

Sustainable architecture and eco-building design retrofit: Reviewing the thermal performance estimations after completion of a building.

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ABSTRACT: A previous paper showed the study of the thermal analysis and architectural proposal to achieve the reduction of the energy consumption for the main airport of the country, redesigning the north (33°27' S.H.) and the west (now included) pavilions by means of shading devices. In it were presented the general results of simulations of the existing situation and of the predicted retrofitted building.

Nowadays the building is finished and in full use, a complete spring and summer periods have been faced with good results. The present report shows the general results of temperature reductions and images after the strategies recommended.

Keywords: energy reduction, design retrofit, shading devices.

1. INTRODUCTION

1.1 The general situation.

During the last 15 years the principal international airport of the country, Arturo Merino Benítez, located at the outskirts of Santiago, originally built by the end of the 60's, has been extended several times.

All this with the huge increment of agglomeration of people in it, in particular at the main hall and departure west building, making very complex the climatization and demanding a hard use of the air-conditioning system.

This extensions, including the first buildings, are built mainly in steel and glass. This low mass strategy, not ideal for the climatic conditions of Santiago (Table I), overheats very easily by the sun and by the high internal occupancy rate, being a clear example of the greenhouse effect.



Aerial view of the airport

Thus this building has become into a big energy consumer, even in winter (low incidence of sun angles), fig. I. This cooling load has had a great impact on economical issues of the airport, deciding by 2004 to do studies in order to reduce this consumption.

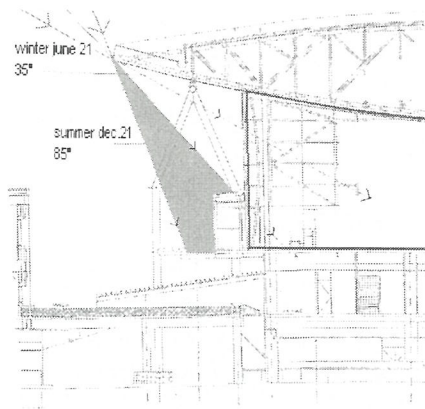


Figure I

1.2 The former situation

The central pavilion of the building faces the north (sun facade) has have a double glazed facade, with a overhang that protects again the summer sun (fig. 1), but for the other months this doesn't work properly. Santiago (see table I) has in general terms a high solar radiation rate, even at the cool period (particularly in winter over a vertical wall facing north).

From here that the two uncomfortable problems are arisen for this case; one is the inconvenient glare effect and at the same time the overheating of the crowded interior.



Picture 1. Interior view, Central pavilion, previous situation.

The glare has caused, for several years, problems at the checking counters for the passengers (mistakes with the designation of seats and tags for the luggages); the flight assistants have had to work with sun at their back, shadows over their desks and with a lot of unwanted reflections over their screens. At the same time the passengers were unable to read the screens of flights because of the glare, waisting several minutes, creating several inconvenients (see picture 1).

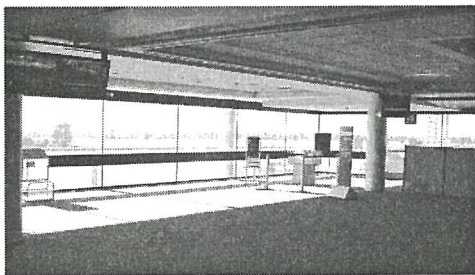
The other building, the west pavilion, the international departure lounge, has the same constructive principles of being highly glazed and lightweight. In this case the situation is more critical due to its orientation to the sunset, receiving all the sun rays without any obstruction. In here the critical inconvenients are absolutely oriented to the passengers that are waiting their turn to enter to the corresponding flight (see picture 2).

But at the end, the final turning point was the economical aspect; to cool down these huge buildings were very expensive, specially nowadays with the high prices of energy, as previously commented.

These two kind of problems for both pavilions, economical and operational ones, leaded the administrators of the airport to look for a solution .

The proposal was elaborated in coordination with the architects of the airport and the enterprice of the shading devices to be installed.

It was also suggested to paint the interior ceiling of the Central pavilion in white, to improve even more the internal visual comfort, but this important recommendation was not accepted because its implementation was going to create several serious problems that will affect the adequate operation of the airport performance (scaffoldings, accidents).



Picture 2. Interior view, west pavilion, previous situation.

2. THE WEATHER CONDITIONS

Santiago, located at 33.27° SL, in summary has a mediterranean type of climate, with a long period of warmth and another shorter but of severe cold; being the main characteristic of having clear skies and a rather big difference in between the high and low temperatures (specially in summer), the precipitations are concentrated in few months (not more than 360 mm/years). See table I.

