THE BAMBOO AS A SUSTAINABLE BUILDING MATERIAL AND EARTHQUAKE-RESISTANT

ZERI®

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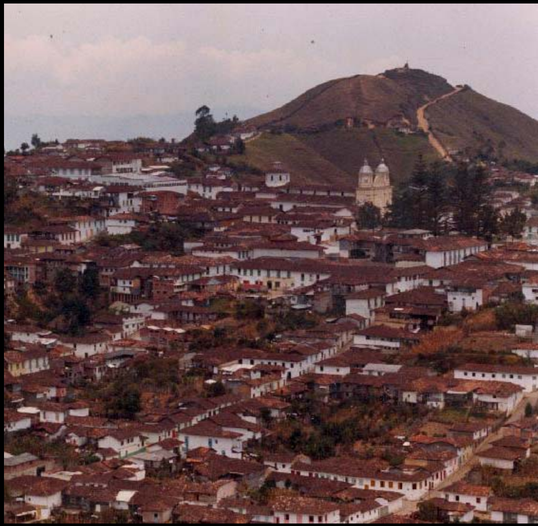
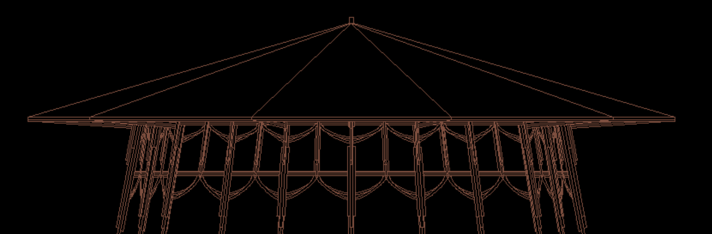
UNIVERSIDAD
NACIONAL
DE COLOMBIA
SEDE MANIZALES



- ZERI Pavilion for EXPO 2000
- Design in a sustainable way
- Guadua as a construction material in Colombia

ZERI PAVILION FOR EXPO 2000



The pavilion was built with the best of nature, combined with the technology and creativity of the human being, applying concepts of sustainability and building techniques that led it to be one of the most prominent and admired in Hanover; therefore, it represented conclusively the theme of the EXPO: “Nature, humanity and technology”.

“The ZERI Pavilion is a rich symbol offering a message, which goes beyond the mere building itself. The ZERI Pavilion offers a number of symbols to the world”.

Biodiversity

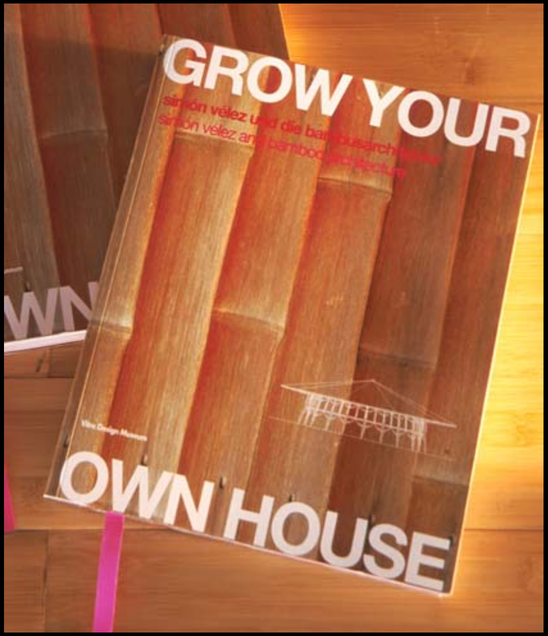
It includes a plant, a flower and two types of grasses, which come from the same Andean ecosystem, with natural coloring from insects and preservation agents extracted from the same bamboo, which preserves itself against insects and molds.

Sinergy

The best of nature is combined with the most creative forms of humanity, i.e. steel and cement. The performance of bamboo is dramatically enhanced with the technique of making joints with cement and iron.

Creativity

There are one hundred million people without a home. ZERI uses waste (used bottles) and weeds (bamboo, *aliso* and *arboloco* are considered weeds) for cheap, functional and beautiful housing as summarized in the book "Grow Your Own House" which is based on the experience gained in this pavilion.



New Economy

The present economy is good, but not good enough. The world needs a better production and consumption system, we need many more jobs. The ZERI Pavilion includes new building materials, grown and harvested sustainably, it demonstrates a preservation system eliminating toxic chemicals, and as such it creates new work and income.

Tolerance

The ZERI Pavilion does not have an entrance nor an exit, it symbolizes the open mind, where all paths are welcome, from wherever they come, but having the same desire, to do more and better to respond to people's needs around the world.

21^{st} Century Architecture

The ZERI Pavilion presents 7 new building techniques and 2 new construction materials approved by the German authorities, it offers a building method offering people a house which dances along with the movements of the Earth, and it is cheap.

Belief & Hope

The Pavilion was built without previous experience, without a clear budget, without a guarantee that the final permits would actually be obtained, though everyone who collaborated believed that it would be possible, and gathered all the energy needed to make it happen. And it did happen!

Perseverance

The ZERI Foundation proposed to build the pavilion twice, once in Colombia in order to undertake the stringent stability tests by German professors, which were passed, to then build it at the World Expo. Never in history has anyone built twice any construction to be able to be present at an Expo. The cost of tests and approvals is higher than the building costs.

Sustainability

This building sequestered as much carbon dioxide as was needed to make it. Bamboo and *arboloco* used in ZERI housing, and fixed 40 times more carbon dioxide than timber; this building system could actually be financed with the CO2 emission rights that the rich are offering the poor. Those who contaminate too much can now pay for social housing.

Youthfulness

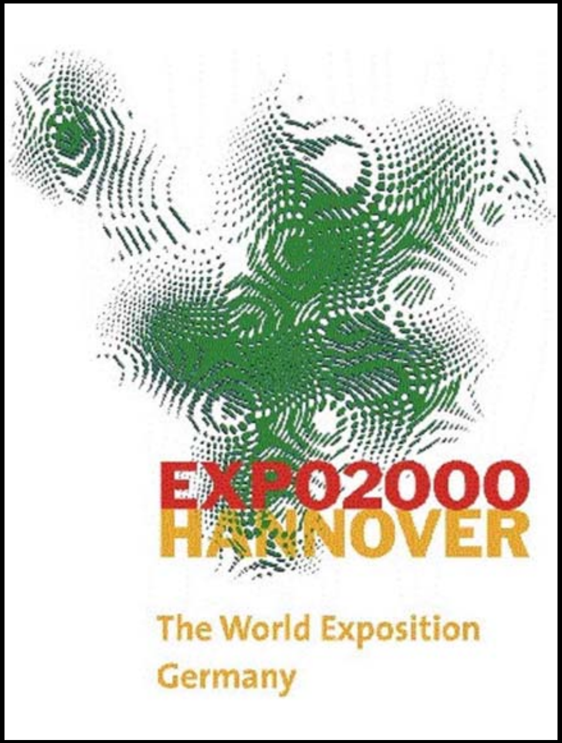
The first ever event held at the ZERI Pavilion was a congress gathering 2.000 young people from around the world who saw in this building an opportunity to contribute to a better world. At the ZERI Pavilion, over 100 volunteers welcomed everyone in nearly 40 different languages. It is an inspiration for all.

ZERI

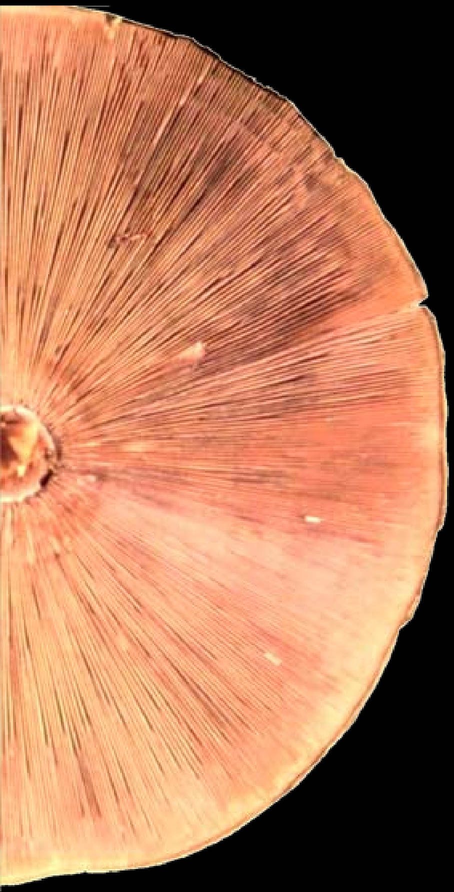
There is no better symbol for the work ZERI wants to achieve, "use all waste and weed to generate food and housing". This pavilion demonstrates that it is possible, and that it is cheap, therefore becoming a symbol for the poorest of the poor who now can take pride in their natural building materials. It is the same for our programs "beer bakes bread", "cement factory goes organic", "water hyacinth fights AIDS"

Expo 2000

The ZERI Pavilion is the only one considered a masterpiece by academics, which lead to the issuance of a diploma to all the workers. But more important, it is the only Pavilion, which introduces 7 new structural building systems, and 2 new building materials that were totally unknown to Germans. It is probably the best case of the theme "Nature-Humanity-Technology"



DESIGN



The pavilion was designed in a way that pushed the limits of materials and technologies.

Facts

- Form: Ten sided polygon inscribed in a circle (diameter=40m)
- Area: Site 2.150m^2 – Foundations 684 m^2 – Mezzanine 458 m^2 – Roof 1.306 m^2
- Height: Total 14.40 m – Mezzanine 4.50 m
- Weight: *Guadua, Aliso, Arboloco and Chusque* 100 Ton – Steel and Iron 10 Ton – Concrete 290 Ton. Total 400 Ton
- Roof slope: 33.3% = 17°
- Columns: 40 *aliso* columns (20 interior – 20 exterior), 40 *guadua* columns on the second floor (20 interior – 20 exterior) Columns slope: 20% = 79°
- Access to the mezzanine: Two spiral staircases from steel and bamboo.
- Length overhang: 7.00 m

Materials

Guadua

- Family: *Gramineae*
- Species: *Guadua angustifolia, Kunth*
- Geographical distribution: Grows in the north of South America. Grows naturally in Colombia, Panama, Venezuela, Ecuador and Peru.
- Ecology: Grows in fertile, rich and humid grounds at altitudes between 400 and 2000 msnm.
- Maximum size of tree trunk: Height 25 m. Diameter: 10-15 cm.
- Environment: The compost of *guadua* leafs protect the earth and its extensive root system secures the existence of water.
- Utilization in the pavilion: Beams, structure of the double flooring, internal columns, "flutes" (extensions of the columns), support of the roof, crowns and rings.

