

The Holcim Costa Rica head office building in San José is a bold departure from the norm, and the site design has ecological merit far beyond that of most office building sites.

Measuring up to the criteria of sustainable construction

Office building in Costa Rica



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Awareness of sustainable construction

By Hans-Rudolf Schalcher, Head of the Technical Competence Center and member of the Management Board of the Holcim Foundation

Most of us are familiar with the concept of sustainable development, or balanced social, economic and environmental progress. But what is sustainable construction? Essentially, it is that part of sustainable development which has to do with building. The construction industry is one of the world's largest consumers of energy and materials, so it offers great potential for improving sustainability performance.

The Holcim Foundation for Sustainable Construction was set up to help realize this potential, and is doing so in several ways. To achieve the greatest effect, we must all be aware of sustainable construction – exactly what it is and why it is important. That's why we have created this publication. It explains the Holcim Foundation's five target issues for sustainable construction and illustrates each point with the example of the head office building of Holcim Costa Rica. We didn't pick this building because it's a Holcim building – we picked it because it's a recognized example of sustainable construction.

The Mexican Society of Architects named this building one of the outstanding projects of 2005 and published it in their Ninth Report on Architecture in Mexico and Latin America¹. It has been featured in many international publications, such as RE, and was published by the Spanish National Centre for Renewable Energy (CENER). In February 2005, the Spanish version of GEO magazine² singled out five pioneering sustainable buildings on the planet and the Holcim Costa Rica office building was one of them.

The building is significant because it is a prime example of sustainable construction and also has great visual impact. It has the power to draw attention to sustainable construction.

¹ Novena Reseña de Arquitectura México, Latinoamérica. México D.F.: Enlace Arquitectura y Diseño.

² GEO Especial. 2005. Cinco ideas para construir un mundo más limpio y habitable. GEO Especial. No. 217. February 2005.

Measuring up to the criteria of sustainable construction

By Bruno Stagno, President of Bruno Stagno Arquitecto y Asociados

Five target issues for sustainable construction

Quantum change and transferability

Ethical standards and social equity

Ecological quality and energy conservation

Economic performance and compatibility

Contextual and aesthetic impact

Sustainable development and sustainable construction are complex subjects that are intertwined with other complex issues. To make sustainable construction easier to understand, evaluate, and apply, the Holcim Foundation developed a five-point definition. These five so-called target issues serve as yardsticks to measure the degree to which a building contributes to sustainable development.

Three of the target issues for sustainable construction are the same as the three goals of sustainable development: balanced environmental, social, and economic performance. One applies specifically to building: the creation and improvement of good buildings, neighborhoods, towns, and cities. And one recognizes the global urgency of sustainable construction: the need for significant advancements that can be applied on a broad scale. This publication explains these five target issues in detail and shows how each criteria is met by the Holcim Costa Rica office building.

Quantum change and transferability

Shading is a simple and direct way to keep indoor climates cooler, and it can be applied anywhere. The Holcim Cost Rica office building has at least seven types of shading systems that reduce thermal gain through the roof and facades.

Outstanding examples of sustainable construction should not only mark significant advancement, the innovative idea should be one that can be copied again and again, thus promising the greatest benefit at a global scale. Transferable ideas are those that are affordable, simple, and broadly applicable.





In hot climates, preventing thermal gain makes much more sense than allowing it and then counteracting it with expensive, energy-intensive mechanical air-conditioning systems.

The significant achievement of the Holcim Costa Rica office building is the way it at once answers the full range of concerns. It uses many (efficient) passive design mechanisms instead of (wasteful) conventional systems, it was built at a relatively modest cost (USD 658/m²), it is a visually intriguing piece of architecture with symbolic power, it serves its purpose fully by providing attractive and functional spaces, it develops the environmental awareness of the occupants (passive building – active people), the landscaping enriches the local ecosystem, and the design meets the client's wish to incorporate a significant amount of cementitious materials. Considered individually, these are not amazing design feats, but considered together, the way the building looks and works is a radical departure from the norm.

Although some aspects of the design apply specifically to the hot tropical climate, many essential aspects can be advantageously and easily transferred around the world. The concepts employed are affordable, easy to understand, and practical to realize.

Target issue for sustainable construction

Contributions to the disciplines of architecture, urban and landscape design, civil, urban and environmental engineering and other related fields pertaining to construction.

Innovative concepts regarding design, integration of materials and products, structure, enclosure and building services.

Outstanding approaches regarding construction technology and processes, operation and maintenance.

Long-term monitoring to evaluate the fulfillment of the initial expectations and goals.

Dissemination of knowledge (project documentation and communication, education and training).

Ethical standards and social equity

A bright, well designed building is a pleasure to work in every day. And a true piece of architecture is an inspiration.

Especially in poor countries, sustainable construction means building to supply urgent and basic needs: shelter, water, schools, access to goods and services, and medical care. In other countries, affordable housing is a main issue. In still others, the problem is wasteful and excessive consumption, which might be financially affordable but is irresponsible. Leaving sufficient materials and resources for others, including future generations, is a moral duty.

Sustainable construction means cities and buildings that respond to the emotional and psychological needs of people by providing stimulating environments, raising awareness of important values, inspiring the human spirit, and bonding societies, communities, and neighborhoods. Many sustainable construction projects are developed by teams using a collective approach through which stakeholders and users are included in the design process. Sustainable construction involves the highly-principled treatment of people during the design, construction, use, and recycling of buildings.





The employees knew they were getting a special office building, but still they were surprised to see how the sensitive design began to change the way they acted and thought.

Like most of us, the employees of Holcim Costa Rica were used to working in standard air-conditioned buildings. Considering the climate in Costa Rica, one can well imagine that some employees had reservations when they heard they would be getting a new non-air-conditioned building. The company held meetings with the employees to discuss the design of their workplace and to explain that sustainable construction is a part of Holcim's commitment to sustainable development.

