Building Envelope Design/Retrofit Utilizing Fresnel Type Overhangs in Hot Climates

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ABSTRACT

The selection of exterior elements for control of solar incidence has been a major concern for engineers, architects, and lighting designers. This concern relates to problems of thermal heat gain, direct glare and veiling reflectance. Of equal concern is the quality of the view impacted by these various shade elements. Researchers and lighting designers have discovered these concerns are integrally connected to each other. (Erhardt 1987) A common denominator is the concept of luminance and adaptation levels that impact occupant perception of the interior lighted space and exterior views. A realistic solution to the control of the visual environment is the Fresnel Overhang System. This element has been available for years but until recently has been largely ignored. The qualities of this system and its relationship to the thermo-visual environment will be discussed.

INTRODUCTION

Building envelope design relative to fenestration deals directly with the components of radiant heat, glare and veiling reflections and indirectly with psycho-physiological factors influencing the building occupants. The traditional emphasis in fenestration design in hot and humid climates focused on the problem of decreasing solar heat gains through the window. The classic approach to window design was to shade the window from direct sunlight while reducing brightness on the upper parts of the window. This was usually accomplished with the use of overhangs. Unfortunately, overhangs reduced the amount of light entering the space. Because overhangs cannot provide complete shading, additional treatment was necessary.

The use of sloping awnings and variations of overhangs followed. These awnings and horizontal louvers covering vertical windows offered the advantages of: (1) smaller horizontal projections from building surfaces, (2) good ground light projections from exterior building surfaces, (3) variable controls to permit light control and ventilation. Some disadvantages were: (1) horizontal louvers required considerable maintenance due to dirt and particle build-up, (2) if louvers were not adequately positioned their ability to control light and ventilation was reduced, (3) louvre space impaired view to the exterior.

Prior to refrigerated cooling systems, when incandescent lamps were used to provide interior illumination, windows were valued as a light source. A major problem with windows as a light source was direct and indirect glare. Nevertheless, many of these louvered shading systems did control daylight while allowing for adequate indirect lighting of the work surfaces.

Louvered screening may not have evolved further were it not for the changes taking place in artificial lighting systems after World War II. The cessation of the war resulted in an increased availability of low cost energy. This energy was, in part, used to operate air conditioning units in new and renovated buildings. Consequently, thermal control realized from natural ventilation and window shading was no longer the primary concern.

The new focus in fenestration design shifted towards increasing the control of direct glare and veiling reflections on the task area. Several techniques were employed to solve the problem. First, tasks were oriented so the windows were outside the field of view of the windows. Second, reliable adjustable controls were added to the louver screens. Finally, reflective coatings were added to the windows to further reduce glare and heat gain.

These solutions created new problems and a new way of looking at these problems. The first group of problems was related to reducing peak loads and realizing energy conservation gains in terms of lighting design. The second group of problems was related to light quality and task performance. The desire to solve these problems brought about a new wave of research. Specifically, researchers were attempting to find the relationship between window design in buildings, the light that comes through the windows, visual acuity, task performance, health and attitudes of people in these buildings. The purpose of this discussion is to summarize the value of the Fresnel Overhang System in the resolution of these problems and suggest how this system can improve the relationship of human needs to the visual environment.

THE FRESNEL OVERHANG SYSTEM

In the 1930's, a miniature louvered sun screen was developed to overcome some of the disadvantages associated with the horizontal louvered system. The louvered sun screen addressed the problems of view, direct glare and heat. The louvers were very small (.05 inches wide) and woven together with fine wire at 0.05 inch intervals. The louver consisted of 17 or 23 louvers per inch (Figure 1).