Materials

Aliso

- Family: *Betulaceae*
- Species: *Alnus acuminata, Humboldt, Bonpland and Kunth.*
- Geographical distribution: Grows in South America in countries like Bolivia, Chile, Ecuador, Peru and Venezuela.
- Ecology: Grows at altitudes between 2100 and 3000 msnm. Prefers humid grounds.
- Maximum size of tree trunk: Height 35 m. Diameter: 75 cm.
- Utilization in the pavilion: Main columns

Materials

Arboloco

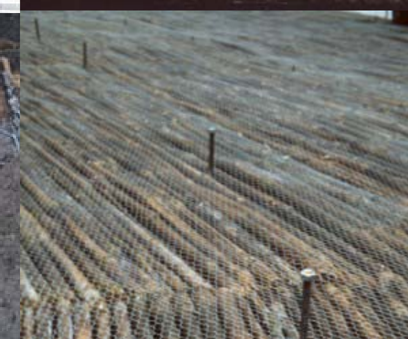
- Family: *Asteraceae*
- Species: *Montanoa quadrangularis, Schultz Bip. In K.Koch*
- Geographical distribution: The Andean Zone of Colombia and Venezuela.
- Ecology: Grows at altitudes between 1500 and 2500 msnm.
- Maximum size of tree trunk: Height 20 m. Diameter: 50 cm.
- Utilization in the pavilion: Beams in the double flooring.

Materials

Chusque

- Family: *Poaceae Gramineae*
- Species: *Chusquea serrulata, Pilger*
- Geographical distribution: Grows in high barren plateaus in the Central and Oriental mountain range of the Andes.
- Environment: *Chusque* secures riverbanks and protects rivers from evaporation, due to the shade it provides. *Chusque* also has an esthetical value in gardens.
- Utilization in the pavilion: Woven into the double flooring.

Materials



Technologies

SUPPORT FOR PILLARS

By inclining the columns added support is achieved, making the pavilion stable and adding to its indifference to earthquakes.

Technologies

FIBER AND CEMENT

The combination of bamboo fiber and cement is an innovation that can replace the asbestos in cement with natural fibers. This technology is using in the making of the roof of the pavilion.

1420 slates - 50% cement 50% bamboo fiber

Product from Teiheiyo Cement (Japan)
Made in Indonisia

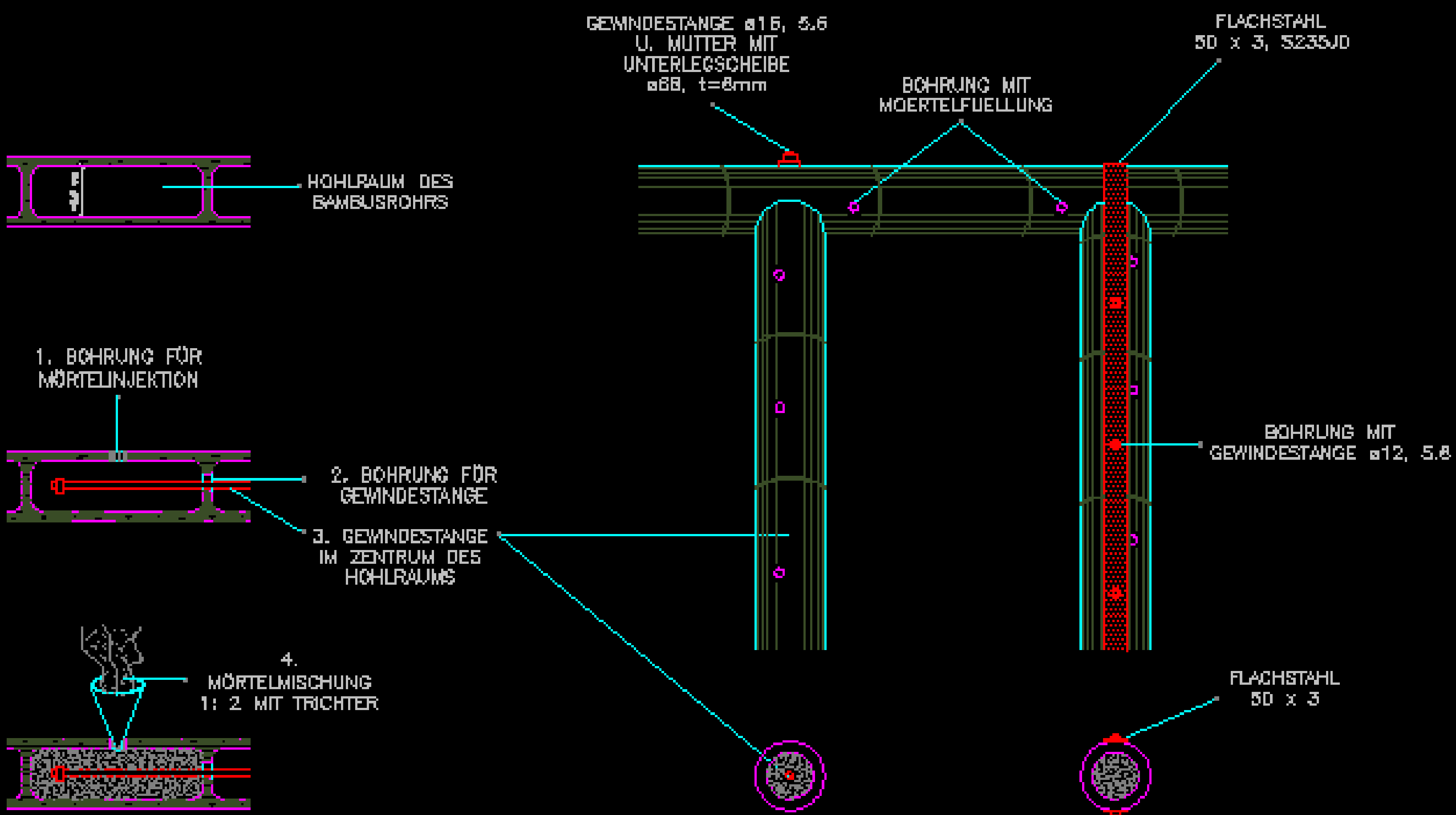
Technologies

CEMENT AND *GUADUA*

Cement filled into the *cañutos*, the open chambers of the *guadua*, serve as reinforcement at the supportive points and also secures the iron fittings.

Technologies

FILLING THE *CAÑUTOS* (internal chambers of bamboo) with a mix of cement, sand and water.



Technologies

FILLING THE *CAÑUTOS*

Technologies

GUADUA RHIZOMES

This supportive construction uses the solid *guadua* rhizomes to strengthen the structural system of the pavilion.

Technologies

PILLARS

Pillars made out of concrete protect the wood from humidity coming from earth

Technologies

SMOKED *GUADUA*

Immunization through the smoking of the ***guadua*** is a productive and sustainable alternative to chemicals used today. Speed of immunization is radically decreased, as is pollution.

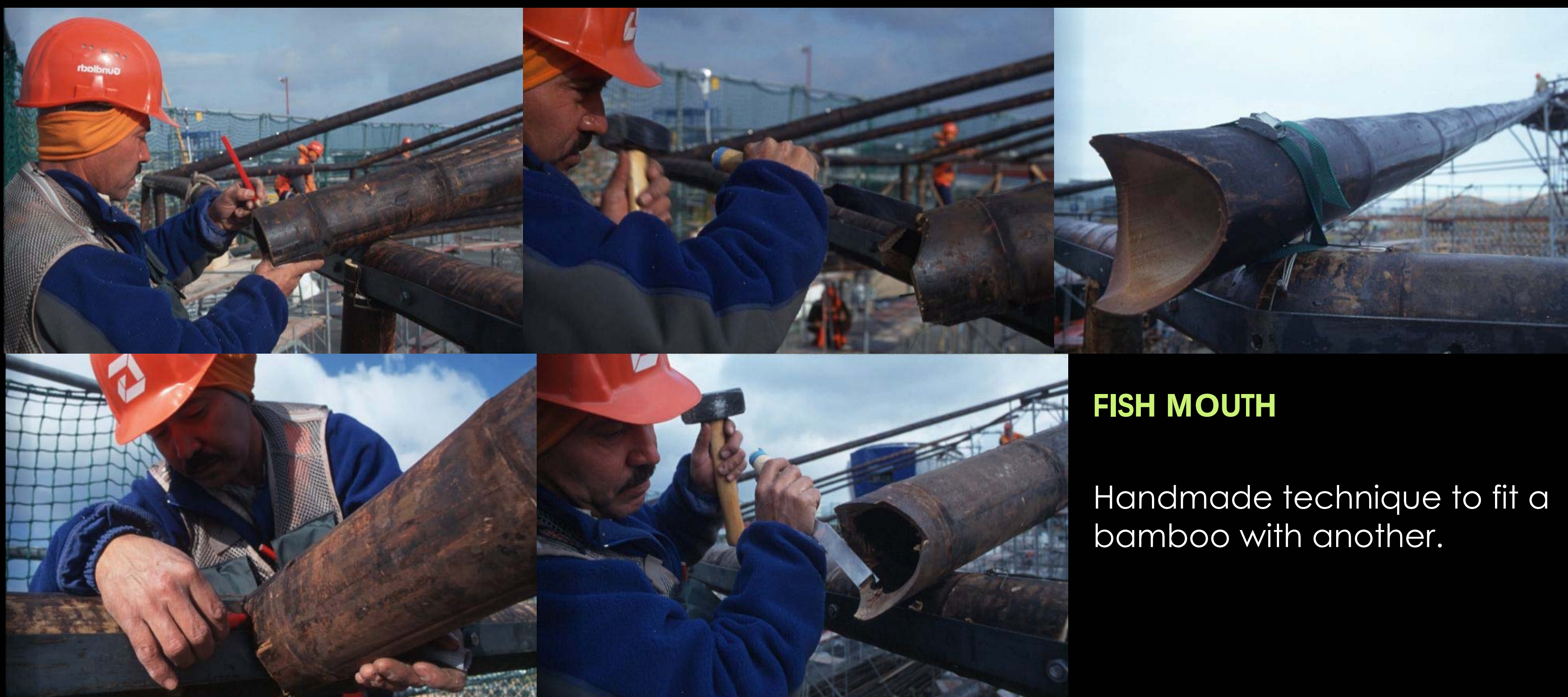
Every single ***guadua*** was immunized with smoke technique. The ***guadua*** used in the ZERI pavilion was immunized in two ovens, most of them in Armenia, by Antonio Giraldo and the others in Pereira by Gabriel German Londoño, both in Colombia.

Technologies

OVERHANG

The length of the eaves protects the wood structure from water

Construction Techniques



FISH MOUTH

Handmade technique to fit a bamboo with another.