The owner and the architect followed strict ethical principles and used transparent practices during the design, bidding (tendering), and construction phases of the project. All contractors were required to meet high standards of social responsibility, especially concerning worker safety and environmental protection. About 150 people were involved in the construction work, and not a single accident was reported among the workers or engineers.

Once the building was erected, the company held training sessions to teach employees how to adjust the systems in response to changing climatic conditions. Supporting the employer's objective of happiness

at work, the building offers the employees a comfortable, attractive, and inspiring working environment that includes a variety of amenities such as a gym, cafeteria, many toilets with showers, and beautiful places for relaxation. The design encourages social interaction – employees can often be seen sitting and chatting in their free time or enjoying the breeze and the shade on the decks.

The building provides a stimulating environment in which to work, inviting the occupants to participate visually, mentally, and physically. It transforms values, changes the way people think and act, and raises awareness that we can and should take care of the environment. This eye-catching building dramatically symbolizes Holcim Costa Rica's care for its employees and the environment. It gives a bold identity to the company and to its commitment to social responsibility. This example has encouraged other companies to adopt the same principles.

Target issue for sustainable construction

Ethical standards and social equity

The project must adhere to the highest ethical standards and support social equity at all stages of construction, from planning and building processes to long-term impact on the communal fabric. The project is to provide an advanced response vis-à-vis ethical and social responsibility.

Adherence to ethical standards in all phases of the project's life cycle.

Contributions to the formation of socially viable environments and the values of communities.

Participation of stakeholders (client, users, neighborhood, local authorities, non-governmental organizations and others).

Quality of working conditions in the suppliers' workshop, on site and during operation (compensation, safety, basic needs, gender issues).

Political transparency and correctness.

Ecological quality and energy conservation

Modern architecture can blend magnificently with nature. If we are to build sustainably, it must.

A fundamental principle of sustainable development is to keep our planet in condition to indefinitely support future generations. This is an enormous challenge because our global ecosystem is in a state of stress and overuse. Finite sources of energy and materials are being depleted, and much of our environment is being polluted or spoiled.

The construction industry plays a great role here as a large consumer of materials and energy. At the building scale, sustainable construction aims to provide longlasting, healthful, and useful buildings while conserving finite resources of materials and energy by using durable, recyclable, and renewable materials, through energy-efficient design, and by using environmentally neutral energy sources (wind, sun, geothermal, etc.) and mechanisms (shading, simple evaporation cooling, etc.).

At the urban and regional scales, sustainable construction involves planning that preserves environmental quality, conserves energy through efficient design, reduces waste and consumption through sensible design, and reduces pollution by establishing efficient transportation networks. At all scales, sustainable construction aims to support ecosystems through design with nature (establishing and improving habitats for wildlife, supporting biodiversity, replenishing groundwater instead of channelling rainwater into storm sewers, etc.).





The building design takes advantage of many renewable resources and assets available on the site including sunlight, shade, vegetation, sea breeze, and water.

The design concept of the Holcim Costa Rica office building can be summed up as “passive building, active people.” Departing from conventional building practice, the idea is that the occupants should actively control their indoor environment by operating the passive building systems. They should develop an awareness of heat transmission and airflow, and they should operate the windows, vents, and shading devices to maintain comfortable temperatures and humidity. In conventional buildings, with automatically controlled mechanical air conditioning systems, people are passive.

Renewable or unlimited resources in the tropics where the Holcim Costa Rica office building is situated include sunlight, shade, vegetation, wind, and a breeze from the Pacific coast 55 kilometers to the west. The more we use these and other simple, natural, and efficient mechanisms to achieve indoor comfort, the less non-renewable

energy resources we consume. This design principle can significantly contribute to sustainability. In this building only the auditorium has mechanical air conditioning; the rest of the building is naturally air conditioned by cross ventilation, which works because of the breeze and the courtyard garden.

The courtyard garden, designed as a *jardín de climatización*, is situated to catch the prevailing wind. The air circulates, keeping the courtyard fresh and humidified. In the dry season, jets in the garden spray mist for ten seconds every ten minutes to moisten the climbing plants that cover the rocks, and these in turn humidify the air. Umbrella-shaped almond trees shade the courtyard to retain the moisture. The pergolas that screen the western sun and carefully placed trees provide shade and cool the area around the building, improving the air quality, enhancing the appearance, and filtering dust. These plant





High-quality modern building materials such as metal, glass, and concrete are energy-intensive to produce but highly durable, making ecological sense in the long term.

materials are growing and their beneficial effects will improve over time.

The use of durable and low-maintenance materials is another hallmark of sustainable construction. The Holcim Costa Rica office building uses concrete, stone, glass, wood for the floors and window blinds, and fiber-cement panels for the siding. The materials are not painted; the surfaces are left to age naturally and develop the beautiful patina of durable natural materials.

Expansive glass walls make artificial lighting unnecessary during the day. The ceilings are painted white to reflect the light. Louvers diffuse the light and control solar gain.

Rainwater is collected in a tank. This water is used for the fountains and channels at the entrance, the courtyard humidification system, and plants. This 'free' water source not only saves money, it conserves

the limited and energy-intensive communal drinking water.

The landscape design incorporates several ecological principles to benefit the environment. Many existing trees were conserved, and many native species of new trees were planted to better support wildlife. The landscape design includes 174 tree species and 1,100 new coffee bushes. The coffee and fruit trees were planted for use by the company. The number and diversity of animals thriving on the site have increased – especially indigenous birds, insects, and other small animals. This has improved the quality of life for all species, including humans, who enjoy this pleasant setting.

Earth movement during construction was limited, and all materials were reused (even rocks that had been excavated when the factory was built several years earlier were used in the courtyard garden).

Target issue for sustainable construction

Ecological quality and energy conservation

The project must exhibit a sensible use and management of natural resources throughout its life cycle, including operation and maintenance. Long-term environmental concerns, whether pertaining to flows of material or energy, should be an integral part of the built entity.

