Assessing the Efficiency of Sunscreens in University of Baghdad Campus

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Abstract. Sunscreens play an important role as exterior solar shading devices that block a certain amount of the sun radiation from entering the building. Thereby, they improve indoor environmental qualities by reducing heat gain, controlling glare and decreasing contrast ratios leading to increased human comfort, satisfaction and productivity. In University of Baghdad campus design, Gropius's main aim was "Let climate control dominate the university architectural motif". Sunscreens were thus essential features and functional both from the practical point of view to protect windows, and as a prominent design element of sculptural quality. The campus, over the past decades, was subjected to many changes and new buildings were added to the master plan. Sunscreens were imposed on the new buildings' elevations as unifying design elements without considering the climatic and orientation aspects, causing excessive heat gain in interior spaces. The paper aims to explore and evaluate the efficiency of sunscreens in University of Baghdad campus, in both the original and new buildings, to determine the optimal building orientation and the effective sunscreen design that improves the passive energy performance of the buildings.

1. Introduction
University of Baghdad campus was designed in 1960, by the famous German architect Walter Gropius, one of the pioneering masters of Modern Architecture. Gropius took a functional and aesthetic approach in designing the physical plant by corresponding to the spiritual atmosphere and the climate of the zone.
The sunscreens; the gracefully designed system of baffles protecting the exterior walls against the excessive heat, for instance, had been elaborated into a design factor that gives rhythm and depth to the elevations, thereby establishing the campus's architectural character. These elements were designed in accordance with orientation determinants, where each façade had a unique sunscreen design that corresponds to the sun radiation and the functional needs of occupants in the indoor spaces. The direction of most of the original buildings is such that windows are put mainly on the northern and southern parts, with little dependence on the eastern elevations. While the western elevations were protected by open access galleries or by cantilevered floor slabs. In the past decades, new buildings were added to the master plan, and sunscreens were added to building elevations as unifying design elements that blend with the original buildings, but with little or no consideration to climatic and orientation aspects. In order to evaluate the efficiency of the sunscreens in the University of Baghdad campus, it is essential to review the climatic and orientation determinants in Baghdad city.
2. Climatic evaluation of Baghdad

The arid climate of central Iraq is characterized by large annual temperature fluctuations. It is very hot in summer, pleasant in winter, and dry throughout the year. In terms of human comfort, the summers are oppressive. Winters compare well with the spring season in Paris. Baghdad possesses elements of both tropical and temperate climates and yet it is not typically sub-tropical. The considerable range of mean monthly temperature is characteristic of a continental type of climate with hot uncomfortable days and cool comfortable nights. The region is extremely arid. Meteorological data of Baghdad confirms that Iraq is similar to the climatic profile of Phoenix, Arizona, USA area which is also a hot dry region [1].

3. Radiation effects on external sides of buildings in Baghdad

The sun is perhaps the single most important natural element to consider in building designs where energy conservation is an important goal. It affects virtually every portion of a building's design, from its shape and orientation, to its envelope and glazing, HVAC and lighting systems, and operating and maintenance policies [2].

To compare the yearly effects, two typical days were chosen: the coldest (January 21) and the warmest (July 21) as indexes for winter and summer in Baghdad. The radiation effect is computed for a clear day. The impact on the various sides of the building expressed in numerical values is illustrated in Figure 1.

![Figure 1. External Solar Impacts on Sides of Buildings in Baghdad [2].](image)

From the computed external solar impacts, some general conclusions can be drawn:

- The south side of the building works favorably receiving roughly about three times as much radiation in the winter as in the summer period. The east and west are unfavorable receiving about two times as much radiation in the summer compared to the under heated period. Of the two sides, the west is the more critical one as to the high afternoon heat coupled with the solar radiation. The north side receives a little amount of winter radiation, but in summer it approaches the amount of the south side. The radiation impact on the roof in summertime exceeds all other sides. From this data, the following can be concluded:
  - The importance of proper arrangement and shading of the openings.
  - The importance of preferable orientation.

4. Orientation

Orientation for sun means the relatively best position of the building in regard to insolation. The insolation – the sun's heat – is important both positively in the cool periods for utilizing the solar energy, and negatively in hot periods to avoid it.
In Figure 2, the first diagram shows the total yearly radiation expressed towards all orientations. This, then, is segregated into two diagrams according to the vertical surfaces in the under heated (when it is needed) and in the overheated periods (when it should be avoided).