REPORTS & PERMITS

Experimental evaluation of the load bearing properties of the pavilion, by Prof. Dr.-Eng. Klaus Steffens from the Experimental Statics Institute at the University of Bremen, Germany

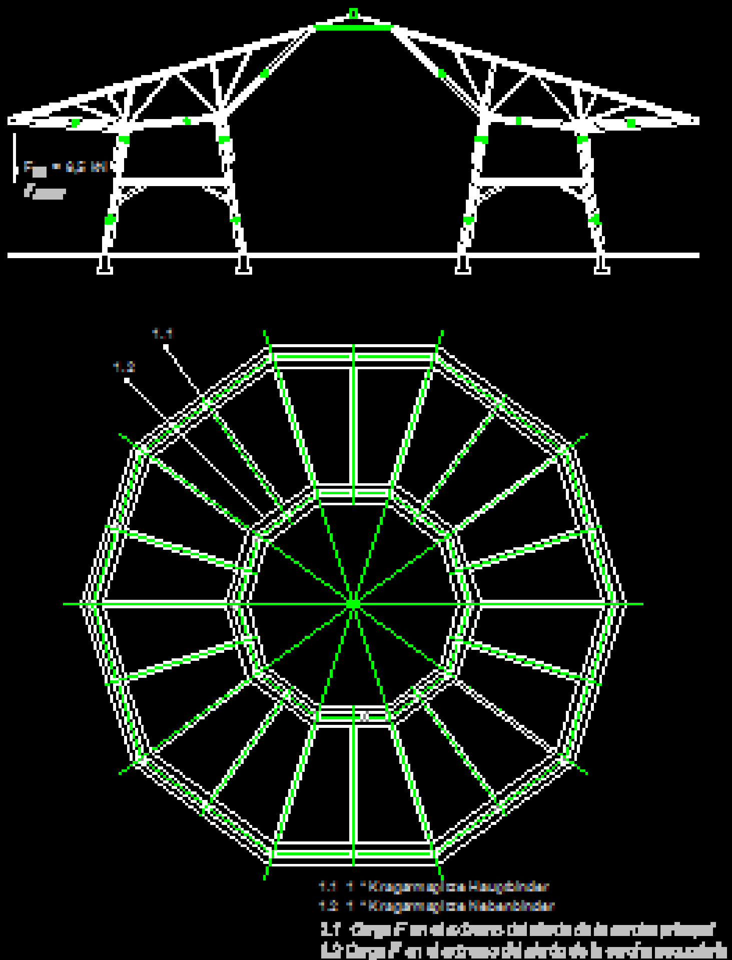
Professor Klaus Steffens (director since 1980 of the Institute of Experimental Statics of the University of Bremen) has realized experimental evaluations of load bearing and safety for the reconstruction of the Reichstag building in Berlin, among others.

1.Cantilever-roof

2.Ceiling of gallery

3.Frame

Experimental evaluation of the load bearing properties of the pavilion, by Prof. Dr.-Eng. Klaus Steffens from the Experimental Statics Institute at the University of Bremen, Germany



Cantilever-roof

Consisted of determining the load bearing capacity of the cantilevers (a 7.30 meters overhang).

This was done by hanging a weight of more than 650 kilograms in the middle of the third of their spans. A deformation of 7 millimeters was observed, which the structure recovered when it was freed of the burden.

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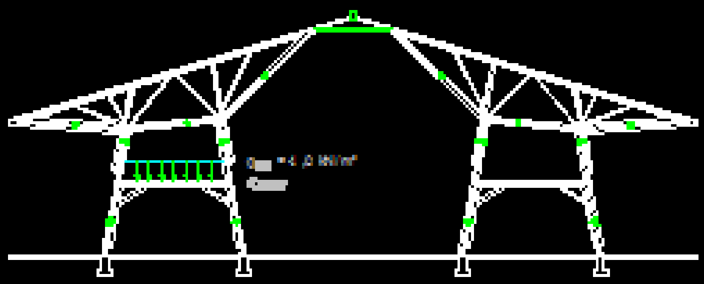
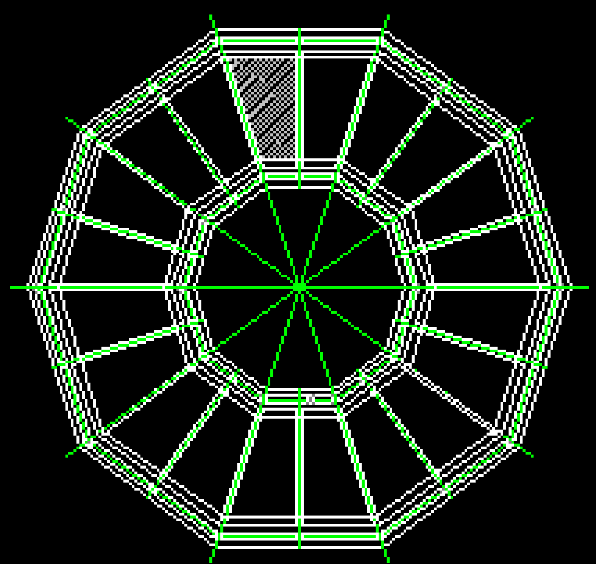
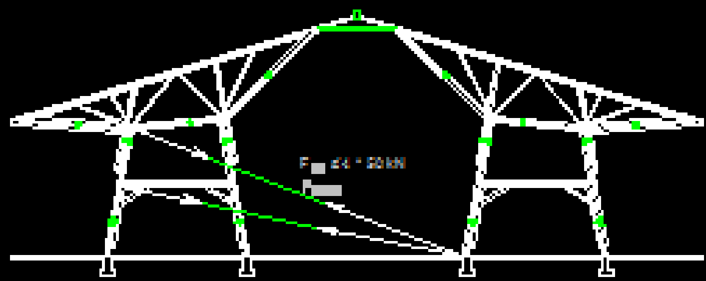


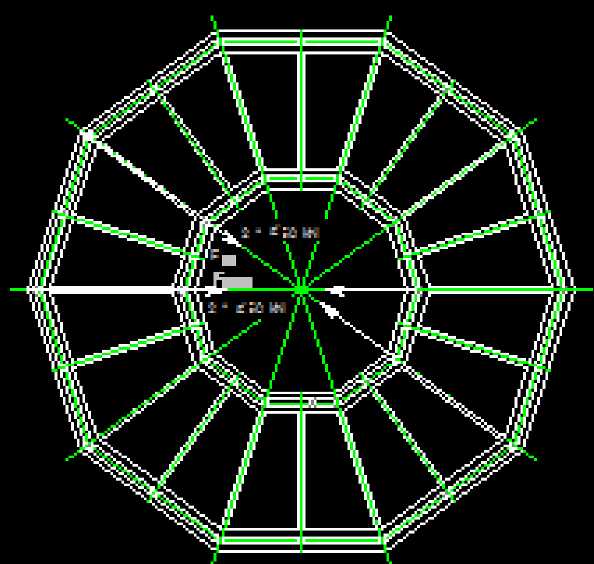


Ceiling of gallery

To test the capacity of the upper floor, this structure as loaded down with 55 gallon barrels, which were uniformly spread over the surface and filled with water until they reached a load of 400 kilograms per square meter. When the deformation of the upper floor under this burden was measured, it came to 5 millimeters, which were recovered when the weight was removed. It is important to note that the estimated deformation for this test was expected to reach 25 millimeters, which means that the result was a fifth of the estimate.

Experimental evaluation of the load bearing properties of the pavilion, by Prof. Dr.-Eng. Klaus Steffens from the Experimental Statics Institute at the University of Bremen, Germany





Frame

The third test involved a simulation of wind stresses and consisted of pulling the structure in a horizontal direction. This was done by placing one cable in the middle part and another in the upper part of each one of the pediments of the pavilion and the subjecting each cable to a horizontal load of five tons. The result obtained was a horizontal displacement of one centimeter.

Experimental evaluation of the load bearing properties of the pavilion, by Prof. Dr.-Eng. Klaus Steffens from the Experimental Statics Institute at the University of Bremen, Germany

After carrying out these tests in Manizales, Professor Steffens issued a technical assessment that helped to support the application for the construction permit that was granted for the pavilion in the Hannover Expo-2000 Fair.

This study was complemented by a structural calculation carried out by Professor Joseph Lindemann, an estimate that was based, in part, on the results of traction, compression and flexion tests done by him in Germany.

Thus ***guadua*** passed all the tests and was officially authorized for architectural use in one of the countries with the strictest construction codes in the world.

Prof. Dr.-Ing. Klaus Steffens, *Hochschule Bremen – Institut für Experimentalle Statik (IFES)*, Germany

Dip.-Ing. Josef Lindemann, Structural Analysis, Germany

Preliminary Stages

Before the construction process, there were some stages developed in Colombia. The previous stages were very important in order to obtain the German permits.

Prototype – Manizales, Colombia

Preliminary Stages

SELECTION AND CUT OF MATERIALS

Guadua

Donated by Sr. Gabriel German Londoño Gutierrez from his farm *"San Jorge"* located in Pereira – Colombia. Cut in decreasing moon 3.500 pieces of *guadua* (9 m long) and 240 *guadua* roots.

Aliso

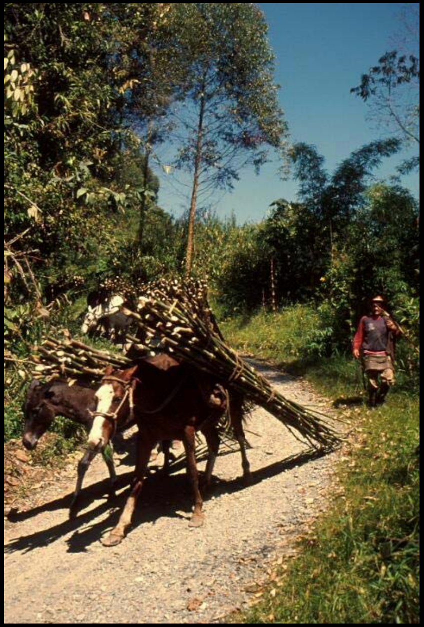
Donated by *Aguas de Manizales S.A. E.S.P.* from its farm *"Río Blanco"* located in Manizales – Colombia.

200 *aliso* logs.

Arboloco

Some of the logs were donated by *Aguas de Manizales S.A. E.S.P.* from its farm *"Rio Blanco"*. The others were bought from *Maderas y Celulosa S.A.* in Manizales.

80 arboloco logs. 160 half pieces.



Chusque

Donated by the *Comite de Cafeteros de Caldas* from its farm *"Pedro Uribe Mejía"* located in Manizales – Colombia.

8000 pieces of chusque (3m long) carried by mules.