Table I: Average temp. (°C), Relative Humidity (%), Solar Radiation mean horizontal kwh/m²/day (SRMH), Degree Days 18°C

Month	A.T.(°C)		R.H. (%)		S.R M.H	D.D 18°C
	max	min	max	min		
JAN	29.4	11.8	70	38	7.88	0
FEB	29.0	11.0	78	40	7.65	0
MAR	26.1	9.4	86	41	5.92	0
APR	23.8	7.4	89	46	4.92	72
MAY	18.2	4.8	92	58	2.55	202
JUN	14.3	2.8	93	64	1.97	282
JUL	15.1	2.8	91	60	2.20	279
AUG	16.6	3.8	91	58	2.90	242
SEP	18.8	5.5	89	55	3.83	177
OCT	21.9	7.2	83	50	6.03	106
NOV	25.6	9.1	73	41	6.73	0
DEC	28.6	10.2	69	38	8.12	0

As seen in Table I, there is in general terms a difference in between the max. and

min. temperatures, almost 20° in summer and over 10° in winter; clear sky conditions are abundant all around the year, meaning a good possibility to avoid or store the sun radiation.

3. THE BUILDINGS

3.1 General information

The central pavilion has approximately 150m length, 35m width and its internal high is 9m, built in steel and surrounded by a double glazing skin (0.64 transparency factor and $U=3.3 \text{ W/(m}^2\text{K)}$). The roof-ceiling complex is also in steel ($U=1.5$) and its inner volume is 73.500 m³. The average of air changes per hour assumed is 2.2, the internal gains estimated in 1080 kWh/day as average and the direct solar gain in 1550 kWh/day for January, in 5550 for June and in 5590 for October.

See figure II as a general plan information. For security reasons it is not allowed to present further plans or information of the building.



View of the Central pavilion on its early stage.

The west pavilion, has almost the same length and 25 mts. of width, 2.80 of internal high and built with the same building materials.

In this case the main reason of the overheating is the no existance of any device for solar shsding. This is increased occassionally by the passengers waiting for the call to enter the aircrafts.

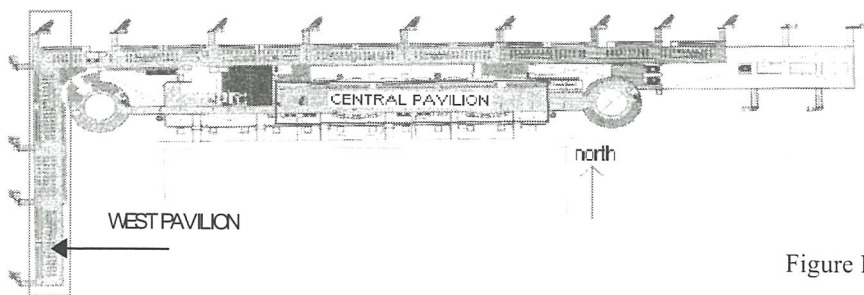


Figure II

3.2 Environmental problems solved after proposal, completed by mid 2006.

- Reduction of high cooling loads, with the consequent high air conditioning expenses.
- Undesirable green house effect eliminated.
- Contrasts in between dark of shadowed surfaces and sunlit ones disappeared; no glare effect.
- Thermal discomfort reduced.
- Visual discomfort practically eliminated; there is no difficulty to observe the screens with the flights, delays in checking, long cues and mistakes in reading general information related with airlines and schedules are reduced.
- The airlines attendants at the counters do not have the heat at their backs and their own shadow over their own computers doesn't exist.

4. GENERAL RESULTS OBTAINED AND OBSERVED

4.1 Previous estimations.

The estimations were done for three different months, the extremes (January, the hottest; June, the coldest) and a mid season situation (October). The results were obtained by calculating the peak interior temperatures, based on mean conditions under a semi-state condition. The critical

hour of peak temperatures is around 4:30 and 5:00 pm. It is important to notice that higher internal temperatures are obtained in this glazed building with low mass rate in June, mainly because of the lower angle of sun radiation.

Estimated temperature rise over the mean max.:

January + 2.4 °C

June + 3.3 °C

October + 3.4 °C

4.2 Retrofitted situation

The problems were solved with an exterior shading device implantation. This re-orientates the incident sun rays towards the interior ceiling (with a specific angle, 35°), reducing the glare and the green house effects [1].

The shading is a micro perforated zinc-alum alloy fixed system, mounted to the existing structure of the building (fig III).

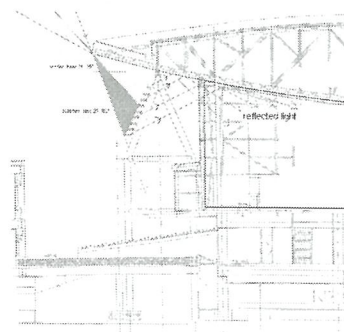


Figure III

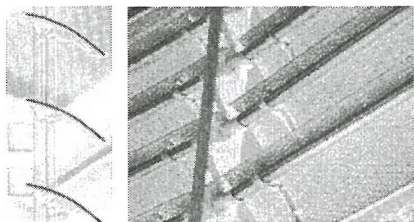
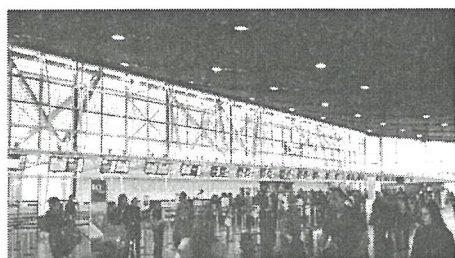


Figure IV

The micro perforation (25%) (fig IV) is to allow some direct natural light coming in, further more permits to see the sky with out the glare effect. The color of the shading is brilliant white, great capacity of reflectance and matches with the aesthetics of the architecture.