Energy and material efficiency in construction, operation and maintenance.

High ratio of renewable energy to fossil energy in construction, operation and maintenance.

Land use efficiency.

Low environmental impacts over the project's life cycle.

Robust products and technologies.

Economic performance and compatibility

The investment in shading will pay off every day throughout the life of the building by greatly reducing the cost of air conditioning.

Through efficiency of design, construction, maintenance, operation, reuse, and recycling, sustainable construction seeks feasible projects that provide long-term economic benefits for owners, users, and communities. Such benefits can take many forms besides profits or lower costs, for example: strengthening the economic base of a region, boosting the local economy, giving residents more control over their housing costs, or even giving people a financial base.

Innovative deployment of financial resources, durability, adaptability, lifecycle cost planning, 'free' low-tech natural resources, and other attributes can work together to make sustainable construction not only financially feasible but the preferred choice and a sound long-term investment in the future.





The use of durable weather-resistant materials keeps maintenance costs low.

The construction cost of the Holcim Costa Rica office building came in at just under USD 2.6 million (a relatively modest cost of USD 658/m²), slightly over the original budget, but in line with the changes that arose during the project. This figure does not include the site work and landscaping, access roads, parking area, and the cost of furnishings.

The building was designed to incorporate Holcim products for two reasons: to save costs and to express the identity of the company. Holcim products used include prefabricated foundations, columns, beams and floors, standard and special posts, cement and concrete, and various aggregates.

The design and the construction methods and processes were adapted to the capabilities of local construction contractors and the construction industry in Costa Rica. Except for the tensile structures and the wind diapason, the

construction is conventional: no technological miracles, no sophisticated materials, no spectacular architectonic feats.

By making efficient use of free energy sources (wind, daylight), and simple low-tech mechanisms (shading, humidification with rainwater), the building is economical to operate, requiring much less electricity than a comparable conventional building with mechanical air conditioning and artificial lighting. The rainwater collection system also saves money. And by using durable weather-resistant materials, maintenance costs are kept low.

Through its comfortable and unique working environment, the building promotes a high level of productivity of employees, sustainably enhancing the economic performance of both the company and the employees.

Economic performance and compatibility

The project must prove to be economically feasible and innovative as to the deployment of financial resources. Funding must promote an economy of means and be compatible with the demands and constraints encountered throughout the construction's life span.

Innovative models for financing.

Financial resources over the project's life cycle and their regional impact.

Flexibility with regard to future changes (user, ownership, laws and regulations).

Robustness to economic conditions (interest rates, taxes, inflation).

Economy of resources deployed in construction.

Contextual and aesthetic impact

The building is a pleasure for the eye from many angles.

Design quality is the aspect that clearly distinguishes sustainable construction from other forms of sustainable development. Visual expression and fitness of form are two essential qualities of all good architecture and planning, and these are also central to sustainable construction. This applies at all scales: land use planning, urban planning, and architectural design.

Land use planning should preserve natural areas and the inherent qualities of the landscape. Besides providing an efficient and functional infrastructure, urban planning should create spaces and places of cultural significance and social value. Urban redevelopment projects and large public projects should heal and upgrade neighborhoods and city quarters. And architectural projects should not only meet the owner's requirements (program), but match the physical context (site and neighborhood) and improve the local surroundings.





The rhythm of the elements, the contrast of light tensile fabrics and massive concrete pillars, the interplay of sky and shade – one could think it's sculpture, but it's all there to create a good working environment.

The Holcim Costa Rica office building perfectly suits its tropical context, expresses corporate responsibility and the products of Holcim, offers durable, functional, pleasant, flexible spaces, fits into its industrial setting while improving the site as a natural habitat, and is visually attractive from many perspectives.

The solid concrete building masses are interspersed with light shafts that regulate solar radiation, reduce the thermal mass of a building, and provide cross ventilation. The tensile structures shade the roofs and windows and contrast beautifully with the heavy concrete masses below. Fiber-cement exterior louvers shade windows at critical times of day. Wooden interior blinds are adjustable to control and direct ventilation. Horizontal parasols shade the upper floor windows all year round. All these architectural elements not only contribute to indoor comfort – as visual

elements they boldly proclaim the passive energy concept of the building and in concert they make the building a pleasure to look at.

The architecture is at one with the landscape design. Trees and plants are not just ornamental, but part of the overall design, planted for shade and treating the indoor air. The courtyard is an integral part of the building's climate control system, and the indoor climate complies with ISO comfort standards. The building proclaims that we must recapture a balanced relationship between architecture and nature.

Target issue for sustainable construction

Contextual and aesthetic impact

The project must convey a high standard of architectural quality as to the manner in which it addresses its cultural and physical context. With space and form of utmost significance, the construction must have a lasting aesthetic impact on its surrounding environment.

Improvement of existing contextual conditions responding to the natural and human-made contexts.

Interdependencies of landscape, infrastructure, urban fabric and architecture.

Cautious restoration and alteration of the built environment.

Programming strategies (use, flexibility, multiplicity of functions, change).

Architectural quality and its aesthetic impact (space, form, light, ambiance).