Quality Control

The German authorities request a quality control of *aliso* logs according to *DIN 4074.*

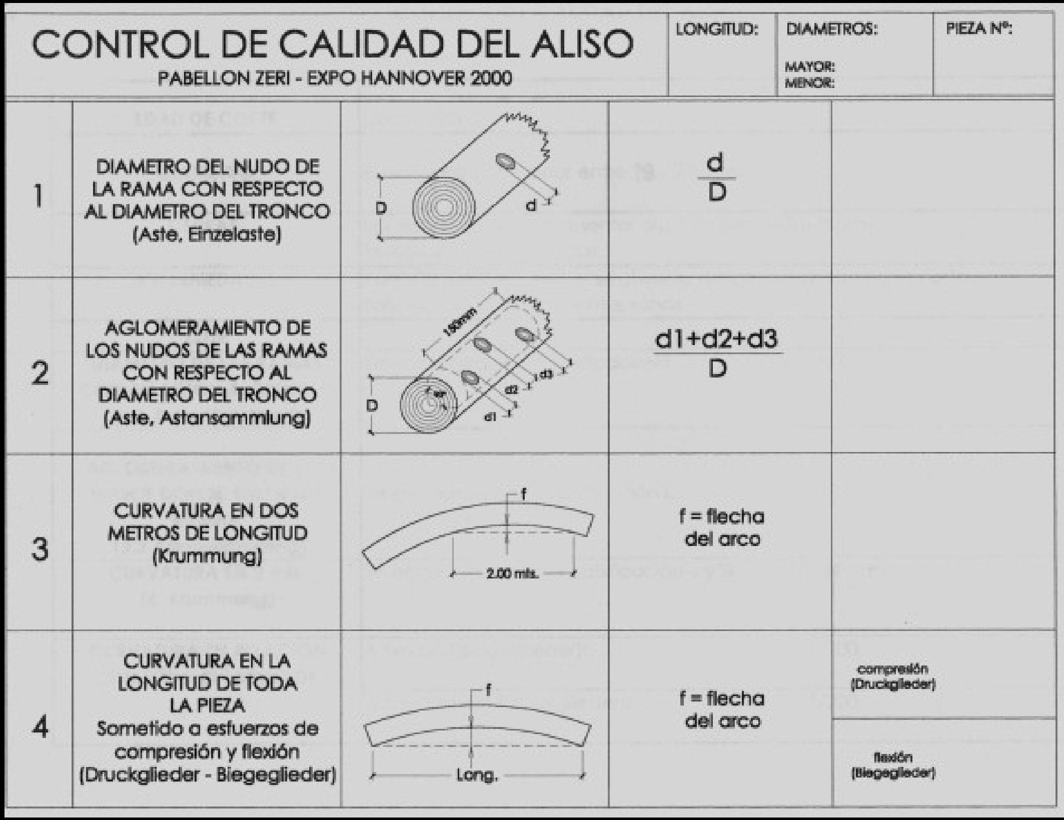
The ***guadua*** quality control was made according to a standard created by Colombian experts and German engineers, especially for this construction.

Quality control was not necessary for ***arboloco*** and ***chusque***.

ALISO QUALITY CONTROL

Quality control was performed to every single log.

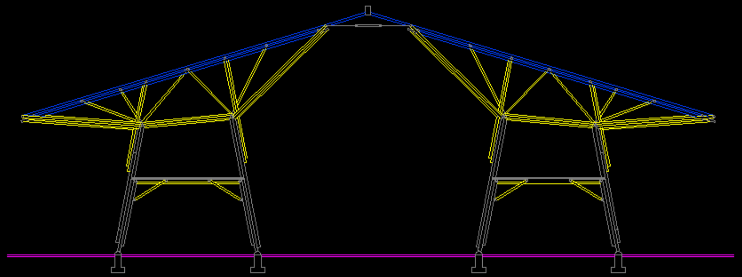
The diameters of the logs should be from 18 to 25 cm.



CONTROL DE CALIDAD DEL ALISO PABELLON ZERI - EXPO HANNOVER 2000			LONGITUD:	DIAMETROS: MAYOR: MENOR:	PIEZA Nº:
1	DIAMETRO DEL NUDO DE LA RAMA CON RESPECTO AL DIAMETRO DEL TRONCO (Aste, Einzelaste)	D d	$\frac{d}{D}$		
2	AGLOMERAMIENTO DE LOS NUDOS DE LAS RAMAS CON RESPECTO AL DIAMETRO DEL TRONCO (Aste, Astansammlung)	150mm D d1 d2 d3	$\frac{d1+d2+d3}{D}$		
3	CURVATURA EN DOS METROS DE LONGITUD (Krummung)	f 2.00 mts.	f = flecha del arco		
4	CURVATURA EN LA LONGITUD DE TODA LA PIEZA Sometido a esfuerzos de compresión y flexión (Druckglieder - Biegeglieder)	f Long.	f = flecha del arco	compresión (Druckglieder) flexión (Biegeglieder)	

This form was filled for every single log with 4 different tests. The logs should be in Class I or II according to the *DIN 4074* standard.

Preliminary Stages



GUADUA QUALITY CONTROL

Class I

Top: cross-sectional area A>40 cm² and ø ≥ 10 cm (e.g. ø10, t=15 mm)

Base: cross-sectional area A ≥ 55 cm² (e.g. ø14, t=15 mm or ø12, t=20mm)

Middle: cross-sectional area A~47 cm² (ø12, t=15 mm) and ø ≥ 12 cm)

Class II

Top: cross-sectional area A>30 cm² and ø ≥ 10 cm (e.g. ø10, t=11 mm)

Base: cross-sectional area A≥40 cm² (e.g. ø12, t=12 mm)

Middle: cross-sectional area A ≥ 35 cm² and ø ≥ 11 cm (ø11,t=11 mm)

Class III

The ***guaduas*** that do not match Class I and II, are not good for construction.

Preliminary Stages

LOAD AND UNLOAD MATERIALS

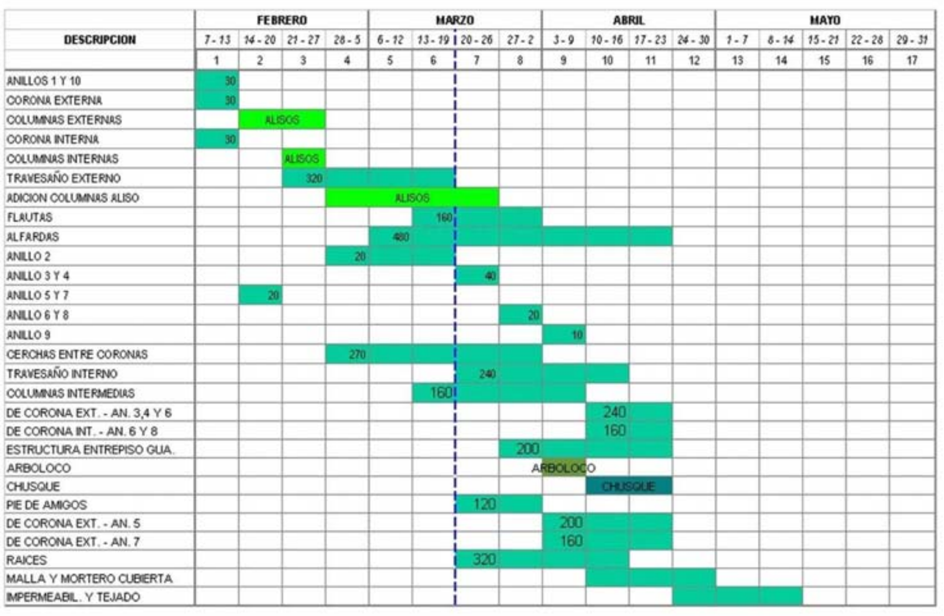
Manizales: Two containers with *Alisos*, and one with ***Arboloco*** and ***Chusque.***

Pereira: Ten containers with ***Guadua***, ***Guadua*** roots and ***Macanas.***

Most of the containers departed from Cartagena Port (Atlantic Ocean) and the others from Buenaventura Port (Pacific Ocean) in Colombia. They all arrived in Hamburgo Port in Germany, and then the containers were transported by trucks to Hannover. The transportation between Colombian and German ports took approximately 24 days. Panalpina was the company in charge of the transportation.

Timeline

Colombia: eight months to build the pavilion



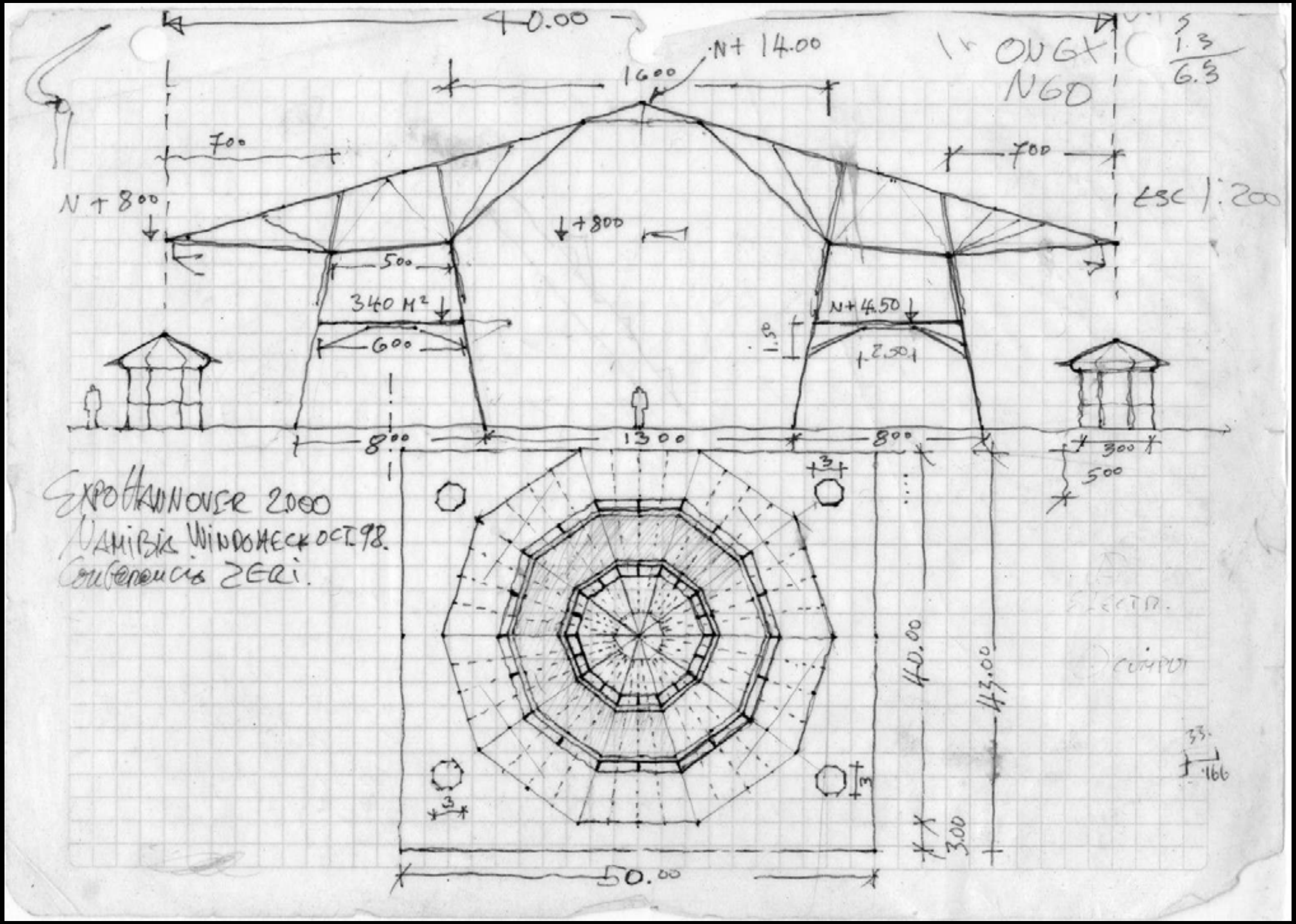
Germany: three months and two weeks

Sketches & Drawings

The prototype of ZERI pavilion in Manizales was made with the original sketches of Architect Simón Vélez.

