	96	91	91	90	93	94	93	95	92	91	85	82	88	82	88	93	97	90	89	93	94	98	97	96	86	82	78	90	80	76	82
20:00	95	91	92	91	93	93	94	95	93	92	85	85	90	85	90	94	97	88	92	92	94	97	98	97	89	82	80	90	83	80	86
21:00	95	91	93	91	94	93	95	95	93	93	86	88	92	87	93	94	97	86	95	91	94	97	98	97	91	82	82	90	85	84	89
22:00	63	61	62	61	63	62	63	63	62	62	57	59	61	58	62	63	65	57	63	61	63	65	65	65	61	55	55	60	57	56	59
23:00	32	30	31	30	31	31	32	32	31	31	29	29	31	29	31	31	32	29	32	30	31	32	33	32	30	27	27	30	28	28	30

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005 Month: November

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	30	21	22	23	24	25	26	27	28	29	30
Time																														
0:00	91	90	86	83	89	80	94	89	89	96	91	76	96	96	96	96	96	86	93	96	96	94	96	97	95	94	98	93	84	89
1:00	79	82	81	79	80	75	87	84	86	96	81	70	85	83	88	84	85	81	85	90	90	87	88	93	91	92	96	86	78	81
2:00	66	75	75	75	70	71	80	79	83	95	71	64	75	71	90	72	74	76	76	85	84	79	79	88	87	91	94	80	73	74
3:00	54	67	70	71	61	66	73	74	80	95	61	58	64	58	72	60	63	71	68	79	78	72	71	84	83	89	92	73	67	66
4:00	51	61	59	65	56	63	64	73	75	86	54	53	56	54	65	58	57	61	61	69	71	67	64	78	77	83	85	66	59	59
5:00	49	56	47	60	51	60	54	72	69	77	47	47	47	49	59	55	51	52	55	58	65	63	56	73	70	76	78	58	52	53
6:00	46	50	36	54	46	57	45	71	64	68	41	42	39	45	52	53	45	42	48	48	58	58	49	67	64	70	71	51	44	46
7:00	47	47	39	53	41	53	45	69	63	66	41	42	39	46	51	51	44	40	47	48	55	55	52	63	62	68	63	48	43	45
8:00	47	45	43	51	37	50	46	68	62	65	42	41	40	48	50	49	42	37	45	48	51	51	56	58	60	67	55	44	41	44
9:00	48	42	46	50	32	46	46	66	61	63	43	41	40	49	49	47	41	35	44	48	48	48	59	54	58	65	47	41	40	43
10:00	55	48	54	53	38	50	51	70	67	68	47	44	47	56	58	54	50	43	53	56	58	54	66	63	65	69	56	51	45	50
11:00	63	53	62	55	43	55	56	75	72	74	51	48	55	64	67	60	60	51	62	63	67	59	72	72	73	73	66	61	49	58
12:00	70	59	70	58	49	59	61	79	78	79	55	51	62	71	76	67	69	59	71	71	77	65	79	81	80	77	75	71	54	65
13:00	73	63	71	61	52	63	69	83	79	82	58	53	68	75	79	72	73	63	70	76	80	72	81	83	85	81	79	70	58	71
14:00	76	67	73	64	56	68	76	86	79	85	61	55	74	80	82	78	76	66	70	80	84	80	83	85	89	86	82	69	63	78
15:00	79	73	74	67	59	72	84	90	80	88	64	57	80	84	85	83	80	70	69	85	87	87	85	87	94	90	86	68	67	84
16:00	81	73	75	70	63	78	85	89	82	88	67	66	83	86	86	85	82	73	70	86	87	88	85	89	94	92	85	70	69	86
17:00	82	76	77	72	68	83	86	87	85	88	69	74	87	87	88	88	85	75	72	87	87	88	85	92	94	94	84	73	70	89
18:00	84	78	78	75	72	89	87	86	87	88	72	83	90	89	89	90	87	78	73	88	87	89	85	94	94	96	83	75	72	91
19:00	84	79	79	77	74	90	87	86	89	89	73	87	91	90	90	91	87	81	76	89	90	91	88	94	94	96	84	77	75	91
20:00	84	79	79	79	77	90	87	87	91	90	73	92	93	92	91	91	86	83	79	91	93	93	92	94	94	96	85	79	79	90
21:00	84	80	80	81	79	91	87	87	93	91	74	96	94	93	92	92	86	86	82	92	96	95	95	94	94	96	86	81	82	90
22:00	56	53	53	54	53	61	58	58	62	61	49	64	63	62	61	63	57	57	55	61	64	63	63	63	63	64	57	54	55	60
23:00	28	27	27	27	26	30	29	29	31	30	25	32	31	31	31	31	29	29	27	31	32	32	32	31	31	32	29	27	27	30