Universal principles of sustainable construction

Of course the Holcim Costa Rica office building is just one example of sustainable construction. Other examples can be found around the world, and each is unique – a product of its creator, function, climate, budget, site, local materials, local culture, and other factors. Although the specifics may differ, the principles of sustainable construction apply universally, regardless of climate, culture, or economic situation. The idea is to achieve lasting environmental, social, and economic benefits through the construction of well designed buildings and cities. Applying this idea once can make an remarkable building; applying it worldwide would be a giant step toward global sustainability. Bruno Stagno, architect of the Holcim Costa Rica office building

Technical report



Site

The site is in San Antonio de Belén, Alajuela province, in the western part of the central valley of Costa Rica. The parcel of land is in an industrial park at 10°N, 84°E, on a hill with superb views and considerable wind exposure, at an elevation of 800 meters. The local climate is hot, tropical, and strongly seasonal with a well-defined dry season. Temperatures are high year-round; the average temperature on the site is 22°C. Humidity fluctuates strongly; average humidity is 78%. Illuminance is high year-round. Strong trade winds from the northeast (~ 20 km/h with gusts up to 74 km/h) blow across the site from mid-December to March. Lighter southwest winds (~ 10 km/h) blow from September to December. Average annual rainfall is 1.9 m; most rain falls from mid-May to mid-December. Costa Rica is not in a normal hurricane path, but hurricanes in the region do produce heavy rainfall that can be damaging.

Location	San Antonio de Belén, San José, Costa Rica
Climate	Tropical
Terrain	Flat hilltop
Site size	24,384 m ² (192m x 127m)
Setting	Suburban industrial park
Number of parking spaces	117

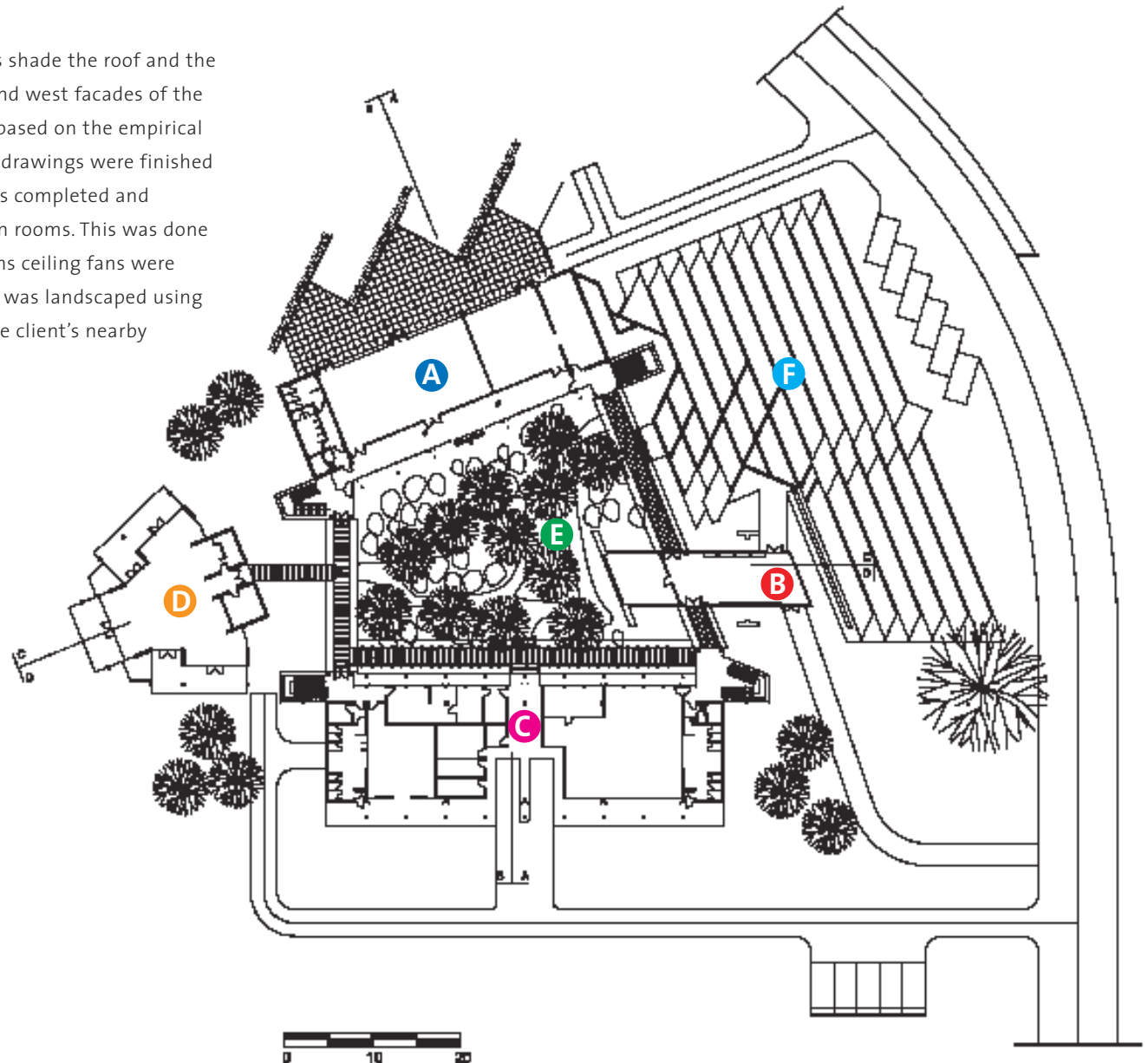
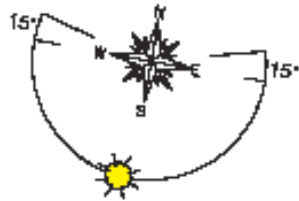
Architectural design

The office building, designed in 2003 and built in 2004, is conceived to provide a comfortable indoor environment using passive means instead of mechanical means such as air conditioning. The floor area of 3,896 m² is divided among four two-story wings, strategically situated around a climate-regulating courtyard (*jardin de climatización*). The building allows much light and air to enter and incorporates shading devices to control glare and limit heat gain. The landscaping includes 174 trees, 1,100 coffee plants, and bushes of various size and species that augments the sparse vegetation originally on the site. Most of these species are endemic, selected to attract and support local fauna. Plants are also part of the indoor design, moderating the indoor climate, adding shade where needed, and filtering dust. Of the four wings, the entrance wing is exposed to the greatest winds. It is partially shielded by a perforated wall of polished concrete, the so-called wind diapason.