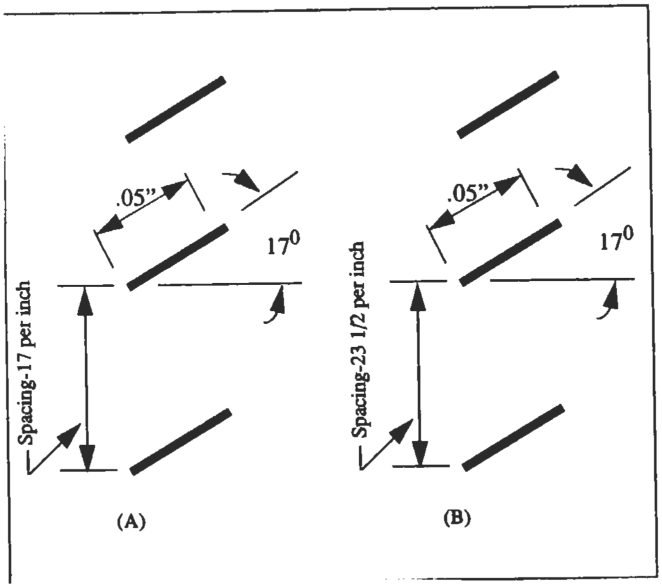

Figure 1. Cross section of minute-louvered material of darkened bronze. (A) Standard spacing. (B) Close spacing

The effectiveness of the miniature louvered screen as a brightness shielding device as viewed from the inside is directly related to shading effectiveness. Ewing and Biesele (1958) found that the proportion of the unimpeded exterior view which is actually visible between the slats for various lines of sight outward through the louvers is very high. (Figure 2)

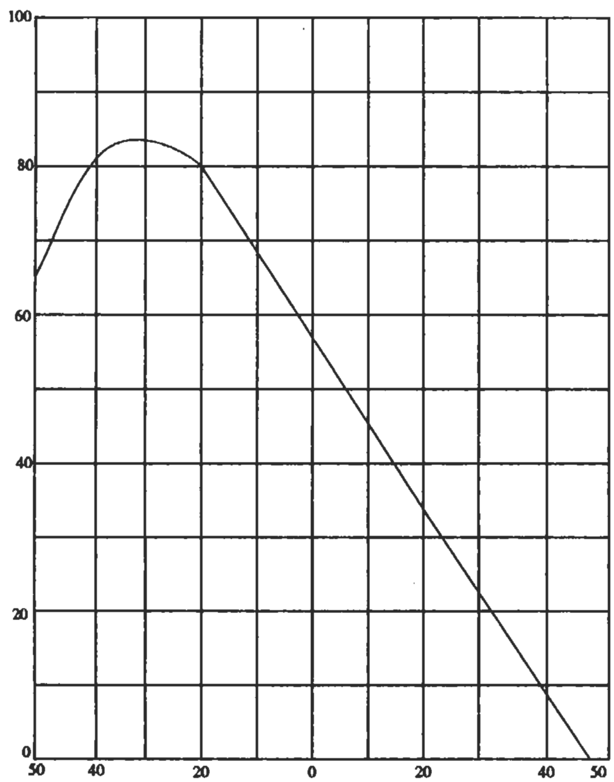

Figure 2. Per cent of view out, which is unshielded by minute-louvered material, standard spacing.

The shading and brightness characteristics of the fresnel overhang system are augmented by the impact on the view out through the window. This characteristic is directly related to slat geometry or the width-to-spacing ratio of the miniature louvers. The field of vision of wide band louvers typical of venetian blinds or exterior louvers greatly impedes views. Miniature louvers in the fresnel overhang system by comparison, are much less distorting of the view. (Figure 3 & 4).