Hourly Relative Humidity (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month: December

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time																															
0:00	98	96	93	86	60	79	91	98	95	95	95	89	85	70	92	91	96	87	85	93	93	89	85	97	88	81	93	81	85	95	86
1:00	89	87	86	78	57	76	86	87	86	81	83	82	78	66	85	84	95	83	76	82	82	87	81	93	80	78	83	71	75	84	77
2:00	81	79	80	70	54	72	81	76	76	66	72	75	72	61	77	77	95	80	67	72	72	85	76	88	71	74	74	62	66	74	69
3:00	72	70	73	62	51	69	76	65	67	52	60	68	65	57	70	70	94	76	58	61	61	83	72	84	63	71	64	52	56	63	60
4:00	64	60	66	58	48	62	64	56	58	48	52	60	55	52	63	62	81	67	51	55	54	76	68	74	60	65	60	48	49	54	54
5:00	55	49	58	54	44	56	53	46	50	44	43	53	45	48	56	54	68	59	44	48	48	70	63	63	58	60	55	45	41	45	49
6.00	47	39	51	50	41	49	41	37	41	40	35	45	35	43	49	46	55	50	37	42	41	63	59	53	55	54	51	41	34	36	43
7:00	45	40	49	51	37	47	39	38	38	38	33	42	36	40	47	44	56	51	36	40	41	64	55	50	51	51	47	35	34	35	41
8:00	44	40	46	53	33	45	38	39	36	37	32	38	38	38	46	42	56	53	35	39	40	64	52	47	47	49	44	30	35	34	39
9:00	42	41	44	54	29	43	36	40	33	35	30	35	39	35	44	40	57	54	34	37	40	65	48	44	43	46	40	24	35	33	37
10:00	52	50	49	59	35	53	46	48	44	46	42	39	43	46	53	48	62	57	46	47	44	67	53	51	48	50	45	31	46	38	43
11:00	63	58	53	64	42	64	56	55	56	54	53	42	48	58	62	55	68	59	58	57	48	70	58	58	53	54	49	39	58	42	50
12:00	73	67	58	69	48	74	66	63	67	69	65	46	52	69	71	63	73	62	70	67	52	72	63	65	58	58	54	46	69	47	56
13:00	76	71	62	70	49	72	69	68	70	74	71	53	54	69	70	68	72	65	72	72	59	74	68	71	63	58	55	47	74	52	57
14.00	79	76	65	72	49	71	72	73	72	78	78	60	55	68	68	73	72	69	73	77	67	77	72	78	69	57	55	48	78	57	59
15:00	82	80	69	73	50	69	75	78	75	83	84	67	57	68	67	78	71	72	75	82	74	79	77	84	74	57	56	49	83	62	60
16.00	84	80	73	68	53	73	79	82	78	84	85	69	60	74	68	81	72	68	78	84	76	81	81	81	73	63	60	52	85	63	63
17:00	86	80	78	64	55	78	84	85	82	84	86	70	64	79	68	85	73	64	82	85	78	84	85	78	72	68	63	54	88	65	67
18:00	88	80	82	59	58	82	88	89	85	85	87	72	67	85	69	88	74	60	85	87	80	86	89	75	71	74	67	57	90	66	70
19:00	90	83	85	59	62	84	88	87	87	86	88	76	69	86	77	90	76	63	86	88	82	87	90	77	74	78	76	60	91	71	75
20:00	91	87	88	59	66	86	89	86	88	86	90	80	70	88	85	91	78	67	88	88	83	89	90	80	77	81	84	64	91	75	80
21:00	93	90	91	59	70	88	89	84	90	87	91	84	72	89	93	93	80	70	89	89	85	90	91	82	80	85	93	67	92	80	85
22:00	62	60	61	39	47	59	59	56	60	58	61	56	48	59	62	62	53	47	59	59	57	60	61	55	53	57	62	45	61	53	57
23:00	31	30	30	20	23	29	30	24	30	29	30	28	24	30	31	31	27	23	30	30	28	30	30	27	27	28	31	22	31	27	28