Holcim materials were used for the concrete masts, the wind diapason (with special aggregates, mix, and finish), the concrete walls (with a special smooth texture), the polished, random-cut concrete floors, and the large boulders in the central courtyard garden.

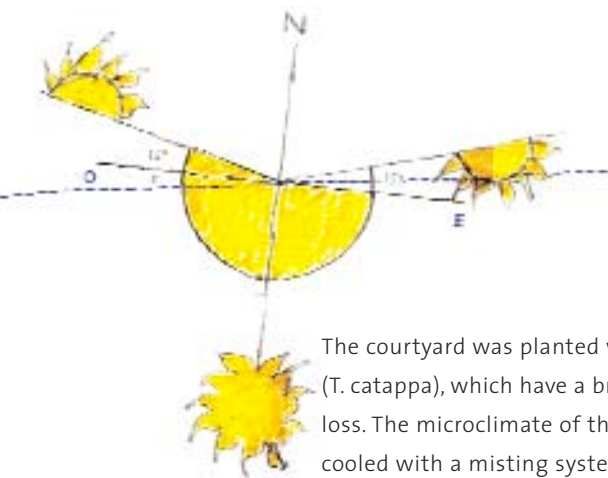
During the design phase the indoor climate of the north and south wings (those with the most occupants) was studied using a simulation program called 'Comfort.' The climate data used was obtained from the nearest meteorological station, located 8 kilometers north of the site. The studies provided information that was used to optimize the construction without changing the architectural design. The biggest improvement gained thereby was the reduction of thermal gain through the roof. To optimize the insulating performance of the roof, an assembly of ventilation, insulation,

and shading layers was designed. Tensile structures shade the roof and the facades. Massive concrete walls insulate the east and west facades of the two wings. Without further scientific support, but based on the empirical knowledge of the geography and local climate, the drawings were finished and construction carried out. Once the building was completed and occupied, it was necessary to reduce glare in certain rooms. This was done by tinting the glass. In some densely occupied rooms ceiling fans were installed to improve comfort. The central courtyard was landscaped using boulders that were left from the construction of the client's nearby industrial plant.



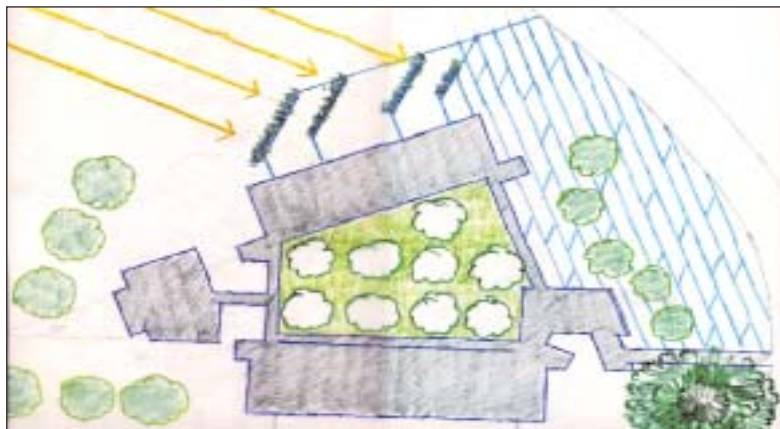
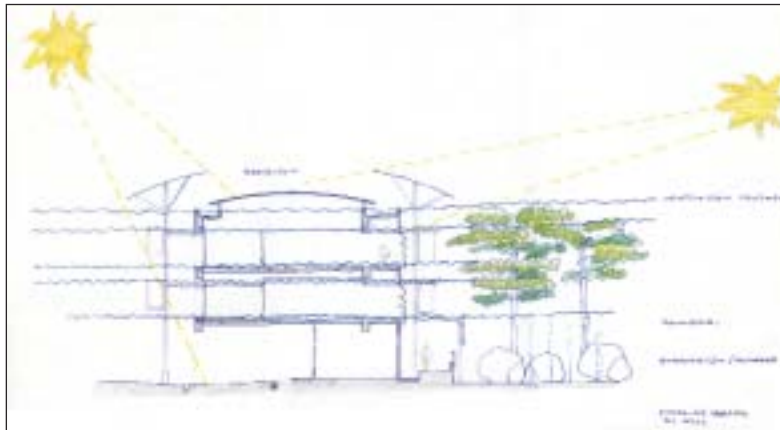
The Holcim Costa Rica office building is approached from the east, across a plaza with an array of climatic fountains and channels. The building comprises four wings surrounding the *jardin de climatización*.

- A North wing
- B Entrance wing
- C South wing
- D Administration wing
- E *Jardin de climatización*
- F Fountains and channels



The courtyard was planted with grass, ivy, and beach almond trees (T. catappa), which have a broad canopy, providing shade to reduce moisture loss. The microclimate of the courtyard can be further humidified and cooled with a misting system, which is activated every ten minutes for ten seconds, from 6 am to 6 pm on working days during the dry season. Plants are watered every morning and evening.

Response to the environment – especially solar radiation in the tropical climate of Costa Rica – was a prime consideration during the design phase.



Building statistics

Year of construction	2004
Building type	Office
Building volume	15,214 m ³ in four wings
Maximum number of occupants	162
Gross usable floor area	3,896 m ²
Number of finished floors	2
Number of basements	–
Construction system	Reinforced concrete slabs, walls and post-and-beam frame; extensive shading systems for roof and facades
Construction cost (building only)	USD 2,564,800 or USD 658/m ² gross floor area
Construction cost of typical office buildings in Costa Rica	USD 580/m ² gross floor area*
Annual operating cost (cooling, lighting, mech. systems, etc.)	USD 9.24/m ²
Annual operating cost of typical office buildings in Costa Rica	USD 27.60/m ² *

* Source: Claudio Soto/National Company of Power and Electricity (CNFL)



Performance

The performance of bioclimatic buildings (those designed in harmony with nature) must be assessed. Is the design effective? Is the indoor climate as planned? Does it meet ISO comfort standards?

