Bioclimatic design strategies evaluation of the School of Petroleum Engineering buildings of the Universidad del Zulia

Carlos Quirós¹, José Rincón², Yoan Mosquera², Yusela Loaiza² and Lizbeth Morán¹

¹Instituto de Investigaciones de la Facultad de Arquitectura y Diseño (IFAD), Universidad del Zulia, Maracaibo, Venezuela
²Departamento de Energía, Escuela de Ingeniería Mecánica, Facultad de Ingeniería, Universidad del Zulia, Maracaibo, Venezuela

ABSTRACT: The objective of this paper is the design strategies evaluation of solar control and wind utilization in the building group of the Petroleum Engineering School projected by the Venezuelan architect Carlos Raul Villanueva and built for the Universidad del Zulia in Maracaibo (Venezuela) in the period 1954-1958. For such effects, a planimetric information search with its digitalization, a metric calculation for facades and openings, a metric site report of the solar projection and winds utilization systems and the insolation and ventilation conditions analysis, with simulation programs and graphic tools was carried out. Through the results of the analysis, it can be evidenced that the original building group of the Petroleum School is an architectural work that responds to solar radiation and wind effects, since numerous and right solutions are presented against the solar beams incidence and in favor of predominant breezes, in order to avoid the heat excess and the glare in the different enclosures.

Conference Topic: 2 Design strategies and tools
Keywords: energy, comfort, solar control, ventilation, building envelope

INTRODUCTION

The city of Maracaibo is located 10° 40.5’ latitude north in the intertropical zone, on a low altitude plain and close to two large water masses, the Lake of Maracaibo and the Gulf of Venezuela. Because of its geographical location, the city is characterized by an intense insolation and, by a similar duration of diurnal and nocturnal periods, and by a maritime climate, known for high temperatures and relative humidity values, during the whole year. Predominant winds are north-northeastern with average values of 3.5 m/s [1].

Higrothermics values for Maracaibo during the whole year are outside the thermal comfort zone, specifically, above the shading line and inside the zone of comfort amplified by ventilation of the Olgyay bioclimatic chart [2]. In these conditions, shading and air movement is required as constant to reestablish the comfort condition (Fig. 1).

The shading avoids the impact of the direct solar radiation on the human body and the surroundings surfaces, accentuating in this way, the difference of temperatures between such surfaces and the body, what permits a greater heat loosening of the body by radiation, conduction and convection. The ventilation is necessary to produce heat looses of the body by convection and evaporation and thus, to reduce the impact of the temperature and to alleviate the inconvenience sensation caused by the vapor pressure excess.

Figure 1: Bioclimatic record of the hygrothermic parameters for Maracaibo in Olgyay’s chart.

In this work will try the evaluation of the bioclimatic principles and strategies of solar control and utilization of the prevailing breezes through original design of the Petroleum Engineering School (1954-
1958) of the recognized Venezuelan architect Carlos Raul Villanueva.

1. METHODOLOGY

1.1 Planimetric information location and digitalizing

The first step was the search and summary of the planimetric information of the original project of the Petroleum School building group. This was obtained in the National Library in Caracas and in the Infrastructure Maintenance and Development Address of the Universidad del Zulia. Secondly a, digitalization of the obtained architectural plans was carried out using the program AutoCad® 2000, to reach a greater precision and versatility in the managing of the planimetric information.

1.2 Strategies identification of solar control and winds utilization

Through an exhaustive reading of the architectural and constructive plans, as well as of a labour of recognition accomplished in site through run circuits by different sectors and levels of the Petroleum School building group, strategies and devices for solar protection and utilization of the prevailing breezes in the different buildings and in the free spaces located among them, were identified.

1.3 Facades and openings metric calculations

Starting from the annotated plans of the different buildings that structure the group, the calculations of the areas of facades surface according to its orientation in the site were elaborated. Metric calculations of glass surfaces and the relationships of areas among the exit and entry openings of the air flow were carried out the in the different enclosures of the Petroleum School.

1.4 Solar protections systems report and digitalization

In order to obtain greater precision in the representation and evaluation of the solar protection systems used in the Petroleum School building, a metric report in the site of the different shading devices was accomplished. For such effects, the engineering regulations were followed to reduce the mistake percentage, using tapes of different metrics length, a vernier for thickness and depths measurements an optical clinometer and an optical compass to obtain the slope percentages and the azimuts and shadows angles. After obtained the planimetric information in the site, was proceeded to digitize using it the AutoCad® 2000 package to obtain a greater precision in the graphic representation of the solar protection systems as well as in the shadow angles reading.