The combined result is expressed in numerical values on the same chart. The relative best position of the building in Baghdad is evaluated from the data. The elongated shaped building turned 25 degrees east of south, shows closed surfaces towards the adverse directions but opens up towards the beneficial sun impacts [3].

With such an arrangement, the essential heat needs are best balanced. At the same time the daily temperature distribution is more equal throughout the year – receiving radiation in the cooler morning hours and avoiding it in the hot afternoons. The east and west sides should be as far as possible closed surfaces. On the north side, smaller openings are preferable to utilize the air movements. Fortunately, this orientation falls nearly perpendicular to the prevailing wind directions and hence offers good locations for the air movement inlets.

![Diagram of Solar Radiation and Building Orientation](image)

**Figure 2.** Solar Radiation and Building Orientation The researcher depending on [3].

5. **Shading considerations on materials**

The maximum receipt of solar radiation on the earth’s surface over the whole of a clear summer day is not at the equator or even within the tropics, but somewhere between 30-45 degrees latitude. The incident solar radiation received by a vertical surface often exceeds 200 Watt per square meter. If the surface is glass, most of this heat is transmitted to the building interior instantaneously in an air-conditioned structure; this heat must be removed at considerable extent. Shading devices may reduce the instantaneous rate of heat gain through glass by as much as 85 percent.
This indicates the important role of shading devices in minimizing energy consumption in buildings [4].

Figure 3 reveals the comparison of total heat transmission for glass surfaces—in a summer day—in accordance with different orientations. The east and west glass surfaces indicate a very high amount of heat transmission compared to the north and south glass surfaces, while the shaded glass shows minimal heat transmission [2].

The sun's path is precise and predictable. The designer uses this as an opportunity to control the sun's effect on the building. Sunscreens, or any other form of shading device, should provide a control that assures that sun heat should be available in cold weather and cut off during hot periods. In other words, the shading device should let in the sun in the "under-heated period" and provide shade in the "over-heated period".

6. University of Baghdad campus / the case study

Figure 4 shows the central academic area of University of Baghdad campus, surrounded by a ring road. The present paper specified the five principle building orientations used for the academic buildings in the central area which included the original buildings designed by Gropius in 1960, [5], and the new ones added between 1990-2010. These orientations are related to true South as follows: 4 degrees E, 6 degrees E, 9 degrees W, 13 degrees E, and finally 22.5 degrees E, as shown in Figure 4. Many other academic buildings were added outside this area, but the research limits its focus on buildings within the ring road as the same case applies to all new buildings.
Figure 4. Building Orientations Related to True South for Central Academic Area

Three buildings with different orientations are selected for the study
Figure 5 displays three representative orientations out of the total five, to be tested in accordance with the sunscreen devices applied to each orientation. The three selected orientations are: Type (1): 4 degrees E, Type (2): 9 degrees W, and Type (3): 22.5 degrees E, respectively. A diagram at the left shows the physical relation of the building to true south. To the right is a record of the direction of the sun, obtained from the sun chart of the region [6]. The longest day of the year: the equinox (21 March – 21 September), and the shortest day of the year in winter (21 December) are recorded in this chart. The profile angle and the bearing angle of the sun are recorded at two-hour intervals throughout the day.

6.1. Assessing the efficiency of the exterior sunscreen devices:
The case study represents a graphic study to assess the effectiveness of the exterior sunscreens in controlling radiation of the east, south and west elevations of buildings in the central area. Of the five main orientations of buildings, three orientations were chosen for this study (as previously stated) that represent three academic buildings: the first two buildings of the original master plan (Biological Science Department: 4 degrees E of South, and the Architectural Engineering Department: 9 degrees W of South), and the third is a new building added in the past decade (Computer Science Department: 22.5 degrees E of South).

In order to correctly assess the functioning of the sunscreens, shadows are cast on each elevation. Shadows are cast for two times of the year: at the equinox and at the winter solstice. The time between the two equinoxes, March 21 until September 21, approximates that time of the year where "overheating" of the building occurs. The sun-shading device is tested at this time to make sure it is effective in keeping direct solar radiation off the window surface. It is also important that there be some solar gain to help warm the building during the "under-heated" period of the winter months. Because of this, the sun-shading device is also tested at the winter solstice to see how much radiation strikes the window at that time.

For a sun-shading device to be most effective, it should block the sun during periods of "overheating" while allowing maximum sun penetration during periods of "under-heating".

The following configurations represent the assessment of the efficiency of the existing sun shading devices in the selected buildings to determine the optimal building orientation and the effective sunscreen design that improves the passive energy performance of the buildings.

