RELATIONSHIP BETWEEN BUILDINGS' HEIGHTS AND THE DISTANCES BETWEEN TWO ADJACENT BUILDINGS FROM SOLAR RADIATION PERSPECTIVE IN THE CONTEXT OF DHAKA CITY

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Summary

Dhaka city is an example of high density urban area. From climatic context it is located in warm humid climate. In such climate solar shading of any hard surface of a building, both horizontal and vertical is one of the major considerations for achieving thermal comfort both for indoor and outdoor. Because solar shading of any surface can help in minimizing solar radiation heat gain by the surface, that is exposed to sun either directly or indirectly.

In such densely built-up urban area there could be many options for achieving solar shading. Mutual shading by adjacent built-forms could be an effective tool to generate shadows on the building facades. So for generating shadow on one building by the adjacent building the height of that adjacent building could have relationships with the width of the adjacent building to building set back open space.

This paper intends to find out the relationship between building's height (H) and the distance from the adjacent buildings (W) from solar radiation point of view in the context of Dhaka city. In addition to that this paper also explores the threshold value of H/W, which helps in achieving optimum solar radiation heat gain by the building facades.

1. Introduction

Dhaka City has mainly two distinct seasons – hot period and cool period. The hot period or summer is longer than winter It is observed that 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 for Dhaka city the minimum solar radiation heat gain with the help of adequate shading and the maximum natural airflow within the urban grid are the major considerations to achieve thermal comfort.

In densely urban area, depending on airflow for thermal cooling is not a reliable source. As the roughness of the surfaces created by the buildings reduce air velocity and often to some extent it leads to calm conditions (Ahmed, 1995). In this situation reduction in solar radiation heat gain by the building can be considered as a prime step to achieve thermal comfort.
Any surface on earth receives solar radiation in three ways- one is direct radiation from sun, one is diffused radiation from its surrounding environment and another is reflected from other surfaces (Aronin, 1953; Givoni, 1969). The direct radiation is received in short wave radiation and the surface loses heat by outgoing long wave radiation. This heat transfer between surfaces and sun depends on radiosity and the absorptive property of the surface (Ahmed, 1995). Besides, it also depends on the absorption, scattering and reflection properties of the atmosphere (Ahmed, 1995). On these atmospheric properties human being has little control. But selecting appropriate low thermal storage material for warm climate, manipulating building form and layout and by optimizing shading, the incident solar radiation can be reasonably controlled by human beings. The study is focused on analyzing and developing guidelines for building block layout to achieve thermal comfort and therefore the shadow simulations were performed, concentrating on the design aspects of building block layout.

For warm climate shading of surface has been identified as an important design consideration (Koenigsberger et al, 1973; Givoni, 1989; Ahmed, 1995; Hyde, 2000; Rahman 2004). In a dense urban area this can be achieved by mutual shading of the surrounding surfaces of the buildings (Figure 1). So to some extent the impact of impinging solar radiation on the dense urban area depends on the ratio of height of the building and the spacing (width) between them, i.e. the H/W ratio of the spaces between buildings.

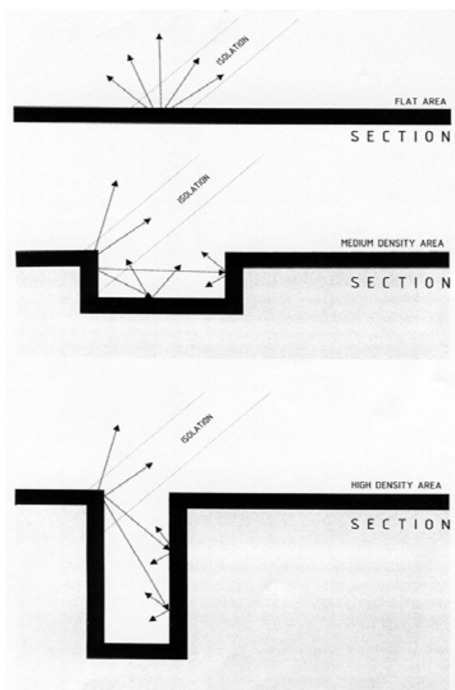

Figure 1 Schematic diagram of disposition of insolation (Source: Givoni, 1989)

For example, low H/W ratio provides scope to the building surface to get more exposure to direct and diffused solar radiation, so that the result is high ambient temperature, while due to high H/W ratio, a shaded environment is created and it produces thermally agreeable ambient climate (Ahmed, 1995).

