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A Sustainable Business Hub

stimulating upgrading by spatial intervention in the embattled ward of Dharavi-Mumbai-India

by
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Working together to change faces of poverty...
working together to change lives.

UNCHS (Habitat) and The World Bank

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Figure 1: A view inside Dharavi.

Picture courtesy of Urban Body group, TUDelft.

Figure 1: Urban situation of Dharavi

Abstract

An estimated one-third of all urban residents live in informal settlements or slums—the vast majority in developing countries. Globally, almost one billion people live in slums according to United Nations estimates.

Some of the world's biggest slums are situated on ground with a very high value. In the cheaper outskirts of the city centers where the slums originally were located, the balance is changing. City centers are expanding and quality areas are shifting, exerting a huge pressure on the previously unwanted slum areas. City planners are drawing new built up areas over the slums, without concern for the existing infrastructure and people. They are beginning from scratch, and the slum-dwellers will have to find a new place, or are given a place in huge social housing projects, away from their origin.

Mumbai, the "maximum city", epitomizes the transformation that the Indian sub-continent is undergoing at a time of extremely rapid economic growth, urbanization, and rural-urban migration. It is estimated that more of the half of Indian city's population live in squalor. Recently, a "top down solution"[1] was developed by the Indian government for the area known as "the biggest slum of Asia", Dharavi.

A personal position against the top down solution, for the specific case of Dharavi, encouraged me to elaborate a study project that considers the social problems that this area has and to deal with these problems in a sustainable manner.

1 The Economist, article : "Inside the Slums", 27/01/05

The present study used the backcasting method as a stimulator to find creative ways to formulate a more sustainable alternative, that can scale up the quality of life for the slum dwellers of Dharavi and to break the isolated position in which the area currently is positioned. New elements are put into the city as generators to provoke pre-determined changes and the generators will lead the evolution of the city. The city will change by itself, and the generators are starting and guiding this change.

The intervention is called “the master pilot project”. The intervention is going to be the node that intends to introduce quality to the area and connect Dharavi to unused economic potentials; it is the desire that its qualities are going to be spread as a part of the pilot project ripple effect. The spatial intervention will be done by the people while enhancing the community’s cultural heritage and diversity, and will stimulate sustainable self-development and participation.

The elements of intervention are:
the craft tower were small individual companies typical for Dharavi can display their craftsmanship, the communal center where organizational public activity takes place and the living bridge as integrative feature, thus brightening up the entrance to the slum while at the same time reconnecting the area with its historical past. The creek near the river will be used for cultivating land, water cleaning system and material production (bamboo), while the boulevard in front of the Mahim Creek will be used as large bus stop that will connect Dharavi in a more city level.

Picture courtesy of National Geographic

Chapter one

Introduction

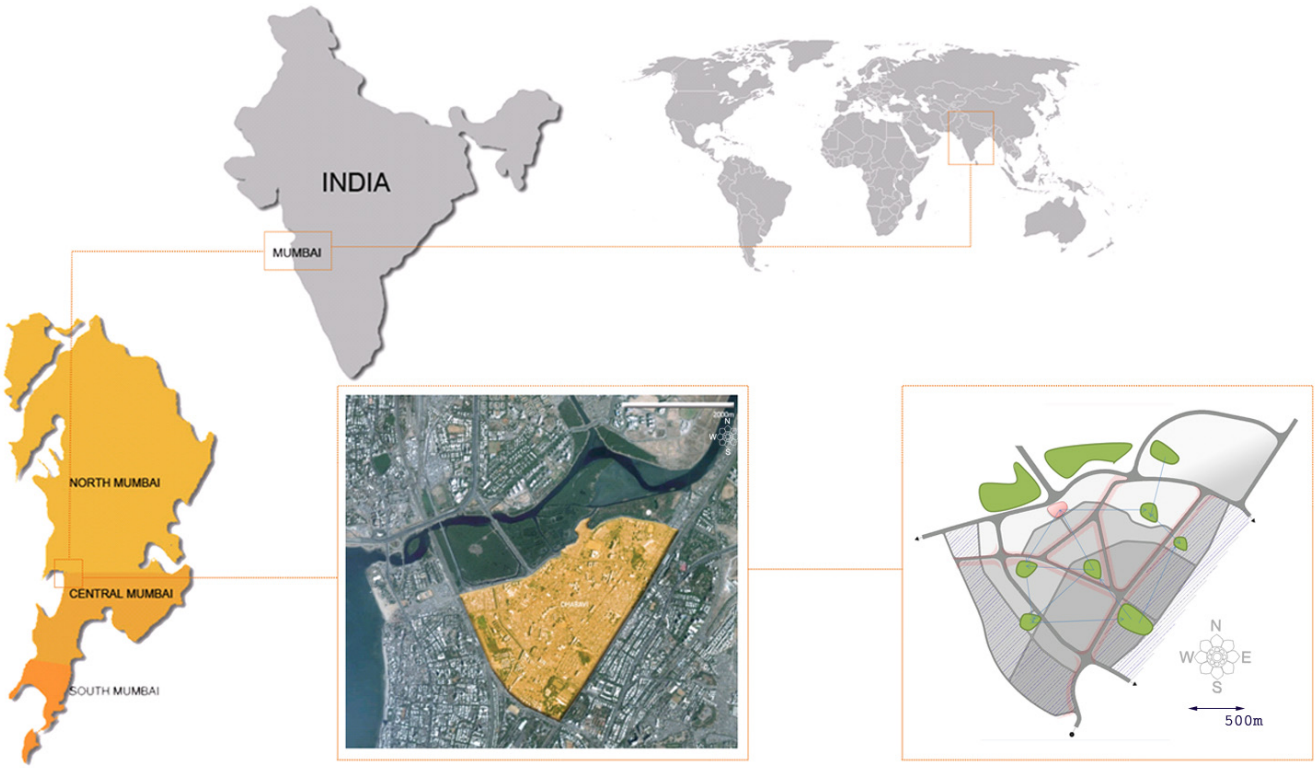


Figure 2: Locating Dharavi through maps.

Introduction

1. The selection of the topic and the area

When the opportunity arises to have total freedom in the elaboration of a study project, there exist plenty of excitements to find the correct topic that will allow you to conclude your studies with success. That is the case of many students like me that try to conclude a phase of their live with satisfaction. However to select the correct topic is not an easy task.

As an unknown member of the idealist society, wishing to contribute to solving world problems, I started to investigate about changes that impact on the way people live. The research is called: overview worldwide threats. In general, the research establishes that climate change and the demographic shift of population from rural to urban areas are the aspects that have an enormous impact in our present society.

On the one hand it is well known that climatologic variations the earth suffers are part of its natural process. However, during the past years has been a warming-up trend leading to climate change due to anthropogenic (man- made) effects. Even skeptic scientists start to be concerned that the climate fluctuation has been increased by a rapid human-induced warming, due to our rapid industrial development. The exact risk of global warming remains uncertain, even so, impacts such as the increasing intensity and frequency of natural disasters or the changing pattern of temperature, are consequences which are already visible.

On the other hand, the year 2007 marks a turning point in history. One out of every two people is living in a city[2].This means that for the first time in recorded history the world population becomes more urban than rural. The trends predict that by 2030 the urban population will have risen to 5 billion out of a world total of 8.1 billion. In the 2003 UN-HABITAT report it was calculated that one of every six human beings are slum dwellers, their trends predict that by 2030 almost half of them will be living in squatter settlements.

When the need appears to define a specific study area that struggles with climate change, urban areas and poverty, different names such Ajegunle, Kibera, Dharavi and Orangi Township stresses. Coincidently the ‘Urban body group’ from TUDelft was doing a research study with students in Dharavi - Mumbai. This convinced me to take Dharavi as the location for my final project, the other alternatives where less accessible and less safe for one female student.

In Dharavi, Mumbai, a conjugation of a large amount of these global problems can be found in a very small and dense area: a very high number of inhabitants, a high population density, extreme urban poverty, and intensive climate patterns. The studies developed for the United Nations predict a trend that would see the population of Mumbai almost double, making it the world’s second-biggest city after Tokyo.

2 UN-HABITAT State of the World’ Cities Report 2006/7

2. Format curriculum

A. Problem statement

Cities all over the world need to respond to the demographic and economic pressure that is causing urban growth[3]. In this aspect, the Indian government, classified as a developing nation with a fast growing urban economy, is impatient to see big changes in its social and economical structure; changes that will classify India as a power Nation and Mumbai as the first financial Capital of Asia.

Parts of the government changes include disappearing all decrepit areas to make way for new modern spaces. Included in the group of decrepit areas is the place in question, Dharavi. However, Dharavi is not just an example of how rural population is concentrated chaotically in the suburbs of a coast line city, where the lack of basic infrastructure, government support and secure tenure, trapped one million habitants in the cycle of poverty. Dharavi is also a land with a history of fishermen behind them, a fishering community that tries to find creative's ways to deal with the reduction of its production due to water pollution problems[4].

Furthermore, Dharavi is a land of opportunities where the hard working residents are unconsciously trying to break out the social caste system throughout a progressing informal industry. One conservative estimation places the annual value of goods produced in Dharavi at USD 500 million. At the same time, Dharavi is a geographically vulnerable area considering a raise in sea level caused by climate change. Its proximity to the river and the weather conditions confront its residents to annual flooding damage during the monsoon season.

However, during the last years Dharavi has attracted worldwide attention. The rapid growth of the Indian economy and rapid urbanization has generated a high pressure for redevelopment for the strategically favorable location of Dharavi. Dharavi is now a prime piece of real estate with two faces. [1]

For one side the government of India, with its urgent plans to redevelop and transform the slum into a modern township, has elaborated "a sustainable, mainstream, slum-free Dharavi plan", in which only officially registered slum dwellers, a very small percentage of the total amount, receive secure housing and amenities while middle classes gain new residential and commercial spaces. A group of residents from Dharavi protested against the top-down pro-developer solution. This plan ignores the generations of incremental self-development that have made Dharavi the unique and product alive place it is today, as well as, created the cultural significance that this area has for Dharavi and for Mumbai.

There is a range of reasons why Dharavi, despite its constant industrial growth, remains deadlocked in the vicious circle of poverty. Most of which are external factors. However, the habitants of Dharavi are conscious that with more government support, the improving of sanitation, participation of inhabitants of Dharavi in the decision making for the area and with more education, the development of the community can be addressed. These means a better future can be addressed through supporting a self-

3 http://www.urban-age.net
4 The Economist, article : "Inside the Slums", 27/01/05

B. Problem Statement Question

•Does another way exist to redeveloped Dharavi? A way that does not affect the typological complexity of the slum and at the same time takes into account the livelihood of the poor?

How can a spatial intervention, including different scale-levels, help the unique urban slum in Dharavi to survive effects of urban pressure and even improve its living standards?

C. Objective

•General objective: intervene to lower urban pressure on the undeveloped area of Dharavi.

•Specific objectives: to develop a spatial intervention that will work as a node generator of quality and which will connect Dharavi to unused economic potentials, while at the same time:

. to enhance the community's cultural heritage and diversity;
. to stimulate sustainable self-development and participation;
. to address points of vulnerability (flood, fresh water, amenities, etc.).

Figure 3: Slum dweler finding his way...

D. Strategy

•Integrate bottom-up strategies by taking the needs, wishes and foremost the skills of the slum dwellers in the whole design process.

•Use sustainable design principles from the concept phase till the construction detail.

•Use different tools available (3d prints, testing machines, parametric modeling, finite element analysis) to allow more diversity in the experimentation of the research and accuracy in the results.

F. Scope and delimitations

Being conscious that the process to develop a "world class township" is much too broad and complicated to be studied only for one person of one specialization and in a period of a year, this research will focus on generating a sustainable communal space for the study area, Dharavi.

A sustainable communal space for Dharavi is defined as a self supporting community that enhances its cultural heritage and diversity, and stimulates sustainability and participation in pro to improve the living standards of their coming generations.

This previous definition is translated into a concept plan for Dharavi. The concept plan is based on a node generator of quality that will create positive ripple effects that are contagious to the entire community.

This concept stimulates independency from the surroundings in basic services such as water and energy; in addition it creates integration between the internal societal organizations that Dharavi has.

The internal societal organizations will need each other to close their cycle process of independency from the other urban areas of Mumbai, in this respect waste management, industrial production or specialized education will be promoted to work as an independent community but will need an exterior connection to close its cycle process.

E.Design Phases:

The thesis project is divided in the following phases:

Chapter two

Macro phase

Picture courtesy of flick.com

Macro phase:
design strategies for the embattled area of Dharavi

Note: Official information of Dharavi does not exist. The information from this chapter is based on personal observation during the visit to the area, data obtained through the urban body group of TUDelft, the workshop called Urban Typhoon and journalistic sources about the area.

1. The current situation of Dharavi

Dharavi, India. Spread over an area of 1.75 square kilometers in the heart of Bombay (Mumbai), and with a population of more than 1 million people, Dharavi is called the "largest slum in Asia."

Dharavi was predominantly a mangrove swamp prior to the late 19th century, inhabited by Koli fishermen. When the creek dried up, new spaces were provided for migrants from different parts of India. These migrants brought their different traditions to the area such as, pottery, textile, leather and embroidery.

During that time the informal sector continued evolving and now the squatter community is home to a constantly growing industry. The district has an estimated 15,000 single-room factories[5]; almost every house serves as a space with double or triple function. During the day the house can be used as an area for production; during the afternoon, some exterior spaces can be rented as an informal sales point; and when people get tired, their homes become the place where their production is stored and where they recover energy to work with the same intensity the next day.

The slumdwellers really take advantage of any square meter of land; however this effective use of the spaces seems to be broken in some areas of Dharavi were the introduction of high-rise building happens. In 1995 private developers received incentives from the government through the Slum Rehabilitation Scheme (SRS) in which developers construct buildings with free 225 sq. ft. flats for slum dwellers in exchange for building rights in other parts of Mumbai where land to built is available. Most of the high-rise buildings that appear on Dharavi's skyline were constructed under this scheme.

At first hand these multi-story buildings seemed like a good solution for the lack of secure housing, but the unregulated policy and simplistic reezoning of the government has brought out seven storey blocks of extremely poor quality. The minimums space to continue with the productive life that the slum dwellers used to have in their two store houses and the maintenance costs that they cannot afford, have introduced "vertical slums" into the landscape.

Adding to these unfruitful interventions, Dharavi is facing severe problems related to public health. Just a small walk is needed to notice the accumulation of garbage in the main streets of Dharavi, the inadequate water supply and the scarcity of toilet facilities; or to get annoyed by the horns of taxis or the machinery of the small industries.

5 The Observer. Article: "Waste not, want not in the £700m slum", Sunday March 4, 2007

Water pollution is another severe problem in the area, water colored by dyes used for coloring leather and garbage dumped are some of the main contributors to this contamination. Contamination that increases in severity every year during the monsoon season (June-September), the period in which Dharavi gets flooded.

The lack of amenities is another important aspect to discuss; open spaces, schools, health care centers gym or even small cinemas can be found inside Dharavi; I do not consider that Dharavi has a lack of amenities, at the contrary for me it is an area where you can find all what you want, it is a quasi autarky[6] community.

The main problem with regards to its amenities for me is the quality of the services and the inefficient interventions of the government. It is common to see in front of the health care center cars parking and commerce that produce strong smells such a market fish; or schools with a recreation area full of garbage and without toilets; it is also common to see open spaces closed by brick walls because they are part of a private sectors or part of the government interventions. The amenities are there but they need to increase their quality and capacity to reach an upgrading of the slum.

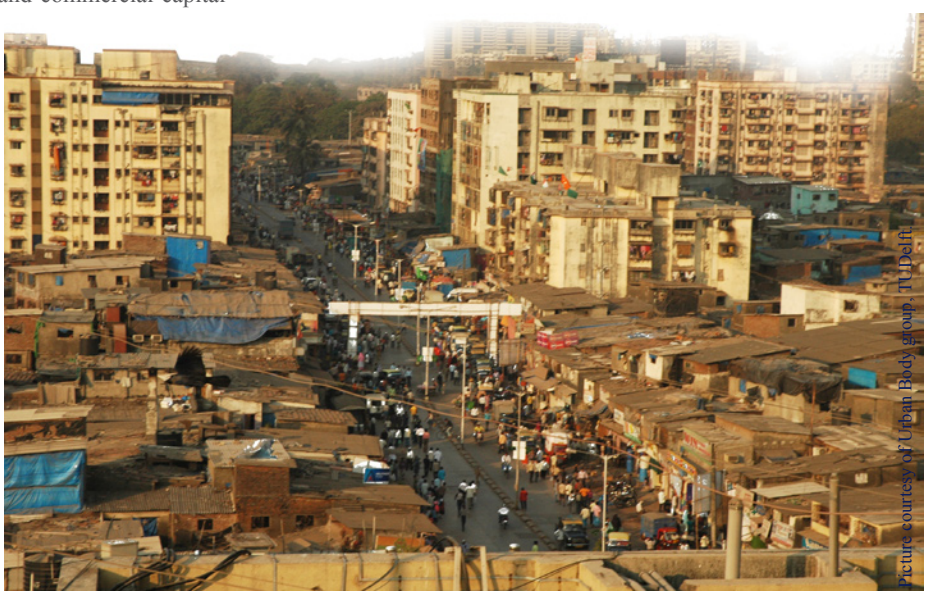
Slum upgrading is a much used word the last years for which was once an informal settlement on the outskirts of the city and that becomes now the geographical heard of the financial and commercial capital of India.

This geographical position and the rapid economic growing that is undergoing in Mumbai have changed the vision the government had of Dharavi. From a land without hope now Dharavi is an extremely valuable property.

The Govt. of Maharashtra has accepted the proposal submitted by Architect Mr. Mukesh Mehta for the redevelopment of Dharavi. This redevelopment plan implies a complete elimination of the structure of Dharavi and gives place to a new township with many amenities, wider roads, electricity, ample water supply, etc. The government considers this a “win-win solution” while the slum dwellers see it as a top down solution that does not take their needs into consideration.