6.1.1. Biological Science Department (4 degrees E):

Figure 6 represents the testing of the efficiency of the sunscreens utilized in the Biological Science Dept. (4 degrees E), where shadows are cast on two elevations; the East elevation and the South elevation, in accordance to the direction of the sun from the sun chart of the region Figure 5: type 1.

The figure shows no significant solar radiation on the North elevation of the building, therefore it is not included in this study. As for the West elevation, it is protected by a cantilevered floor and allocated just for services.

Figure 6-A shows the testing of efficiency of sunscreen on the East elevation at two selected periods; the Equinox (21 March – 21 September), and the winter (21 December), at two selected hours (8 AM – 10 AM), which represent the maximum solar radiation on the East elevation. While Figure 6-B shows the testing on the South elevation at the same two periods and at two selected hours (12 PM – 2PM), representing the maximum solar radiation on the South.

6.1.2. Architectural Engineering Department (9 degrees W):

Figure 7 represents the testing of the efficiency of the sunscreens utilized in the Architectural Engineering Dept. (9 degrees W), where shadows are cast on two elevations; the East elevation and
the South elevation, in accordance to the direction of the sun from the sun chart of the region Figure 5: type 2. The figure shows no significant solar radiation

**Figure 5.** Three Selected Buildings with Different Orientations Related to True South for Central Academic Area. The sun angles for each orientation are obtained from the sun chart of the region [6].
Figure 6. Assessment of efficiency of sunscreens of the East and South elevations of Biological Science Department (4° East of South).
Figure 7. Assessment of efficiency of sunscreens of the East and South elevations of Architectural Engineering Department (9° West of South).
Figure 8. Assessment of efficiency of sunscreens of the East and South and West elevations of Computer Science Department (22.5° East of South).

On the North elevation of the building, therefore it is not included in this study. As for the West elevation, it is protected by a cantilevered floor and allocated just for services.

Figure 7-A shows the testing of efficiency of sunscreen on the East elevation at two selected periods; the Equinox (21 March – 21 September), and the Winter (21 December), at two selected hours (8 AM
– 10 AM), while Figure 7-B shows the testing on the South elevation at the same two periods and at two selected hours (12 PM – 2PM).

6.1.3. Computer Science Department (22.5 degrees E):
Figure 8 represents the testing of the efficiency of the sunscreens utilized in the Computer Science Dept. (22.5 degrees E). This building was built in the past decade following the original façade pattern, while sunscreens were added as a unifying element without thoroughly considering the suitable orientation. Shadows are cast on three elevations; the East, the South and the West elevations, in accordance to the direction of the sun from the sun chart of the region Figure 5: type 3. The figure shows no significant solar radiation on the North elevation of the building, therefore it is not included in this study. While the West elevation is considered in this study, as it is allocated for academic spaces.

Figure 8-A shows the testing of efficiency of sunscreen on the East elevation at two selected periods; the Equinox (21 March – 21 September), and the Winter (21 December), at two selected hours (8 AM – 10 AM), while Figure 8-B shows the testing on the South elevation at the same two periods and at two selected hours (12 PM – 2PM). Figure 8-C shows the testing on the West elevation at the same two periods of the year, and at two selected hours (2 PM – 4 PM), that represent the maximum solar radiation falling on the West elevation.

6.2. Results and discussion:
(Table 1) shows the results of the assessment of efficiency of sunscreens in the three selected buildings as follows:

| Building | Efficiency of sunscreens | Solar radiation transmission |
|----------|--------------------------|-----------------------------|
|          | East                     | South                       | West                      |
| 1- Biological Science Department (4° E) | Equinox | 83% | 100% | N/A |
|          | Winter                   | 70% | 81%  | N/A |
| 2- Architectural Engineering Department (9° W) | Equinox | 72% | 100% | N/A |
|          | Winter                   | 38% | 62.5% | N/A |
| 3- Computer Science Department (22.5° E) | Equinox | 85% | 81.2% | 41% |
|          | Winter                   | 70% | 86%  | 23% |

6.2.1. Biological Science Department (4 degrees E):
(Table 1) shows that the East elevation's sunscreens were effective by a rate of (83%) in blocking solar radiation in the Equinox period at the two selected and effective hours (8 AM-10 AM), while the rate decreased to (70%) in Winter, at the same selected and effective hours (8 AM- 10 AM), where the solar radiation transmitted (30%) is considered desirable at that time of the year, especially at the early hours of the day.
As for the **South** elevation, the sunscreens were efficient at blocking (100%) of the solar radiation at the Equinox, and (81%) at winter at the two selected and effective hours for solar radiation at the South elevation (12 PM- 2 PM) for both periods of the year. The results indicate a successful and efficient design for sunscreens of the East and the South elevations that block all or most solar radiation in the Equinox period, while allowing a permissible amount of solar radiation to be transmitted in winter where it is desirable, especially at the early hours of the day. The results coincides with Figure 2-D, as the building is within the good orientation for Baghdad city (0-38 degrees East of South).