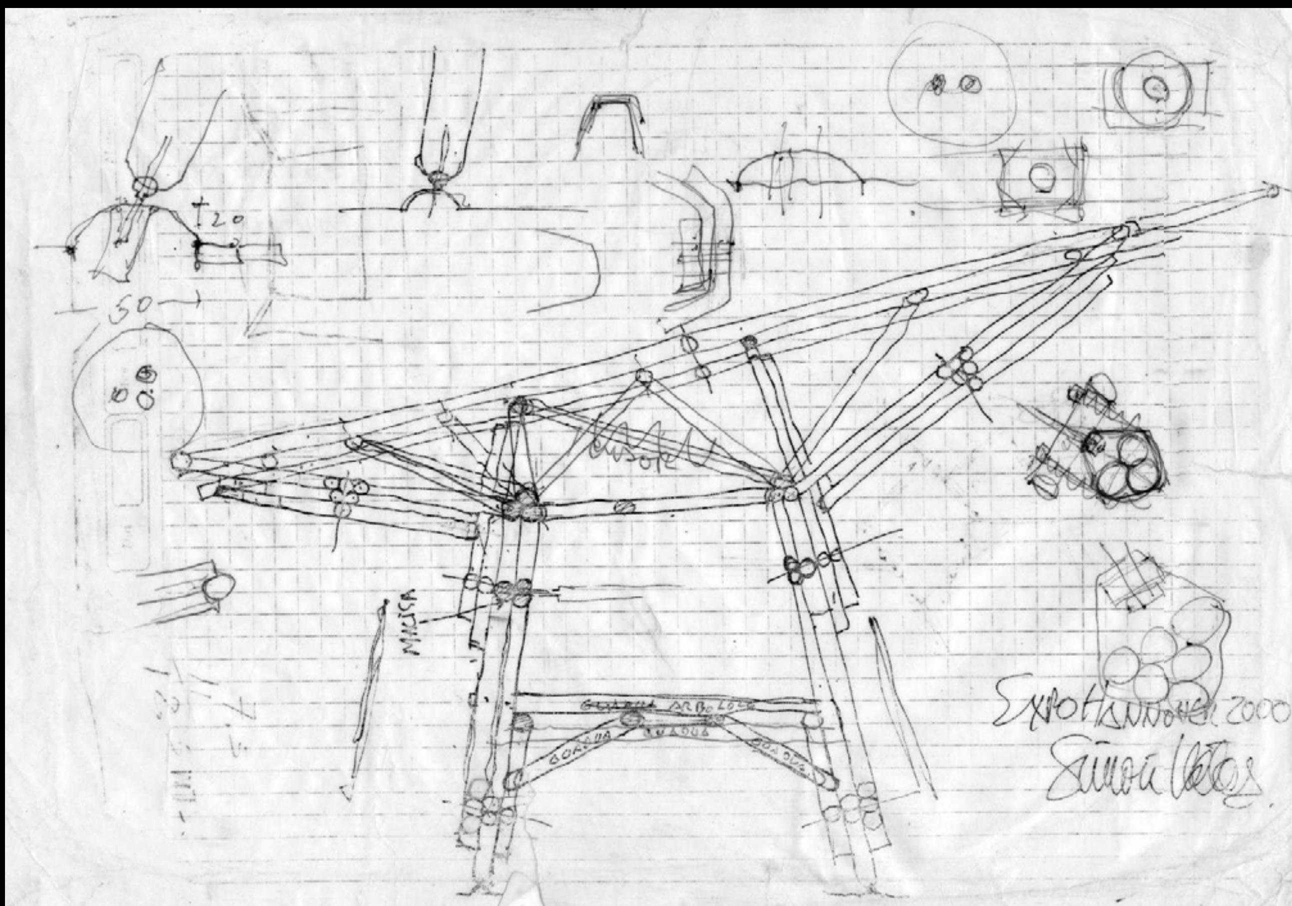
To get the construction approval in Germany we had to make the complete drawings with all the structure details. Then the drawings were reformed and approved by, Dipl. Eng. Josef Lindemann and German authorities.

Sketches & Drawings



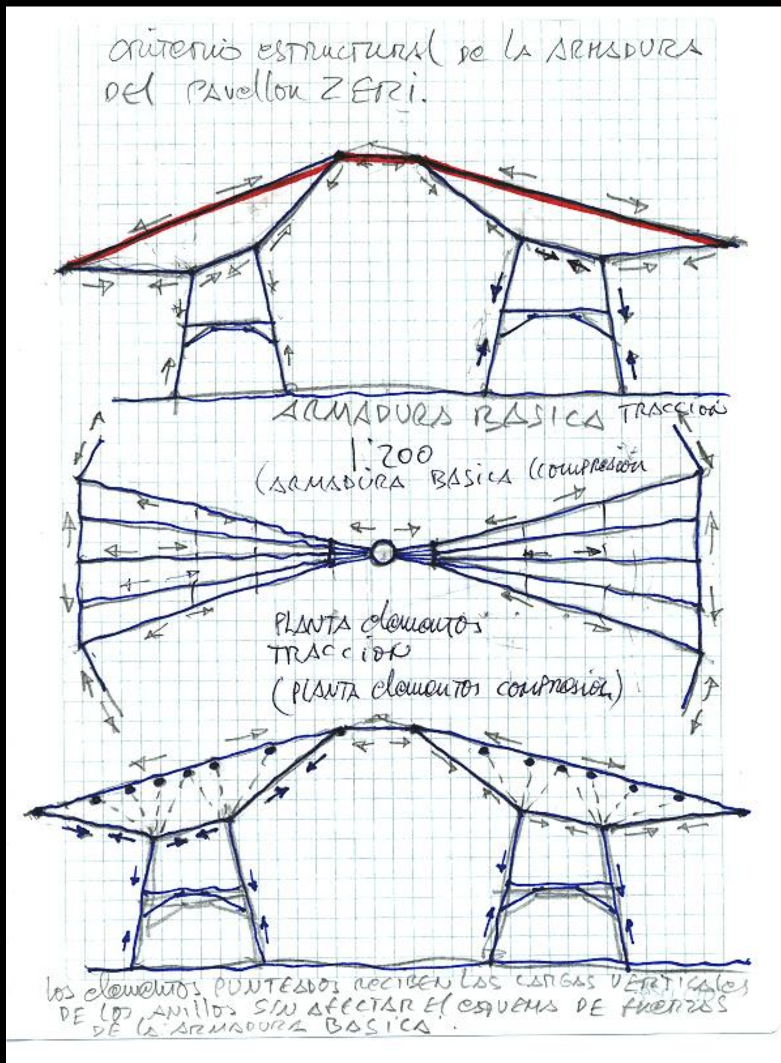
Simón Vélez Sketches

Sketches & Drawings



Simón Vélez Sketches

Sketches & Drawings



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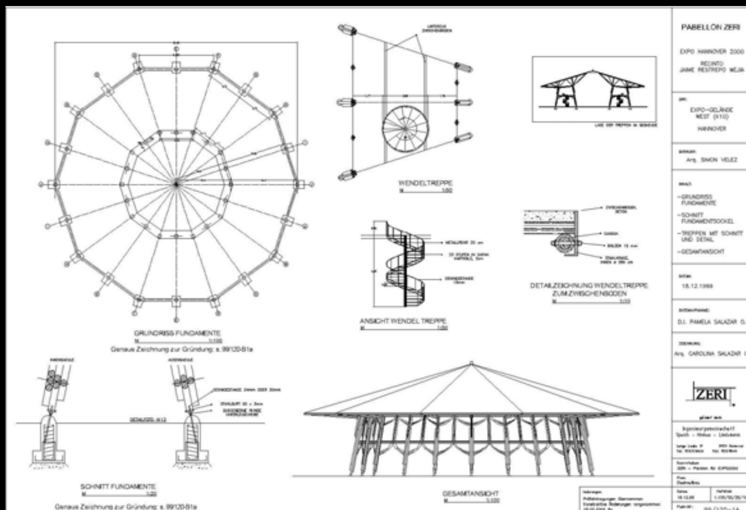
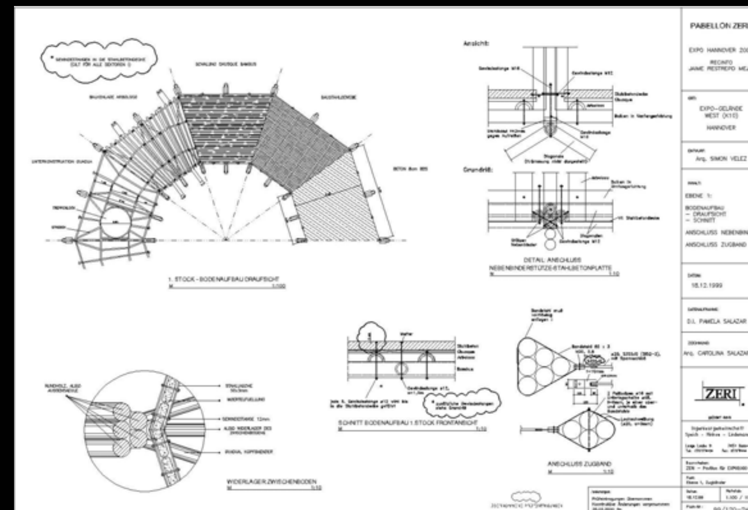
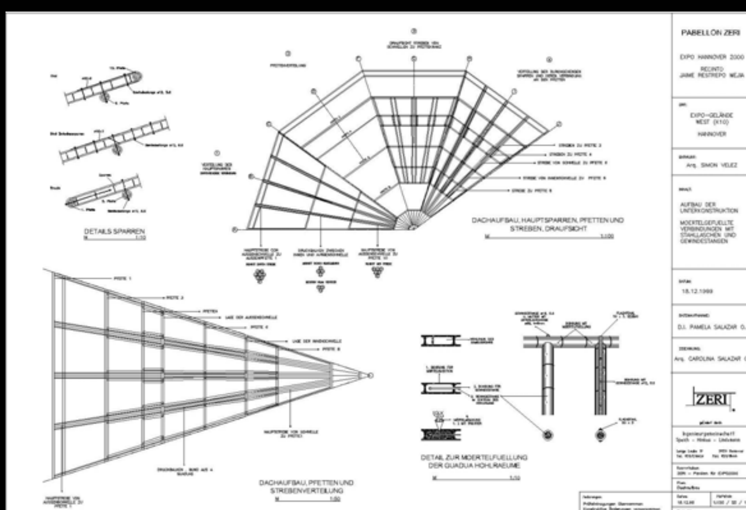
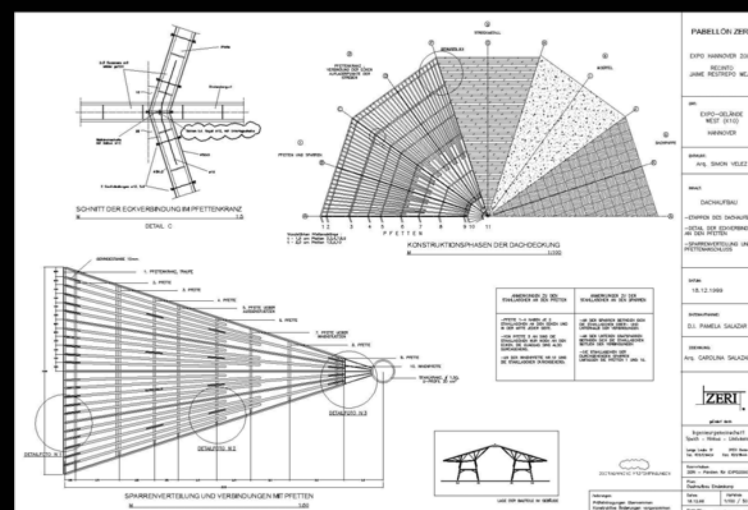
Sketches & Drawings