This plan ignores the generations of incremental self-development that have made Dharavi the unique and product alive place it is today, as well as, created the cultural significance that this area has for Dharavi and for Mumbai.

Other international organizations are supporting the slum dwellers opinion publically, but to get a better understanding of the current situation of Dharavi, it is necessary to go through some general aspects of the area and to know more about the position of the stakeholders involved. Both aspects will be explained in the following pages.



Picture courtesy of Urban Body group, TU Delft.

Figure 4: Dharavi Main Road, a intensive commercial street inside Dharavi.

6 Timmeren, A. van, Kristinson J., Roling, L.C., Building & Autarky. The Netherlands, 2004

Picture courtesy of Typhon workshop, Dharavi.

Figure 5. *Koliwada Dharavi, amenity space*

1.1 Geography

Mumbai, the capital of the Indian state of Maharashtra is located on the west coast of India just south of the tropic of Cancer. Dharavi forms part of one of the seven islands that were joined together into one landmass through three centuries of reclamation.

Despite its seismically active zone and its climatic variation that provides rainfall from the South Asian Monsoon between June and September every year, Mumbai has grown far into the mainland both to the north and the east. As a result, Dharavi that once was located in the suburb of Mumbai, now lies at the heart of the city next to one of its most sought-after commercial districts, the Bhandra-Kurla Complex.

The 1.75 square kilometers of Dharavi is sandwiched between Mumbai's two main suburban railway lines, the Western and Central Railways, and to the Mithi River on the north site which empties into the Arabian Sea through the Mahim Creek.

The Mahim Creek is a creek that forms the boundary between Dharavi and Mithi River. It is swamped by mangroves and has a mini-ecosystem within it that has been extremely deteriorated during the last decades. Now it is used as a dumping ground for waste or as a place for urination and defecation.

1.2 Environmental aspects

Dharavi has severe problems with public health, due to the scarcity of toilet facilities, compounded by the flooding during the monsoon season. As of November 2006 there was only one toilet per 1,440 residents in Dharavi[7]. Mahim Creek, a local river, is widely used by local residents for urination and defecation, leading to the spread of contagious disease[8].

The Mithi River originates at Powai and flows through residential and industrial complexes which discharge raw sewage, industrial waste and garbage over a distance of about 15 km.

The area also suffers from problems with inadequate drainage, inadequate water supply, noisy pollution and garbage everywhere.

Percentages cannot be determined, but it is just enough to mention that if there exists any free space in the area, it will be occupied by a tonal of garbage in a matter of hours. It is this accumulation of pollution that attracts scavenger birds to the area, or predators such as rats and street dogs.

7 Toilets Underused to Fight Disease, U.N. Study Finds, November 10, 2006
8 Wikipedia, http://en.wikipedia.org/wiki/Dharavi

1.3 Population

According to the State of the World Population 2007 report by the United Nations[9], India's slum residents account for more than 15 percent of the country's overall population and more than 55 percent of those who are urban dwellers of which between 600000 and a million live in Dharavi .

During its history people from around the country came to Dharavi to fulfill their dreams of a better chance of life. This is why Dharavi has a multicultural population. Tamils, Andhras, Assamese, Biharis, Bengalis are just some examples of the 50 communities that have imported their village atmosphere into Dharavi.

Dharavi's main population consists of Tamilians and Maharashtrian, each comprising about a third of the population. However, Hindus, Muslims and Christians can easily by recognized for their publics religious activities and their religious infrastructures, such as mosques, temples or chapels.

Indian cities as well as Dharavi have more male residents than female, reflecting a natural increase element in rapid population growth in the city in the 1970s, but also the migration of young men to cities[10].

At the moment of work; men, women, children everyone takes part in the work, but as an Indian society it is clear that there exists a distinction in the type of work and function a women can exert. The Indian men have a narrow outlook when it concerns women.

1.4 Land and Housing

The Brihanmumbai Municipal Corporation (BMC) owns most of the land in Dharavi, with private landholders and the central government controlling the rest. An informal real estate market operates in the area, with prices varying by location and building quality. While some residents live in structures with tin walls and plastic sheeting, many have moved up to brick or concrete and have added lofts, upper stories and decorative elements.

Some owners lease spaces to tenants, having purchased more than one house or moved out of Dharavi. Although a majority of structures constitute "slum housing," Dharavi also contains other housing typologies, including the former village structures of Koliwada, planned government chawls and transit accommodations, and government-sponsored high-rises[11].

The different types of houses founded in Dharavi can be classified in two groups. We can split this group in two parts, the fully leased formed by the slum dwellers with a lack of secure tenure. Lacking secure tenure, slum-dwellers have few ways and little incentives to improve their living qualities. The second group is formed by the slum dwellers that have ownership rights of their land, security tenure led slum improvement initiatives are much more likely to be undertaken and, in fact, succeed.

9 UNFPA, State of the World Population 2007, http://www.unfpa.org
10 Urban Age, http://www.urban-age.net/10_cities/_data/data_UAC.html
11 http://www.dharavi.org/A._Introduction

1.5 Transport

The proximity that Dharavi has to the four major railway stations; the Western, the Central and Harbour lines, set up the slum as a strategic living point for all people wishing to find cheap housing inside Mumbai.

Even so, the train network in Mumbai is constantly struggling to cope with the growing population. A train compartment is usually filled with over three times the passengers it was meant for at peak hours, and there have been more than 20,000 deaths in the last five years[12].

The road traffic is concentrated in the main streets of Dharavi; buses, taxis, autorickshaw, motorbikes can be seen everywhere. Over 70% of traffic flowing through these roads is part of the private sector and only 5% of traffic is public transport, the other 25% is divided between trucks and two wheels transport.

If we analyze the traffic flows inside the slum we can see that there does not exist any penetration route in a radius of 1 KM; even in the principal routes inside Dharavi any public transportation is exhibit. This can be seen as a positive point in an area where all transportation is saturated by their users, and where walking is a faster alternative to be chosen.

In this transport aspect it is important to mention that cars and people are in constant obstruction; roads are not only congested for other transports but also by people, and people because of lack of pedestrian facilities are constantly intimidated by cars.

1.6 Economic situation

Dharavi is not only a residential space, but also a major economic hub representing the city's vast informal sector. Dharavi's commercial enterprises include recycling industries, leather tanneries, heavy metal work, woodwork, and manufactured goods such as garments, shoes, luggage, jewelry. Industries generally serve all of Mumbai, and many products are even distributed in global markets. One conservative estimate places the annual value of goods produced in Dharavi at USD 500 million[13].

Commercial and manufacturing enterprises are relying on a decentralized production process based on networks of small home-based production units. In Dharavi there are approximately 4902 industrial units of which the textile industry is one of the largest one with 1036 units. Followed by 932 pottery units, 567 leather and 478 plastic processing and recycling units. Last named industry is considered being the largest recycle center in India and it is helping thousands of slum dwellers in gaining some money by recollecting garbage from all parts of Mumbai. 3000 and 15000 rupees a month (£40-£200)[4].

The informal industries developed in Dharavi provide employment for 85 % of slum dwellers of the area, only 10 per cent of the commercial activity here is legal, most of the workshops are constructed illegally on government land, power is routinely stolen and commercial licenses are rarely sought[15].

Figure 6: Dharavi is located close to 4 major railway stations on western, central and harbour lines.

12 Macalester college, Minnesota District, USA. http://www.macalester.edu
13 The Economist, article : "Inside the Slums", 27/1/05
14 The Economist, article : "Inside the Slums", 27/1/05
15 Wikipedia, http://en.wikipedia.org/wiki/Dharavi

1.6 Internal organization of Dharavi

With respect to its internal organization, Dharavi is composed of over 85 Nagars, which in turn are further sub-divided into many housing societies, chawl societies, or other type of social group that is bifurcated based on cultural boundaries and household economic opportunities.

Though there does not exist any official data that each Nagar in Dharavi has an internal organization, during the study time in the area it seems that the different social groups have an internal democratic administration organized for the same group of people concerning. This administration mainly consists of a leader and different committees.

The committees focus on solving specific tasks, for example the latrine committee is responsible for the construction and maintenance of public latrines. In the case of the leader, he is most responsible to serve as a middle link in the communication process within the committees or with other leaders. There exist well established internal norms and agreements made by the leaders which have resulted in the patterns followed by their community members.

These internal organizations are normally supported by non-governmental organisms such as SPARC or the National Slum Dwellers Federation (NSDF). These NGO's assist slum dwellers ideas and ameliorate the communication between the government and their residents; furthermore, these organizations take actively part in stimulating the up-grading of the slum through active participation of the different communities.

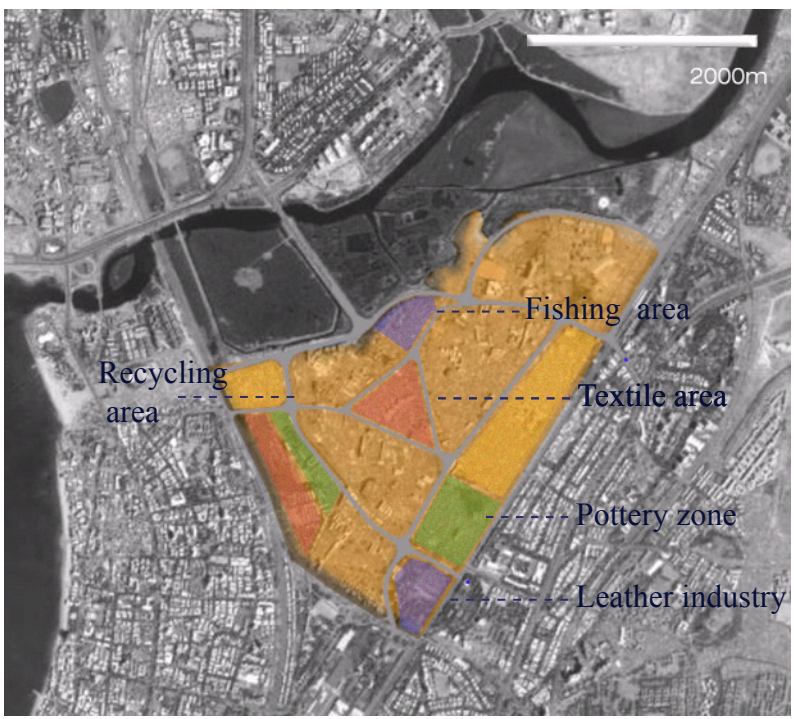


Figure 7: Dharavi is divided by sectors. The sectors are organized by its economic system, based on activities related to their cultural origin. The picture shows the location, in the map of Dharavi, of some of these sectors.

Main graft ability:
.pottery
.textile
.leather
.recycling

16 http://www.dharavi.org/A._Introduction
17 http://www.dharavi.org/A._Introduction

1.7 Local Government

The government has provisionally approved a plan called 'Vision Mumbai' -- to create a world-class city by 2013. Inside this plan is included the Redevelopment plan of Dharavi.

Redevelopment plan

The recent "Redevelopment Plan" for Dharavi was elaborated a decade ago by US-based architect and consultant Mukesh Mehta and approved by the state government of Maharashtra in 2004.

Vision from the government: Sustainable, slum free Dharavi of middle class people.

Title: Known as the Dharavi Redevelopment Project (DRP)

Situation: Valued at Rs. 93 billion (around USD 2.3 billion), the plan —which authorities have dubbed "The Opportunity of the Millennium" — divides Dharavi into five sectors to be developed by global firms after a competitive bidding process. Profits from the sale of high-end developments will fund the resettlement of eligible slum dwellers (those who can prove their residence prior to January 1, 1995) in free 225 sq. ft. flats in multi-store buildings.

Developers are also charged with providing some amenities and infrastructural improvement. In January 2008, SRA officials announced a shortlist of 19 bidders out of the 26 who had submitted expression of interest documents since tenders were invited in August 2007 [16].

Problem: Although many laud the plan's transcendence of a piecemeal approach, the project has been criticized for being pro-developer instead of pro-resident; for proceeding without transparency towards consent, or consultation with the community; and for adopting a tabula rasa approach that ignores the generations of incremental self-development that have made Dharavi the unique and productive place it is today [17].

Figure 8: Recent "Redevelopment Plan" for Dharavi elaborated by the architect and consultant Mukesh Mehta and approved by the state government of Maharashtra in 2004.

2. A sustainable development for Dharavi

2.1 Program of possibilities

Understanding that Dharavi is an administrative ward that combines several risk factors: a very high number of inhabitants, a high population density, urban poverty, and the serious sanitation issues, while at the same time it is a progressing informal society already working for the improvement of its living standards for a better future of their generations. It was clear that a guiding path, that will hold out theoretically the design proposal, was needed. Therefore, to determine the best possible alternative to upgrade the study area the following questions were formulated:

What does Dharavi need?

Dharavi needs alternative plans that help to reach the goal that the government wants: a "Sustainable, slum free Dharavi of middle class people". This new alternative has to allow continuing, or even reinforcing, the existing social, cultural and economic network that Dharavi has.

How to formulate this desirable alternative plan?

Starting from a more deep understanding of the societal groups of Dharavi, the next step will be to formulate a desirable future vision, for this aspect the backcasting method was used.

Backcasting is a process whereby the construction of a future vision or normative scenario is followed by looking back in time and creating a strategy or action plan for proceeding from the present towards that desired future [18].

18 Dr Marielle Snel and Dr Mansoor Ali, Stakeholder analysis in local solid waste management schemes, March 1999, London School of Hygiene & Tropical Medicine, UK.
19 Urban Acupuncture - A Methodology for the Sustainable Rehabilitation of "Society Buildings" in Vancouver's Chinatown into Contemporary Housing.

Urban acupuncture focuses on the selective redevelopment of appropriate sites within the historic fabric. It carefully removes what isn't working and inserts a contemporary, appropriate intervention to stimulate urban regeneration [19].

As Maurizio Marzi mentioned, in his paper "urban acupuncture: a proposal for the renewal of Milan's urban ring road", urban acupuncture is spawned by the necessity to achieve sensitive effects in shorter time periods with respect to planning, and operates principally within structured contexts.

To avoid a break in the existing system of Dharavi (economic & cultural structure) the best possible way that I found was to insert a network of points that will introduce quality to the existing system, through small seams and interventions of substitution; and will improve environmental quality, through local solutions which match local needs.

Urban acupuncture is a new approach to the upgrading process of slums, however it has been applied successfully in different other cases. Two interesting cases to mention are the case of Curitiba in Brazil and Soho in London.

Curitiba boasts a number of spectacular civic structures, some, such as the wire opera house and the Free University of the Environment, which have transformed abandoned quarries and other former eyesores into some of the most distinctive man-made visual attractions in the entire

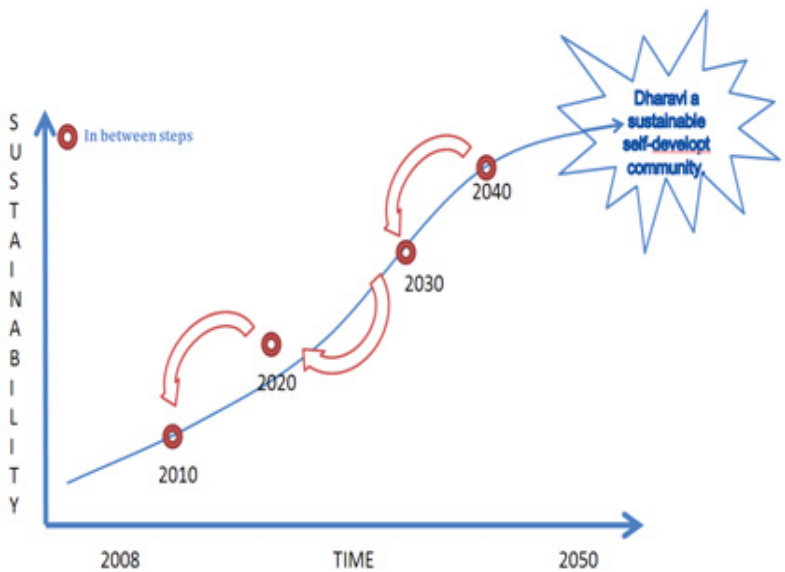
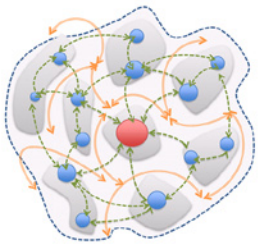


Figure 10: Graphic showing the backcasting time line.

20 Schwartz, Hugh. Curitiba, Brazil: Urban Renewal, Municipal Revitalization. Brazilmax.com, 2005.

BACKCASTING

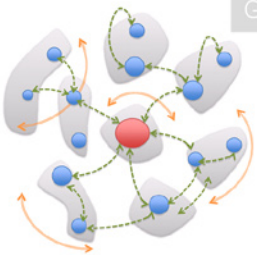
Steps back for a sustainable self-develop community.



2058

THE MEGA-SYSTEM

Dharavi is a sustainable self-develop community with a strong sense of belonging to a vibrant complex system.



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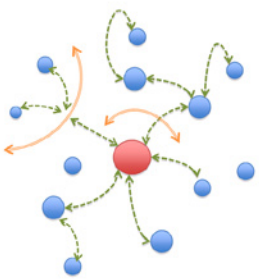
THE MACRO-SYSTEM

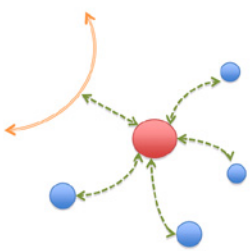
All the nodes inside the 8 zones have specialized as a group in a specific community services.



2038

THE MESO-SYSTEM

The 85 Nagars have as minimum one self sufficient node clearly differentiated from the other nodes by his culture background and personal needs.



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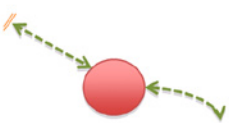
THE MICRO-SYSTEM

Nodes begin to be generated as part of the pilot project ripple effect. Improvements, personal needs and culture background of each Nagar are adapted.



2018

THE NODE

The 1st pilot project is totally developed. It is self sufficient, enhances the community's cultural heritage and diversity and stimulate sustainable self-development and participation.