**6.2.2. Architectural Engineering Department (9 degrees W):**

(Table 1) shows that the **East** elevation's sunscreens were effective by a rate of (72%) in blocking solar radiation in the Equinox period at the two selected and effective hours of the East solar radiation (8 AM-10 AM), while the rate decreased to (38%) in Winter, at the same two hours, where the rate of the solar radiation transmitted (62%) is considered desirable at that time of the year and at the early hours of the day.

As for the **South** elevation, the sunscreens were efficient at blocking (100%) of the solar radiation at the Equinox, and (81%) at winter at the two selected and effective hours for solar radiation at the South elevation (12 PM- 2 PM), for both periods of the year. The results indicate a successful and efficient design for sunscreens of the East and the South elevations that block all or most solar radiation in the Equinox period, while allowing a permissible amount of solar radiation to be transmitted in winter where it is desirable, especially at the early hours of the day.

**6.2.3. Computer Science Department (22.5 degrees E):**

This building approaches in its location the optimum orientation for Baghdad City (25 degrees East of South), demonstrated in Figure 2 D, with a main difference that the West elevation is not blocked but utilized for academic spaces with windows exposed to solar radiation. (Table 1) shows that the East elevation's sunscreens for this building, were effective by a rate of (85%) in blocking solar radiation in the Equinox period at the two selected and effective hours of the East solar radiation (8 AM-10 AM), while the rate decreased to (70%) in Winter, at the same two hours, where the rate of the solar radiation transmitted (30%) is considered desirable at that time of the year and at the early hours of the day.

As for the South elevation, the sunscreens were efficient at blocking (81%) of the solar radiation at the Equinox, and (86%) at winter at the two selected and effective hours for solar radiation at the South elevation (12 PM- 2 PM), for both periods of the year. This indicates a questionable error in design where the sunscreens block more solar radiation in winter than in the Equinox, although it is still within acceptable limits.

The West elevation in this building is allocated for academic purposes, and the simple imprecise detail-free sunscreen design is utilized for the West elevation. (Table 1) shows a noticeable failure in the sunscreens in blocking the solar radiation at both periods of the year and at the two selected critical afternoon hours of the West elevation (2PM- 4PM), where the sunscreens blocked only (41%) of solar radiation at the Equinox period, and (23%) at Winter, allowing a considerable amount of solar radiation to be transmitted in the academic spaces at the hours of the highest temperature of the day, during the Equinox and Winter, causing excessive heat gain in interior spaces, as well as the inconvenience consequences of glare and contrast ratios.

The results indicate an efficient design for sunscreens of the East elevation, and an unverified design for the South elevation. While the West elevation indicates a failing and unsuccessful result, as it did not take into consideration the negative and unfavorable impacts of this critical elevation as explicit in Figure 3.

**7. Conclusions**
1- Sunscreens are important façade components that should be designed in accordance with orientation determinants of a special region, in a way that corresponds to the solar radiation as well as the functional needs of occupants of indoor spaces.

2- The successful sunscreen design should provide shade in the (over-heated) period and allow solar transmission in the (under-heated period), providing control on the total heat gain and heat loss of solar radiation.

3- The relative best position of building in Baghdad is the elongated shaped building turned 25 degrees east of south, with closed surfaces towards the adverse directions and opens up towards the beneficial sun impacts.

4- The study revealed a successful performance of the sunscreens of buildings designed by Gropius, as it proved highly efficient in blocking the solar radiation in the hot weather and allowing a permissible amount of radiation to be transmitted to the inside in the cold weather.

5- The new buildings added to University of Baghdad master plan in the expansion phases in the past two decades followed the original design as a whole, but sunscreens were imposed on the new buildings' elevations as unifying design elements without considering the climatic and orientation aspects.

6- The study revealed a failure in design of the new building's sunscreens, and excessive solar transmission in interior academic spaces, especially in the West elevation, in both periods: the Equinox and the winter, in the hours of the highest temperature of the day.

7- The study concludes the importance of proper arrangement and shading of openings, as well as considering the preferable orientation that improves the passive energy performance of the building.

8. References

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