

# A border customs control building at 4.700 m. above sea level in Southern Andes plateau: a challenge for design in extreme climatic conditions

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**ABSTRACT:** At 18°17'SL and about 4700 m.a.s.l, a border control building had to be designed. Climatic conditions are those of a high altitude desert: dry air, slight rain in summer and snow in winter. Temperature ranges are -3°C to 20° C in summer and -10°C° to 12° C in winter. Wind is frequent and its speed is 70 km/hr from West in the morning and from East in the afternoon. The environment is a wild protected area which poses further restraints and sustainability requirements. The building has to be used during the whole year. Employees live there for periods of at least ten days. Transitional spaces and their connectors have been considered as a design strategy in the first place. Stone surrounding high walls and wind deflectors are used as an envelope for protecting the whole building from wind and cover the area where waiting vehicles line up to be attended. Form is overall compact for each building. A microclimate is created in permanent residential areas through a covered internal courtyard providing light, ventilation, and water vapour through a pond and vegetation. Heavy thermal mass is considered. Energy and hot water is supplied by solar collectors and photovoltaic panels.

**Keywords:** extreme climate, wind tunnel, thermal simulation

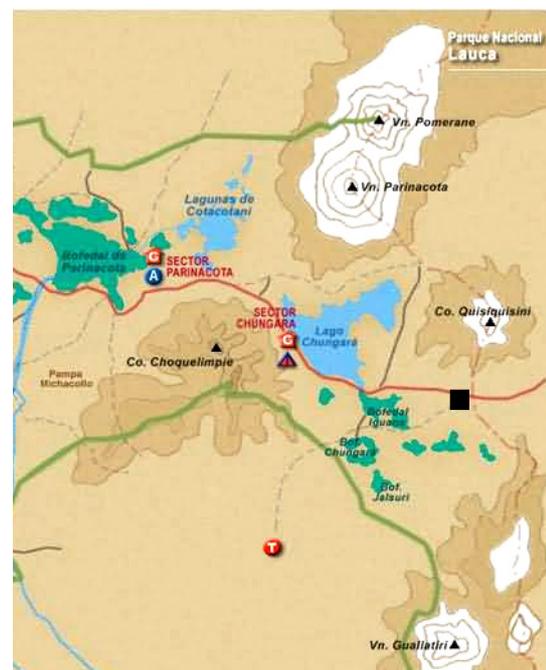
## 1. INTRODUCTION

Last year, the Chilean Ministry of Public Works call for a public design competition for a border control building situated at Lauca National Park. The professional team who won the competition is now in charge of the project development. An Environmental Impact Statement is also being made. [1] Final design would be finished by November 2006.

Environmental design constraints, strategies and preliminary modelling results of the developing project are presented.

## 2. PROJECT CONSTRAINTS

The Lauca Biosphere Reserve is situated in the Puna bio-geographic region, in the northern part of Chile in the Andean Chain. The area comprises three protected areas: Lauca National Park, 'Las Vicuñas' National Reserve and 'Salar de Surire' Natural Monument. The Biosphere Reserve has high floristic value, representing a large part of Andean biodiversity in Chile. The vast plateau of the Altiplano consists of meadows, crossed by deep gorges, dotted with lagoons, dark lava outcrops and occasional white sparkling salt pans, with a number of permanent fresh, brackish and saline lakes, marshes, as well as fast flowing mountain rivers and streams [2]



**Figure 1** Black square indicates building site in the Biosphere Reserve Park.

Lauca National Park is situated at the Chilean border with Bolivia. The place for the border control building is at 4.700 m. over sea level with very extreme climatic conditions.(Fig 1)

There is a high solar radiation, a clean atmosphere and cold nights. During all year daily temperature range is 22° K, but yearly swing is only 8°C. Wind speeds are about 70 km/hr coming from East and West. Relative Humidity is low. Rain precipitation occurs during summertime and reaches 190 mm. annually. During wintertime there is some snow precipitation.

Functional restrictions arise from the workers need to stay outdoors during vehicle checking. This means not only being exposed to a harsh natural climate but also to dirt, noise and fumes from heavy vehicles.

On the other hand, as the building is placed at a natural park and Biosphere reserve, it has higher environmental restrictions than an ordinary building, such as, to use as little and clean energy as possible, to use little fresh water, to fully treat waste water and to recycle all litter.