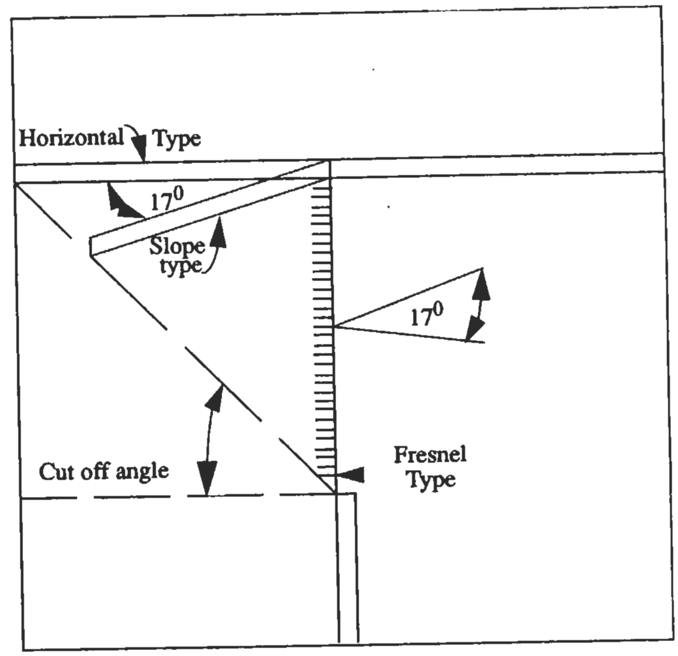

Fig. 3 Three equivalent overhang types.

