CONFLICTS AND COMPROMISES IN WINDOW DESIGN

ZEBUN NASREEN AHMED *

ABSTRACT :

The nature of the problem faced during the process of window design is such that it is not possible to specify any absolute values as solutions. The problem is further aggravated when one is faced with climates with seasons having contrary demands. Bangladesh falls in a climatic zone called "Composite or Monsoon" in which we are faced with three distinct seasons--hot-dry, warm-humid and cool-dry. Whereas design solutions for the two dry seasons often coincide, it is very difficult to find compromises when the third, warm-humid season has to be considered. (1). During the course of a research conducted in Sheffield, UK (2), a wide range of variables were studied, relative to building-climate interaction and their effect on window design. The objective of this paper is to bring to light the contradictions faced and compromises arrived at, when attempting to co-ordinate the wide range of varied aspects involved in window design.

CONTROLS FOR ACHIEVING COMFORT :

The 'comfort status' of a space is defined as the expected physical response in terms of thermal sensation of the occupants in a space. The aim of the designer is to produce comfortable interiors, and therfore any change in the comfort status should be towards the 'comfortable'. As situations diverge from the desirable 'comfortable' condition, different controls come into operation.

The first control and probably the most important one from the designer's point of view, is termed 'planning control'. This deals with proper

* *Assistant Professor, Dept. of Architecture, BUET, Dhaka*

window orientation; to catch the breeze in humid climates or the sun in cold climates or to avoid the sun when overheating could result. This control comes into play during the design stage of a building and should make best use of available climatic resources, such as the cooling of breezes, warmth of the sun, and adequate daylighting where and when desired.

The second form of control takes account of the occupier's instinctive response to uncomfortable situations and is termed 'human adjustments'. Thus, the occupant would, in case of 'hot' discomfort, open windows, reduce clothing layers and activity and finally when temperatures outside reach levels higher than that of the skin, would close windows, perhaps try to humidify the surrounding surfaces and induce evaporative cooling and so on. In case of 'cold' discomfort, the occupant would respond in an opposite manner and try to wear more clothing, shut windows, increase activities and so on. Thus, the designer must take into account that when the 'comfortable' condition deviates, people try to do their utmost to bring it back to the desired mean.

Even control by 'human adjustment' has its limits and when the environmental parameters conspire against each other to such an extent that indoor conditions become intolerably 'hot' or 'cold', mechanical controls have to be adopted. The point at which mechanical controls will start to be put to use in a particular situation will depend on the occupants' economical status and the costs and suitability of the various mechanical systems available.

Air-conditioning and heating both belong to this category of control. Table 1 indicates the controls for achieving comfort.

HOT	mechanical control	Air conditioning as last resort
		Close windows as air temperature rises above skin temperature
		Supplement air movement to countecact still conditions
	human adjustment	Reduce activity level
		Reduce clothing content
		Open windows as wide as possible
	planning control	Reduce solar insolation by proper window orientation and shading
		Orientating window for maximum breeze
		COMFORTABLE
COLD	planning control	Increased solar insolation by proper window orientation
		Use of heat absorbent surfaces where likely to receive direct solar radiation
	human adjustment	Closed windows to reduce air movement
		Increase activity levels
		Increase clothing content
	mechanical control	Heating as last resort

Table 1. Controls for achieving comfort

THE FUNCTIONS OF A WINDOW :

Not only should the window contribute to the thermal comfort in a space, but it should also allow daylight to enter, and the occupant to have a pleasant view. The window should exclude rain and dust totally, noise as much as possible, and not work against the privacy requirements of the occupants. The fuctions of a window are shown in Table 2. The relative importance of each of these functions depend partly on climatic demands and also to a certain extent on social and cultural needs.

Daylight is undoubtedly, one of the desirable influences that a window should allow, within limits, to be filtered into an enclosure. Studies show that light has specific influences on the human body, other than that normally associated with vision (3). A window can convey the changing effects of daylight, every hour of the day, and so provides the inmate mental relief. Daylight design therefore, has the responsibility of providing enough light to enable efficient visual performance, while at the same time attaining the psychological and physiological goals.