Figure 11: Action Plan for Dharavi base on the urban acupuncture theory.

- ✓ **Livable place:** The energetic live that exists in the area will be spotlighted by high quality spaces, where work, living and leisure interact harmoniously without affecting any householder group. The leisure and learning process is completely integrated in the sustainable living.

- ✓ **Interesting place to be:** the tourist will continue visiting the area to see how this so complex society is organized, to learn about their small scale sustainable industries and to use the services that they offer.

- ✓ **The modern cultural heard of Mumbai:** The different cultures or religions that exist in the area will be highlighted. All the shawls are easy to identify because their architecture, building, food or music differs from each other. The concept of Dharavi is reinforced in their cultural legacies.

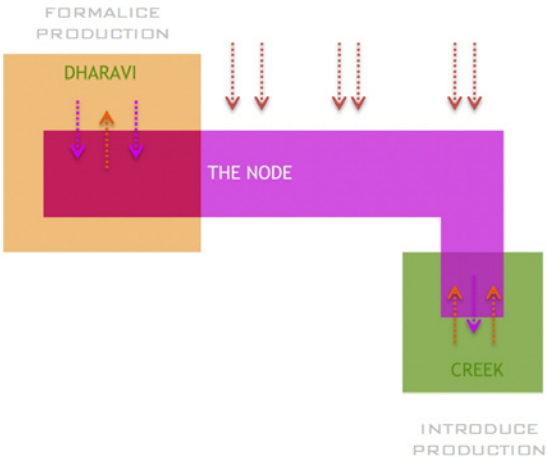
- ✓ **The green center:** spaces will be generated to give place to communal activities. The landscape is pronominally colored by fruit trees, rest areas, agriculture, water retentions, etc. Slumdwellers work voluntary in the maintenance and improvement of its spaces (private and communal).

- ✓ **Well administrate community:** the internal organization of the community will be based on peoples participation. To reach an administrative balance a dynamic and loop process between all the stakeholder needs to be preserved.

- ✓ **Competitive:** The productivity of the area is economically supported by themselves. An intensive sustain is done for all different scales and types of skills, products and process.

- ✓ **Self- sufficient in food, water, energy and basic services (school, shops, health care centers, etc).**

- ✓ **The impact on the ecosystem should also be minimal; the surrounding ecosystems and the city's own ecosystem should be preserved.**



2.2 General plan lay out:

Having formulated the guiding plan for Dharavi, two aspects are remaining before beginning to define an architectural program. The first remaining question is: where to start to implement this sustainable self development community? , and the second aspect remaining is: what to do in that location?

What?

To solve this question a "stakeholder's analysis" took place.

The "stakeholder's analysis": It is a tool for assessing different interest groups around a policy issue or intervention, and their ability to influence the final outcome[21]. The stakeholders recognized in this study are split into three main groups. In the first group the inhabitants of Dharavi are considered; in the secondary group the politicians & government; and finally, in the external group all the societal organizations and Media & communication are included. The interest, importance and influence of each stakeholder group, in relation to the problems being addressed by the upgrading of the slum, have been identified.

The analysis reveals that the principal actor of the 'transformation' will be the citizens of Dharavi; slum dwellers are the group that will be more beneficiary if a positive change is reached. It is important to take into consideration that young and middle-aged men exert a strong influence in the Dharavi society, especially activists. The role of the activist is critical for the upgrading of the slum. Activists are community members who are already aware of problems, think about them and try to resolve them.

However, a more professional point of view is necessary if a more successful end is wanted; in this respect, societal organizations and Regional & local government exert an important function. They have the task to guide the process correctly and efficiently. These societal organizations are normally more able than the government itself to educate the public and build support around sustainable upgrading issues. For that reason it is interesting to integrate in the process of transformation more innovative NGO programs, such as Global Action Plan's EcoTeam Programme that actively encourage citizens to participate in environmental solutions.

Finally, the Media and communication group are not of a high importance in the process of transformation, but they exert a good communicative influence. Especially the local economy has to be considered to be an important tool to make the whole process participatory. And it also can be used as a way to create consciousness that the sustainable change is needed.

21 EC-FAO, European Union. Understanding the Users' Information Needs. Annex I. Stakeholders Analysis, 2006.

Aware of the influence that these three groups exert in to the upgrading of the area, it was defined that the first pilot project has to be a communal space. As a "communal space" it refers to a shear urban infrastructure that will permit:

•stakeholders: improve their living standards via allowing new opportunities to expand the market, to improve the quality of their products and to trade with increased profit;

•politics & government: sustainable rehabilitation of the biggest slum in Asia, while continue stimulating the continuous economic grow of India;

•societal organizations and Media & communication: stimulate more community participation, while at the same time solidify the multiculturalism of the slum, while preserving and enhancing the traditional skills (embroidery, henna paint, etc.).

Where?

The identification of the area in which the pilot project is going to be developed was not a difficult task. Because there exist a need to reduce to the minimum the impact in the existing societal and economical configuration that the area has, it was decide to look for spaces without permanent infrastructure.

First, with the help of an aerial map (Google earth), potential open places where identified. The identification of open spaces to aerial map was fundamental in the selection of location due that most of the open spaces identified where of private owners, this means that the area is completely surrounded by a brick wall, and any physical observation cannot take place.

Eight potential places were identified. The next step was to identify these spaces during the visit to the area; the selection of the final location was based in the following requirements:

- •easy accessibility from neighboring areas;
- •visible from surrounding areas (generate visual impact) ;
- •in a strategy location where the majority of slum dwellers walk regularly.

There exist other potential open spaces that can be used in the future as nodes generators of qualities, most of them having already a communal use such as the cemetery in the south west of Dharvi or the cricket ground on the North.

Geographical location of the selected area:

The area selected is located in the North West of Dharavi, facing the Mahim Creek and giving the back to one of the more ancient streets of Mumbai and commercial roads of Dharavi, called Dharavi main road.

In the two sides of the plot there are small Nagars formed of houses of about two stories high. As a background of the location there are scattered some buildings knowing as vertical slums, they are around six or eight floors high. There also exits a faded selection of trees, in good conditions, that make a bit softer the view.

Few meters to the right, following the river, there is Koliwada, the oldest fisher communities of Mumbai, and some meters more to the left is 13th compound, know as a the biggest recycled industry of Mumbai and also it is one of the busiest areas of Dharavi.

Existing use:

In the map of the Special Planning Authority (SPA) it appears this location is owned by a private sector. However, the reality is that the plot is mainly an empty open land with few chawls and trees (two ficus religiosa and three moringa oleifera).

The location is used as a parking for trucks, as a open toilet or as a garbage dump. The area has a bad reputation, is known that woman and men of bad reputation, alcoholics and prostitutes live in the decrepit shacks.

Physical characteristics:

The plot is a flat space with almost rectangular shape of 176m x 80m, whith its longest side facing the Northwest. Total area 1408m2.

The road facing the Mahim Creek (Northeast), starts to go up in an angle of 60 giving a sensation that the plot is going deep towards the Northwest.

To allow integration with the surrounding it was decided to incorporate the open areas (free spaces) that surround the area. In some cases the walls that limit the boarding shawls are assumed to be out.

Stakeholder analysis

Definition	Group	Examples of groups included	Interest	Importance	Influence
1.2 By gender	Primary Group	all members that live, work or owner a property or business in Dharavi.	Target group: ultimate beneficiary of poverty reduction strategies.	As a group 4	As a group 3
Girls and women	Primary	under/unemployed women; victims of violent marriages, unable to attend school due income; single or married...	. Have more space where they can communicate and express themselves. Provides a legitimate safe space for women to socialize with friends and neighbours. . Women's empowerment.	4	3
Boys and men	Primary	Low-skilled; internal migrants; homeworkers; owners and managers, with or without a full family, activist...	. More privacy certain activities. . Spaces where more physical activity can be done.	4	4
1.2 By age	Primary Group	all members that live, work or owner a property or business in Dharavi.	Target group: ultimate beneficiary of poverty reduction strategies.	As a group 4	As a group 3
Babies	Primary	All slumdwelers under the age of two.	Save places where they can stay during the time that the parents are working.	4	1
Children	Primary	All slumdwelers between 2 – 18 years old.	. Much places to learn dance, act, draw, sign... . Much places to play.	4	3
Young	Primary	All slumdwelers between 18-39 years old.	. Increased household income and living standards. . Better future for their small generations. . More family privacy.	4	4
Middle-aged	Primary	All slumdwelers between 40-59 years old.	. Having a better and cleaner place. . Being involved in the planning and implementation of the change.	4	4
Older	Primary	All slumdwelers between 60-74 years old.	. Recognise their antiquity by giving rights of land and house.	4	3
Old-old	Primary	All slumdwelers from 75 and older .	. Preserve the same social group, family and friends near. . Enhanced health status	4	1
1.3 by Employment	Primary Group			As a group 4	As a group 3
in Government Service	Primary	Waste pickers/Local people employed on schemes; bus drivers,	. Opportunities to move into better paid jobs due to skill. . Increased demand; chance to upgrade skills further.	3	2
in Private Service	Primary	All person that for their knowledge learned in intellectual centres can be employed by private sector, like banks, universities... outside or inside Dharavi.	. Change the image of Dharavi to get better opportunities of jobs reference. . Facilitated services that can take care of their children.	3	2
Self employed	Primary	potters, masons, seamstress, recyclers, leather producers... all members how owner or rent a space to fabric or sell products or services.	. New opportunities to expand the market, to improve the quality of their products and to trade with increased profit . . Find alternatives to prevent standing still without income during the monsoon season.	4	3
Casual labour	Primary	Orchards, greengrocer.. all small sellers that do not have a permanent space where to produce/sell.	. Retention of jobs; . More opportunities for upgrading and training .	4	1
Retired – Disable	Primary	Unemployed; low benefits; dependent on family; lack of suitable care and/or rehabilitation services; drug addicts; school drop-outs	. Increase public free services. . More opportunities for upgrading and training .	4	1

2.- Politics and government	Secondary			As a group 3	As a group 4
National government Dharavi become a	External	state government, headed by a Chief Minister	. Rehabilitation of the biggest slum in Asia. . Stimulate the continuous economic grow of India.	1	1
Regional & local government	Secondary	Government of Maharashtra and the Metropolitan Planning Committee conformed.	. Transform Dharavi into world class township. . Undertaking a sustainable development.	3	3
Local representatives	Primary	Nagar leaders; the water comity, the latrine committee, the health committee...	. Strengthening transparency and civic engagement. . Ensure a fair distribution of goods and services.	3	4

3.- . Societal organizations	Secondary / External			As a group 3	As a group 2
Welfare groups	Secondary	PROUD, SPARC, Urban Typhoon group, Slum/Shack Dwellers International, National Slum Dwellers Federation (NSDFI)...	. Contribute with financial support for programmes . . Encourage actively slumdwelers participation in pro of upgrading.	3	3
4.3 Cultural, religious and sporting associations	Secondary /External	Daya Sadan Community Centre, Mennonite brethren bible institute, National Alliance of People's Movement, etc.	. Solidify the multiculturalism of the slum. . Preserving and enhancing the traditional skills (embroidery, henna paint, etc.) . Stimulate more community participation.	3/2	1
The Interest	External	This group includes members like me or other groups of students, or professional interested in Dharavi. Example, urban body group of TUDelft , water experts, etc.	. Acquire more knowledge about slums . . Formulate interesting solutions, more efficient, economic or beauty. . Propose new alternatives to contribute in the process of transformation.	3	2

4.- Media and communication	External			As a group 2	As a group 2
Dharavi media	Primary /secondary	Any open source that is used as a informative media inside Dharavi, such as independent radio, local flyers and web pages (dharavi.org), local journalist...	. Being used as a support and communicator of the measures taken from internal and external organism. . To be the stimulator and active participator for a positive and balanced change.	2	3
National and International media	External	State and International radio, TV and newspapers, internet, books, movies...	. Inform success or failures, justice and injustice during the whole process of transformation. . Make conscious to their users that poverty is facing changes.	1	1

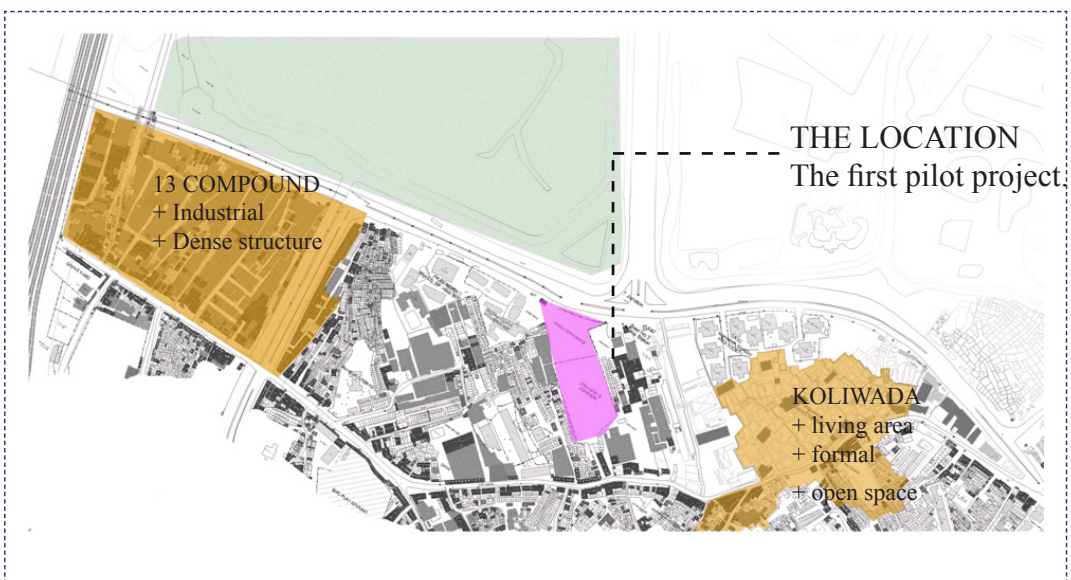


Figure 13; The selected location for develop the pilot project.

GENERAL FLOOR PLAN

Figure 14: General proposal for the pilot project.

Chapter three

Meso phase

Meso phase:

building level

1. Design brief :

The general concept:

For the elaboration of a design proposal in the selected area one important characteristic was summarized:

"The economic system that the area has, based on a series of activities relateed with their cultural origin".

Such as, for example the potter communities from western India (Gujarat), which migrated to Dharavi and made of their craft ability the way to earn their living.

This conceptual idea derives from the wish to organise these "lucrative artisanal occupations" in a way that can be more exposed and accessible to external consumers. The goal is to increase sales, by intensifying the commercialization of their products. If sales increases, income increases and hence living standards will upgrade.

The first proposal consists of the design of a building that will incorporate the most representative craftsmanship of Dharavi. In this way, external visitors can get an overall view of the diverse craft production of the area. At the same time they can observe the production process, they can buy the products or go to the central production area inside Dharavi.

The first architectural element proposed is the so-called "the craft tower". In brief the building will attract new market (consumers) and will exteriorize its content "craft production".

As was explained in chapter II section 1.6 of this report, in Dharavi exist internal organizations in which the different social groups take part. Because there is a latent threat to displace the existing community (redevelopment plan), these internal organizations are intensifying their activities and are trying to work in a more integrated way as one unit, "one Dharavi".

The second architectural element deals with the need that the area has to generate a common space where the community can interact culturally and organizationally. This second architectural element, called “the community center”, is a space in which decisions and cultural activities can take place. This center also generates a physical space to intensify the interaction with other organizations.

The third architectural component is the integrator feature called the “living bridge”. The main function of the bridge is to introduce consumers into Dharavi in a more subtle way.

Due to its condition of slum Dharavi has gained a bad reputation; external people (no slumdwellers) are normally afraid to visit Dharavi.

By introducing a bridge, so by generating a level detached from the ground, the visitor will not have a direct contact with the ground that used to be frightening.

General justifications:

• Intensify identity by reconnecting the original fisher community to their historical roots by giving direct access to the Mahim Creek.

• To give fast access to the new productive area located in the Creek.

• Introduce new market commercial standards by attracting external consumers.

• Reciprocity between settlement and green area. Introduce the Mahim creek into Dharavi (green areas) and productivity into the Mahim Creek (agriculture).

• Flood adaptation by the introduction of a second level of activities.

• Improve flow of mobility by reducing pedestrian crossing.

• More fluid traffic will reduce the sound concentration.