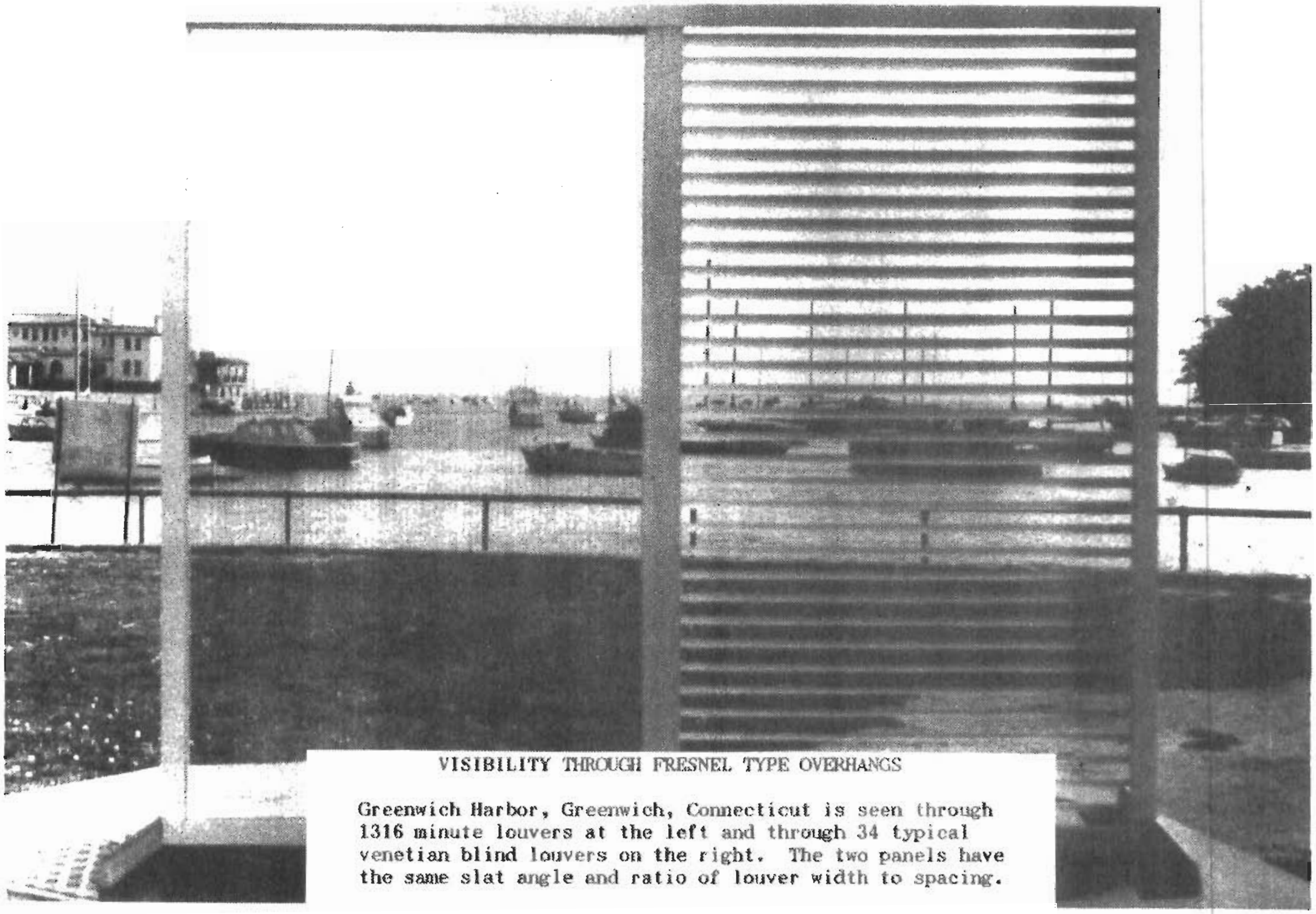

Figure 4. Visibility Through Fresnel Overhang System

The effect of the miniature louvered materials on the luminance and illumination distribution produced in the interior of a room is equally impressive. Based on equal exterior incident illumination, the result is a more uniform distribution, although at a lower average level than in an unscreened room (Ewing and Bisele 1958). (Figure 5) The change in the distribution pattern of illumination produced by the fresnel overhang system is the result of the selective shading of the direct skylight component but also their admission of reflected ground light. This characteristic of the louver tends to favor daylight penetration to the inner portion of the room.

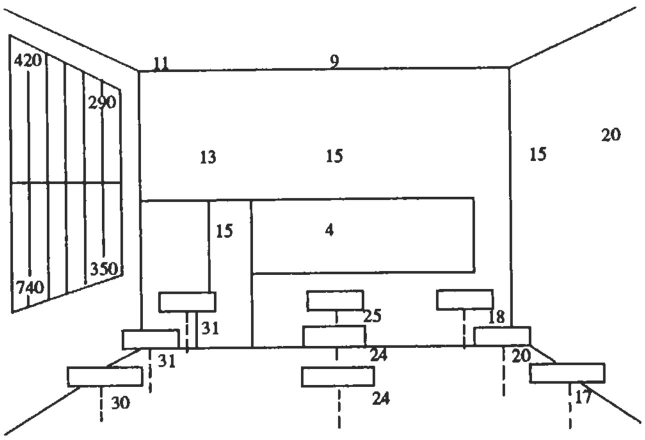

Figure 5. Test classroom at Hillcrest High School, Dallas, Texas, with minute-louvered material on clear glass windows, overcast sky, 1000 footcandles incident illumination on windows, of which 87 footcandles is from below the horizon. Values at desks are illumination, in footcandles. All other values are brightness, in footlamberts.