Ventilation is also one of the prime functions of a window, and its aim is three-fold (4), health ventilation, ventilation for structural cooling nd comfort ventilation, when air movement is needed to induce comfort to the occupants of a space.

Table 2 Functions of a window

Function	To achieve	To avoid
Ventilation	● comfort ● health ● structural cooling	● too much breeze when a, cold b) air temperature is warmer than skin temperature.
Daylighting	● Efficient visual performance ● psychological satisfaction ● physiological needs.	● too much light, as this causes a) glare b) overheating in warm/hot climates.
Solar Penetration	● heat during cold ● Psychological effects ● Physiological needs	● overheating
View	● information content ● aesthetic needs	● undesirable views ● distracting views

A window by its orientation can allow solar penetration in interiors at certain times of the year, a function which becomes particularly important during cold winters. Not only does this raise interior temperatures appreciably, but even when the heat is allowed to escape by ventilating the space, the psychological effects created by solar penetration are considerable. However, overheating at all costs must be avoided.

From the user's point of view, another prime function of the window is the provision of a view. The view should be adequate enough to sustain aesthetic demands and should be balanced with respect to information content. Distracting or undesirable views should be avoided.

The window, being an important architectural element of the three-dimensional expression of a space, must reflect the function, characteristic and aesthetics of that space. Climatic considerations will almost never be the only deciding factor in window design and this is perfectly acceptable, as there are no calculations that can dictate the right size, shape or orientation of a window in any space. Moreover, the demands are so conflicting that compromises are inevitable, but these can be logically derived from the analysis of different variables.

CONFLICTING SOLUTIONS TO THE FUNCTIONS

The various functions of the window are served in differing ways in response to the different climatic regions. The investigations revealed that even in a particular climatic region, the different functions demand conflicting solutions in window design. A brief discussion is required of the conflicts in the different seasons: cool dry, warm humid (when air temperature remains below skin temperature). and hot dry (when air temperature starts to rise above skin temperature). Here each of the functions of a window and their solutions as to size and orientation are examined against the other functions in turn, for the three seasonal conditions and found to either contradict each other or be compatible (as the need dictates). Table 3 sums up this comparison at the end of this section.

Ventilation and daylighting

When cold, the exterior light is insufficient and daylighting solutions would point to large windows. Ventilation requirements however, would dictate the

need for small, sealed windows with only minimum ventilation provision for health. Thus, the two requirements conflict.

In warm climates, with air temperatures usually below skin temperatures, ventilation requirements dictate the need for very large open windows with maximum provision for breeze penetration. Daylight requirements on the other hand, may in most cases indicate the need for smaller windows, as light is abundant and too much light entering would contribute to heat build-up in the interior resulting in unwelcome raised internal temperatures. When hot, air temperatures rise above that of skin and most often outdoor light is in abundant supply and both daylighting and ventilation requirements indicate the need for windows as small as possible.

Ventilation and Solar Penetration Requirements :

When cold, the criterion for solar penetration would suggest properly orientated windows, large enough to allow adequate solar insolation. Ventilation needs indicate small windows and conflict with those for solar radiation.

In warm climates, ventilation demands large windows properly orientated to catch the prevailing breeze; solar radiation requirements indicate small and properly shaded windows facing away from the sun. When the directions coincide, the requirements conflict.

When hot, both these functions are best served with small windows and thus, the solutions to these requirements are compatible.

Ventilation and View :

View requirements in all climates indicate the need for large windows, provided the view outside the window is worth looking at or is pleasant. Thus, in cold and hot climates, where ventilation requires small windows, the functions provide contradictory solutions. In warm climates, where ventilation requirements demand large openings, the two functions are complementary.

Ventilation and the need for privacy, Noise, Rain and Dust Exclusion.

In all climates the need for privacy and that for the exclusion of pollution and the elements would indicate preferences for small windows. Where ventilation requirements also indicate small windows as solutions, as in cold and hot climates, these requirements are compatible. In warm climates, as the ventilation criterion dictates the provision of large windows, these requirements conflict.