To help the community of Dharavi being upgraded, and not to create an island in an island (Dharavi inside Mumbai), two more conceptual interventions are considered. These elements are:

. the boulevard;
. the productive Mahim Creek area;

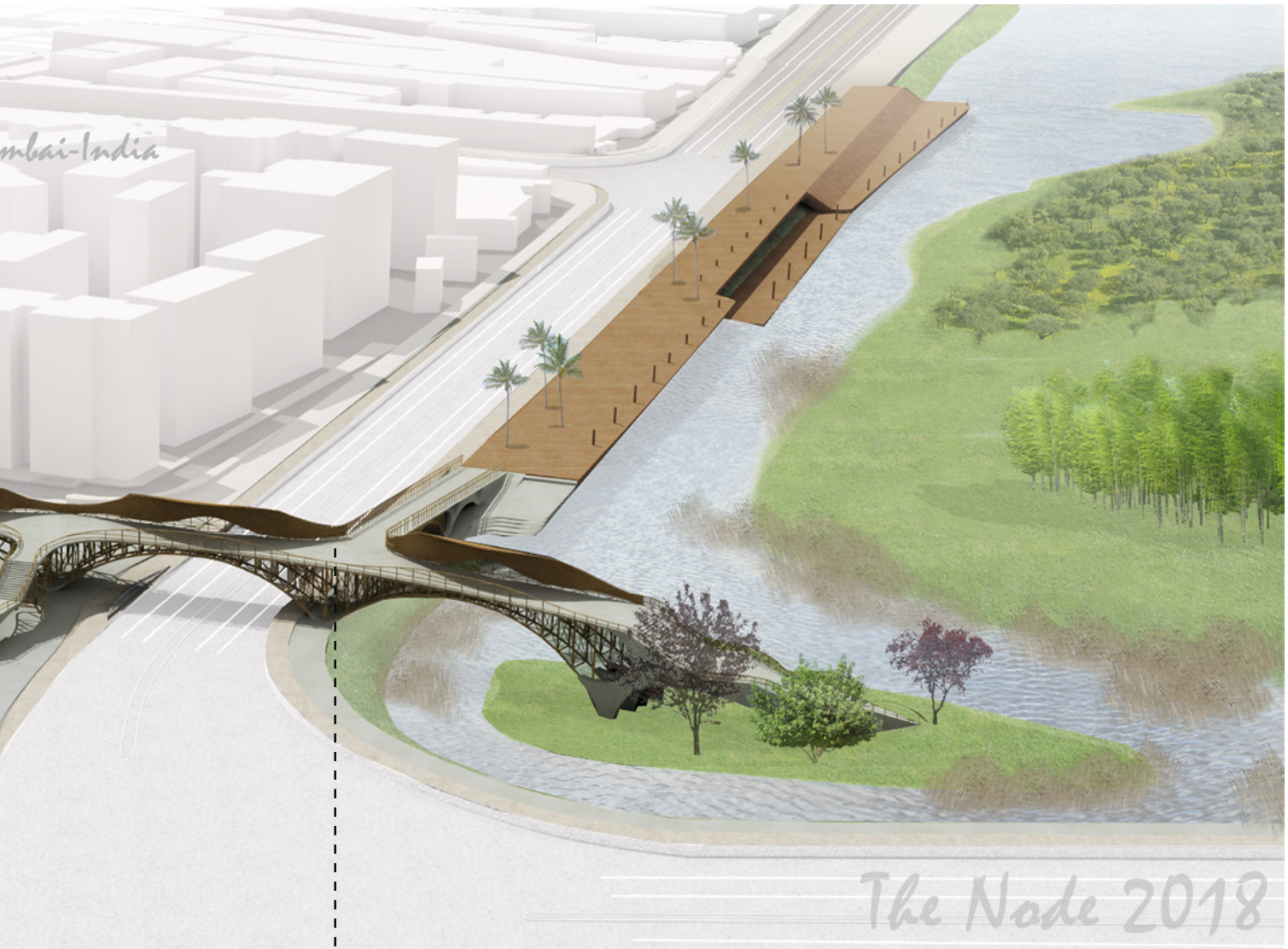
The following graphic shows the integration of these two elements with the pilot project (the first node of Dharavi).

A Sustainable Bussiness Hub

stimulating upgrading by spatial intervention in the embattled ward of Dharavi-Mu

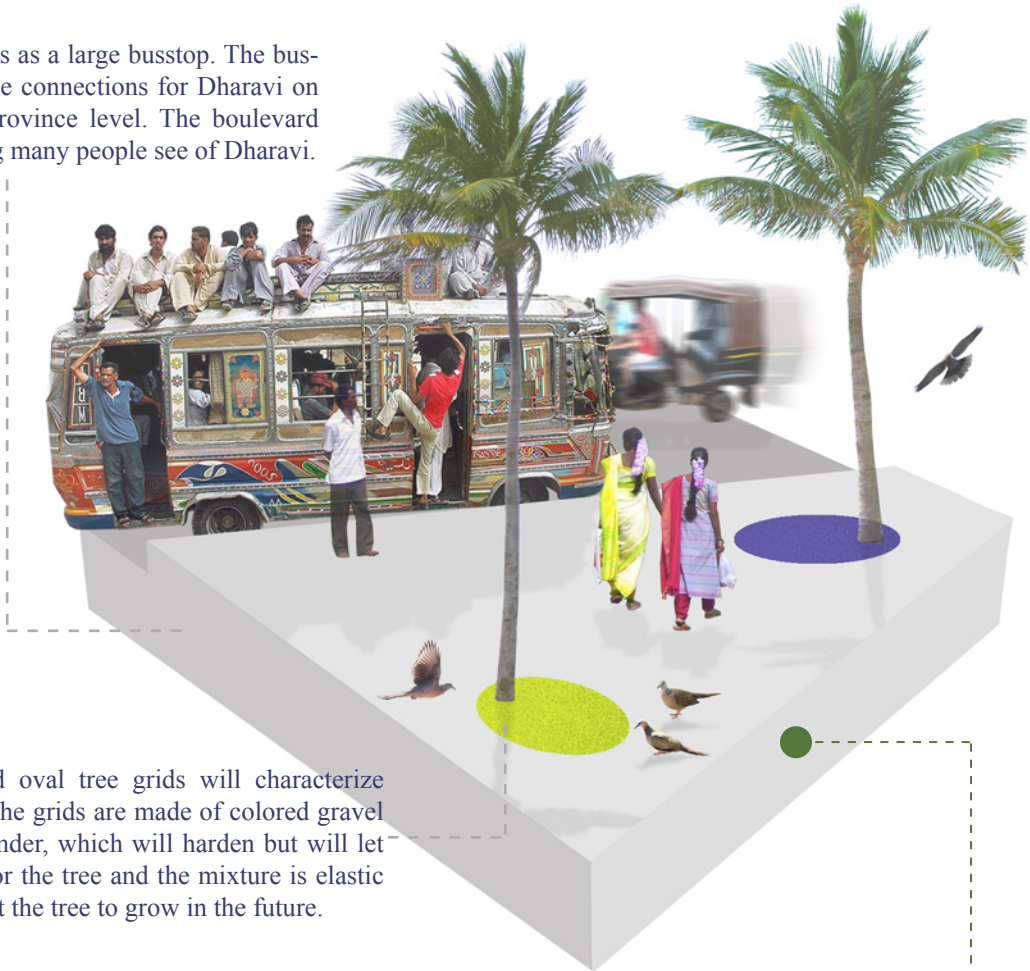
The Crafts Tower

The Community Centre



The Living Bridge

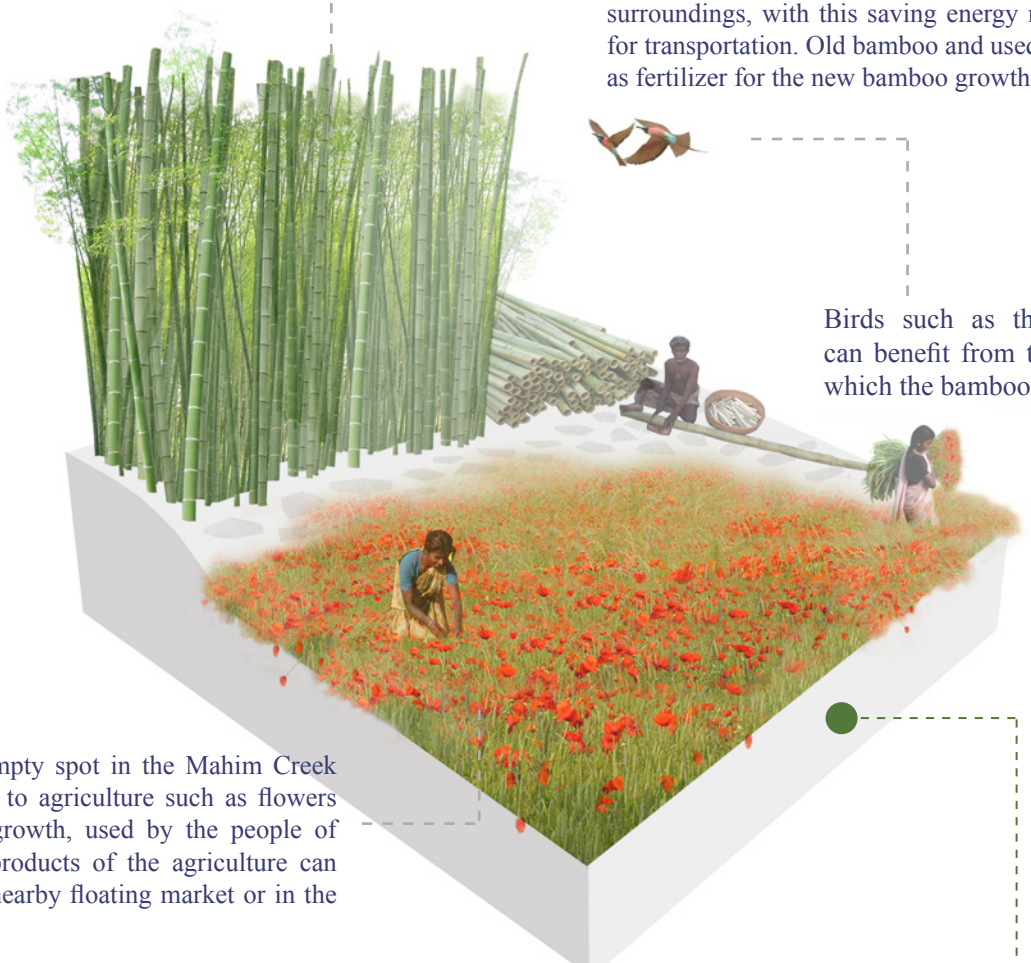
The boulevard works as a large busstop. The bus-stop is increasing the connections for Dharavi on city level and on province level. The boulevard will be the first thing many people see of Dharavi.



Brightly colored oval tree grids will characterize the boulevard. The grids are made of colored gravel mixed with a binder, which will harden but will let through water for the tree and the mixture is elastic enough to permit the tree to grow in the future.

The bamboo plantation will give labour the local residents, creating work. The bamboo can be used for various means, such as construction, in the direct surroundings, with this saving energy normally used for transportation. Old bamboo and used will function as fertilizer for the new bamboo growth.

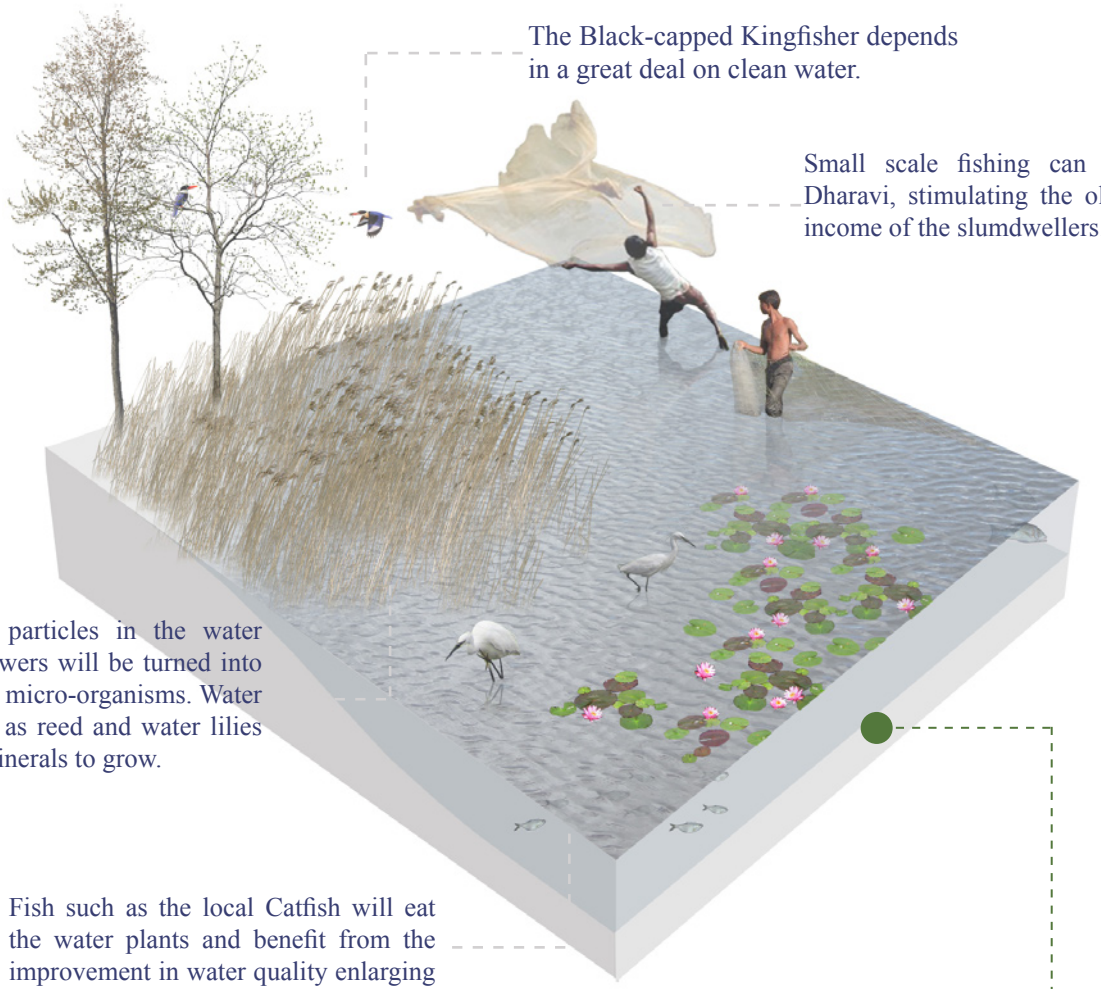
Birds such as the Bea Eater can benefit from the protection which the bamboo forest gives.



The existing empty spot in the Mahim Creek will give place to agriculture such as flowers or vegetables growth, used by the people of Dharavi. The products of the agriculture can be sold in the nearby floating market or in the boulevard.

The Black-capped Kingfisher depends in a great deal on clean water.

Small scale fishing can return to Dharavi, stimulating the old way of income of the slumdwellers.



The waste particles in the water from the sewers will be turned into minerals by micro-organisms. Water plants such as reed and water lilies use these minerals to grow.

Fish such as the local Catfish will eat the water plants and benefit from the improvement in water quality enlarging the biodiversity.

The products of the agriculture can be sold on the floating market surrounding the boulevard.

Large parts of the Mahim Creek are subjected to flooding in the monsoon. To make good use of these areas floating agriculture is introduced. Crops that are commonly grown on the floating islands are ladies finger (okra), cucumber and snake gourds.

Figure 20: The Crafts Tower

2. The crafts tower:

Overall objective:

To design a low tech icon by using local materials such as bamboo and rammed earth.

Specific objective:

To make a space where the craftsmanship of Dharavi can be exhibited and to give space to more intellectual and spiritual matters concerning the local people.

General description:

The crafts building is an eight floors structure which will be used as a show room for the most representative industries that Dharavi has. The top floors of this building are designed for intellectual and spiritual matters, such as documentation about Dharavi and a pray centre.

The floor plans are free to be divided and there are no inner walls in the design. In the centre of the floor plan is the service core with stairs, a lift and a shaft for installations.

On the ground floor is the main entrance and on the third floor a second entrance via the bamboo bridge.

Natural lighting inside the building is provided by the vide in the centre and by the windows in the facade. The windows do not contain glass, but contain bamboo lamellas which can be opened or closed manually and guarantee natural ventilation.

Concept:

The building functions as a billboard to attract consumers and tourists to the area of Dharavi. At the same time it functions as a showroom for the craft production of slumdwellers.

The internal space will work as an interactive place where potentials buyers can observe, buy or even participate in the production process.

The pattern of windows carved into the earth walls are based on traditional Indian henna, to give the building and its expression a local origin.

The inside oid connects all the functions inside the building and shows the craftmanship of Dharavi as a whole.

Technical aspects:

The round shape of the building makes good use the properties of the rammed earth wall, such as its good resistance against pressure forces and to keep tension forces to the minimum. The inside structure of the building which carries the floors is made of a combination of bamboo columns with steel beams and a concrete floor laid on half bamboos.

To make full use of the life expectancy of the different materials it is possible to replace the bamboo columns by new ones, which have a shorter life expectancy then steel and concrete. To make this possible the bamboo is filled with concrete at the end and this forms the connection to a steel plate, which later can be disconnected easily because of the cone shape of the steel. The steel plate can be bolted to the steel beams on which the floor is lying.

The inside of the building is fully detached from the outer rammed earth to avoid problems caused by different properties of the inside and outside structure such as thermal expansion. The building stands on a concrete foundation with a concrete ground floor to detach the building from water coming up from under the building.

Sustainable aspects:

The craft building contains sustainable aspects considering its use and considering the construction materials. It is constructed mainly of local materials such as earth and bamboo, which will reduce the energy necessary for transport and which will stimulate local economy.

Bamboo as well rammed earth are materials that have properties that, if they are well employed, can add passive environmental control to the building in a more economic way. For example, the thermal mass of the thick rammed earth wall will keep the building relatively cool during the hottest period of the year, while at the same time will work as a acoustic insulator. More information about bamboo can be found in chapter four section two of this report.

By placing the 'belly' of the round shape towards the north and the more vertical façade towards the south, sun radiation on the surface is kept to a minimum.

The opening on the top of the building is closed towards the northwest, which is the main wind direction, and opens towards the southeast, creating a draft inside the building up to the roof, ensuring good natural ventilation.

The draft is reinforced by detaching the floors from the outer wall, letting heated air on the south-side pass up along the façade, thus preventing this warm air to go into the used spaces.

At night cross ventilation can be made by opening the windows, which will cool down the building at night and slow down the warming up of the building during summer. Also the build up of heat during the daytime will radiate out at night via the open windows. At daytime the lamellas are more closed and ventilation is reduced to a minimum to keep the hot air and sun radiation outside.

Rainwater is collected in an underground water tank during the summer rainfalls to be used in more dry parts of the year. Before the water is stored in the tank it passes through a sand bed which will clean the water until a certain degree. The water is used to feed the plants in the vide inside the building. These plants will evaporate this water and this evaporation will cool down the building inside during the hot periods of the year.

Rainwater is let inside the buildings through the windows, which do not contain glass but lamellas, and is guided via the outside walls to the ground floor, where it is collected and stored. This path is possible because the floors are detached from the outside wall, so that they do not stop the water on the facade.

The waste water coming from the building and possibly from other buildings will pass through the central natural water cleaning system located in the Mahim creek, before it is dumped into the river.