To answer these questions, the indoor environment of the Holcim Costa Rica office building was measured during the rainy season of 2004 (August 30 to September 15) and the early dry windy season of 2005 (February 1 to March 15). Most measurements were taken on the second floor, where most of the daily activity occurs from 8 am to 7 pm.

Measuring illuminance, temperature, humidity, and air speed

Illuminance was measured in lumens per m² using a Hobos system (model Ho8-004-02) set up in the southern wing. One sensor monitored average light conditions in the building and a second sensor was directed toward the north-facing windows to read during the late afternoon and sunset hours, times when illuminance could become excessive.

Air temperature and relative humidity were monitored at six locations in the building using the same Hobos system. In the north wing, sensors were positioned in the middle of the room and inside an office. In the south wing, two sensors were placed in the middle of the hall and one in the stairway between the ground floor and upper floor. Another sensor was positioned in a shaded corridor on the southern side of the courtyard. All sensors were programmed to record average values at ten-minute intervals during 24-hour cycles. Readings taken in the stairway were not used in calculations of average values for the building.

Several shading devices protect the north wing against the low late-afternoon sun, including three metal trellises (right) that will soon be covered with vines.



Air movement inside the building and wind speed outside the building were measured during times of maximum winds (October 2004 and February 2005). Two pairs of anemometers (MetOne, model 014A) were set up, one on the upper floor of the administration wing (west wing), and the other on the ground floor at the east end of the building. In each case, one anemometer was positioned inside and the other outside the building. The data was recorded by a data logger (Campbell Scientific model CR10X) programmed to record average and maximum wind speeds at ten-minute intervals during 24-hour cycles.



Shading and ventilation instead of mechanical air conditioning provide a comfortable indoor climate. Three shading mechanisms are visible here: a fabric canopy, vertical sun-blocks, and horizontal louvers.

Optimizing the indoor climate

Illuminance inside the building was measured to be within the comfort range, typically below 1,500 lumens per m² (Figures 1A, 2A). In offices and halls with north- or south-facing windows illuminance was found to be excessive all day, and especially during early morning and late afternoon. To correct this problem additional louvers and screens were installed. Temperatures measured at five locations in the building show the diurnal pattern typical of tropical climates, with strong diurnal fluctuations (10°C or more), but stable average conditions throughout the year (Figures 1B, 2B). Minimum daily temperatures were typically observed at pre-dawn hours (5 am to 6 am), and varied from 18°C to 20°C during both rainy and dry seasons. Maximum daily temperatures were observed during the early afternoon (12 noon to 2 pm) and varied from 26°C to 28°C during both seasons. Average temperatures during working hours (8 am to 7 pm) were

near 24°C to 25°C during both seasons. Compared with mean and maximum temperatures observed outdoors (22°C and 28.5°C, respectively), the building provided a comfortable climate, with indoor temperatures close to the average recorded outdoors, but with far lower maximum temperatures. The stairway between the ground floor and upper floor is an exceptional situation. This volume is wrapped in glass, which creates a greenhouse effect throughout the day. Temperatures here reached almost 32°C, uncomfortably hot. The temperature here is expected to drop substantially once the shading plants and trees grow. Mean and maximum air temperatures predicted using the Comfort model were 24.9°C and 24.4°C during the dry season and 26.6°C and 25.9°C during the rainy season, respectively. In comparison with actual values measured in the building, the model underestimated maximum air temperature during the rainy season (see table page 47).

Figure 1:
Diurnal patterns (in days) of illuminance, air temperature and relative humidity inside the Holcim building during rainy and dry seasons

- Illuminance (lum m⁻²) x 10⁻²
- Temperature (°C)
- Humidity (%)
- Days

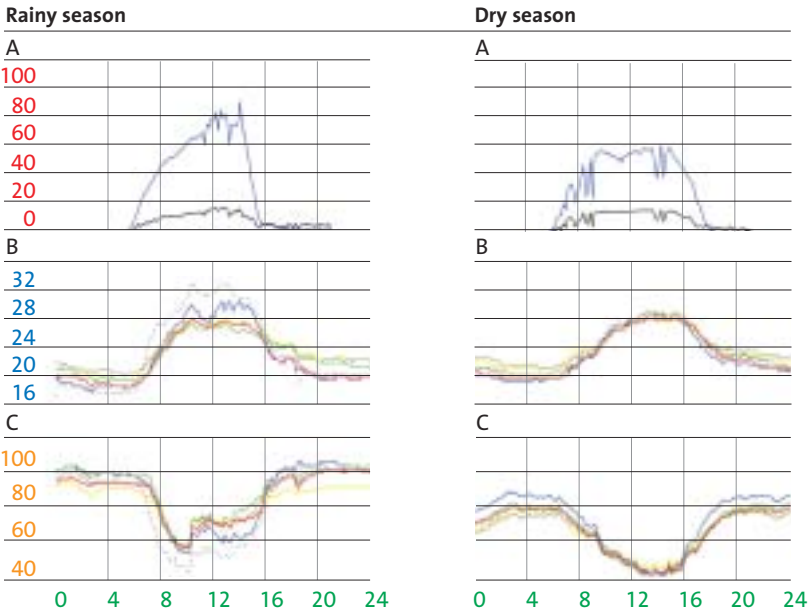
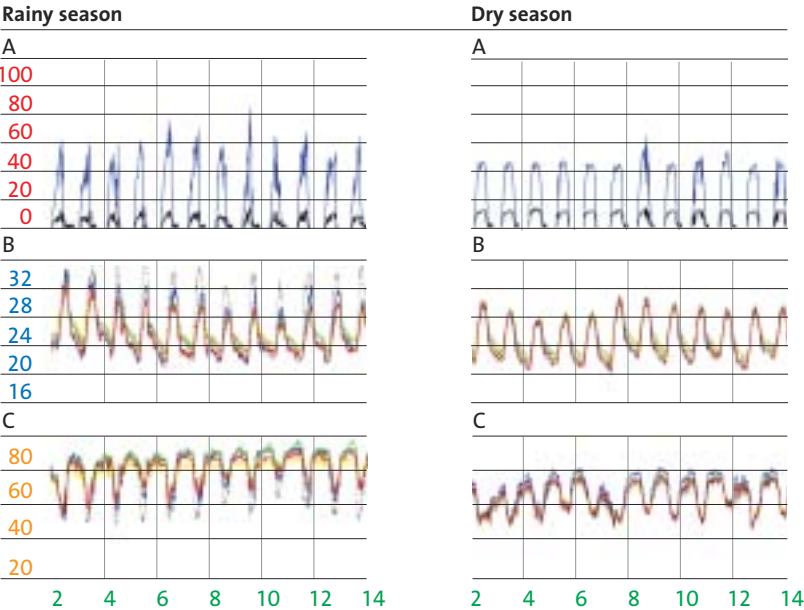