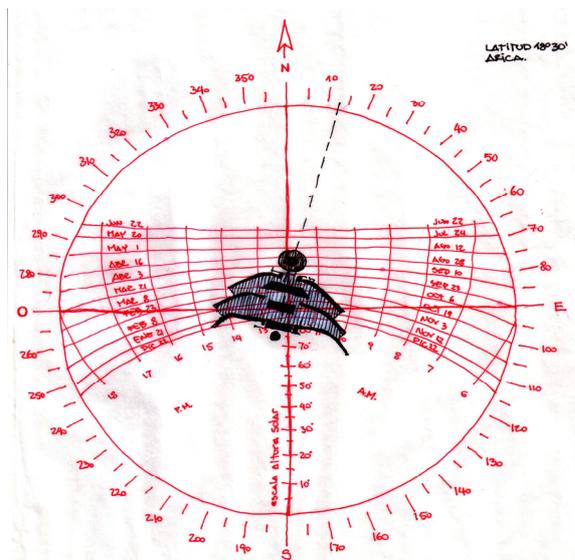
### 3. PROJECT BIOCLIMATIC STRATEGIES

#### 1.1 Orientation

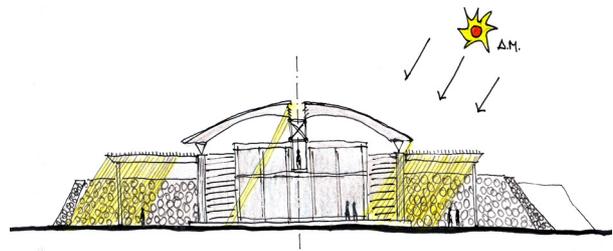
In a Ministry document [2] that recommends design strategies for public buildings at 9 climatic zones, it could be found that orientation strategy proposed for this area is to have similar development of E-W and S-N axes. A good solution is to surround small courtyards with habitable zones and to place openings towards north and south. (Fig. 2)

Design proposal has two areas:

- a) Working zones which are protected from wind mainly with buffer spaces, and high stone surrounding walls.(Fig 3)
- b) Residential building is surrounding a courtyard provided with a pond and vegetation. Small windows are oriented preferentially north, with views to Chisquisini Mount. (Fig 2 and 5).



**Figure 2** Project orientation sketch: living spaces facing North for sun exposure and views.



**Figure 3** Border Control Building protected from wind. Large roof that covers the open yard area is provided with transparent patches in order to let light and sun get through it.

#### 2.2 Form

Recommendations about project form are: to have a compact plan for each building and protect both open yard and interior public areas from strong wind coming from east and west.

There are 3 separate buildings divided by different pattern of utilization and function.

A large convex roof covers all inner and open working areas. These areas cannot be enclosed due to continuous traffic of heavy lorries, so service buildings follow traffic lanes and provide shelter for drivers and passengers. (blue shapes shown in Fig.4)

#### 2.3 Wind breakers

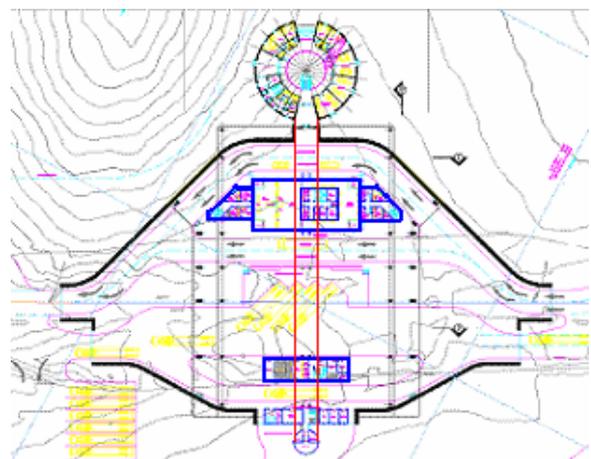
High wind speed was the central constraint which shaped form of the 4.5 m. height unprocessed raw stone walls surrounding the site (black lines in general plan shown in Fig.4).

Zoning follows a gradual arrangement: from exposed areas to most protected areas through wind barriers and deflectors, and the large roof.

Raw stone walls protect open areas and the two public services buildings from wind. (black lines in general plan shown in Fig.4).

A separate building for living spaces is placed outside the stone wall and has a round plan to reduce wind impact and a small central courtyard to create a gentler microclimate.(top circle in Fig.4)

A long suspended enclosed corridor situated above traffic lanes provides a protected and naturally lit connection for all buildings ( central red lines in plan shown in Fig. 4).