1.5 Insolation and ventilation conditions analysis

The evaluation of the solar protection systems effectiveness was carried out through the use of precision graphics tools as the solar stereographic chart [3] and the shadow protactor; also they were used resources of the physical simulation through a french heliodon and digital simulation through the use of the Render of the AutoCad® 2000 package. For the evaluation of response facing to the prevailing winds, was accomplished the analysis of the ventilation conditions of classrooms and free areas through programs of flows simulation of ventilation using as tool the computational fluids dynamics.

2. SOLAR RESPONSE

2.1 Facades orientations

The direction of the constructions has an important influence in the energetic contributions toward the inhabited spaces. The longest facades of Wings A, B, C and D of the Petroleum School building group (87%), are oriented northward and southward (Fig.2). While the shortest (13%), are exposed eastward and westward where the sun is more intensive during the morning and the afternoon respectively. The corridor and the library volumes, are placed transversely to the previous buildings, orienting their prevailing facades toward the east and the west. In this mentioned case, where the assumed direction is contraindicated, were applied by the architect other strategies, that compensate and/or attenuate the thermal effects that are generated in such situation.

2.2 Windows distribution

This employed strategy is referred to the glassed openings distribution according to the different orientations assumed for the facades. In the Wings A, B and C of the Petroleum School, the greater proportion of glassed openings is located toward the north direction with a 63%, while in the south is found remaining 37%; In the Wing D, are distributed in similar proportion northward and southward. Toward the east and the west, the existence of glassed openings is null. If the recommended orientation for the buildings is north-south, the north results more favorable for the openings, due to the fact that is exposed effectively four months per year to the solar beams, while the south is exposed for 6 months and on the other hand, the solar incidence angles are superior (> 66º) to those of the south direction (> 56º) [4]. In the library building the windows are distributed by equal among the facades east and west, while in the north and south facades, there are not openings.

2.3 Volumetric conception
The Petroleum School building group present various examples of volumetric solutions to the local insolation conditions:

a) Protective appendices

Toward the east extreme of the Wings A, B, and D and the west extreme of the Wing C, are visualized the appendix-volumes those which, in addition to constituting the envelope of the vertical circulation space, act as protective elements of the facades oriented toward the rising and the setting direction (Fig. 2). This volumes project shadows from 7 to 10:30 hrs on the east facade and from 14:30 hrs until the sunset on the west facade.

b) Vis-à-vis volumes

The facade planes of parallel and faced volumes at a distance relatively small, as is the case of the east facade of the library building and the west of the corridor-building, permit the such facades shading as well as of the horizontal space limited by the self-same (Fig. 2). The building-corridor projects shadows partially on the east facade of the library and in a 100% on the interior patio area from 7 to 8:45 hrs; until 10:15 hrs throws shadows in a 50% of the same. While the east facade of the library building starts to project shadow from 13 hrs on the internal patio area, covering 50% until 14:30 hrs and 100% starting from 16:15 hrs as well as, the west facade of the corridor building in partial form.

c) Articulated volumes

The architectural volumes that are articulated mutually permit to reduce facade areas that they could be exposed directly to the solar beams. The Wings A and B connection with the corridor building, permits to reduce 60% and 56% of the facade area of the respective wings exposed to the solar radiation, while in the east facade of the corridor building is reduced in a 48%. The connection of the Wing C in its east extreme with the corridor building reduces in a 78% the facade area of the Wing, while the west facade of the connecting volume is reduced in a 27% (Fig. 2).

d) Projected volumes

The first floor plans projecting and the withdrawn ground floors, permit the shading projection on the inferior levels facades. This volumetric design strategy can be evidenced in the north facade of Wings A and C, in the north and south facades of Wings B and D, and in the east and west facades in the library building and Wings A and B. In the case of northward and southward projecting, is provided a seasonal solar protection according to the date of the year and in the case of the volumes projected toward the east and the west, is offered partial protection in the morning and evening (Fig. 3 to Fig. 5).

2.4 Chamber spaces

Toward east and west extremes of the buildings that integrate the Wings A, B and C, are located inhabitable spaces parallel to the facades, generally service areas, which permits the access toward the perimetral corridor destined to maintenance of windows and solar protection systems. These spaces act as ventilated chambers that protect of the ingress of an excessive thermal load to the enclosures located toward the east and west.

2.5 Outdoor treatment

The open spaces of the building group count on surfaces cover of grass with certain isolated vegetation elements those which reduce the solar radiation reflection and long wave radiation toward the walls and openings (albedo). Also, thanks to the evaporative processes generated in the vegetal coverage surface, is produced a temperature reduction, being maintained nearby to the air temperature.