Figure 2:
Diurnal patterns (in hours) of illuminance, air temperature and relative humidity inside the Holcim building during rainy and dry seasons.

- Illuminance (lum m⁻²) x 10⁻²
- Temperature (°C)
- Humidity (%)
- Days

Relative humidity also showed typical tropical patterns (Figures 1C, 2C), characterized by strong diurnal and seasonal fluctuations. During the rainy season, average air humidity was close to 73% (table page 49). Humidity inside the building reached the highest levels at night (~ 90%) and progressively declined as air temperature increased during the daytime, reaching the lowest values around midday and early afternoon (~ 50%). In contrast, average air humidity during the dry season was only 53%. Indeed, maximum humidity during the dry season was typically below 80%, reaching lowest values close to 40% at midday and remaining low during the early afternoon. Humidity remained low (below 70%) during most of the working hours, causing a slightly uncomfortable climate for the occupants. In response, the misting system was installed in the courtyard to increase the humidity, cool the air, and improve indoor comfort.

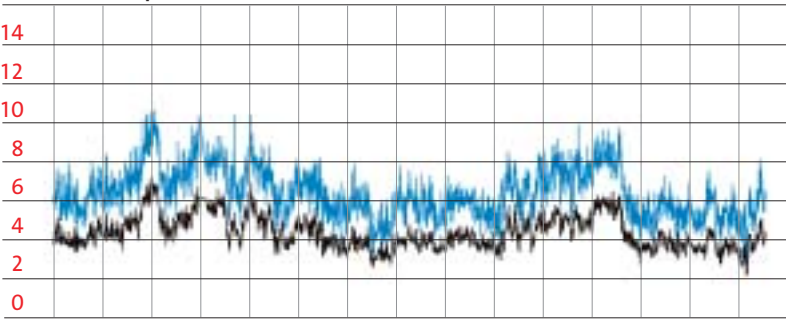
Controlled amounts of air, heat, humidity, and light enter the offices in the south wing, creating a comfortable indoor environment that consumes very little energy.



During the second half of the rainy season (September to mid-November), winds blew predominantly from the southwest and showed a clear diurnal pattern. Wind speed was very low at night and increased to maximum values of 3 to 4 meters per second (mps) during the day. In contrast, air movement measured indoors reached much lower maximum values close to 0.6 mps, although gusts close to 3 mps were observed, which caused slight discomfort in some offices. During the dry season, trade winds blowing from the northeast prevailed, with average values of 4 to 6 mps measured outdoors (Figure 3). These winds peaked at speeds greater than 10 mps. Inside the building, average air movement was usually lower than 0.5 mps, although gusts close to 2 mps were recorded.

Dry season 2005

Outdoor wind speed



Indoor air movement

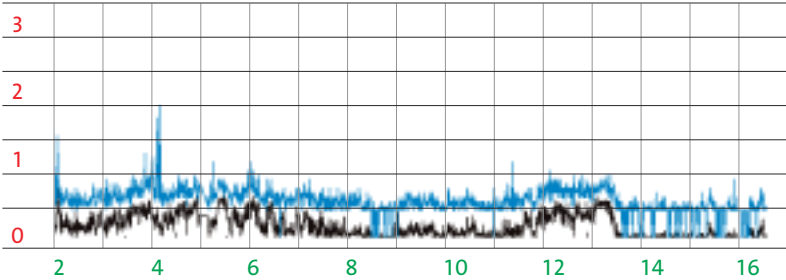


Figure 3:
Wind speed measured outside the building and air movement measured inside the building during the dry windy season.

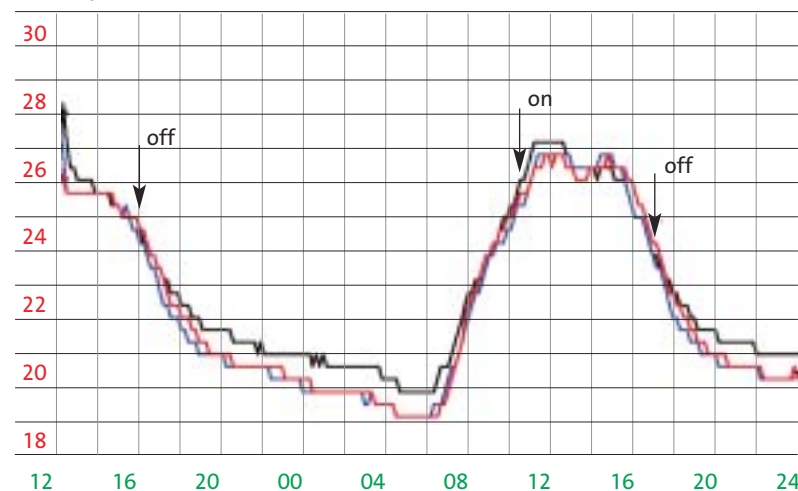
● Wind speed (mps)
● Days
— average
— maximum

Conclusions

Excessive air movement caused several problems. Papers were blown about and dust was spread, particularly during the early dry season. The excessive air movement made cooler weather chillier and made hot dry weather worse by contributing to dehydration and overheating. Air movement was an asset during hot and humid weather because natural ventilation speeds evaporation, thereby improving comfort. Ceiling fans were installed in some rooms (Figure 4).