Daylighting and Solar penetration :

In cold climates, daylighting and solar penetration requirements both demand large windows and hence do not conflict with each other.

In warm and hot climates again, the needs are compatible, as both criteria indicate the use of small windows, because of the abundance of daylight and its accompanying heat load.

Daylighting and View :

The view criterion is independent of seasonal variations and it is usually desirable to have large windows when exterior view is pleasant. Daylighting design indicates the use of large windows in cold conditions, as the lighting level may be considerably low. This makes the two requirements compatible.

In warm and hot seasons though, the requirements conflict, as daylighting demands small windows to avoid excessive glare and overheating.

Daylighting and Privacy :

In cold climates, where large windows are necessary to provide adequate internal lighting, these needs conflict with that for privacy, which advocate smaller windows.

In warm and hot climates where daylight is in abundant supply, the needs do not conflict, as both are benefitted by small windows.

Solar Penetration and View :

These requirements are compatible in cold climates, as both demand large windows, as long as external view is pleasant.

In warm and hot climates, solar penetration requirments indicate the need for small windows, properly orientated with respect to the sun. View, being independent of seasonal variations, would demand large windows for pleasing views, thus making the requirements conflict, specially when the direction of view and solar position in 'overheated' periods coincide.

Solar Penetration and Privacy;

Privacy requirements, irrespective of seasonal variations and climatic characteristics, demand small windows. In cold climates, large windows are required for adequate solar penetration, thus making the two requirements conflict.

In warm and hot seasons, where much smaller windows would serve the solar penetration requirements, these donot conflict.

Solar peneration criterion, almost always in cold climates, conflicts with the need to preserve the internal environment and a balance has to be struck between the heat gained by solar insolation and that lost through glazing.

View and Ventilation;

View requirements, being independent of weather conditions, demand large windows as long as external view is pleasing to the occupant. Ventilation requirements in cold and hot conditions demand small, sealed windows, and this conflicts with view requirements.

In warm climates the solutions to these needs are compatible, both indicating the use of large windows.

View and Privacy :

These two requirements conflict in all climatic types, as they are independent of seasons and thermal comfort conditions. Privacy requirements demand small windows and view requirements large ones.

View requirements also conflict with the need to preserve the internal environment in cold and hot climates, where small windows are best suited to serve this purpose. In warm climates where internal and external environments are very close because of large, open windows, there is no 'internal' environment as such, needing to be preserved.

Teble-3 Conflicts in Design Decision

Function	conflicts with	in season.
Ventilation	Daylighting	cold/warm
	Solar Penetration	warm
	View	cold/hot
	Privacy	warm
	Rain, Dust, Noise exclusion	warm
Daylighting	Ventilation	cold/warm
	Solar Penetration	-
	View	warm/hot
	Privacy	cold
	Preservation of internal environment	cold
Solar Penetration	Ventilation	warm
	Daylighting	-
	View	warm/hot
	Privacy	cold
	Preservation of internal environment	cold
View	Ventilation	cold/hot
	Daylighting	warm/hot
	Solar Penetration	warm/hot
	Privacy	all
	Preservation of internal environment	cold/hot

Results of the investigation;

To adequately serve all the functions of a window the designer is faced with effecting a series of compromises and the setting up of priorities. The results of the investigation carried out in this research are summarized here to aid in design decisions involving these compromises. With the lack of detailed climatic data, assumptions and prediction techniques had to be relied on to provide some basic data, especially with regard to solar intensity levels and prevailing wind speeds and directions.

The model of a test house built for experimentation in an available boundary layer wind tunnel (6) revealed the following results; (for Bangladesh)

a) Air movement induced by natural means was not enough to ensure comfort for most afternoons of the year.

b) Air change rate in the same rooms was found to be extremely high. This may be advantageous when considering odour removal, but will be associated with penetration of outdoor pollutants, dust and grease.

Three kinds of inlet-outlet combinations were examined for indoor airmovement. These were;

1) Single-sided ventilation

2) Windows on adjacent walls

3) Windows on opposite walls.

It was found that single-sided ventilation is definitely the worst situation possible for windows in Bangladesh. For the second group, in rooms having one window on the south, the performance was markedly better than when the south was blocked. For the third group, it was found that rooms with windows facing north and south had better air movement than those with east and west openings.