2.6 Solar protection devices

The opaque elements utilization that are interposed among the sun and the openings of the architectural enclosures, for total or partial control of the solar radiation inward ingress, it is an architectural constant in the building group of the Petroleum School. However, the use of these devices is not limited for protection to glassed surfaces, but also to exterior surfaces of floors and walls.

a) Vertical fins protective box

Given the glass use in the extension of the buildings skin, the vertical solar protections continue parallel to the fenestration and the building become involved by a second skin, tracing what could be called a vertical fins protective box, defined by the vertical fins and the lateral extension of the cover, floor slabs and facades planes (Fig. 3 and Fig. 4).

Figure 3: Vertical fins protective box in the Wing D.

- Movable vertical devices

These solar protection systems are constituted by movable vertical fins that rotate about an axis to permit their graduation according to the solar beams angles. The paper that perform these shading elements at the protective box is the openings protection to the solar beams lateral and frontal incidence. For its mobility, the utilization of this solar control alternative is directed to eastward and westward facades, as is the case of the library building facades, where the insolation is critical because the solar paths are perpendicular to the
facades and the conditions vary daily, by the continuous variation of the solar declination (south-north-south). However, this solution is applied also in the facades with north and south orientation, where the devices can be maintained fixed in perpendicular direction to the facade during the year, without affecting the interior space conditions notably.

- Cover extension
  The lateral projection of the cover slab fulfils the objective of offering to the openings a zenithal protection to the solar beams, that is to say, for the meridian hours in which the sun reaches its greater altitudes over the horizon plane (Fig. 4).

- Floor slab extension
  The lateral projection of the floor slab complements the protection reached by the cover, specifically for the openings located in the ground floor of the mentioned buildings. This extension does not reach the edge girder therefore it does not close totally the lower part of the protective box, letting in this way, a free space that permits the vertical circulation of the air to the box, that favors the heat loss of the protective surface (Fig. 4).

- Facade plane extension
  The prolongation of the facade plans constitutes a solution to avoid the lateral penetration of the solar beams toward the extremes of the protective box.

  The vertical fins protective box offers a total protection to the solar beams during the year to the first floor plants of the north and south facades (Fig. 5). Particularly, the Wing C by having double shading box in the north facade, have total solar protection at first floor as ground floor. In the ground floor of the north facades, the protection is partial from 7 to 8 hrs and from 18 to 19 hrs, being more accentuate the lateral penetration, toward the east and west extremes of the overhang. In the south facade ground floor, exists a solar penetration from 7 to 8 hrs and from 17 to 18 hrs; however, toward the noon from 11 to 14 hrs, from November to January, is presented also the solar beams access to the openings, due to the fact that the solar paths at such hours, cross under the cover in the opening between consecutive vertical shading elements. The east and west facade of the library first floor, in spite of not to count on the sufficient extension of the cover, it can reach a partial to total protection, rotating the devices northward or southward.

  Figure 5: Shading effects simulation on the heliodon with a Wing A physic model (June 21, 9hrs).

b) Movable horizontal louvers
  The inferior third of the north facade fenestration surface of the Wings A, B, C and D, the south of the Wing D and the east and west of the library building first floor is constituted by opaque movable horizontal systems that permit a possibility of regulation until 30° of vertical shading angle. These systems structured by wood louvers, opposed to other superiors thirds (2/3) structured by temperate glass louvers, complement the protection supplied to the interior space by the rest of the elements that structure the vertical fins protective box.

c) Fixed horizontal louvers
  In the Petroleum School building group is emphasized the volume of the cafeteria provided in its nor-northeast facade with a box structured by a fixed concrete louvers system, separated 12 cm and inclined under an angle of 32° that totally controls frontward the solar beams entry. However, in its upper part permits as a light filter, the access of certain solar beams that generate a lighting plastic effect that varies throughout a year, in the internal garden defined by the louvered box.

d) Perforated blocks solar screens
  Constitutes vertical surfaces structured by perforated block systems that generally limit and define visually to the circulation spaces in the Petroleum School building group. These screens shape a second skin that is placed before of the windows that open toward the circulation spaces...
located southward in the different wings and also constitutes the protective appendices envelope. The hall and corridor (pedestrian street) present this solar protection solution in their facades (Fig. 6). The perforated concrete blocks used (known as “Villanueva block”), whose dimensions (in cm) are 40x19.5x20 presenting some perforations of 6.8x7 and of 7x16.7, permit a total protection northward and southward, and partial protection eastward (until 8 hrs) and westward (from 17 hrs).