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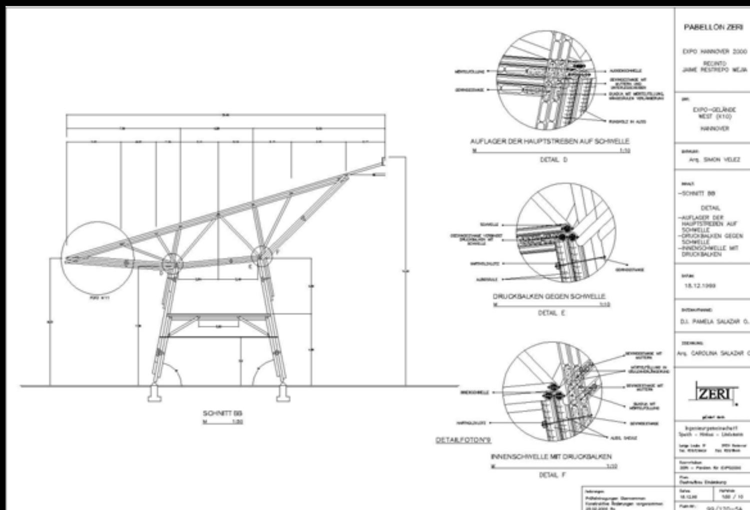

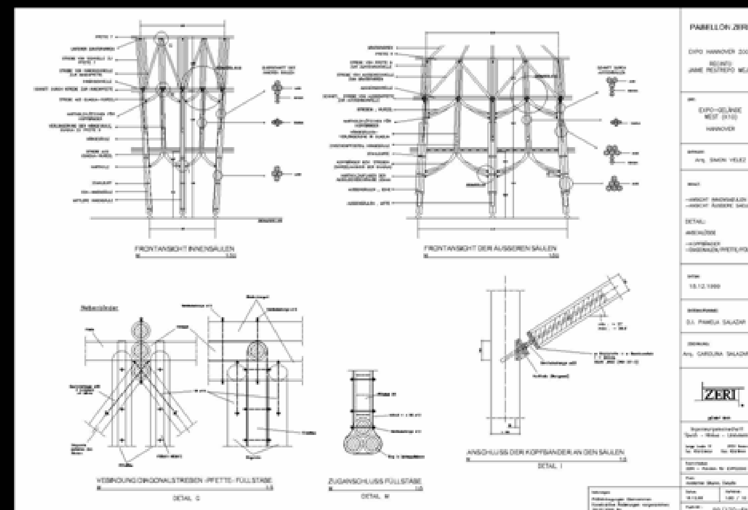

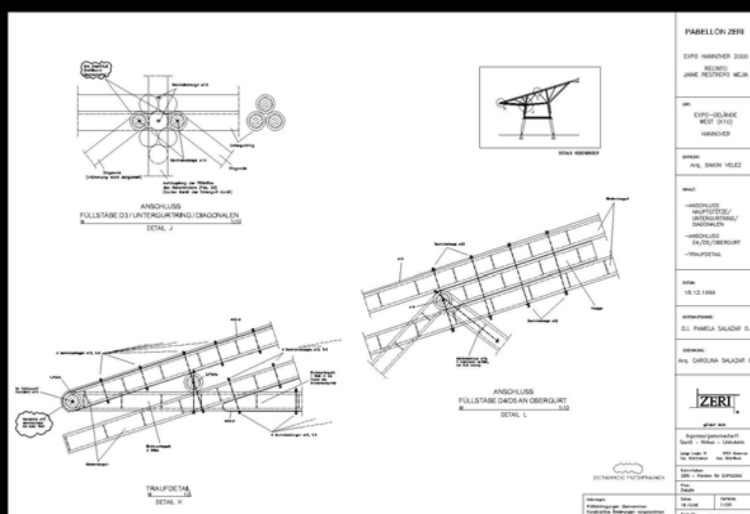

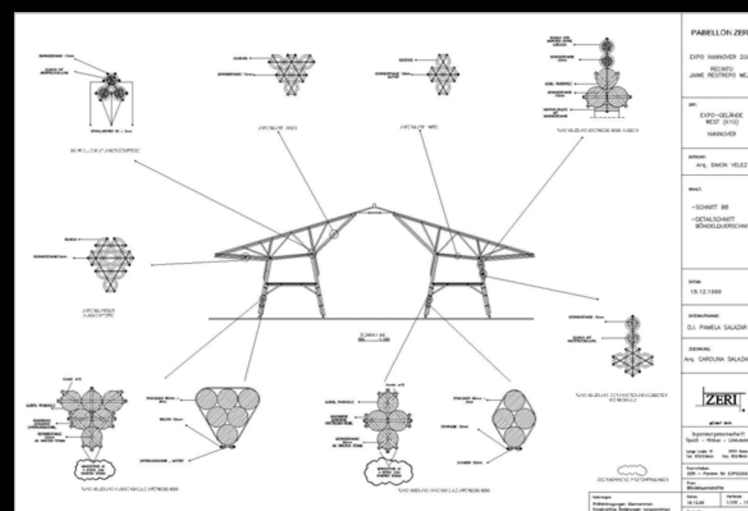

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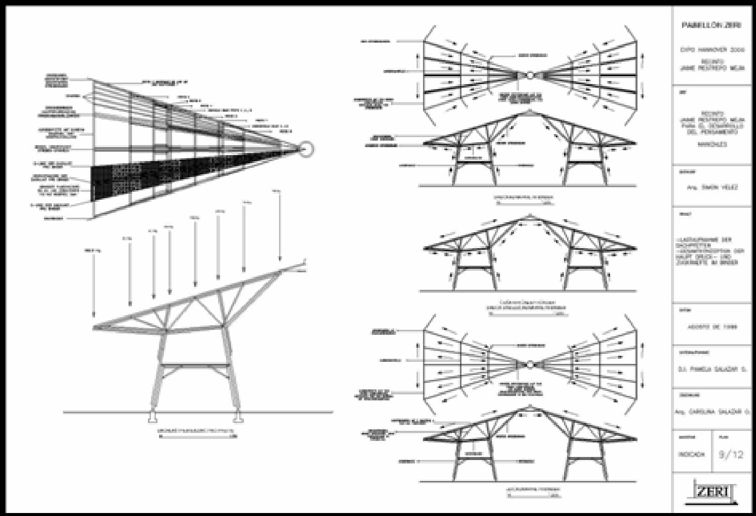
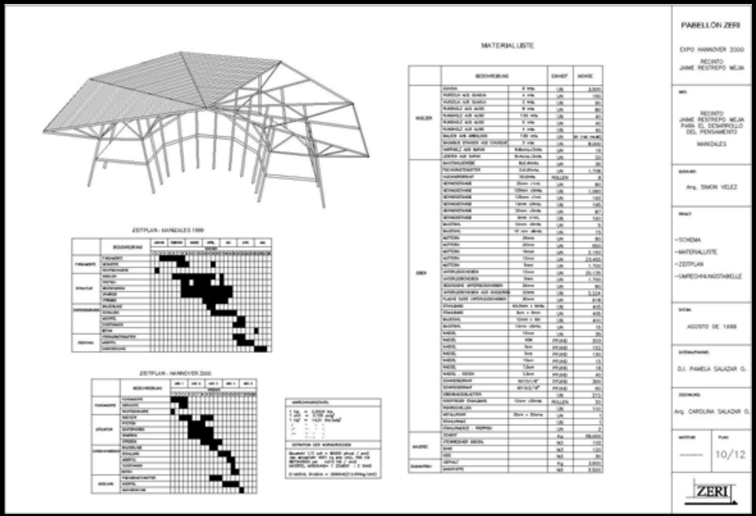
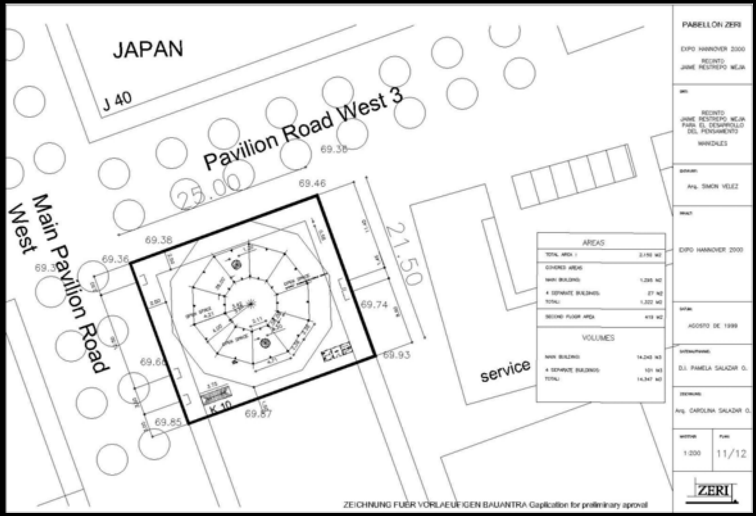
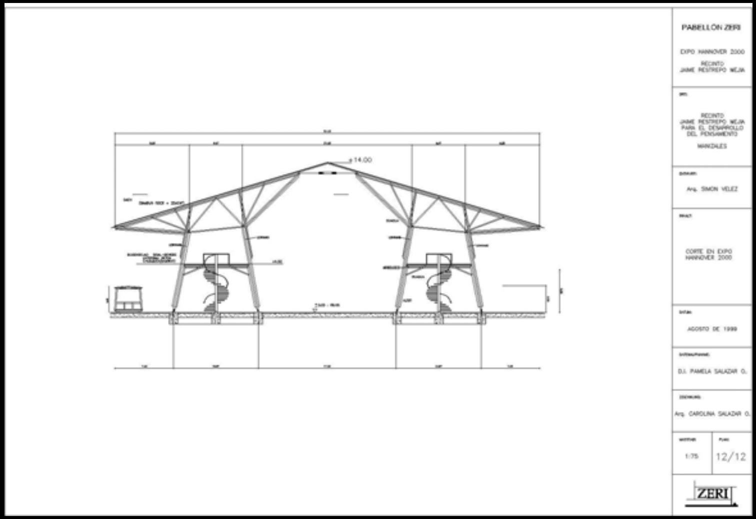
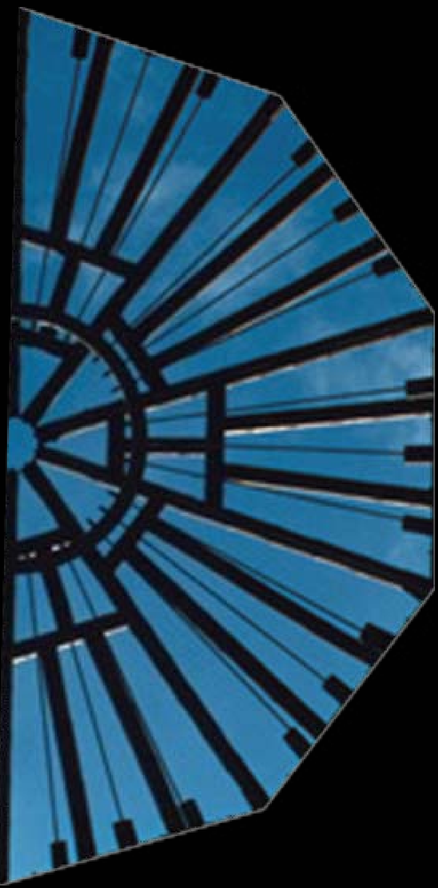








