# Holcim Foundation for Sustainable Construction

## Dematerialized tropical façades: the Holcim office building in Costa Rica

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**Introduction**

Natural climate is a major resource that should be exploited to achieve comfort in buildings and as an energy reduction strategy. Bio-climatic architecture is a coherent and sustainable approach to deal with the environment.

That is why harnessing comfort through climate seems to be a valid practice for developing countries. Bio-climatic practices must be recovered and championed as an effective alternative to modern artificial methods of microclimate control. It is also important to validate the performance of bio-climatic buildings to assess their capacity to provide habitability, and to verify the effectiveness of the architectural elements and techniques to create a sense of comfort.

The microclimate conditions inside the building were compared with environmental measurements obtained outdoors and with results from a model run to plan the building design. The data collected in the field was used to assess the performance of the building following ISO comfort standards.

**Site and building descriptions**

This office building was designed in 2003 and erected in 2004 in an industrial complex, and has and area of 3,896$m^2$ Holcim Costa Rica is a company that produces cement, aggregates, concretes and prefabricated elements for buildings. The selected site was a hill with great views. The building is located in the Central Valley of Costa Rica, at approximately 10°N, 84°W and an elevation of 800m above sea level. Climate here is hot, sub-tropical and humid, with a well-defined dry season. Average annual rainfall is of roughly 2,000mm distributed between mid-May and mid-November.

Average air temperature ranges between 17°C and 27°C. During working hours the temperature extremes are closer. Average humidity is 78%. Strong trade winds (≈20km/h) affects this region from mid-December to March, while lower speed winds (≈10km/h) strike the building from September through December. Sudden strong winds gusts of ≈75km/h occur during the dry season. In addition, the daily climate regime features small but perceptible variations in wind speed, air temperature and humidity, which result in daily fluctuations between contrasting maximum and minimum values.

The architecture of the Holcim office building aims to achieve indoor environmental comfort using natural energy as a main resource to avoid the use of artificial conditioning. The result was a set of four buildings strategically located that surround a courtyard.

The four buildings are permeable to the external elements, feature architectural elements to provide shade, and the landscape added near the building 174 trees, bushes of various sizes and different species (hosting, fruit and nectar-bearing trees) and 1,500 in its surrounding area. Many of those species are endemic, and planted to attract the local fauna. The vegetation is also important for the acclimatization of the building as well for blocking excessive sunshine and reducing dust deposition. The access building, the most exposed of all four, is partially shielded by a perforated wall of polished concrete—the "Wind Diapason". People walk across climatic fountains and narrow channels towards the access building.

During the design phase, a simulation of the performance of north and south buildings was carried out. This modeling exercise provided important information to improve the architecture, and the building's construction process. The most relevant improvement was the reduction of the effects of solar radiation on the roof. To improve the performance of the roof insulation, a system of ventilated and insulated layers were designed. Tense structures act as umbrellas on the roof and façades, and the closed concrete walls insulate the east and west façades.

Without further scientific support, but based on the empirical knowledge of the geography, the weather and the local experience, construction drawings were finished and the construction began. Once the building was completed and occupied it became necessary to reduce the illuminance inside the halls by darkening the tint used on the window panes. In some more densely occupied areas ceiling fans were installed to improve comfort.

The central courtyard landscaping was designed using large boulders that were left after the construction of the industrial complex, planted with grass and covered with ivy. The beach almond trees used (*T. cattapa*) have a pagoda shape that helps reduce radiation and evaporation.

The microclimate created in the courtyard can be further humidified and cooled during working hours with the operation of misting devices. Watering of the plants is done every morning and every evening, while misting is activated for 15 seconds every 10 minutes from 7 am to 6 pm during the dry season.

The operation of bio-climatic buildings requires the active intervention of their users to regulate indoor comfort. While electronic sensors and devices activate the machinery that controls the interior climate in automatically-conditioned buildings, people are in charge of this control in passive bio-climatic buildings, by manipulating mechanical devices (i.e., louvers, blinds, windows, wind deflectors).