Interior view, central pavilion after proposal.

Also important to mention is that there is an air space in between the shading and the glazed façade, which allows the air to ventilate the constructive elements.

The results predicted obtained after this strategy in general terms are:

Temperature change over the mean max.

January -0.5°C , originally was $+2.4^{\circ}$

(Overheating risks are reduced)

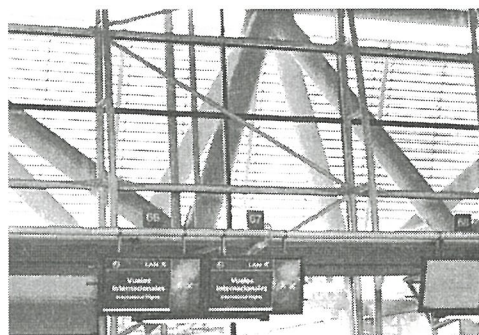
June $+2.1^{\circ}\text{C}$, originally was $+3.3^{\circ}$

(Some heating will be needed in few occasions)

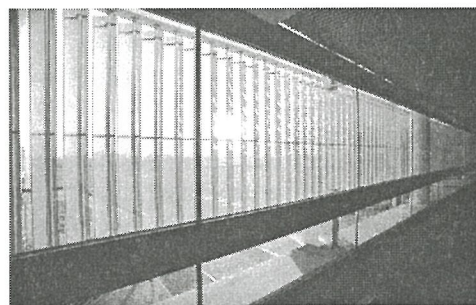
October $+2.2^{\circ}\text{C}$, originally was $+3.4^{\circ}$

(Overheating will not occur)

In January the internal mean max. temperature will be about 3°C lower than the original situation. This reduction in summer in this building of 73.500 m^3 means a huge amount of energy reduction in cooling, becoming the proposal worthwhile. The payback period for such investment was estimated in around 7-8 years, according with local energy prices of electricity and general forecast of them.



Interior view, central pavilion, after proposal



Interior view of west pavilion after proposal.

4.3 The results after retrofittings.

The predictions in general terms were very close to the measures taken after the building was finished, see 4.2; being the internal temperatures reduced in between 0.5 and 1.5°C in january and increased 2.0 to 2.8°C in october (as averages over or under outside conditions, see Table 1).

The exact figure of energy reduction in kWh is difficult to establish by now, because other strategies were taken at the same

period of this proposal (better lighting among others), it will be needed a more exhaustive analysis.

One of the most important benefits of the proposal for the administrators of the airport, is the elimination of the glare effect, improving the performance of the workers at the airline counters and the easiness to read the screens that are announcing the flights for the passengers.

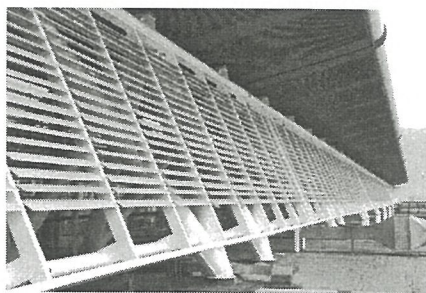
5. CONCLUSIONS

Overheating in highly glazed buildings is very probable in climatic conditions as Santiago, not only in summer, but also in mid-seasons periods, due to the clear sky conditions and to the solar angles of incidence in a vertical north facade. The strategy of creating an external shading device is quite effective, providing a carefully design to create shadows without letting the interior dark.

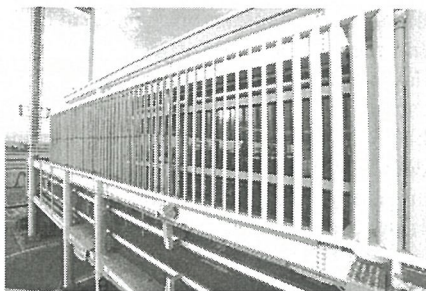
Energy reduction is very important nowadays, but also is relevant the benefits to achieve comfort by itself, regardless the economical aspects, specially when comfort leads to a better behaviour inside crowded buildings.

REFERENCES

- [1] Del Rio, J. 2003 and 2007. Guía Básica de Diseño de la Protección Solar. Ediciones Publicitarias Hunter-Douglas. Chile.



Central pavilion from outside.



West pavilion view.