PEOPLE

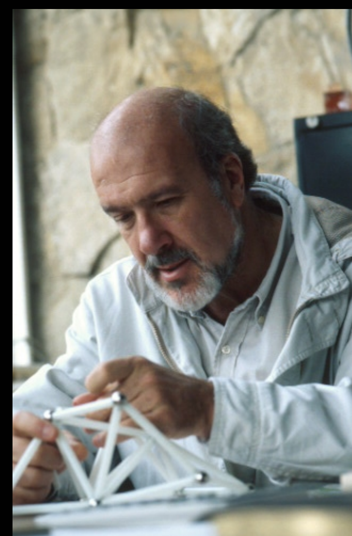


From idea to the construction, who has been involved?

Idea

Gunter Pauli, Founder and director of ZERI foundation, Belgium

Simon Velez, Architect, Designer of the Pavilion, Colombia



Paolo Lugari, Founder and director of *"Las Gaviotas"*, Colombia

Mario Calderon Rivera, President of ***Camara de Comercio de Manizales*** in 1999, Colombia

Carlos Bernal Quintero, Director of ZERI Latin America, Colombia

Construction

Sabine Bode
Architect - Project coordination
Germany

Volker Wehrmann
Architect - Site direction
Germany

Carolina Salazar Ocampo
Architect - Site supervision
Colombia

Pablo Atehortua
Foreman
Colombia

Construction

20 tradesmen and 20 laborers, Colombia

Supervising & Approval

Wolfgang Schulz, *Ministerium für Frauen, Arbeit und Soziales*, Germany

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Photograpy

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Cooks

EXPO 2000

EXPO2000
HANNOVER

The World Exposition
Germany

Press

DIE WELT

TAGESZEITUNG FÜR DEUTSCHLAND

Wie viel Druck darf auf alten Gemäuern lasten?

Bremer Statik-Institut prüft Bauwerke in ganz Deutschland auf ihre Tragfähigkeit – Experimente können Millionen-Ausgaben sparen

Wiesbadener Tagblatt

Die Stadtzeitung

Report

Hier hört man das Gras wachsen und die Wale singen

Ungewöhnlicher Pavillon einer Stiftung auf der Expo 2000 in Hannover / Potentielle Revolution für die Bauwirtschaft / Kein Abfall

KURIER AM SONNTAG

SONNTAGSAUSGABE VON WESER-KURIER · BREMER NACHRICHTEN · VERDENER NACHRICHTEN

Nr. 48 (280) · Sonntag, 28. November 1999

Zurück in die Zukunft

Bremer Hochschullehrer überprüfte in Kolumbien Pavillon für die Expo 2000

Aus aller Welt

Orkan am Bambus-Pavillon

Expo-Gebäude aus Gras: Mit tonnenschweren Lasten wird die Statik geprüft

Hochfliegende Pläne für das Bambushaus

ZERI sucht Unterstützung der Umweltstiftung – „Intelligenz der Natur kreativ nutzen"

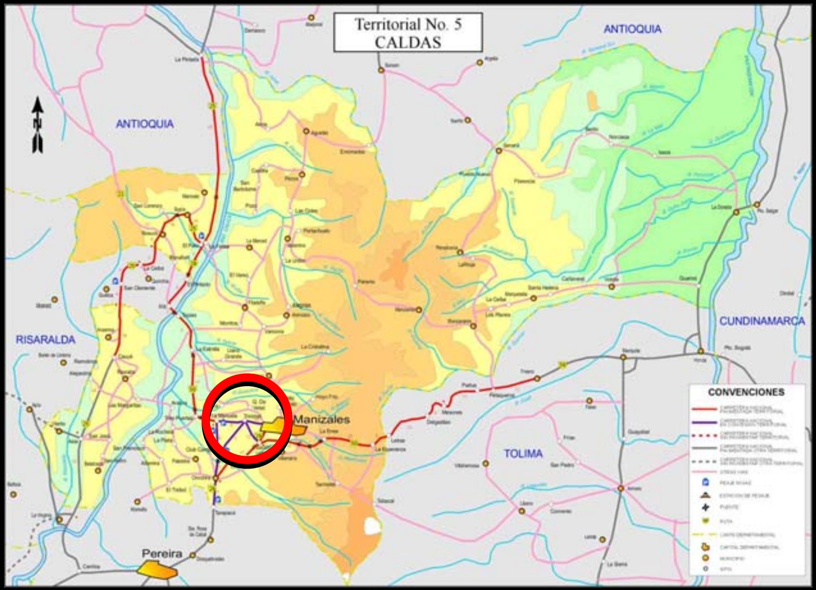
„Bauen mit Bambus hat Zukunft"

Pictures

MINHOCA - Experimental Farm

Development of an experimental farm in the coffee zone.
Implementation of various technologies, processes and systems, which can contribute to sustainable development of the coffee zone. These technologies meet the basic needs of the environment, such as water, food, health, housing, energy, labor and education.

Location



Vereda la Trinidad, Manizales, Caldas, Colombia

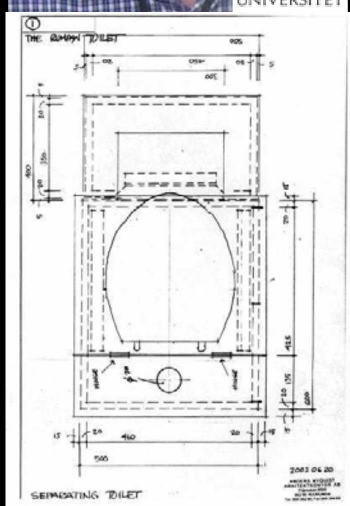
Weather: warm and wet.

STAGE I

To start this project a first house of small dimensions was built (October 2003 - January 2004), which was designed taking into account the determinants of place and ecological principles: Dry sanitary – Natural Ventilation - Construction with smoked bamboo - Utilization of ZERI pavilion technologies

First level area: 43.63 m2 - Warehouse and bathroom area: 34 m2 - Total Area: 77.63 m2 - Height: 5.90 m
Ceiling: At two waters - Foundation: Reinforced concrete - Warehouse and bathroom walls: Confined brick in concrete structure - First level walls: Bamboo, vein mesh and plaster with mortar - Covering structure: bamboo - Cover: Clay tile - Painting: Cal (white) and earth mixed with water and *Acronal* (terracotta)

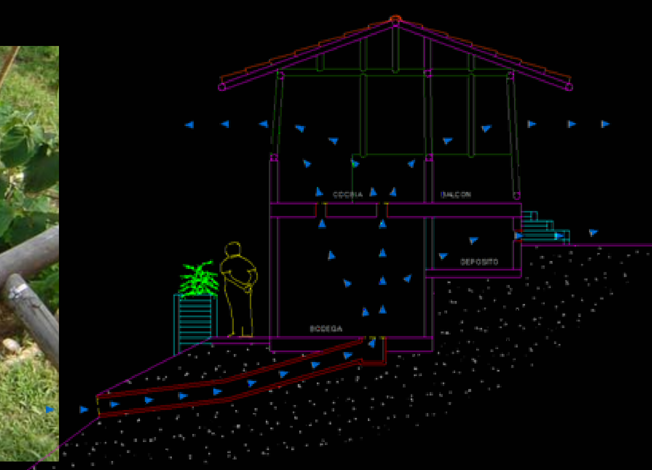
Concepts Applied



DRY SANITARY

GRAY WATER TREATMENT

SELF SUFICIENCY IN WATER



NATURAL VENTILATION SYSTEM

STAGE II

This project is based on a high quality housing, no frills, designed with ecological concepts and innovative technologies. All design meets the basic needs raised by the ZERI Foundation (Zero Emissions Research & Initiatives), applying concepts of conservation, adaptation and environmental friendliness.