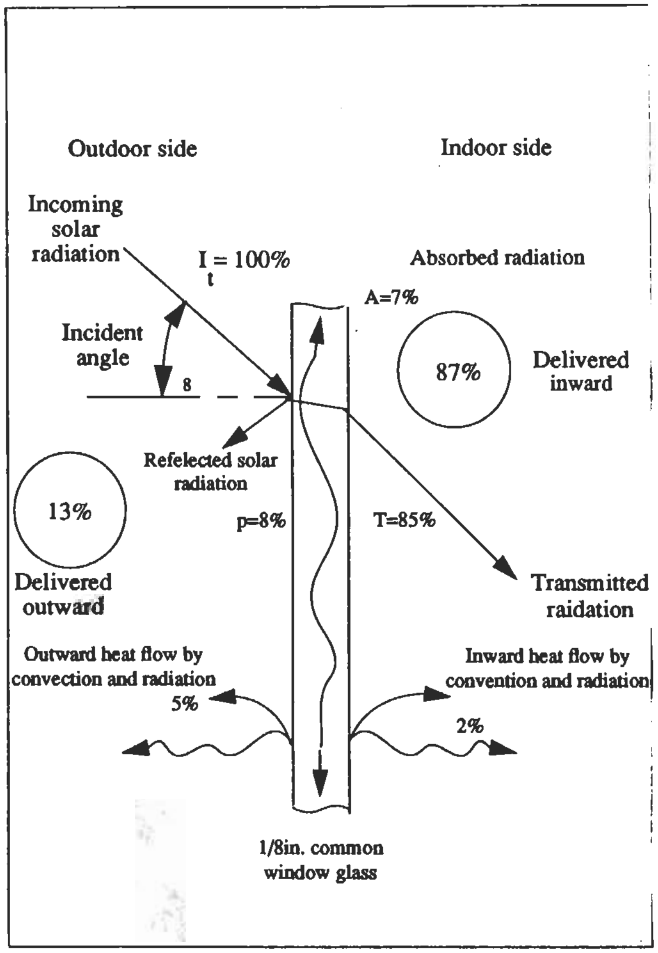

Figure 6. Distribution of energy when a solar ray impinges on a sheet of common window glass at a fairly direct incident angle.

Finally, there is the concern for heat loading through the fenestration to the interior space. Energy derived from solar incidence comes from direct solar gain, conductance or diffuse and nondirectional rays emanating from random reflectance off objects in the atmosphere. These diffuse and nondirectional rays constitute 10 to 25% of the total solar incidence.

Figure 6 illustrates the distribution of energy when solar rays impinge on typical glass. Approximately 8% is reflected and immediately rejected to the exterior. Approximately 85% passes through the glass and becomes part of the interior cooling load. 7% is absorbed in the glass. (Pennington 1968) Figure 6 shows that 87% of the solar radiation reaches the interior.

When a miniature louvered screen is placed on the exterior of the window but not in contact with it, the distribution of energy is quite different (Figure 7). approximately 25% of the diffuse solar radiation comes from below horizontal sources. This portion can pass through the louvers and reach the glass surface. It has been found experimentally that approximately 10% of the energy that is absorbed in the screen ultimately finds its way into the interior cooling load. This is a reduction of 77% (Pennington 1968).

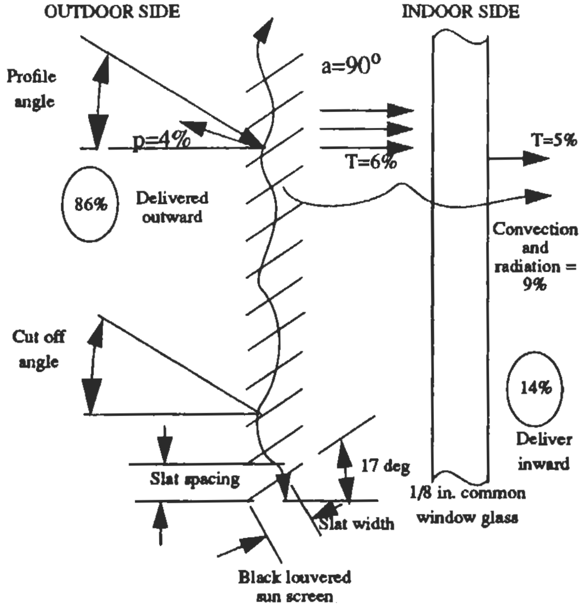

Figure 7. Distribution of energy when window glass in Figure 6 is protected by black louvered sun screen on the exterior.

THE VALUE OF THE FRESNEL OVERHANG SYSTEM TO THE INTERIOR VISUAL ENVIRONMENT

The Fresnel Overhang System can solve several problems related to the control of the thermo-visual environment. The most obvious is the heat reduction opportunities it affords. Cooling loads are therefore lower, and energy conservation can be achieved. This cooling load reduction has the added benefit of giving the lighting designer a greater degree of freedom in the selection of luminaires and other lighting equipment.