Based on the above perception shadow simulations were performed to identify the geometric factors of building layout that affect the shading. In the following section impact of H/W ratio of open space between buildings and the buildings heights was examined on the bases of solar energy received by the surfaces of the buildings facing that open space for different orientation of that space.

2. Instrumentation

There was a PC based program for this purpose named SHADOWPACK developed by R. J. Peckham of Joint Research Centre, CEC, Ispra for solar radiation simulation. The Shadow Pack program was designed to run on IBM personal computers. The programs allowed the users to create a 3D model of a building or group of buildings and then analyze the effects of shading on the solar energy received on the various faces of the model or on the ground planes. Models were generated by using ICON module of the program and saved in sequential data files. A qualitative appraisal of the overall shading situation could be obtained using the graphical display facilities of ICON, varying the viewpoint and the latitudinal location of the model along with its orientation, month and the hour of interest were required for the shading calculation. For the quantitative assessment for different orientation Global, another component of the Shadow Pack, was used. It estimated the amount of solar energy incident on the surface of interest. The program performed calculation for a distribution of four days per month at an interval of fifteen minutes for a selected number of months. The plane area was multiplied by the incident solar radiation (using Test Reference Year or Clear sky Conditions) and the values were integrated to derive a monthly total for that particular plane. Quantitative values for the energy received on particular faces of interest were tabulated with the program GLOBAL. GLOBAL module was used to calculate the solar energy incident on the plane of study and the unit of the incident energy is mj/sqm.

2.1 Simulation parameters

The quantitative and qualitative assessment was based on the following parameters:
Location: Dhaka (24° latitude), Bangladesh.
Months: Simulations were performed for the months of March to September (Hot dry and Hot humid period of the year).
Orientation: models were examined for south, east, west, north-east, north-west, south-east and south-west orientation. North facing surface was not considered, because due to latitudal position in Dhaka city north does not get direct solar radiation. It is always under shaded situation.

3. Objectives

It was identified that shading of the exterior surfaces of a building was one of the important considerations to avoid solar radiation heat gain. It was observed that the surfaces of the building that were exposed to direct radiation resulted in high ambient temperature, while shaded environment produced thermally agreeable ambient climate.

Based on the above perception shadow simulation was done on different ratio of the building block canyon for the following objectives.

- The impact of different H/W ratio of the canyon on reduction of solar radiation incident on the exterior vertical surfaces of building.
- The effect of orientation on solar radiation incident on the above mentioned vertical surfaces for different H/W ratio of the canyon.

4. Methodology

The model for the shadow simulation was simplified into a canyon section with symmetrical buildings (Figure 2). The canyon was composed of the open space and two rows of equal height buildings along the open space paralleled to each other. The block model was developed on the basis of existing building codes. This type of block was evident in Dhaka for the development of new area.

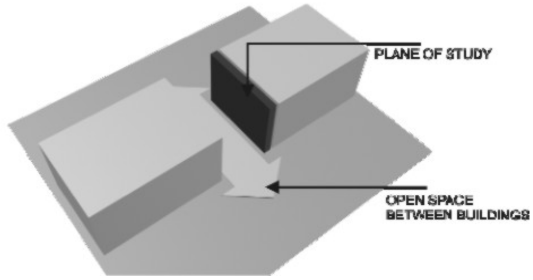

Figure 2 *Model showing study plan for which incident solar radiation calculated under different canyon ratio*

These block models were generated and examined in SHADOWPACK program. The quantitative assessments of the incident solar radiation on the vertical surfaces of the residential canyon were based on the following parameters. Model was composed of a number of buildings parallel to each other along an open space. The orientation of the model referred to the axis, which was parallel to the open space that was laid between the buildings. The H/W ratio was varied by altering the width (W) of the open space, keeping the building height (H) constant. The plane for which the calculation was done was the vertical building façade (Figure 3). The four basic orientations for which the calculation has been done were north-south, east-west, northeast-southwest and northwest-southeast. The H/W ratios investigated were 1:1, 2:1, 3:1, 4:1, 5:1and 6:1. Solar radiation per square meter on the vertical plane (plane of study) was considered as criteria for performance analysis.