The importance of landscape design and functioning to adjust the climate of the Holcim office building and to create comfort has also been apparent. A clear example of this is the role of different types of plants in creating shade and reducing the radiation load, air temperature, and evaporation. Furthermore, trees planted as windbreaks or in small forest patches and biological corridors may contribute substantially to solving the problems associated to high-speed winds observed virtually all year round at this location, and to promote the conservation of local biodiversity.

According to ISO comfort norms, the Holcim office building provides habitability and comfort during working hours. Environmental conditions inside the building qualified as comfortable but slightly hot during a few days of the dry season and as comfortable but slightly humid during a few days in rainy season. Bio-climatic design was thus successful in creating sustainable architectural solutions in highly seasonal tropical environments, characterized by year-round high illuminance and warm temperature, and strong annual fluctuations in rainfall, radiation, humidity and wind speed.

Dr. Marco Gutiérrez, a biologist specializing in microclimates for greenhouses, led these studies and concluded that "even in tropical climates with important seasonal variations, a comfortable internal climate may be achieved in buildings by means of passive cooling and humidifying systems that are both ecological and economical, instead of mechanical systems that entail an intensive energy consumption."

The key issue for these buildings is the regularity of external conditions, which is why the more vegetation there is, the more regularity there will be. Vegetation has a positive impact on temperature which is kept more constant, illuminance is regulated, leaves help bring down dust in suspension, trees protect from gusts of wind and preserve humidity in the air, critical for achieving comfort in the highland tropics.

The feeling of comfort is relative, which is a partially studied aspect, and therefore limited data exist. The information available is that which is applied to the design of air conditioning systems. It defines comfort levels at a temperature of 23ºC and 50% relative humidity. This has been established from experiences in four-season temperate climates, which is why in the tropics we see people wearing jackets in air-conditioned buildings under these parameters. This means we are lowering temperatures excessively, which is important to note since it constitutes a waste of energy. For example, lowering temperature of an office by 1ºC — say, from 24ºC to 23ºC — represents a 10.5% increase in electricity consumption.

If the internal comfort variables are not in tune with the external and with an environmentally adapted architecture, you lose energy and money. There are countries that pay no heed to this synchrony and end up consuming up to 50% of their entire energy bill supply just to air condition poorly designed buildings.

Concerned about the waste of energy that this represents, a German laboratory has concluded that people in the tropics have different comfort levels when compared to people who live in temperate climates. They have established that the limit to the feeling of comfort in tropical latitudes is 28ºC and a relative humidity of 80%. This data on Thailand also appears to be the case for Costa Rica. Keep in mind that 40% of the world population lives in tropical zones.

Bio-climatic projects are the key issue of contemporary architecture. With the rising cost of energy, this topic has become more salient than ever. The Holcim office building boasts annual energy savings of US$18.36/m$^2$, or a total of US$64,260/year, plus a savings of US$308,000 (12% of US$2,564,800) for choosing not to install air conditioning systems in the offices, only the auditorium and the IT area (2004 data).

The full implementation of a bio-climatic building, with natural ventilation and light and the use of manual systems to control its microclimate, will obviously depend on its users' acceptance of a less consistent comfort level, who are willing to manipulate the devices to respond to climate changes. The reason is that climate and the natural environment are seldom consistent.

In the end, the issue will always be a socio-economic one that depends on the level of comfort and convenience for it to be deemed acceptable by a community, and adaptable to an ecological rationale.

A bio-climatic building, with its positive impact on the ecological agenda, emphasizes the user's comfort, since it emphasizes their environmental awareness. Every day, its users have the opportunity of experiencing the external environment with its seasonal changes, instead of living in a hermetically sealed and homogenous artificial environment throughout the day and the year.

**Sustainable architecture**

Five "target issues" for sustainable construction developed by the Holcim Foundation in collaboration with its partner universities are illustrated with the example of the Holcim office building in Costa Rica. This building was designed in 2003 and built in 2004. In words of Professor Hans-Rudolf Schalcher[1], "the building is significant because it is a prime example of sustainable construction and also has a great visual impact. It has the power to draw attention to sustainable construction".