Architectural Design Concept – Implementation of technologies

Sun and warm protection in a natural way

Use of natural resources

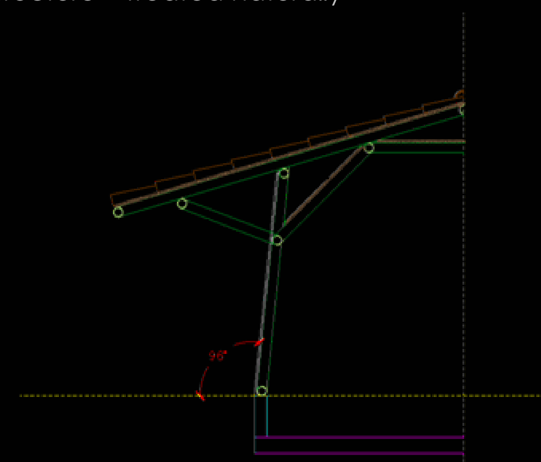
Design with organic forms

Guadua structure – Treated naturally

Sun as an energy source

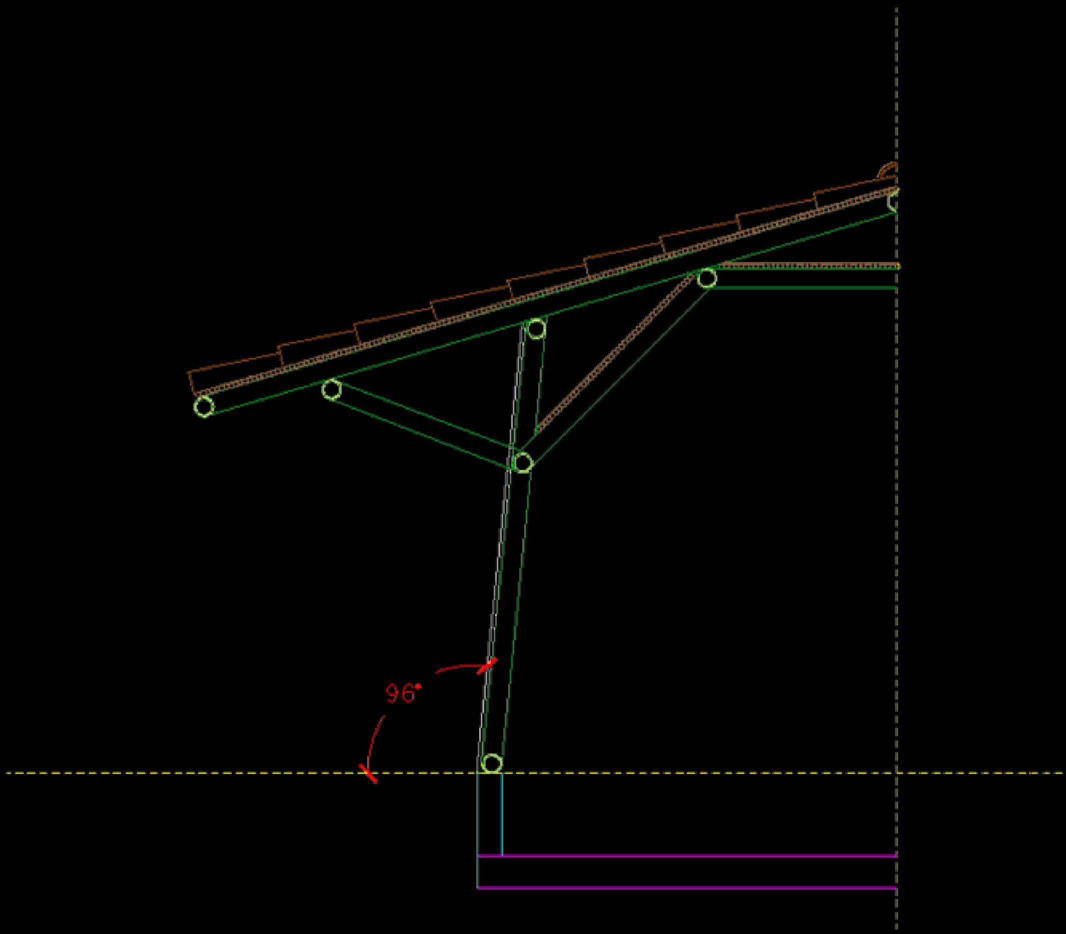
Bahareque – traditional technique

Wall inclination



Implementation of Technologies for Construction in Bamboo

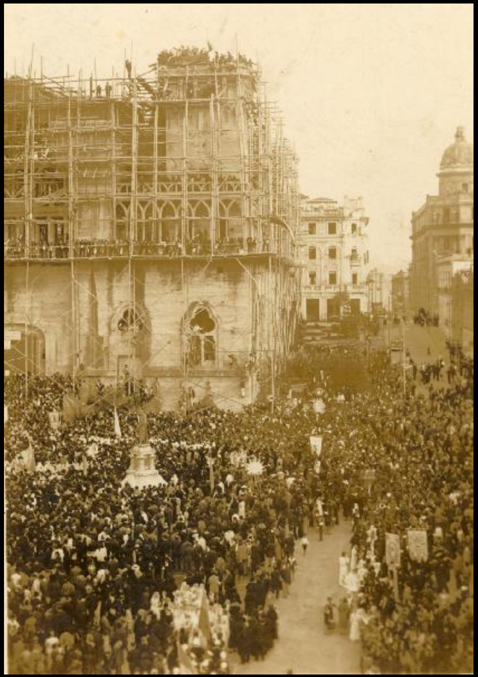
Walls inclination for better stability.



THE BAMBOO AS AN EARTHQUAKE-RESISTANT MATERIAL

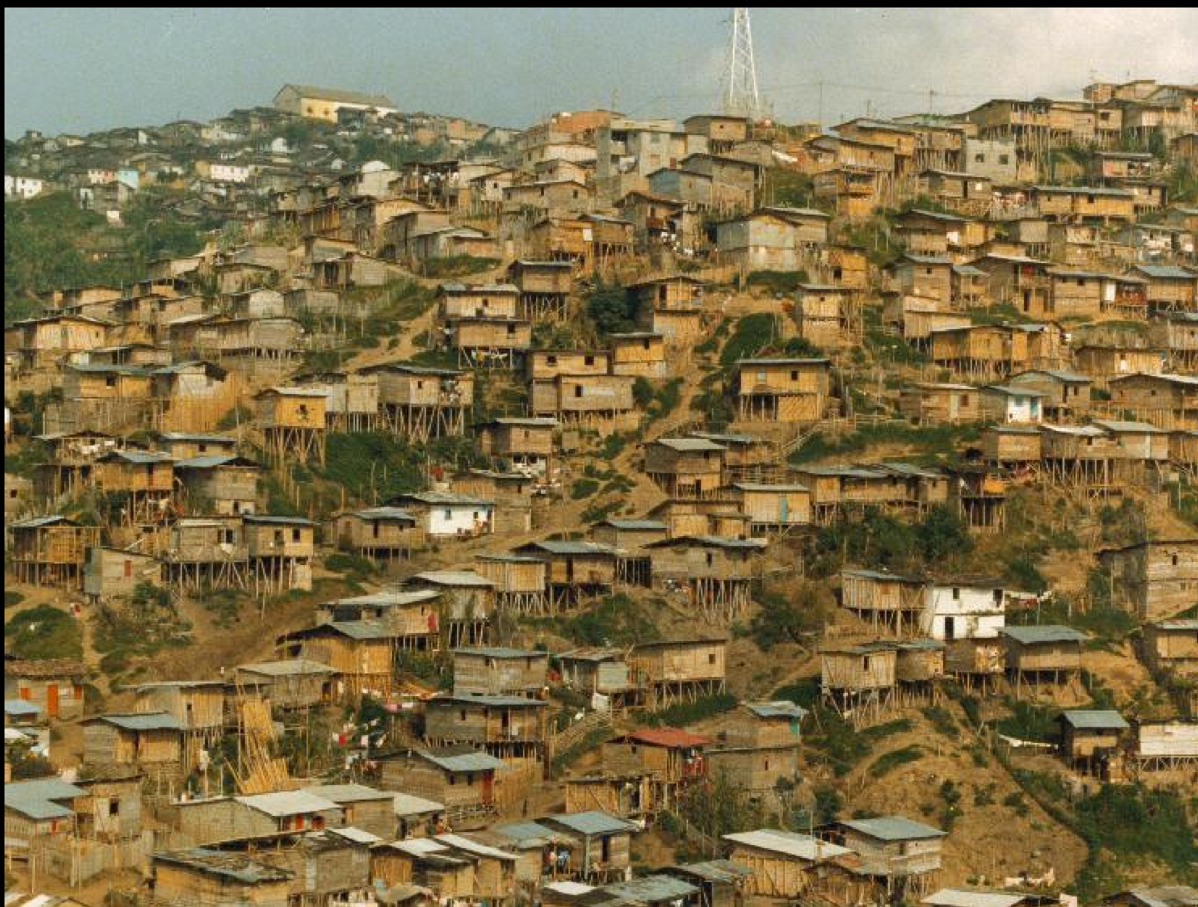
In the case of Colombia in 1999 there was an earthquake in the coffee region where many structures were severely affected and the houses built with bamboo were the less damaged, besides these constructions are lightweight that minimize the impacts. In this sense we must recover the local materials and the typical construction systems of each region, and thus take advantage of our ancestors´ wisdom to overcome natural disasters, and also we must maintain the intention to innovate with new techniques.

GUADUA AS A CONSTRUCTION MATERIAL IN COLOMBIA



The guadua is traditional material for construction in Colombia.
Must of the rural houses are made of guadua with the" bahareque technique" and there are still a lot of construction in the historic center in Manizales.
It has been used as a scaffolding system.
Because we have a lot of bamboo and you find it everywhere, there are some people that don't appreciate its value.

FROM A SYMBOL OF POVERTY TO A SYMBOL OF TECHNOLOGY...



Bamboo Houses at "El Nevado" Neighborhood, Manizales, Colombia.

Social Housing
Arq. Gilberto Florez
Manizales, Colombia

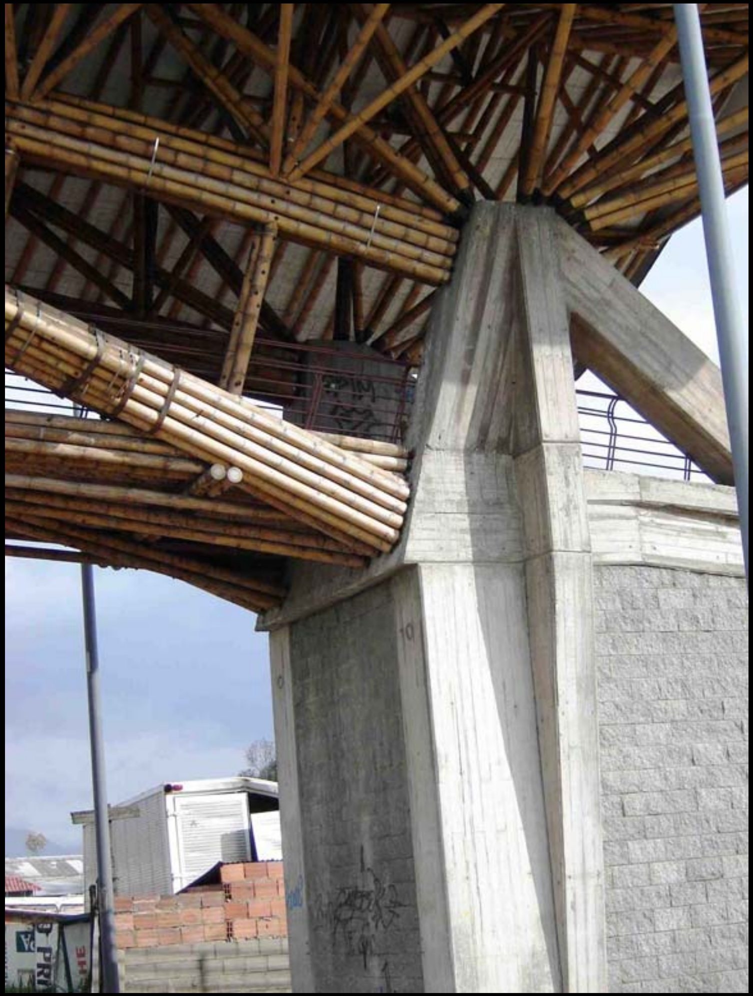
GUADUA ARCHITECTURE IN COLOMBIA

Gaudua Toll, Autopista del Café, Colombia.
Arq. Simón Hosie Samper

GUADUA ARCHITECTURE IN COLOMBIA

Bus stop, Autopista del Cafe, Colombia.

GUADUA ARCHITECTURE IN COLOMBIA



Bridge Jenny Garzón in Bogota, Simón Vélez.

GUADUA ARCHITECTURE IN COLOMBIA

Provisional Cathedral, Pereira, Colombia.
Simón Vélez

GUADUA ARCHITECTURE IN COLOMBIA

Biblioteca Pública, La casa del pueblo
Guanacas, Cauca, Colombia
Arq. Simón Hosie Samper
1er puesto Proyecto Arquitectónico
XIX Bienal de Arquitectura - Colombia

Gracias

Grazie

Tack

Dank u

感謝

Obrigado

Merci

Thanks

Dank

ZERI®

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