APPENDIX E: Hourly Cloud Cover (%)

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month: January

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month: February

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year [illegible] Month March

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year [illegible] Month April

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month May

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month June

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month July

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2005 Month August

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2015 Month September

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year 2015 Month October

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year [illegible] Month November

[illegible]

Hourly Cloud Cover (%)

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year [illegible] Month December

[illegible]

APPENDIX F: Daily Total SunShine Hours

Daily Total SunShine Hours

Source: Bangladesh Meteorological Department, Climate Division, Agargaon, Dhaka

Year: 2005

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Month																															
January	7.3	5.8	5.1	1.4	6.7	8.2	8.2	8.0	7.7	8.1	0.0	8.7	7.5	8.1	6.7	7.3	5.2	3.9	4.9	8.5	8.0	2.8	0.0	6.7	8.9	7.9	7.6	4.2	4.0	8.3	8.4
February	0.8	9.0	8.4	8.9	7.6	5.2	7.2	8.0	8.6	8.6	9.1	9.6	9.6	9.7	9.7	8.3	6.8	8.4	3.6	4.8	9.9	5.0	8.7	8.8	9.5	9.8	9.5	9.2			
March	9.8	9.5	9.2	9.6	9.0	8.8	7.9	5.8	9.6	8.8	0.1	0.0	8.8	8.3	8.5	9.3	8.2	2.1	5.2	9.2	9.0	6.8	2.6	0.9	8.5	8.3	9.3	8.3	7.1	5.2	2.7
April	7.5	9.0	8.2	9.9	9.3	9.7	8.6	9.0	6.7	8.2	7.7	6.8	9.8	9.4	9.6	8.5	8.6	10.0	7.5	5.6	10.5	8.6	8.8	9.1	7.1	7.5	8.6	8.8	6.4	8.1	
May	7.6	4.4	10.9	5.6	5.9	9.4	10.8	6.8	4.5	9.4	8.9	9.6	9.3	8.7	7.2	9.2	7.4	8.3	3.9	9.4	5.8	1.6	3.2	5.1	7.2	10.0	9.6	9.4	9.9	11.3	11.1
June	9.1	7.7	9.5	4.9	7.6	9.4	8.1	6.4	8.4	3.7	1.8	3.1	0.6	1.0	0.2	0.0	0.3	3.9	2.0	1.8	1.5	0.0	0.3	2.4	0.1	1.6	0.4	0.0	0.0	0.0	
July	0.6	0.0	0.0	0.1	0.4	8.8	10.5	7.6	4.7	0.6	0.2	1.5	0.0	1.4	0.0	0.5	8.9	3.6	4.9	1.9	4.6	0.1	3.4	8.3	10.0	6.2	7.1	7.3	9.1	7.3	9.6
August	8.8	6.0	6.9	2.8	3.6	1.0	3.3	0.2	1.0	0.0	3.2	1.7	2.9	1.8	3.9	3.4	9.5	3.3	1.6	3.9	2.6	2.6	0.7	0.4	0.7	6.1	4.2	9.0	5.6	1.8	4.7
September	2.7	5.4	6.4	3.2	0.0	7.8	1.2	7.2	4.8	5.3	7.7	10.1	4.0	4.7	9.7	9.7	4.4	10.2	7.8	0.0	5.1	5.0	2.3	2.1	0.0	5.3	3.4	2.7	4.3	2.6	
October	0.0	0.0	3.0	1.5	7.1	9.6	6.7	2.9	9.2	8.5	3.5	3.4	6.0	9.4	9.9	3.9	1.8	0.8	1.8	0.0	0.0	0.0	0.0	1.9	9.0	7.1	7.6	0.8	7.6	9.6	9.8
November	5.5	9.7	9.5	9.6	9.6	8.8	8.3	0.0	5.1	7.6	9.3	9.3	9.1	8.4	7.7	8.6	8.2	8.4	6.6	3.9	2.0	3.8	0.9	0.2	3.2	4.0	7.2	8.2	8.2	8.0	
December	7.7	8.3	8.1	4.5	8.2	7.9	8.2	8.0	8.0	8.6	8.4	8.6	8.7	8.5	8.2	7.4	0.8	2.7	7.3	8.3	7.3	0.0	5.2	8.0	8.3	7.1	5.7	7.7	6.1	7.5	7.8