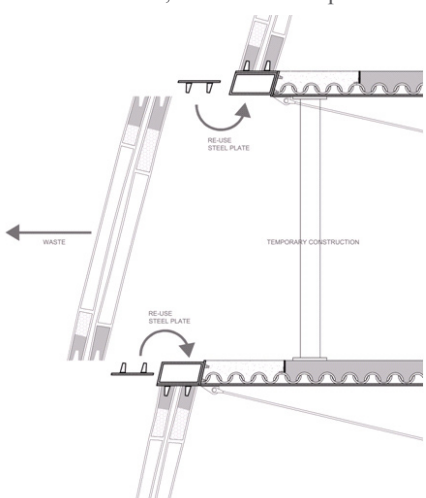
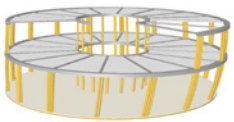
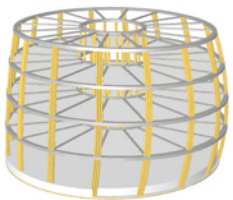


Figure 21: Replacement system of the bamboo columns.



Steel beams connect the bamboo columns.



The floor is made of half bamboos covered with concrete.

Number of columns decreases from the 4th floor.

Rammed earth skin is completely detached from interior structure.

Entrances

Free floorplan

Circulation

Void

Craftsmanship

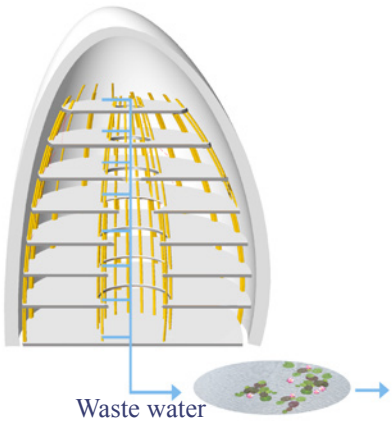
Administration

Documentation

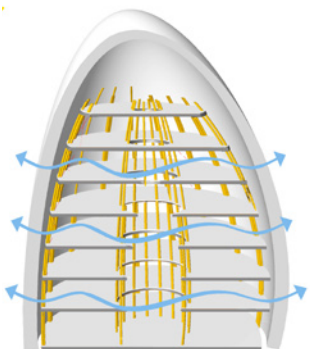
Pray centre

Cooling effect greenery

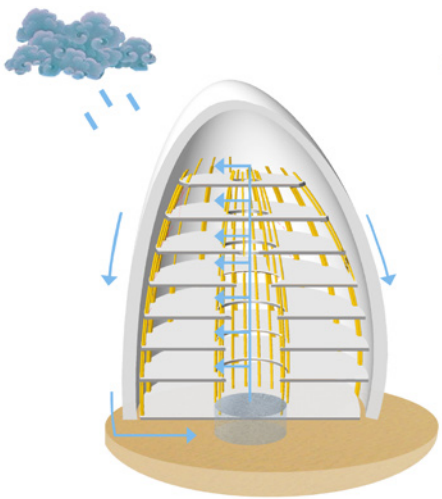
Minimum sun radiation



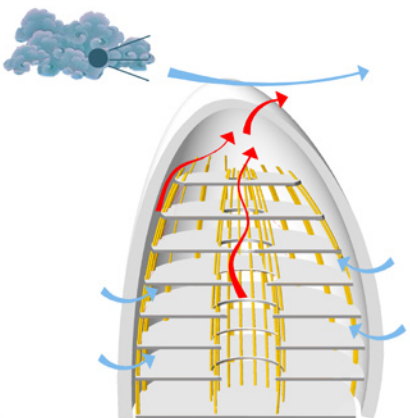
Waste water



Cross ventilation at night



Natural cleaning rainwater



Natural ventilation

Thermical mass

Usage local materials

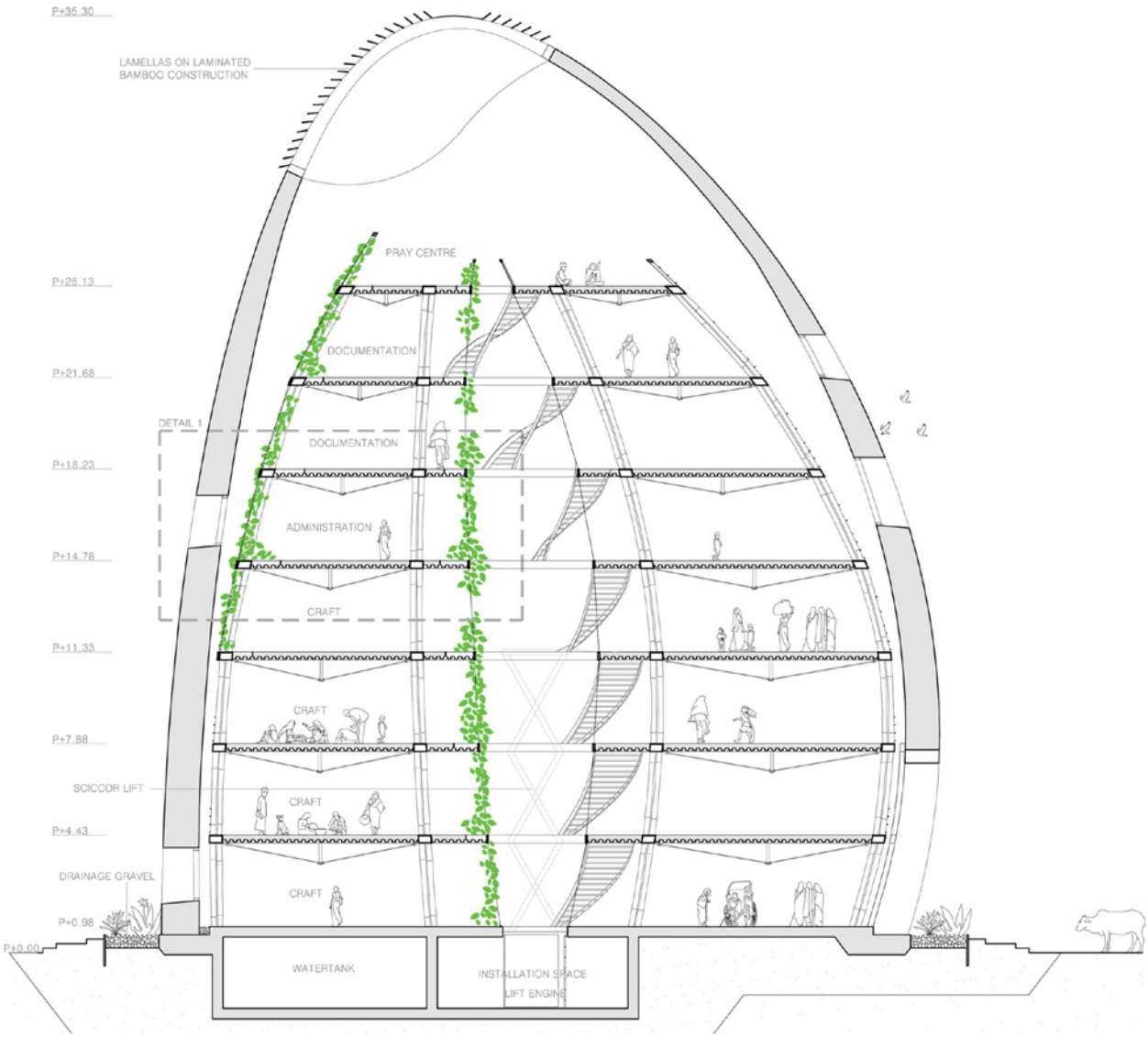


Figure 23: General section of the Crafts Tower

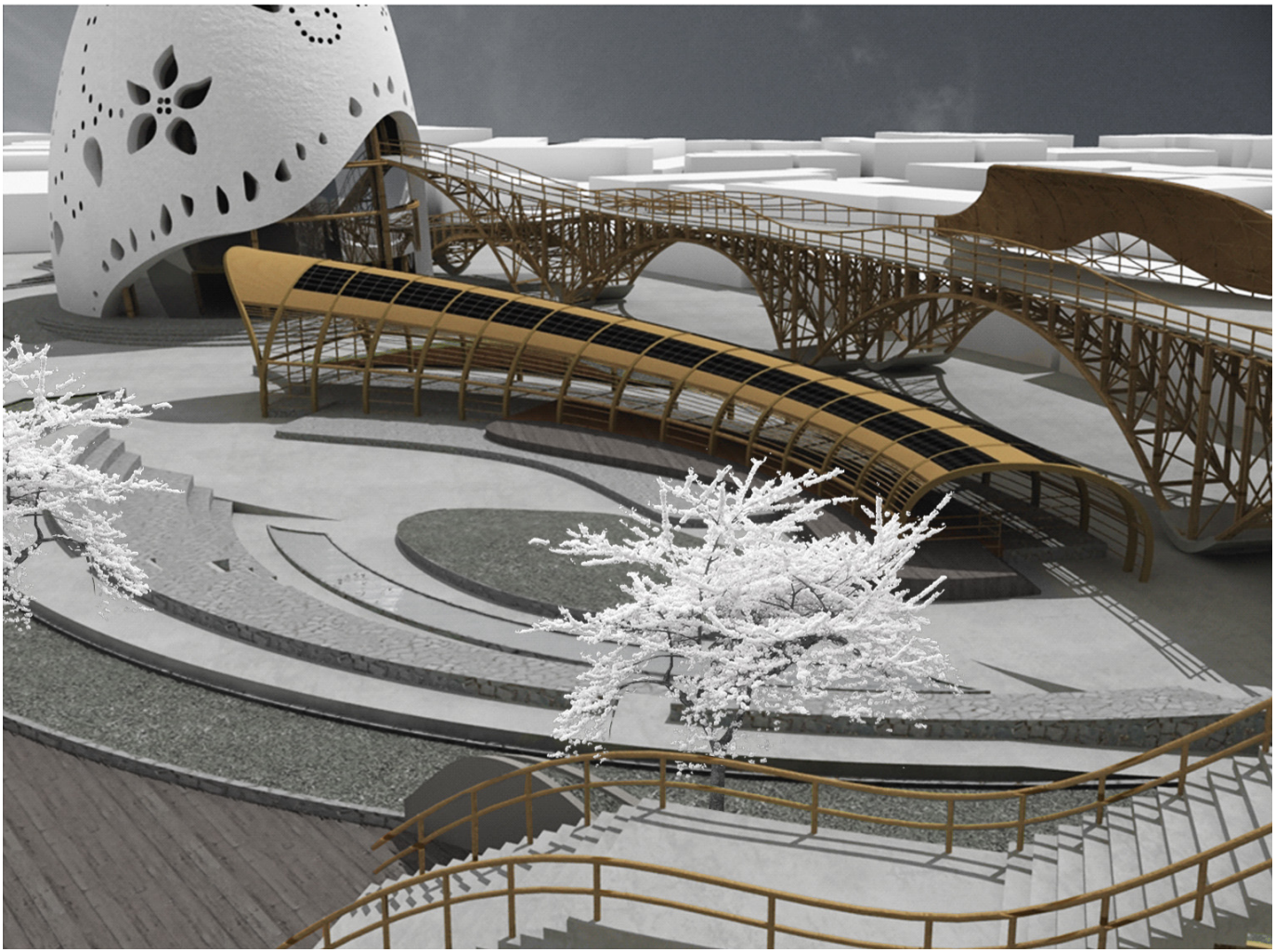


Figure 24: The Community Centre

3. The community centre:

Overall objective:

To formulate the concept phase of a structure that offers flexibility in the use of spaces, while allowing the basic structure to be adapted over time and to the user ‘s desire.

General description:

The community centre is the space dedicated to internal activities of the area, where slum dwellers will get inspiration and take decisions for social changes. At the same time this space will help to preserve their local inheritance and culture.

The community centre is organized in two scales depending of its type of activity. The first scale is the “open air theatre” that allows more massive concentration of people, (approx 500 persons seating) while the second element, the “main hall”, allows a controlled number of individuals (two rooms, 100 persons each one).

The “open air theatre” will be used for cultural activities such as traditional festivals or religious expositions that are common in the area. It can be also used as a recreational or meeting point for outdoor activities. However, the main function of this space is to bring together in one common space members of different communities, allowing the organizational process taking place.

The “main hall” will be used as a learning centre where community’s members can interchange their knowledge or can have grade their products from external experts. The learning process will be done via a series of commercial workshops, where people can learn to produce but also can buy products. This space is more thought for local people while the craft tower is more for external consumers.

The underlying concept:

For acoustical reasons the “open air theatre” will have a curvilinear configuration. To define a more compact unit the community centre will moreover have another curvilinear shape which contents the “main hall”. To allow better integration with the bridge the two mirror curves are displaced from each other,

The first concept of the “main hall” building was to design a massive structure which was conpletely covered by green walls and roof, in this way having the effect of a green hill flowing from the ground.

After a study done about green walls (see appendix two), the impact of the greenery was considered too strong to be used in a low tech project such as this one. The greenery would demand a lot from the structure because of its weight. The present green wall technology[22] is too expensive, and therefore economically not feasible for an underdeveloped area.

The concept have therefore changed into a more transparent and light option. The main hall is conceived as a curved roof which increases its height and width in the corner pointing the craft tower; the intention is to bring the eye view of visitors to this point, highlighting the importance of the craft tower.

The roof will limit its lateral sides with spaces bamboos creating a lamella effect (translucent) of which pedestrians can have fluid visual contact with the activities inside the space.

Building description:

The "main hall" is understood as a curved platform in which spaces are just marked by the creation of different levels. The higher level (+0.80m) functions as an internal atrium for the "main hall", and as an external atrium for the "open air theatre". The lower level (+ 0.60m) is designed for circulation.

The curvilinear structure of the "main hall" covers 600m^2. The structural concept is to use arches, built with the use of spanning principle of portal frames. The arches are made of laminated bamboo and are spaced every 3.5 meters. Its height varies from 4 to 8 meters, thus allowing developed different activities such as carpentry workshops. There also exists the possibility that in the future a secondary floor can be installed allowing more activities taking place.

The structure is closed with half bamboos interlinked. The amount of bamboo will be dense in the top for protection of the rain. Near the ground the density is reduced.

The open theatre is conformed for a seating area and an orchestra. The seating area is organized in a fixed gradient of 1:2 (acoustic and visual reasons), at the back of the stairs is a elevated garden with trees that generate shadow, and with a stone platform that defines the north entrance of the pilot project. The seating area is made of stones in which moss is allowed to grow in the treads.

22 Green wall refers to Living walls are composed of pre-vegetated panels or integrated fabric systems that are affixed to a structural wall or frame.
23 A rain garden manual for South Carolina, Clemson University, February 2009.

The orchestra is located on a low spot below the floor surface. Being covered with grass, this garden will work as a filtration area which will collect runoff water by naturally filtered through the ground.

The infiltrating land is also know as a rain garden. “Correctly constructed rain gardens let nature help with pollution problems. They remove pollutants that otherwise would affect water quality and allow stormwater runoff to slowly infiltrate the groundwatertable. Rain gardens absorb excess nitrogen and phosphorous in stormwater and trap sediment while biological processes filter out other pollutants[23].

Installations:

The pavilion will not contain any other installations apart from electricity and water. It is desire that in the future the solar panels on the south side of the roof will provide energy for the overall project.

As a part of adaptability to the monsoon seasons it was decided to elevate the floor 60 cm, space in which installations will run.

Figure 25: Section of the Communal Centre.