**Figure 4** General Plan

## 2.4 Solar Energy and building envelope

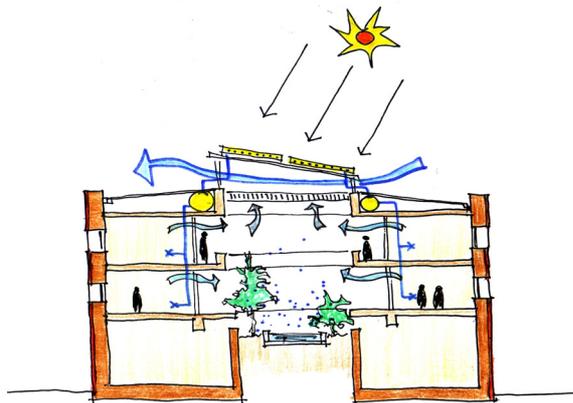
Daily range of 22 °C or even more is a complex challenge for building envelope. Because of temperature high daily range and low temperatures by night the whole year, sleeping and recreational building would be permanently heated and no savings are expected from intermittent heating.

To use thermal mass is essential in living spaces. The small courtyard located in the centre of this building provides a recreational space which is designed as a buffer area. This courtyard provides light, sunshine, fresh air and humidity. (Fig 5)

All building envelopes are thermally well insulated. Double glazing and external insulation is applied to most areas.

Working areas are expected to be in use during a single daytime shift only, so lighter weight envelopes allow for intermittent heating. These areas are daylight with light coming from a transparent fraction of roofs, providing illuminance in the range 1000 to 2000 lux. Wind breakers also act as anti-glare devices.

There are solar collectors for preheating hot water and heating hydronic system. PV devices are used for some lighting circuits.



**Figure 5** Sleeping and recreational building uses passive solar radiation through windows, heavy walls and a central court

## 4. FIRST SIMULATION RESULTS

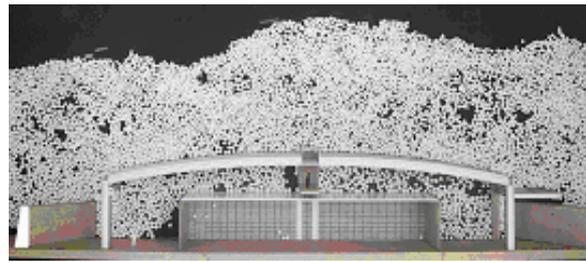
### 4.1 Wind tunnel

The key design strategy to protect office and service areas from strong wind was tested.

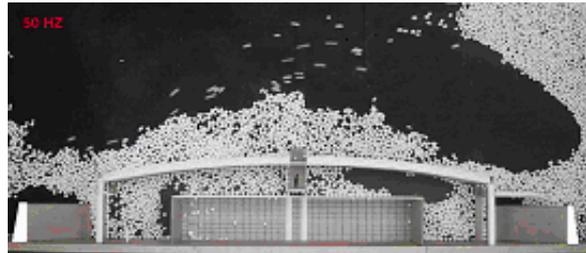
Wind tunnel simulation was organized as follows:

- a) A 1:50 scale model of a cross section of one office building was placed in a boundary layer wind tunnel. Flow visualisation using foam polystyrene beads was photographed from above. Wind was simulated at the tunnel with equivalent speeds between 30 to 50 km/hr. Wind simulates West direction (left side). Miniature cylindrical hot film anemometer probes were located at an equivalent of 1 metre above floor level. Small balls were progressively removed everywhere wind was blowing and stayed still where there was calm.

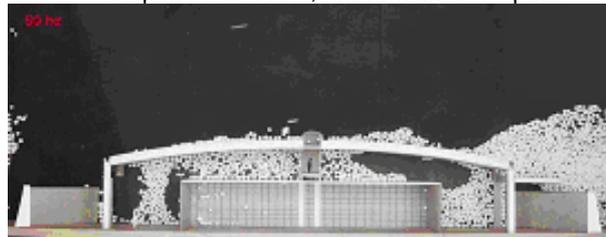
Photographs of one of the wind tunnel section models are presented below.