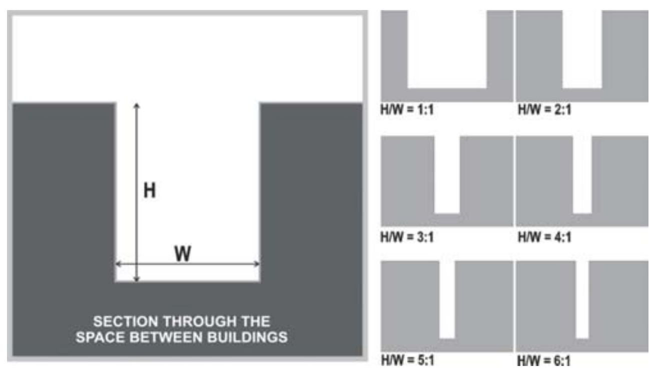

Figure 3 *Sections of different canyon models*

3. Simulation Findings

Vertical surface facing the canyon, which was elongated in the northwest-southeast direction and the surface facing northeast generally receives the minimum annual solar radiation for any H/W ratio of the canyon (Table 1). For any H/W ratio maximum incident solar radiation was on the south-west faced vertical surface. Vertical surface facing south-west (building oriented in northeast-southwest direction) and west (building oriented in east-west direction) received almost identical solar radiation. The vertical surface facing west was slightly better than southwest facing surface (Table 1). Again for vertical surface facing east, south and south-east the incident solar radiation were nearly identical and east facing surface was better than south or south-east face vertical surface (Table 1).

It was also observed that with the increase of H/W ratio of the canyon the solar radiation incident on the vertical surface was reduced for any orientation (table 1). This reduction in incident solar radiation on the vertical surface for any orientation was insignificant with the increment of H/W ratio from 3:1 to above (figure 4). This particular ratio could be regarded as the threshold value beyond which the linear relationship with the decrease of incident solar radiation per square meter with that of increasing H/W ratio became insignificant.

Table 1 Annual (for summer month only) average solar radiation incident on the vertical surface.

	N-S	E-W(W)	E-W(E)	NW-SE	NW-SE	NE-SW	NE-SW
	S. FACE	W.FACE	E.FACE	SE FACE	NW FACE	SW FACE	NE FACE
	mj/sqm	mj/sqm	mj/sqm	mj/sqm	mj/sqm	mj/sqm	mj/sqm
H/W1:1	961.9	1005.1	972.4	977.8	978.2	1013.4	955.5
H/W2:1	344.0	359.4	339.2	345.6	262.6	366.3	247.8
H/W3:1	186.3	191.8	177.6	183.5	173.3	197.8	162.0
H/W4:1	149.7	151.9	141.0	146.1	142.3	156.9	133.8
H/W5:1	145.4	146.2	137.4	141.8	138.2	150.5	129.6
H/W6:1	87.5	80.0	87.4	83.8	78.8	91.1	70.3