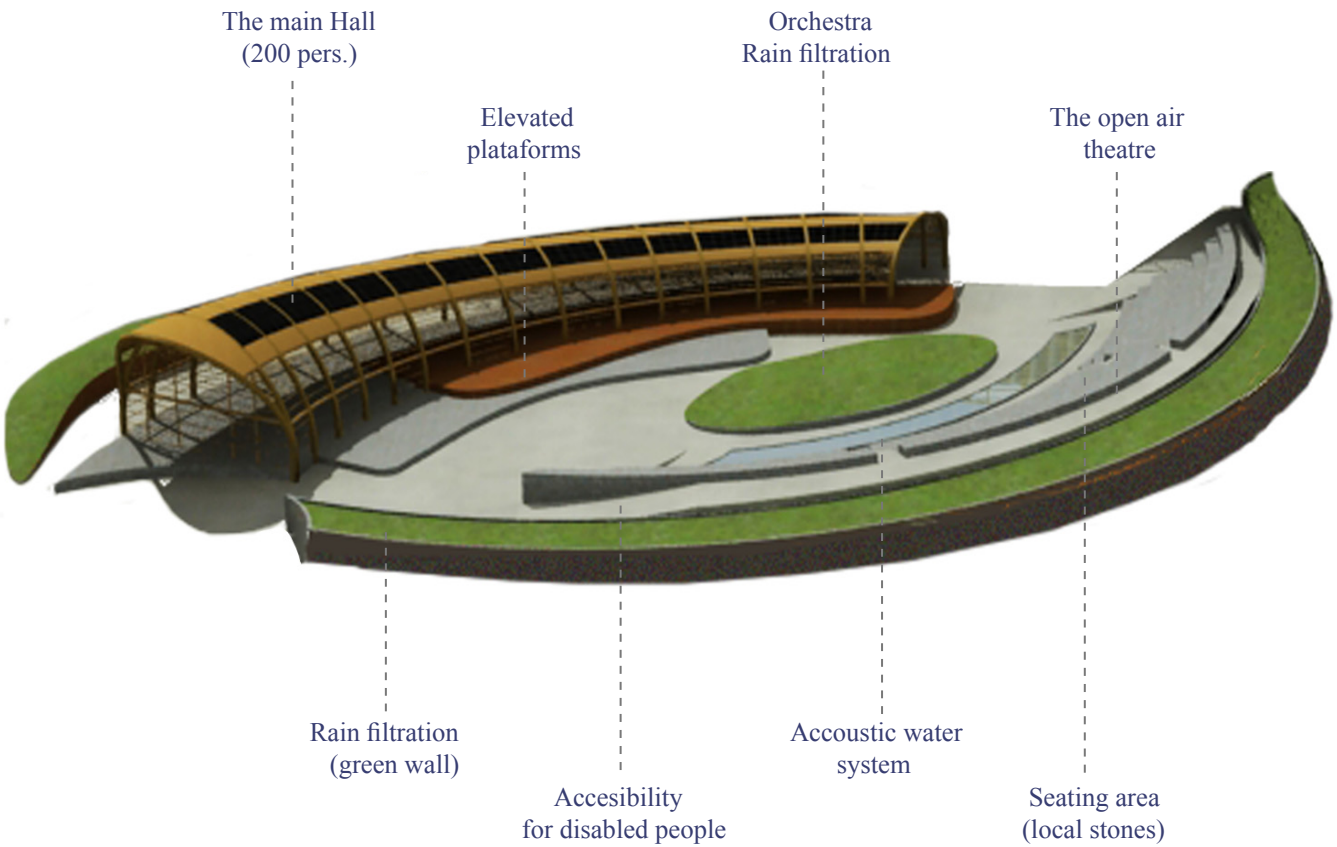
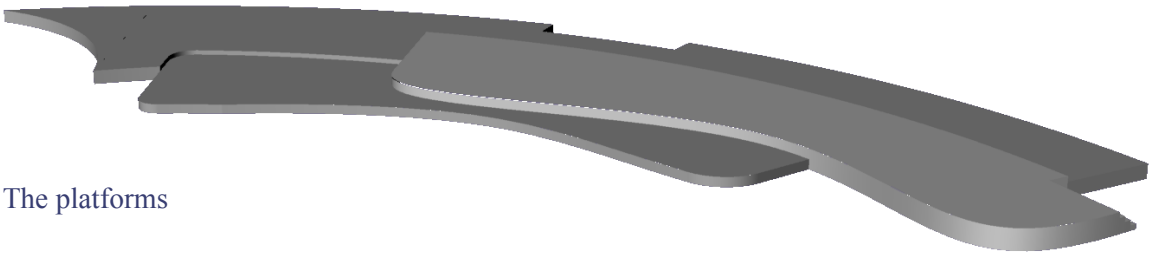
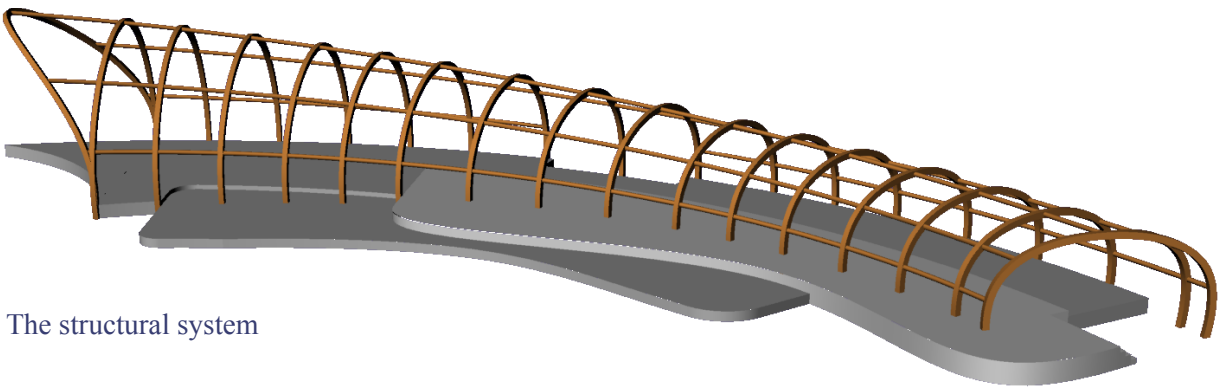


Figure 26: Elements of the Community Centre



The platforms



The structural system

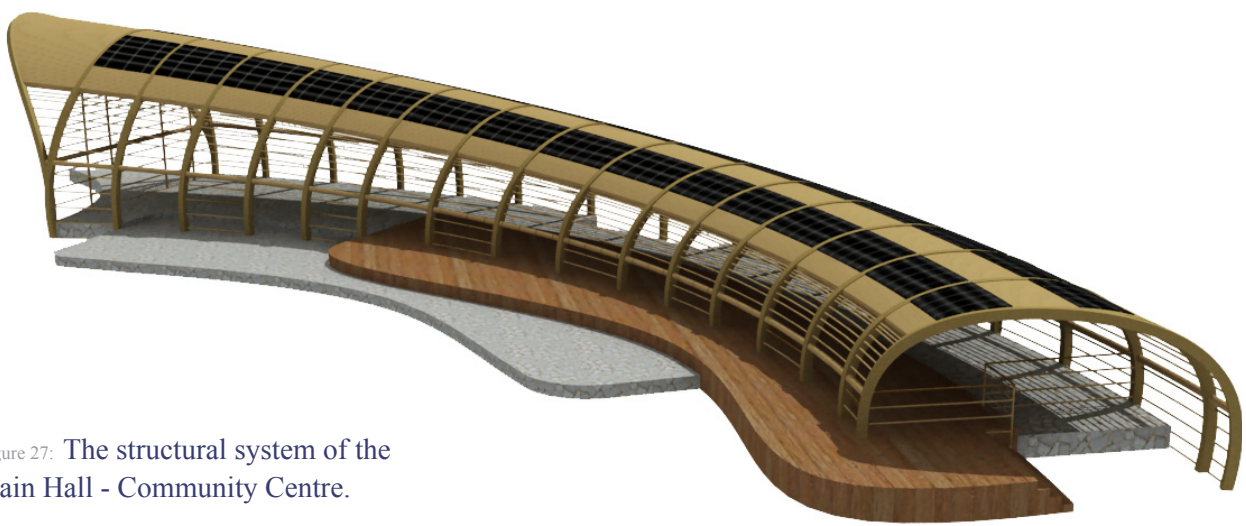


Figure 27: The structural system of the main Hall - Community Centre.

Figure 28: The Living bridge

4. The living bridge:

Overall objective: To design a pedestrian bridge that is both economically feasible and aesthetically pleasing.

Specific objective: To provide a spatial intervention that will be built and maintained by the people and at the same time:

. made of materials that minimize costs and environmental effects,
. keeping life cycle costs low,
. consider relevant aspects on health and comfort,
. structural systems easy to deconstruct and be adapted by the time.*

*Adapted by the time means that extra connections can be integrated or eliminated depending of the necessities of the context and the users.

General description:

The living bridge is configured by a central axis that connects Dharavi with the Mahim Creek and sub modules that interconnect the bridge with other points of interest (exit-entrance). The structure will create different spaces (over and under) allowing various users to generate diverse activities over it (market-resting-meeting-view points).

The concept behind:

The configuration of the bridge emerges from a definition of points (places of interest) that needed to be connected. The connections generate a constant flow of users and services over the bridge. Schematically, the flows define curves and these curves define the horizontal path of the bridge.

The width of the bridge is defined by a series of activities that are proposed on it, such as commerce, recreation, etc.

The height of the bridge is determined by the height of the surrounding access and the need to allow more natural light and air under the bridge, (save energy, quality of space and well-being)

The roof generates the shadow spaces needed to allow the development of activities over the bridge, while at the same time it protects the bamboo structure from the rain.

The Design Process:

The design process started with handmade sketches of different patterns of flows, access and functions. The sketches where translated in three dimensions with the use of Rhino and Bentley GenerativeComponents Program,. During this process concepts of cost, maintenance and structural systems where formulated.

Having obtained a functional, aesthetical and structural agreement of the overall bridge, the calculations took place with the Diana program.

*GenerativeComponents permits to model a parametric design in which different parameters are established to allow the remodeling of changes more easily and visually.

*iDiana allows getting an overall understanding of the structural behavior of the module to be used in the bridge. This program has been used as a technical tool to optimize the bamboo structure.

Technical description:

Dimensioning:

. Central axis: The bridge core consists of five modules of 37.67m main span; its width varies from 7.60 to 9.60 meters. The vertical clearance is 6.38 m and the total height is of 7.58m.

. Access ramps: The access ramps vary from 6 to 8 m wide with a slope of 6°, allowing easy access for elderly and disable people, while at the same time it allows easy transport of goods from one point to the other.

. Stair cases: The curved stairs are adapted with a lateral ramp system of 2 m wide, for a total stair width of 6 meters.

. Handrails: are provided on both sides located 860 mm above ramp surface. A second lower handrail is also being considered for both sides.

. The roof: The width of the roof is the same as the span of the modules (37.67m). Its height is around 4.50m

Materialization :

.The structure: All the other structural elements are made of 8 till 10 cm diameter bamboo tubes, except for the internal roof grid that is made of 6 cm diameter bamboo tubes.

Bigger sides are not recommended for structural elements due to that the material becomes more brittle, for more information see chapter Four point two: “Materialization”, of this report.

. The flooring: is made of half bamboos of 10 cm diameter covered with a layer of cement mortar of 4cm.

. Roof: the internal structure of the roof is of 6cm bamboo tubes, covering with bamboo mats, a water proof membrane and finally a mix of cement with rammed earth of 2cm is applied. Detailed information in chapter Four point two: “Materialization”, of this report.

. Connections: bamboo connections are mainly made of steel rods filled with mortar and reinforced with 2 to 5 mm thick galvanized steel wire. For more information see chapter Four point three: “Connections”, of this report.

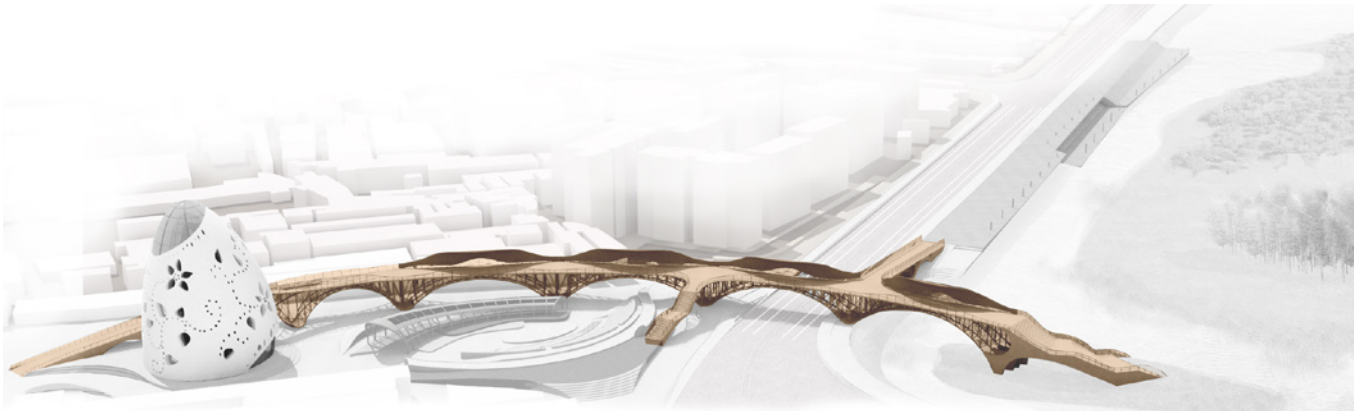
. Finishing: To prolong the life span of the bamboo structure three measures have been taken:

1.Keep the bamboo dry: the whole structure has been elevated from the ground via concrete piers (see the abutment pier detail).

2.The bamboo is previously protected via chemical method of preservation, with a boron-based fertilizer Na2B8O134H2O (disodium octoborate tetrahydrate)*

3.The bamboo structure is protected regularly with natural bamboo oil that can be produced by the same members of the community.

* An advantage of using this chemical is that there is not waste at all, once it has been used in the preservation process for some time and is mixed with starch and sugar from the bamboo, it can be applied as a fertilizer. For more information see chapter Four point two: “Materialization”, of this report.



South view.

The living bridge...

West view.

Figure 29: 3D views of the Living bridge

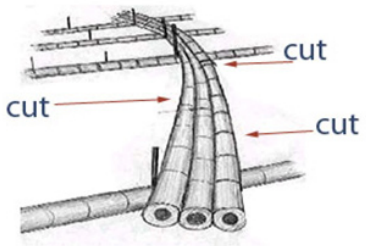


Figure 1: Arch formation

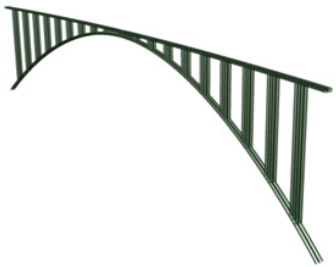


Figure 2: The frame

Figure 3: The rigid arch frame

Figure 4: Two rigid arches

Figure 5: The perimeter

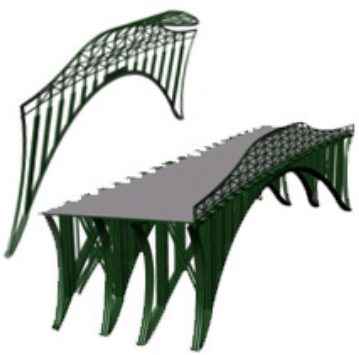


Figure 6: The module

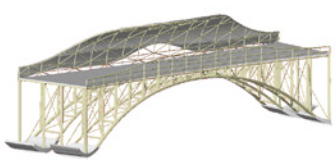


Figure 7: module base

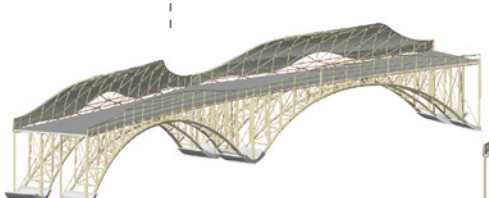


Figure 8: two modules

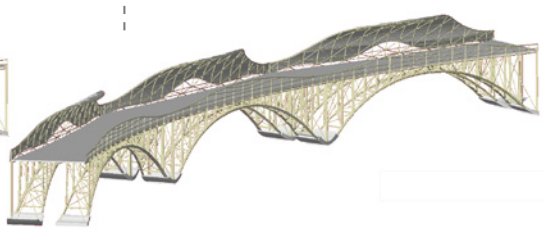


Figure 9: Three modules

Figure 30: 3D views of the Living bridge

Chapter four

Micro phase

Microo phase:
detail level

This chapter is concentrated in the pedestrian bridge that is composed of a curved flat platform and three lateral inclined sub-connections that give the accessibility.

1. Structural analysis :

Overall objective:

For the complexity that developing a bridge implies, the following study will formulate a structural logic overall plan for the total bridge, and a more deep analysis of the structural behavior will be carried out exclusively for the central axis of this one.

Analyzing the overall bridge:

The bridge has undergone different re-adaptations. The first conceptual sketches of the bridges suggested a more organic shape. However, due the challenge to make a bamboo bridge, constant reconfigurations to the original concept have been carried out.

Analyzing the first drawings of the bridge we can observe that the use in the design of flat curve platforms generates a concentration of stresses in the center of the curve. What can be expected?

. The center of the curve will tend to go down. If the curve is constrained at its end, the center part will be the first that collapse; if it is not constrained the whole structure will rotate.

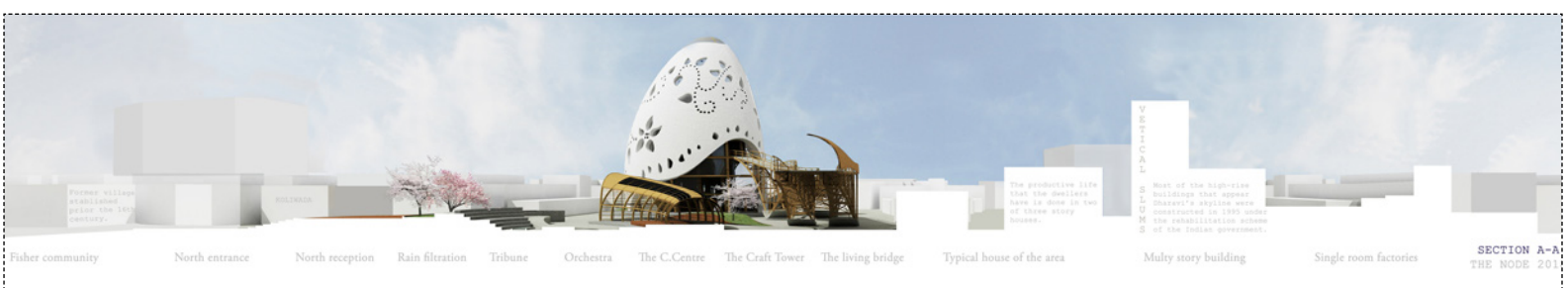
. Increasing the numbers of supports towards the center, the collapse area will be reduced but the tendency to rotate will stay latent.

A study of Curved Bridges from the Illinois Institute of Technology[24] reveals that the bending moment in girders of a curved bridge can be about 23.5% higher compared with moments in girders of a straight bridge of similar span and design configuration. As a result of the curved geometry of the bridge, a torsion moment is developed in the girders. The magnitude of this moment was found to be about 10.3% of the maximum bending moment of a comparable straight bridge.

24 Analysis of Horizontally Curved Bridges Using Simple Finite-Element Models, by E. DeSantiago, J. Mohammadi, H. M. O. Albaijat, Illinois Institute of Technology, Chicago,2005

Figure 31: Section of the Master Pilot Project.

ne C.Centre The Craft Tower The living bridge Typical house



How to solve this problem?

Modern solutions in the elaborations of this type of bridge suggest solutions such as the one observed in the the Gateshead Millenium bridge where the horizontal curve is supported and stabilized from above by suspension cables that are attached to the vertical parabolic arch that makes it the counterbalance.

Another suggestion is given by McDowel + Benedetti with the Castleford Bridge in which twinned double steel columns in a 'V' formation received box steel beams where the double curved platform is attached. Another innovative idea by R. Gary Black from the University of California proposes to suspend the curved deck by cable stays from a tower which is raked to balance the forces of the weight of the deck and the traffic.