Figure 4:
How fan operation
during working hours
affects air temperature
inside the building
during the dry season

February 1 and 2, 2005



Measured by ISO comfort standards, the Holcim Costa Rica office building provides a comfortable indoor climate during working hours (see table below). The indoor climate is comfortable but slightly hot during the dry season, and comfortable but slightly humid during the rainy season.

Environmental variable	Dry season	Rainy season
Mean temperature (°C) (actual conditions, indoors)	24.19 ± 0.11	24.80 ± 0.28
Mean temperature (°C) (‘Comfort’ model, indoors)	24.90	24.40
Relative humidity (%) (actual conditions, indoors)	53.07 ± 1.13	72.90 ± 1.45
Maximum temperature (°C) (actual conditions, indoors)	26.04 ± 0.33	27.47 ± 0.87
Maximum temperature (‘Comfort’ model)	26.60	25.90
Comfort conditions (ISO norms)	Comfortable, slightly hot	Comfortable, slightly humid

Indoor environmental
and comfort conditions
in the Holcim Costa
Rica office building
during the dry and
rainy seasons.

Even in a highly seasonal tropical climate, a comfortable indoor climate can be achieved in buildings with ecological and economical passive cooling and humidification systems instead of expensive and energy-intensive



The misting-cooling system in the courtyard is activated for ten seconds every ten minutes during the dry season. The courtyard air flows into the building, providing humidity and cooling.

mechanical air-conditioning systems. Occupants of bioclimatic buildings must actively operate the building's mechanisms (e.g. windows, louvers, and blinds) to regulate the indoor climate and maintain comfort.

Optimal control of these devices requires an understanding of some simple principles of physics, awareness of one's environment, and an active attitude instead of a passive one.

Landscape design plays an important role in bioclimatic buildings, functioning to make the indoor climate more comfortable. Plants and trees can create shade, reduce thermal gain, reduce the air temperature, and moderate humidity. Trees can serve as windbreaks; in groups and in green corridors they can greatly reduce wind problems year round. Besides creating habitats and supporting biodiversity, plant materials beautify buildings and views from indoors. Intelligent use of plant materials is one of the many skills architects must learn in order to design sustainable buildings in harmony with nature.



Holcim Foundation



The Holcim Foundation for the Sustainable Construction promotes innovative approaches to sustainable construction. The objective of the Holcim Foundation is to encourage sustainable responses to the technological, environmental, socio-economic and cultural issues affecting building and construction, regionally as well as globally – through a range of initiatives, including Holcim Awards, Holcim Forum, and Holcim Projects.

An international competition for future-oriented and tangible sustainable construction projects.

The Holcim Awards recognize any contribution to sustainable construction – irrespective of scale – in architecture, landscape and urban design, civil and mechanical engineering and related disciplines.

Prize money of USD 2 million per three-year competition cycle encourages and inspires achievements that go beyond convention, explore new ways and means, and draw attention to and identify excellence.

The Awards competition is conducted in partnership with five of the world's leading technical universities* who evaluate entries according to the target issues for sustainable construction, and lead the independent competition juries.

www.holcimawards.org

* The partner universities of the Holcim Foundation are the Swiss Federal Institute of Technology (ETH Zurich), Switzerland; Massachusetts Institute of Technology (MIT), Boston, USA; Tongji University, Shanghai, China; Universidad Iberoamericana (UIA), Mexico City, Mexico; and University of the Witwatersrand, Johannesburg, South Africa. The University of São Paulo (USP), Brazil, is an associated university of the Holcim Foundation.



A series of symposiums for academia and practitioners to encourage discourse on the future of the built environment. The Holcim Forum supports sustainable construction in the scientific field, among experts in the construction sector, business and society.

In addition to renowned specialists from around the world, promising international students from leading technical universities are invited, to represent the next generation and to share their visions.

The first Holcim Forum was held at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland, in September 2004 under the theme “Basic Needs.” The second Holcim Forum will be held at Tongji University in Shanghai, China, under the theme “Urban_Trans_Formation.”

www.holcimforum.org



Implementation funding for research projects and building initiatives to accelerate progress and promote sustainable construction.

The Holcim Foundations provides USD 1 million per three-year cycle to support the implementation of research in sustainable construction, and the implementation of building projects. Projects nominated for implementation funding are evaluated according to the target issues for sustainable construction, and must be endorsed by a local Holcim Group company.

The Holcim Foundation acts as an enabler for both research projects and building initiatives so that, whatever their origin, exciting and important new ideas can be more widely implemented and tested by a broader audience of specialists.

www.holcimprojects.org

Holcim Costa Rica office building

Architects	Bruno Stagno Arquitecto y Asociados
Structural engineer	Juan Carlos Sotela
Tensile structures	FTL Design Engineering Studio
Mechanical engineer	Juan Luis Flores
Electrical engineer	Claudio Soto
Landscape architect	Jimena Ugarte
General contractor	RAE Ingenieros S.A.
Bioclimatic survey	Marco V. Gutierrez and Carlos Vega G.
Sources	Gutiérrez, M.V., Soto, D and Alpizar, M. 1997. Forty years of meteorological observations at Fabio Baudrit Experiment Station, Costa Rica. <i>Boltec</i> 30:1-14 "Harnessing Comfort Through Climate. Performance of the Holcim Building. A Case Study in Costa Rica" by Bruno Stagno and Marco V. Gutierrez
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