![Figure 6](image)

**Figure 6**: Solar penetration at 7:45 hrs in March 21 through the building corridor perforated block screen.

e) Isolated overhangs
In the different constructions can be located isolated protective overhangs for specific openings, such as those which are located in the entry of the hall and in the east-northeast entry of the cafeteria. In the first case, the device offers a total protection to the entrance hall from 10:30 to 14:30 hrs; in the second case, the protection is total since 11 hrs with certain solar penetration until 13 hrs from November until by mid February.

f) Connecting covers
The pathway that link the corridor-building with the Wing D and with the library ground floor, as well as the one which connects the cafeteria with the hall of the Petroleum School are protected of the direct solar incidence by a continuous horizontal cover. In the pathway cover toward the Wing D, this protection is reinforced with vertical screens of perforated blocks located southward and westward, protecting to the pedestrians of the austral and evening solar penetration respectively. In the walkway that crosses the library patio, the cover is extended sideways and presents a perforated blocks wall located northward, what permits a zenithal and summer protection.

3. EOLIC RESPONSE

3.1 Facades orientations
The assumed north-south orientation for the greater part of the buildings responded adequately to the prevailing directions of the winds, since the facades are perpendicular and oblique (45°) to the north and northeast breezes, which blow with a frequency of 24.6% and 20.8% respectively. In the first case, is generated the wind maximum pressure to windward and in the second case, the pressure is reduced in a 50%; however, if the wind impacts to 45°, is increased the mean speed of the interior air due to the fact that a greater volume of interior air is involved in the movement that originates the flow of the wind [5].

3.2 Building group form
In hot-humid climate localities as Maracaibo, where the ventilation is the most effective mechanism to reduce the psychological effect of the high humidity, the distribution extended with isolated repeated units proposed by Villanueva for the Petroleum Engineering School, permits a better captation of the winds and crusade ventilation, providing a greater walls area and therefore, a greater contact surface with the surrounding air. In simulations accomplished in the Mechanics Engineering School using as tool the computational fluids dynamic (CFD) in a 3D model of the Villanueva original proposal for the Petroleum School they were obtained the static pressures in the walls, the wind shadow zones and the path of the currents lines that permitted the compared evaluation of the building cluster to the more frequently directions of the winds [6].

In north currents case, the topmost pressure static are found in the north facade, while toward the edges are produced smaller pressure zones. This determines that the maximum speeds are located toward the east and west extremes of the buildings and the minimum values are located in the south zone. In the northeast currents case, the static pressures exercised on the walls reduce and their distribution is more uniform throughout its geometry, due to the resistance decrease that the buildings present to the air path. It is observed a decrease of the recirculation and stagnation zones facilitating thus the air pass over the structure. The greater wind calm zone is located toward the southwest of the building group, specifically westward of the library and of the auditorium (Fig.7).

![Figure 7](image)

**Figure 7**: Distribution of the northeast air currents speeds (m/s) in the Petroleum School building group.

The separation between the Wings A and B and the Wings C and D (about 45 m), the circular geometry of the extremes, the side walk cover articulation between the Wing D and the corridor-building, as well as the stretching of the Wing C
westward with respect to the Wing D, favor the entry of the air to the common space among the buildings.

3.3 Size and location of the openings

In the enclosures generally, the entry opening is located in the high pressure zone, it is larger than the exit opening, located in the low pressure zone, promoting the crusade ventilation of the internal spaces and the wind speed increasing near to the smaller opening, permitting the extraction of the hot and vitiated air and the training of the chimney effect in hours and days without wind. The dimensions relationship between exit and entry openings is 1 to 2.7, in the enclosures of the A, B and C Wings destined to the administrative and educational activities, and 1 to 1, in the library and the laboratories located in the Wing D. In this last case, the required air volume (the double) is in function of the air purity and quality in the work area, in addition to obtain the users higrothermic comfort [7].

3.4 Lateral corridors

The enclosures distribution destined to the administrative and educational activities obeys to a conception plant where, the spaces for extended stays of the persons are located toward the north side and the circulation corridor is located laterally southward. There are exceptions as, the library and the hydraulic and materials laboratories in the Wing D.

3.5 Regulatory devices of the air flow

The entry and exit openings are constituted by windows structured by horizontal louvers systems, which result very versatile operable mechanisms in front of the natural ventilation, since can regulate with a wide range of possibilities, their direction and intensity.

3.6 Shading devices design

The movable vertical fins systems present an aerodynamic form since adopt a rhomboidal shape with rounded and acute extreme angles, what reduces the turbulence effect. Their exercised influence in the air flow conduction toward the internal space is variable attending to the orientation of the facade and the rotation angle of the vertical fins. When the solar protections are perpendicular to the facade and the rotation angle of the vertical fins.

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