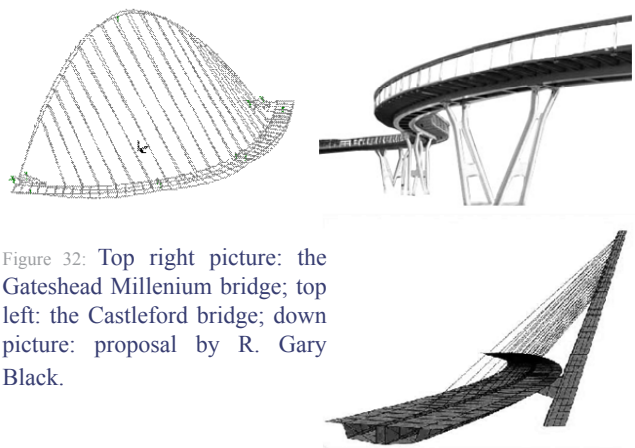


Figure 32: Top right picture: the Gateshead Millenium bridge; top left: the Castleford bridge; down picture: proposal by R. Gary Black.

The structural proposal:

All the suggestions previously mentioned are interesting solutions for a horizontally curved bridge; however the bridges use material and technology that allow these type of solutions. In the case of the proposal of a bamboo bridge the following measures were taken:

1.The structural element will be divided in two parts: the access-exits and the central platform, called central axis.

2.The access-exits of the bridge, because of its direct contact with the ground, will be assumed to be a self sufficient structure, and independent from the central curve axis.

3.The central axis will be divided in five modules, each one has to work structurally independent from each other.

The central axis:

The 189 meters of the central axis are divided in five modules of 37.82m. Each module is composed of two rigid arch frames, an abutment pier at each end, a roadway, and a perimeter (rail, wall or roof).

The access-exits of the bridge:

As it was mentioned in the previous chapter the sub-connections are independent structures that are standing on their own and only are attached to the central axis by a roller support connection.

These structures are designed using the same principle of arches, however were the ramp or stair makes contact with the ground the structure changes to a system of concrete and local stones (blue stone) already used in the area. To add an extra living look creeping thyme or moss is allowed in the spaces between the treads.

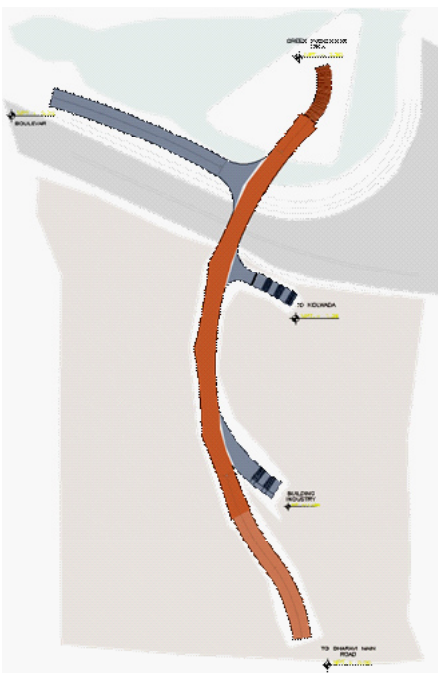


Figure 33: General configuration of the bridge

Structural behavior:

General analysis:

The module is designed as a self supporting structure; this means that each module as a whole is able to resist the forces acting upon it, in that way the module will work structurally independent from the next module and will not need any external support to be stable.

There are four principal structural elements in the module: the deck or platform; the spandrels (vertical elements) that distribute the weight on the deck to the arch below; the two rigid arch frames which transfers the stress of gravity (the traffic load) outward toward the base of the arch; and the supports called abutments that absorb all the coming pressure from the arches and transmits it to the ground.

Why the selection of an arch?

In the search of finding structural elements that cover spans over 30 meters[25] and can be manufactured with bamboo, arches are a structurally efficient option reducing their maximum stresses to half of those in the lintel,* and also have an esthetically pleasant shape easily integrated with the other proposed building elements[26]

* Because of its curvature, arches combine the advantages of bending (which is typical of frame elements), plus the advantages of compression (as in columns), and that the two mechanisms contribute to resist external loads normal to the middle line of the arch.

According to structural type the proposal arch is classified as a simple curved arch with an optimum ratio of 1/5 and combined type of supports at its end.

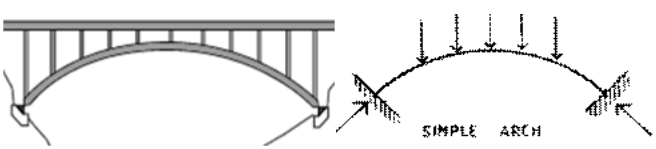


Figure 34: The left picture shows the structural configuration of the bridge, the picture on the right shows a diagram of forces of the arch (load and reaction forces).

25 The constrain to cover span over 30 meters was established by the need to go clean over the front road (26 m)and the river (12m) without any extra support.

26 The other building element refers to the communal center and the craft tower, both proposals of the graduation project.

Finite element analysis :

To have a better understanding of the structural behaviour Finite element (FE) method had been used.

Objectives :

a. Verify if the deflection fulfill the criteria.
b. Verify if the stresses fulfill the criteria.

•Process :

a. Import the axis of the geometry into Diana.
b. Determine meshtype, properties, load and boundary conditions.
c. Calculate
d. Verify the criteria.
e. Improve the prototype.
f. Repeat the process (step a)

•Process :

Analyses type: Struct_3d

Definition of sets: the sets are groups of elements that have a common characteristic. In this case nine sets were made differentiated by their physical properties, meshing type and z direction[27].

Mesh type: The mesh types selected are all elements with the beam element CL18B (needs three nodes for every element), except for the truss element in which we use the mesh type BE3 l2TRU with 2 nodes (division 1).

Material properties: two materials were selected, bamboo and steel. It was assumed that in this occasion bamboo is an isotropic material[28].

	Bamboo	Steel
young modulus	2.000000e+04	2.100000e+05 N/mm^2
poison ratio	3.200000e-01	3.000000e-01
density	7.000000e-06	7.700000E-04 N/mm^3

Physical properties:

PIPE	2.000000E+02	2.000000E+01 (bamboos)
PIPE	9.000000E+01	8.500000E+01 (steel)

Loading conditions: two types of loads are considered, live load and dead load. For the dead load diana program will automatically calculate the weight of the structure by multiplying the given density by calculated volume of the structure. The density includes the gravity factor (9.81 m/s2) and is given in N/mm3.

Load case 1 (LC1): 9.81mm

Live load: Bridge design standards specify the design loads, in the case of this design proposal located in Mumbai, the Indian Road Congress has specified standard design loadings for Foot Bridges.

For the effect of this bridge, a crowd loading is considered, in this effect the Indian Road congress determines that a live load including dynamic effects should be taken as 5.0 kN/m2 of the footpath area. (0, 005 N/mm2)

Supports: The module is constrained in each end of the arches. Each end of the arches is constrained at two points, the first point is where the module makes contact with the ground, the second point is where bamboo meets up with the concrete. All constraints are selected as pinned support.

Post processing: Results

For a better understanding we are going to divide the structure in two parts:

a. The roof: all elements over the road way.
b. The base module: all elements under the roadway.

The first results to examine were the displacement. In picture number 21 the displacement is shown in the tree directions (x-y-z).

We can observe that in the three directions the displacement in the base module is near zero, thus it can be assumed that we have zero displacement.

In the first calculation was observed that the roof has big displacements, the biggest one in the z direction with 984 mm, followed by the y direction with 585mm and 10.5mm in the x direction.

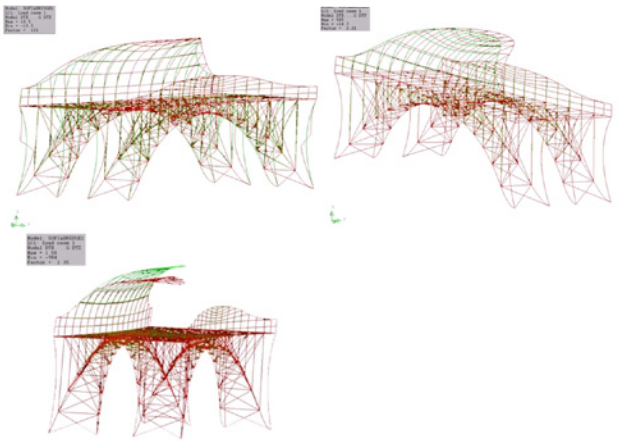


Figure 35: Displacement by applied load LC1 and force. In the up-right picture the diagram shows the displacement in X direction; up left picture shows the displacement in Y direction and the down picture shows the displacement in Z direction.

The second result presented is related with the support reactions. In picture number eight the support reactions are shown.

We can notice that the highest reaction forces occur at the end of the arches, where the module will meets with the ground. Their peaks are found in the inner arches with a value of 140000 N.

In the picture below we can see how the supports react when the load is applied. We observe in red colour that there exists a displacement of the external structural elements towards its x direction, and slight displacement in the y direction. At the ends of the platforms also is observe that the load will cause stresses .

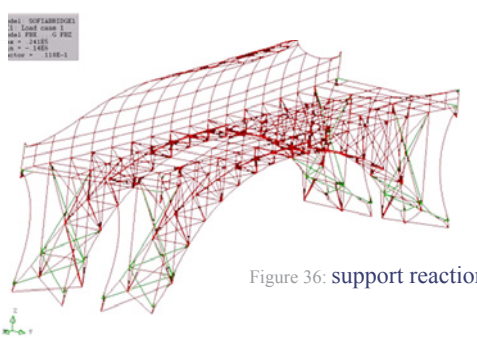


Figure 36: support reactions displacement.

27 There exists a limitation in the Diana program that does not process the information if the geometry z axes of the geometry coincide with the general z axis, the set created allows changing this coincidence through the dat. file.

28 An isotropic material is a material that behaves the same in all directions; bamboo is an anisotropic material, so it behaves different along the direction of each axis. If you specify bamboo as isotropic material you can't trust the shear stresses, however for the trusses it is no problem because we are looking for a structure with as little bending and shear as possible.

Post processing: Discussion

For the results obtained in Diana we can define that there are two points to pay special attention:

1.the roof: this has a displacement of almost one meter in the z direction;

2.the supports: that have a maximum reaction force of 140000 N.

1.The displacement of the roof is caused by a concentration of forces acting on the border of the roof (see picture below). These forces are causing the roof to rotate around the x axis.

We need to apply a counter force that restrains the displacement.

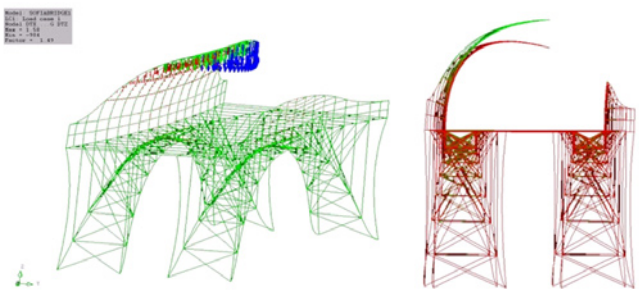


Figure 37: displacement of the roof caused by a concentration of forces acting in the border of the roof .

A fast solution will be to add a column. The column has to be of a light material that can work in compression to transport the load of the roof and in tension to hold it in case a load is applied for under such a wind. The alternative explained is not aesthetically attractive, so it will not be taken into account.

The first module calculated was designed with a periphery of steel material considering that this will help the stiffness of the overall roof. It was observed however that using steel the load was increasing, hence the displacement increased.

So the first action was to change the periphery of the roof from steel to bamboo. By this change the displacement was reduced by almost 90%. To increase safety in the roof, it was stiffed with transversal trusses trough the overall roof. In this way the roof is treated more as a lattice shell structure.

2. The reaction support shows that the highest reaction forces occur at the end of the arches, this means that because of the loading the stresses in an arch increase towards its end. This can cause that arches will spread apart and the whole structure collapses.

What we need to do is to apply horizontal forces that can absorb the pressure that the arches exert. In this way we can push back the side of the arch and prevent it from spreading apart.

A first input in Diana was done by assuming that the two displacements are restrained (hinge supports) but the calculation crashed. The Diana program assumes that the structure was unconstraint. Hence the decision to restrain all degrees of freedom in the support. However, after running the first calculation in Diana all the constrains were changed for pinned support.

If we have the calculation assume that all the supports are fixed the result will be not realistic because if the four supports are restrained in all their directions the material will not be allowed to expand and if a material is not allowed to expand it will break and the whole structure can collapse. Another important aspect to mention is that to built fix supports is more expensive than hinge supports, so if we consider the area where we are building, an expensive solution is not an option.

Considering the supports are being pinned we assume that they will resist vertical and horizontal forces and allow rotation. However, because the horizontal curvature of the module introduces a rotation around its X axes, we need supports that take account of that rotation.

The alternative presented is to pin the supports by two points, the first is the support in the module that makes contact with the ground and the second point is where bamboo meets with the concrete. Both points react in opposite direction creating in this way a moment that will takes the rotation.

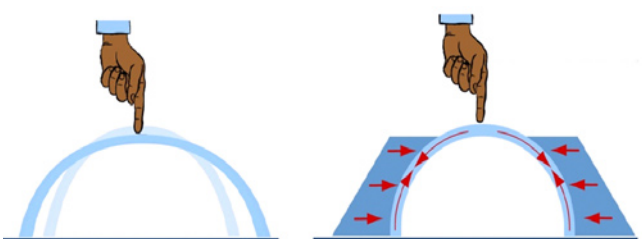


Figure 38: a) state of deformation, b) stopping the deformation.

2 .Materialization : BAMBOO AS A MAIN ACTOR

Why bamboo was selected as a part of the construction material for my graduation project?

Besides the advantages that bamboo holds as a sustainable material, there are four reasons why it was selected as a construction material for the graduation project.

Firstly, availability. The location where the graduation project is developed has a great abundance of bamboo. This raw material is integrated as a useful tool to set up the proposed design.

India is the second richest country in bamboo genetic resources after China. These two countries together have more than half the total bamboo resources globally. The forest area, over which bamboos occur in India, on a conservative estimate, is 9.57 million hectares, which constitutes about 12.8% of the total area under forests.

Secondly, cost. Because the owners (slum dwellers) do not possess the economical resources to develop this project and because the economical support from the part of the government is limited, it is important to reduce costs in all possible ways.

Bamboo within the world of construction materials has been always perceived as a low cost product, for example: a small project at Vigyan Ashram (Pabal, Maharastra) calculated that the cost of a simple reinforced concrete home with a corrugated metal roof for a family was around Rs. 21,000. If a comparably sized home was constructed predominately from bamboo it would only cost Rs. 8,000.

Thirdly, local knowledge. Bamboo has a long tradition in the Indian community, tradition that has been used for a variety of purposes, from paper manufacture till housing. The slum dwellers of Dharavi come from communities with a broad knowledge in the use of Bamboo, knowledge which turns out to be interesting to be applied as a building method.

Fourthly, potential. The last years the interest of the bamboo sector has been witnessing substantial growth worldwide. Interest that is diversifying the uses and applications of this raw material. New uses such as bamboo flooring and panelling are growing the global demand for bamboo, reason why the government of India is looking to develop a bamboo-based economy in the country.

The country today exploits just a tenth of its bamboo-producing potential. The commercial consumption of bamboo globally is worth around $10 billion, which is expected to reach $20 billion by 2015.31

1. General aspects:

Bamboo is an ever green plant and a member of the family Poaceae. Poaceae or Gramineae is a family in the Class Liliopsida of the flowering plants (see table one). Plants of this family are usually called grasses. Communities dominated by Poaceae are called grasslands; it is estimated that grasslands comprise 20% of the vegetation that cover of the earth. This family is the most important of all plant families to human economies: apart from bamboo it includes the staple food grains grown around the world, lawn and forage grasses.

Bamboo is the largest and most productive member of the grass family; in general it can grow up till 5cm per hour, the height of the bamboo vary from 10cm for the smallest species till more than 40m for the largest one. Its form of a slightly conical tube and the outer diameter can vary from 3cm to 30cm depending on the species and can reach a wall thickness of 10 mm.

Bamboo in India has traditionally been used for paper manufacture, scaffolding, construction material and handicrafts. Now there is more diversification such as bamboo flooring and panelling, though only a few people are doing this work

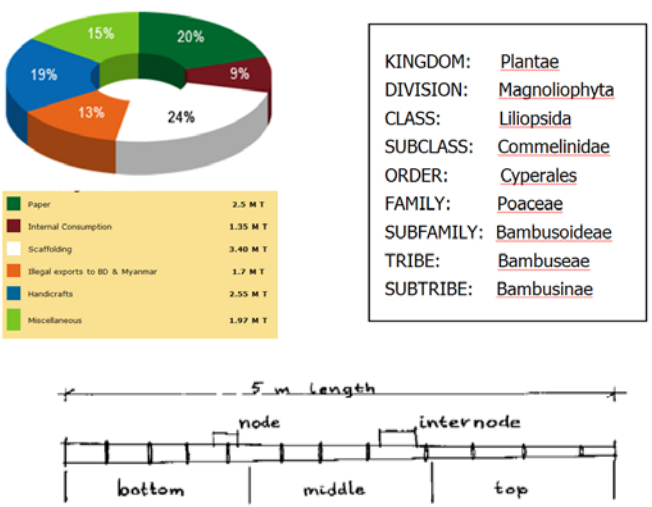


Figure 39: a) common uses of bamboo in India by percentages
b) identification of bamboo parts.

Physical properties:

Moisture: moisture content of a living culm ranges widely (70%-140), as the chemical composition of the culm, the moisture varies according to according to the species, age, culm part and growing conditions.

Culm moisture influences its strength properties, its biological resistance and its treatability. When all the liquid of the culm is evaporated the fiber reached its saturation point (FSP). Strength properties are higher in a dry condition (maximum saturation point), than in a wet conditions where the bamboo has higher probability to fungal attack.

Density: the density of the bamboo is in a range of 0.40~0.9gr/cm3. This mainly depends on the density of the vascular bundles and their composition. As a rule, the density of a bamboo stem increases from inner to outer part, and from lower to upper part.

The density of inner layers of stem wall increases with the grow of the stem and thinning of the wall, while the outer layers only change slightly. The density of nodes are higher than the density of the inner nodes11.