**Step 1** Cross section of main service building: no Polystyrene beads are removed

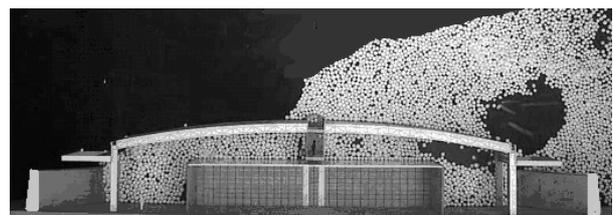


**Step 2:** Wind blows from left 2 minutes. A hole is shaped behind roof, above habitable space



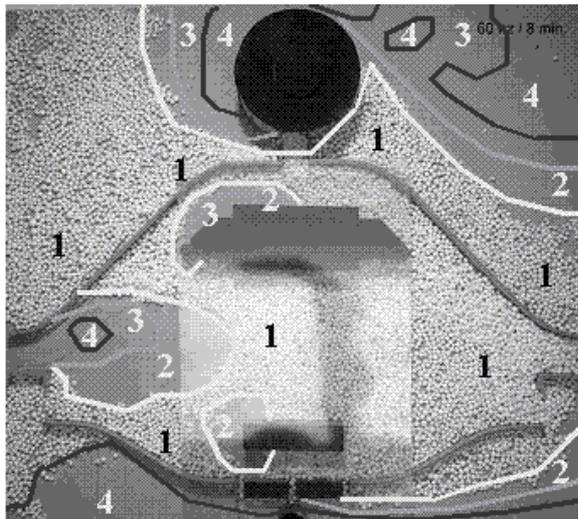
**Step 3** Wind blows from left side. 8 minutes. Some turbulence is detected at ground level under extreme conditions.

**Figure 6** Sequence of wind tunnel simulations of building cross section with wind from West (left side).



**Figure 7** Simulation after adding wind breakers.

Wind effects at human level are reduced and some glare control is introduced.



**Figure 8** Wind tunnel simulation of plan section with wind coming from west side.(left). Wind has slight effects at working areas of the yard. Higher contour values show increasing wind speed.

b) At Fig 8 a 1:200 scale model of a plan section of the whole building project is presented with a clear plastic roof.

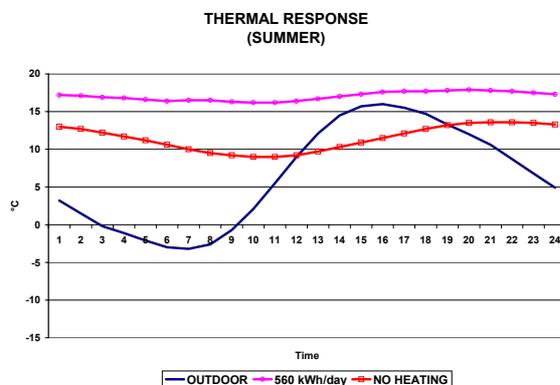
Wind tunnel simulation confirms the effective role of walls and roof in protecting most of the outdoor yard service area from wind under equivalent to full scale 70 km/hr wind speed.

#### 4.2 Thermal response simulation

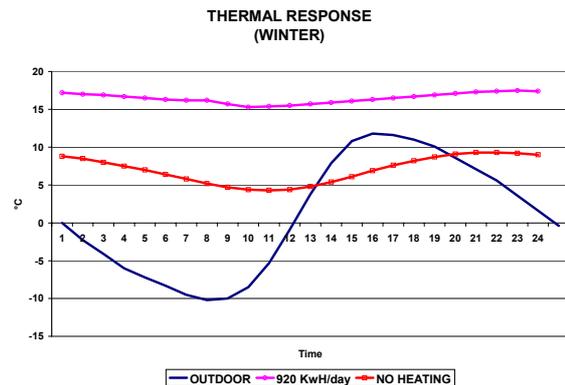
The thermal response was simulated by using the software PASIVA, [3] (Programa para Arquitectura de Simulación de Variables Ambientales) based on hourly data and sol-air temperature calculation.

Sleeping and recreational building thermal simulation is presented for summer and winter conditions.

Results for average temperature difference for this building with external temperature is 6.2 °C in winter and 5.1 °C in summer



**Figure 9** Thermal simulations of the sleeping and recreational building is presented for summertime with and without heating.



**Figure 10** Thermal simulations of sleeping and recreational building presented for wintertime with and without heating

First calculations showed that the building annual heating demand is 180 kWh/m<sup>2</sup>. Further modelling would be carried out with the aim of increasing solar gain and daylighting as much as possible without increasing the risk of glare. Also some openings in the surrounding walls are to be introduced while keeping its purpose as wind barrier.

## 5. CONCLUSION

Case studied on this paper is a proposal that won a design competition for its strong and convincing environmental principles in response to the particular requirements. The challenging constraints and the sustainable values are guiding design since the early stages. Collaboration between modelling and design has shown fruitful and it is expected to finish design with even better solutions.

Preliminary results presented at this paper are proving that first hypothesis were correct.

Design process is currently under way and it is expected that the understanding of wrong decisions by means of further work in calculating, measuring and simulating would improve final solutions.

## ACKNOWLEDGEMENT

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## REFERENCES

- [1]The team is formed by architects C. Purcell, E. López, F. López and P. Flores and environmental consultants G. Armijo and E. Collados.
- [2]<http://www2.unesco.org/mab/br/brdir/directory>
- [3] W. Bustamante G. Armijo and E. Collados "Design tools for energy efficiency and thermal comfort in public buildings. Application to nine climatic regions in Chile", Ministerio de Obras Públicas (2000)