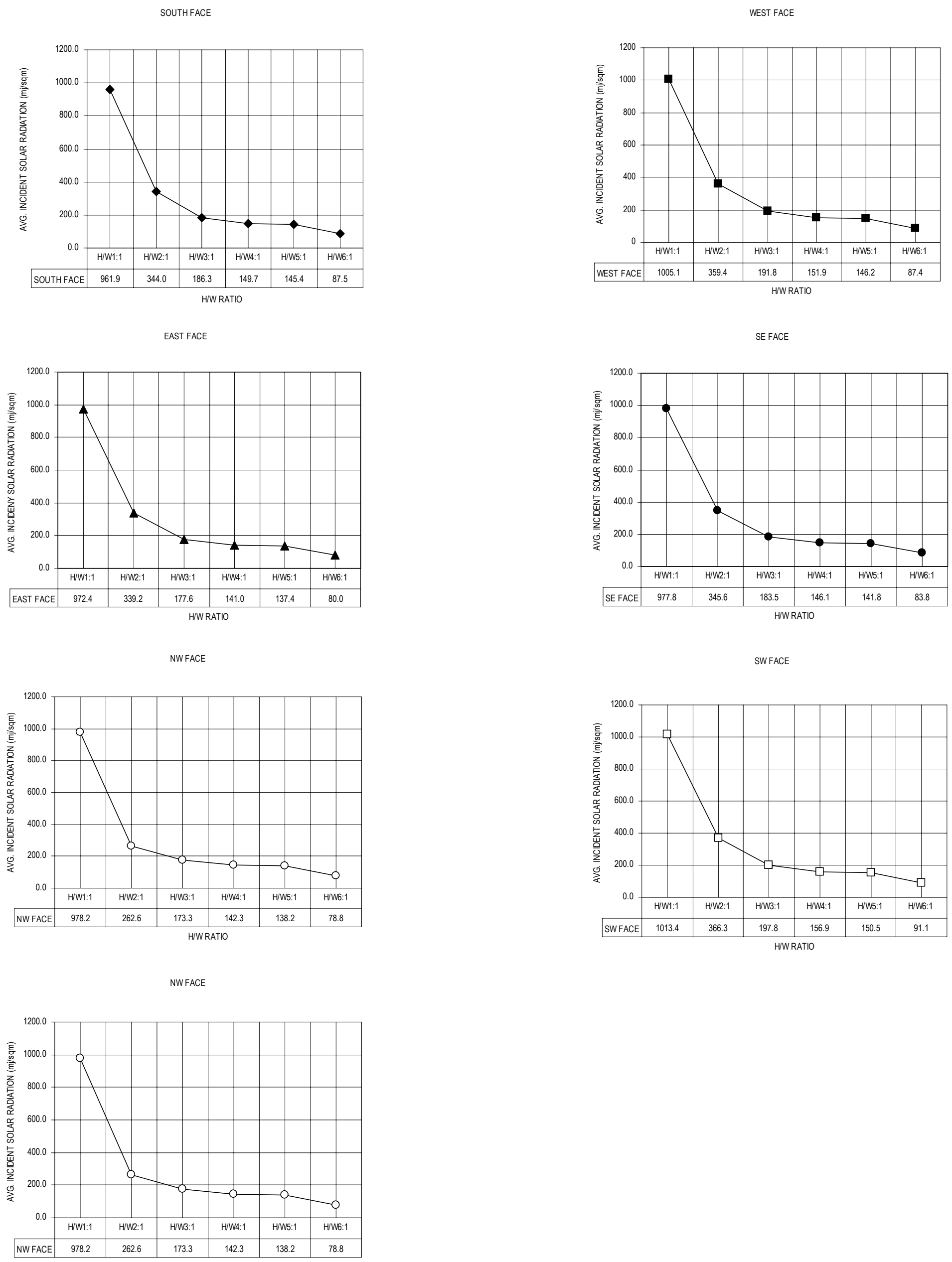

Figure 4 Annual average incident solar radiations on the vertical surfaces of different orientation at 24° latitude

For H/W ratio of 1:1 and 2:1, total solar radiation (direct and diffused) incident on the vertical surfaces of the block were greater than the solar radiation incident on the same surfaces when that block was not surrounded by vertical obstructions of the same height at a certain distance (Table 2). The incident solar radiation was nearer to the solar radiation incident on the different surfaces of the non-obstructed block when the H/W ratio was more than 2:1 (e.g. 3:1 or above).

Table 2 Average incident solar radiation on vertical surfaces under obstructed and unobstructed condition

	NS(S)	EW(W)	EW(E)	NW-SE(SE)	NE-SW(SW)
	mj/sqm	mj/sqm	mj/sqm	mj/sqm	mj/sqm
Non-obstructed block	201.1	284.4	236.9	224.2	242.8
H/W = 2:1	344.0	359.4	339.2	345.6	366.3
H/W = 3:1	186.3	191.8	177.6	183.5	197.8

When the H/W ratio was 1:1 and 2:1, the diffused solar radiation by the vertical surfaces surrounding the block helped in increasing the total incident radiation of the surface. In other H/W ratio (more than 2:1), the impact of this diffused radiation was insignificant on the total radiation. It was because, the major portion of the vertical surfaces were usually shaded during the daytime under H/W ratio of 3:1 or above. So that diffused radiation generated by these surfaces was minimum. Besides, when the distance between buildings was large, the diffused radiation from the ground also played a notable role in increasing total solar radiation incident on the vertical surfaces of the block.

4. Conclusion

It could be concluded from the above simulation studies that with the increase of H/W ratio of the canyon the incident solar radiation on the exterior vertical surfaces facing that canyon decreased. For any orientation of the canyon the threshold ratio (beyond which increasing of H/W ratio did not generate any meaningful decrease in incident solar radiation on the vertical surface) was 3:1. Identifying a threshold value for a particular canyon orientation was important in terms of developing building block layout design guideline. Design guidelines provided recommendation of construction heights along with the width of the open spaces between buildings based on these threshold values, which would ensure optimum solar radiation on the vertical surfaces that created the canyon.

For any facing of the building (except north facing) with the H/W ratio of smaller than 2:1 or equivalent additional shading would be needed to reduce the incident solar radiation on the building surface. Since for H/W ratio of 3:1 or more the variation between incident solar radiations on the vertical surfaces were significantly small than the ratio of 1:1 or 2:1, so for these ratios additional shading was not mandatory.

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