A second valuable attribute of the fresnel overhang system is its ability to adapt to new or retrofit conditions under a variety of aesthetically demanding situations. The system mounts to existing fenestration easily and merges into most exterior architectural facades in a pleasing and harmonious manner. This attribute actually encourages its use.

The design response to stringent energy codes during the 70's and 80's was to create hermetically sealed buildings with fixed glass. Natural ventilation was not possible under that condition. The Fresnel Overhang System allows operable windows and the utilization of cooling breezes when available.

Perhaps the most interesting characteristics of the Fresnel Overhang System are those that influence the quality and distribution of daylight. As previously stated, using mirrored glass or low transmittance glazing results in a dramatic reduction of daylight contribution and an even more dramatic reduction in the exterior view. This has been referred to as the "black hole" effect which creates a "windowless" building. Occupant reaction to these variations in light quality and view opportunity, while not yet fully understood, is believed to significant.

The Fresnel Overhang System has positive impacts on (1) luminance distribution, (2) adaptation levels, (3) direct glare from high sky brightness, and (4) indirect glare from veiling reflections. The luminance distribution is more uniform across the interior of the space since the ratio of reflected daylight from below the horizontal to direct daylight from above the horizontal is greater. The mitigation of high angle light reduces the effect of uncomfortable and disabling direct glare. Brightness is reduced and results in lowered adaptation levels of the occupants. As Erhardt (1987) reports, visual acuity is possible with lower levels of illumination within lowered adaptation levels. Perceptually, the occupant is unaware of lowered brightness as in the problem with mirrored glass or low transmittance glazing since the occupant "sees" actual luminance. Also the problem of indirect glare or veiling reflections is mitigated by uni-directional side lighting to a much greater degree.

IMPACTS OF THE FRESNEL OVERHANG SYSTEM ON LIGHTING DESIGN STRATEGIES

Lighting design strategies are formulated so as to incorporate those variables that are important to the particular needs of the space and its occupants. (Lam 1986) The most innovative strategy to date has evolved from one proposed by Robert T. Dorsey (1972). This integrative lighting design strategy addresses the problems of energy optimization and human performance. The model considers mechanical, economic and psychological factors influencing the use of an interior space. Central to this strategy is the need to consider the impact of light quality on human performance and human perception of the space. For instance, color, contrast, brightness ratios and perceived views are functional components to be considered when rendering a lighting solution to a space. The Fresnel Overhang System can, by virtue of the facts just stated, greatly increase the opportunity for positive human perception and positive human performance within a space.

There are two basic reasons for this. First, the Fresnel Overhang System dramatically changes the way we think about windows in hot climates where heat loads and sky brightness are major problems. These window elements can now be viewed not as problems to be eliminated, screened or tinted out of existence but rather as aesthetic design opportunities that promote human well being and performance.

The Fresnel Overhang System allows for energy savings through reduced heat loads. It also allows for lower levels of illumination required by electric lighting. Since daylight is considered by occupants to be more healthy (Heerwagen 1984), occupants are more satisfied in their work environment. It is widely accepted that people have a need for contact with sunlight (Lam 1977). The Fresnel Overhang System makes the cost of providing windows in buildings more economically feasible.

CONCLUSION

There is a significant body of scientific knowledge which demonstrates the relationship and the impact of the visual environment on task performance. However, the relationship between lighting and productivity and other factors of human performance is less well understood. Current research is responding to this need for greater understanding of human performance. In the interim, we need to develop a practical model of lighting design that clearly establishes the progress made to date.

The Lighting Research Institute (1989) recognized this need. Their studies revealed that regardless of this difficulty "Lighting is one of the most important elements to control in the work environment. It influences not only our ability to see but also our feelings and our health." The Fresnel Overhang System is just one example of how we can make tangible progress towards achieving these ends.

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