Tested for daylighting (7), using the BRE protractor and nomograms, it was found that the minimum lighting levels in the rooms of the test house were above the minimum recommended daylight factors for residences. This indicates that overheating may result. Keeping the same opening area, the daylight factor can be reduced by shading the higher altitudes of the visible sky vault and by lowering the window, measures which may also serve the room better in terms of air movement and solar radiation exclusion.

Shading design (8) revealed the proportions and dimensions of shading devices for different window orientations in Bangladesh. The best orientation from the shading point of view was found to be North. Western windows were found to look directly into the sun during 'overheated' periods and hence not possible to shade without blocking the opening. South-western windows were also found to be difficult to shade adequately and adjacent spaces should be planned to provide some measure of shading to these windows. It was also found that for south and south leaning orientations, a balcony should be placed outside the window to provide shading.

SEASONAL RESPONSES TO WINDOW DESIGN

The climate in Bangladesh, classed as' sub-tropical' monsoon or 'composite' makes it diffiicult for the designer to properly design openings, as many conficting solutions arise and compromises have to be effected. A seasonal calendar (Table 4) shows the response and conflicts faced by the designer in the attempt to solve problems arising from satisfying various criteria for window design in Bangladesh.

Table 4 Seasonal Calendar for Window Design

Month	Thermal condition	Requirements
December	cool-dry	Air movement: small windows
January		Solar Insolation encouraged largewindows
February		Daylighting; large windows
		as light from blue skies
mid-March	hot - dry	Air movement: small windows
April		Solar insolation discouragd
May		small windows
		Daylghting: very bright exterior
		lighting levels, small windows
June	warm - humid	Air movement: large windows
July		Solar insolation discouraged
August		small windows
September		Daylighting: very bright exterior
October		lighting levels, small wIndows
November		

Privacy demands throughout the year................ small windows
View demands throughout the year .... large windows.

A 'SEASONAL WINDOW'

A window, were it to face one season only, could cope with the problems associated with that particular season only. Such a hypothetical window could be termed a 'seasonal window'.

An examination of the cold - dry season in Bangladesh shows that the requirements for ventilation and privacy conflict with those for daylighting, solar penetration and view (Table 4). Obviously for proper window design, a compromise would have to be sought; and the designer, realising that large openings could be closed to serve the reduced ventilation criterion and that privacy could be attained by proper planning of spaces, would probably opt for larger windows for this season alone.

In the hot - dry season, lasting approximately for two to two - and - a - half months, window design would have to cope with a completely different thermal situation.The designer, however, in this season, is not faced with as many conflicts as in the other seasons and here all the climatic factors point to small windows. When faced with the conflicting view demands of large windows, the designer almost always will sacrifice this lone requirement in favour of the combined solution of small windows to all the other requirements.

In the rainy season, which is warm and humid, again the designer would be faced with a series of compromises in attempting to meet the various needs served by a window. Ventilation and view requeirements on the one hand would be in favour of large openings; solar penetration, daylighting and privacy needs on the other hand would point to small windows. Fortunately, solar penetration and too much daylighting with its accompanying glare can be avoided by proper orientation and shading. Thus, were a window desigmed for this season only, despite conflicting demands, large windows would be the chosen solution.

The 'seasonal window' described above, cannot cope with all seasons, and a window will undoubtedly have to face all the seasons. A compromise between the large window for the winter and the rainy seasons, and the small window for the hot - dry summer will have to be effected. There is no single simple solution to the problem as each window, being an integral part of a building, will, like the building itself, have to function for the prevalent situation.

It may well be that the present study has led to a solution resembling the vernacular approach to window design, which takes into account traditional building skills and their relationship to the culture and climate of a region. However, vernacular designing is largely carried out without conscious thought, the design evolving from traditions and established practices.

Designers unfamiliar with these traditions are faced with a lack of published material enabling a systematic design to proceed. This work assembles the multiplicity of variables, examines their importance and significance and considers the implications of coordination in a way which will be of assistance to such designers.

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