[1] Prof. Dr. Hans-Rudolf Schalcher is Chair of Planning and Management in Construction (Institute for Construction Engineering and Management) at the Swiss Federal Institute of Technology (ETH Zurich), Switzerland. He is a member of the Management Board and Head of the Technical Competence Center (TCC) of the Holcim Foundation.

Visit www.holcimfoundation.org/publications to download the booklet on this building.

The impact of the "ecological backpack" of construction and architecture on the environment is vital, and recently there's and ever increasing concern of companies and institutions to reduce its impact. Sustainability will be achieved with endeavors, investments, changes in the design concepts, and tolerance as far as comfort is concerned.

Façade research on sustainable buildings shows that there are two approaches that prove that there are no universal solutions:

1. high-tech façades with artificial indoor climate, and
2. façades that make full use of natural resources.

This comparative analysis may also be done for energy and water consumption, cooling, etc

**High-tech façades** ("intelligent glass façades"): this concept projects, designs and constructs buildings whose comfort is regulated by high-tech sensors controlled by data centers and maintenance personnel. These sensors receive data on the outside climate and automatically adjust the indoor climate, modifying temperature, switching lights on or off, controlling the access of fresh air, increasing or decreasing humidity, etc. These "intelligent façades" began in the 1980s, where several functions are compressed into a thin glass skin that covers the building, in order to achieve stable and artificial conditions of lighting and air conditioning.

Buildings with "intelligent glass façades" have a cost of US$7,500/$m^2$ or more, and are known as "intelligent buildings". These "intelligent buildings" depend on technology and energy consumption, and during power outages, they operate on hydrocarbons. These high-tech skins are only applicable in certain economic contexts where access to high-end technology represents cost reductions.

Façades that make full use of natural resources (“**passive dematerialized facades**”): We have proposed the passive dematerialized façade for developing countries in the tropics with limited access to technology, with which we achieve adequate comfort standards by using the passive renewable energies of the site.

Its design is based on the users’ capacity to achieve comfort by using their energy in the operation of the building’s devices. They open the windows, open the curtains, operate the louvers, direct the breeze, prune the vegetation or strategically manipulate it. The experience is that these buildings, at a similar comfort level to that of the “intelligent” ones, may constitute one-tenth of their cost, which meets the economic context of many of the inhabitants of the tropics.

Instead of avoiding high illuminance with sensors that make glass panes opaque, as in the “intelligent glass façades,” we keep the windows in the shade. Instead of reducing heat from the sun with air conditioning, we keep the windows cool with vegetation and shade. Instead of cooling the building with artificial means, we do it with cross ventilation for which we design louvers and slat-like structures to direct the breeze.

The passive dematerialized façade is more economical and adapts easily to local labor skills; it also synchronizes the building to the latitude, giving it an architectural expression in tune with its environment. Also, new elements may be added on later to improve the building’s performance once it is operating.

These buildings, which may be dubbed “clever” or “sagacious” buildings – or we may even refer to them as “cunning” buildings – are more autonomous and far less costly.

**Conclusion**

Sustainable construction will be achieved when sustainable buildings may be copied and repeated by the vast majority of people, and replicated throughout the planet so that its positive impact may have a multiplying effect on the environment. Only thus will sustainable construction have a broad, effective, and recognized impact.

The buildings that use “intelligent glass façades” as shown are not universally replicable and will remain as interesting exclusivities, without the capacity to generate true change toward sustainability of the planet. On the other hand, those with passive dematerialized facades do have that potential for change.

Avant-gardism for us is to be able to foresee a historic moment that is approaching, more so than the use of a certain technology. As such, the passive dematerialized façade is the true avant-garde for architecture, and not high-tech buildings, which cease to be fashion high-tech when its devices are displaced by those of the latest generation.

For this reason it is so crucial to adapt a project to the environmental, economic, and cultural venue, and being able to select appropriate design strategies, so that the building’s contributions to sustainability have the possibility of being replicated by many.