Drying - shrinkage: Bamboo requires longest periods of drying in comparison with timbers of similar density. When the process of drying starts the bamboo shrink. The longitudinal shrink of the bamboo is minimal but the crosswise shrinkage is greatest.

Mechanical properties:

Bamboo, similar to wood, is a kind of heterogeneous and anisotropic material. Therefore its physio-mechanical properties are extremely unstable, in some respects more unstable than wood.

The mechanical properties of bamboo depend on:

- the botanical species itself;
- the moisture content;
- the position along the culm (top or bottom);
- the positions of the nodes and the internodes themselves produce different characteristics.

In general, the properties of bamboo drop from the top portion to the bottom. The increase in weight is cumulative and directly related with age of the speciment.

Comparison with other materials:

The table below was part of one of the reports of the German journal ”DB magazine” . This table shows a comparison of different properties between spruce, bamboo and steel.

kN/cm²	Spruce	Bamboo	Steel (St37)
Elastic Modulus	1100	2000	21000
Compressive strength	4,3	6,2-9,3	14
Tension strength	8,9	14,8-38,4	16
Bending strength	6,8	7,6-27,6	14
Shearing strength	0,7	2,0	9,2

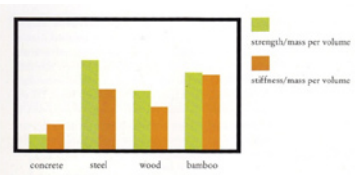


Figure 40: left: comparison (DB, Deutsche Bauzeltung magazine 9/97) Right: Strength and stiffness comparison diagram by J.J.A.

The result is not too difficult to predict, bamboo is stronger than spruce but not as strong as steel. But what it is important to remember is that in certain cases and under certain conditions bamboo is stronger than steel in tension and in bending. Bamboo has also higher strength over weight ratio than wood, and its great bending capacity makes of bamboo a material suitable for earthquake areas.

Other comparison between the materials is shown in figure 53. The diagram answer to the question of how much strength and stiffness (resistant against deformation) does concrete, steel, timber or bamboo give?, the diagram shows that, as far as strength is concerned, concrete is the worst, followed by timber, steel is the best and bamboo is the second best. In relation with the stiffness, the fourth place is for concrete, third for timber, second for steel and the first place is for bamboo.

Important design considerations:

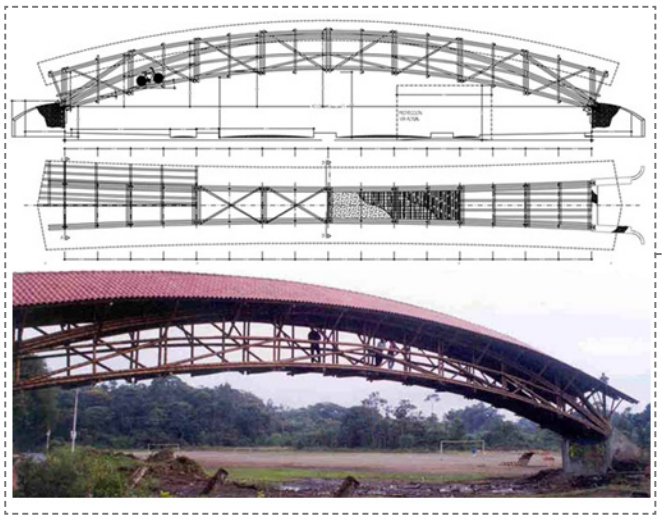
1.Foundations: Bamboo in contact with the soil has a very short lifetime. Therefore a foundation is necessary. This foundation can be done by any material strong enough to support the forces of the structure and to transport these forces to the ground.

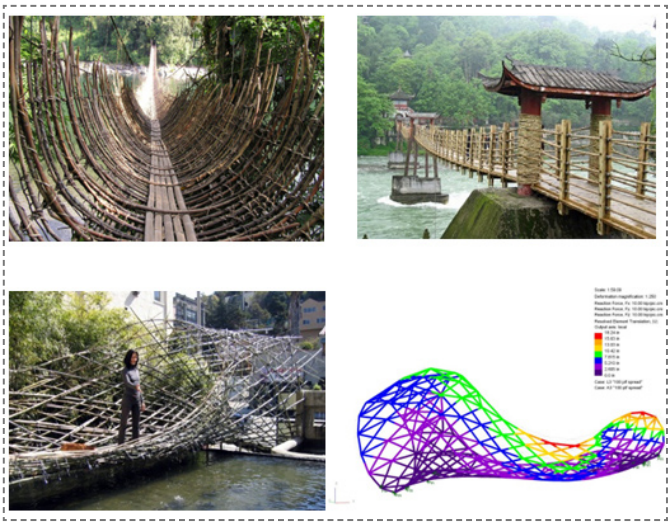
2.Other members: If the bamboo is constantly under water (rain) the lifetime of the bamboo will be shortened. In this case it is more sustainable to design members that can be exchangeable without affecting the whole structure.

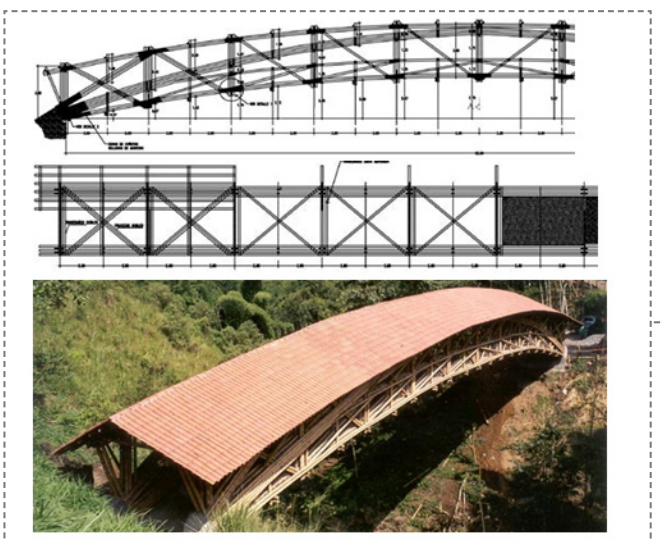
3.Shaping: One of the biggest difficulties when you built a structure with bamboo is the tubular shape of the bamboo. You can deal with this problem and design a connection that reaches the requirement needed by the structure or you can shape the bamboo.

References:

Following, a group of projects related to bridges that use bamboo in a creative way.







Locatition:

Liceo Frances, Pereira

Designer:

Jörg stamm

Span: 52 m pedestrian bridge over two lanes.

Link: http://bambus.rwth-aachen.de/eng/reports/joerg_stamm/referatstamm.html

Locatition:

Tierradentro-Colombia

Designer:

Jörg stamm

Span: 40 m spanning pedestrian bridge over two lanes.

Link:http://bambus.rwthaachen.de/eng/reports/joerg_stamm/referatstamm.html

Picture 1:

Bku village-India

Picture 2:

Anlan Suspension Bridge

China.

Picture 3: Levitas workshop-California

http://www.emanate.org/monsters.htm

Figure 41: *Bamboo is a material that for centuries has fascinated different generations, especially in Latin America and Asia. Traditionally it has been used for paper manufacture, scaffolding, as a construction material and handicrafts. However, as we see in these examples, there are designers who have built architecturally innovative and well designed structures, using bamboo. Among these examples are structurally efficient bamboo bridges with spans over 30 meters that were built by local people. This fact can support the design proposal of the living bridge*

3. Testing with bamboo and concrete:

In order to establish bamboo as a real building material, a lot of research still needs to be done. Especially on mechanical behaviour, for it is not well understood yet.

Goal definition

The goal of the experiment is to know whether structural continuity exists between bamboo an concrete.

Experimental setup

Apparatus:

•Hydraulic testing machine, brand BFG, connected to the computer program DOWTY and to a Schnenck controller;
•Concrete cutting machine, brand PTC;
•Bamboo: Bambusa oliveriana specie original from Indonesia;
•Concrete: C 35/45;
•Two components adhesive, pleximon;
•De-molding oil (Ontkistingsmiddel 95), brand BASF;
•Molds;
•Steel clamps.

Preparation:

In order to execute the experiment, seven testing specimens were made. Each specimen is composed of two elements: a concrete base and a bamboo tube of 250mm height.

The variables of the specimen were:

•Bamboo diameter: 116 mm and 65 mm;
•Concrete mold dimensions: 125x125x150 mm, 270Ø x 122 mm and 118Ø x 130 mm.
•Penetration of the bamboo into the concrete: 100mm.

The specimens are made by filling the molds, previously greased in oil, with the concrete preparation. When the mold is totally filled with concrete, the piece of bamboo is located in the centre of this preparation and introduced slowly, reaching the depth of 100mm.The specimens were left to dry inside a wet room (99.5 % of water content in the air) for a minimum period of 28 days. A period in which the concrete reaches its maximum strength. The mold was taken off after 24h that the dry process started.

On the other hand, steel circular clamps for the top of the bamboo and plate clams for the bottom of the concrete, where made. The clamps where glued to the specimens with the pleximon, to allow the glue reaches its maximum strength (>6N/mm2) a period of 30 minutes is needed.

The specimens are classified in the following groups:

Type #	Mold dimension	Bamboo diameter	Penetration	Characteristic
1-a	125x125x150 mm	65 mm	110mm	Bamboo culm without node.
1-b	125x125x150 mm	65 mm	110mm	Bamboo culm with metal screws.
1-c	125x125x150 mm	65 mm	110mm	Bamboo culm with node.

Type #	Mold dimension	Bamboo diameter	Penetration	Characteristic
2-a	180Ø x 130 mm	116 mm	110mm	Bamboo culm without node.
2-b	180Ø x 130 mm	116 mm	110mm	Bamboo culm with metal screws.
2-c	180Ø x 130 mm	116 mm	110mm	Bamboo culm with node.
2-d	270Ø x 122 mm	116 mm	85mm	Bamboo culm without node.

Method:

The bamboo specimens were tested in a hydraulic testing machine (brand BFG) which can perform tension test up till 300 kN.

Each specimen was placed manually and clamped by two clamps. The machine could then perform tension test on the specimen by loading it with tension.

For the long process of preparation-testing of the specimens the experiment was divided in different days. No special order was established.

The setting of the mechanical testing machine was 0.03 mm extension per second.

The testing machine is connected to a computer program DOWTY, which calculates and presents the testing results both in tables and graphs.

Figure 42: The bamboo specimens tested in a hydraulic testing machine.

Results:

Below, all the results of the practical work, extracted from DOWTY, have been presented in a table.

Type #	Characteristic	Dry period	Force (KN)	Displacement (mm)	Observation
1-a	Bamboo culm without node.	28 days	12.8	30	Bamboo totally out without damage.
1-b	Bamboo culm with metal screws.	30 days	14	6.85	Specimen stays almost the same.
1-c	Bamboo culm with node.	36 days	20	15.8	After pinned in the top when out specimen stays the same.
2-a	Bamboo culm without node.	28 days	-----	----	Break in the wet room.
2-b	Bamboo culm with metal screws.	32days	-----	----	No tested ' se we expected the same results than 2-c
2-c	Bamboo culm with node.	28 days	4.3	3.8	Break the concrete.
2-d	Bamboo culm without node.	38 days	13	30	Goes out totally.

Discussion:

Neither sudden buckling nor cracking of the bamboo pipes occurs.

In specimens 2b and 2c the samples showed cracks in the concrete in the first week of the drying process. The concrete of the specimen 2a breaks totally after two weeks of the drying process. This phenomenon can be explained for two combined reasons:

. The concrete base was too small in relation to the size of the bamboo this made that the concrete stresses more than the specimens type 1.

. The specimens were left to dry inside a wet room (99.5 % of water content in the air), that is good for the concrete because will allow that the quimical reaction of the materials take place, however, the excess of water causes that the bamboo start to swell before the concrete has developed sufficient strength, this means that extra stresses in the concrete will be introduce causing cracking in the concrete.

To prevent cracking it is needed to make the bamboo water proof, to do that we can add a thin layer of coating in the bamboo pipes, if we applied to much the coating will lubricate the surface and weaken the bond with the concrete.The type of coating will depend on the materials available. A brush coat or dip coat of asphalt emulsion is preferable. Native latex, coal tar, paint, dilute varnish, and water-glass (sodium silicate) are other suitable coatings.

Another important aspect which was observed during the testing process was the increase of structural continuity in a specimen made of bamboo with metal screws and a specimen made of bamboo culms without node. The specimen without screws went out totally after applying a maximum of 13 KN, while the specimen with screws remain inside the concrete after applying 14 KN.

In the case of the specimen 1-c (bamboo culm with node), the specimen remains inside the concrete after applying 20 KN. To understand why there did occur so much structural continuity between bamboo and concrete in this specific specimen, a concrete cutting machine was used. The specimen was split into two parts by its vertical axis. It was found that the presence of nodes in the bamboo samples did contribute directly to increase the resistant against the pulling effect.

Figure 43: Cracks of the concrete due to concentration of stresses.

Testing conclusion:

The amount of testing was limited by the quantity of the material and the time consumed in the testing procedure. No definite conclusion can be drawn about the structural behaviour of bamboo and concrete.

However, general observations support the conclusion that a real bond between bamboo and concrete does not exist. The pulling effect is mainly the result of pure friction between the two materials. An increase in resistance can be observed when the bamboo is pinned with metal screws. We can note even more resistance when nodes are taking into account.

Figure 44: section of the specimen # 1

4. Prototype:

To have a more realistic approach of the proposed module for the living bridge and to explore more of the theoretical approach, a prototype scale one to one was built. The prototype concerned one node of the bridge which contains the highest amound of connections between bamboo elements.

Before starting the elaboration of the prototype, it was necessary to work out three dimensional working drawings that would guide the building process.

The time consumed was three working days, not taking into account the time spent in organizing the material and facilities.

The price approximately by node put in Mumbai will be of proximally 1300 Indian rupees (20 euro's approx).

The prototype is built with 13 pieces of bamboo that connects in one point. As connector elements 4 hangs, 3 screws and 3 three bamboo sticks were used.

In the prototype three types of joins are being applied:

. The first one consists of drilling holes through the bamboo. The holes where made close to the knot and where aligned vertically to allow passing a screw, bamboo stick or hinges through it. The screws where not tied too strong, because of the danger of crushing the pipes.

. The second type of join consists of shaping the top or bottom of the bamboo poles. Two shaping forms where required:

- the so-called fish mouth, in which the end of the bamboo acquires a concave shape allowing a horizontal member fit on it,

- and the plug connection, in which the end of the bamboo acquire a form of horns, the horns will enter in the two holes made in the other diagonal member.

. Finally, the bamboo is wrapping with galvanized wire that helps to prevent the ends from splitting, and greatly increases strength and durability.

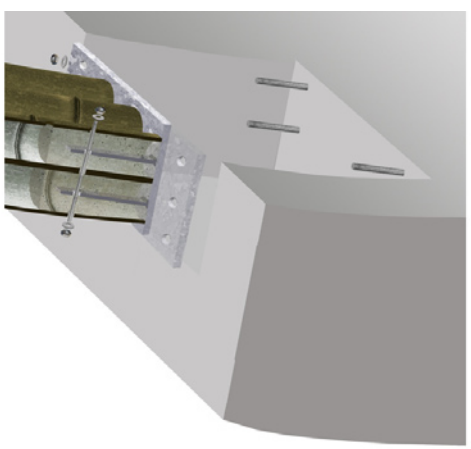
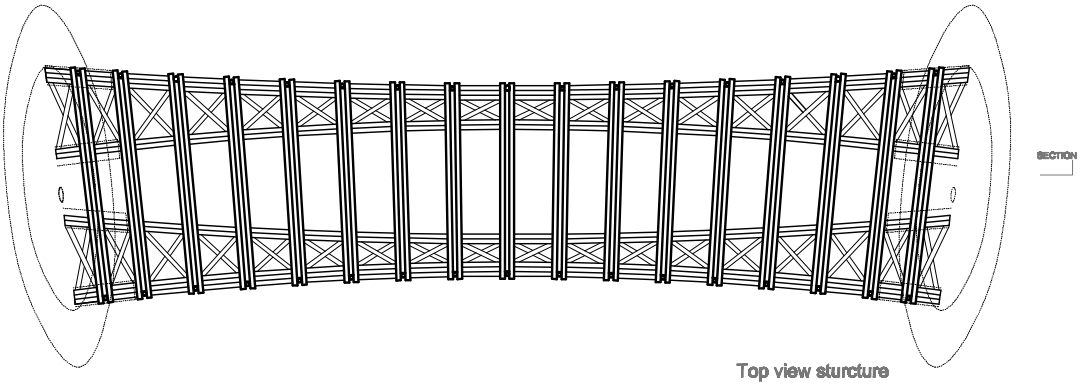
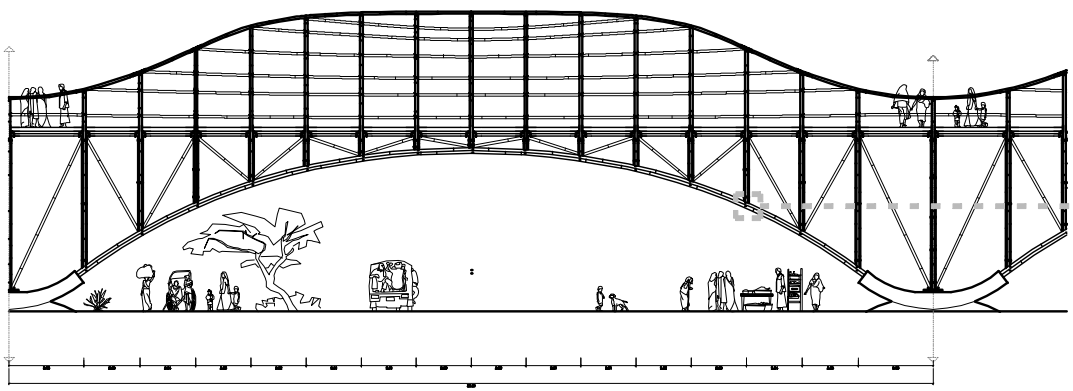


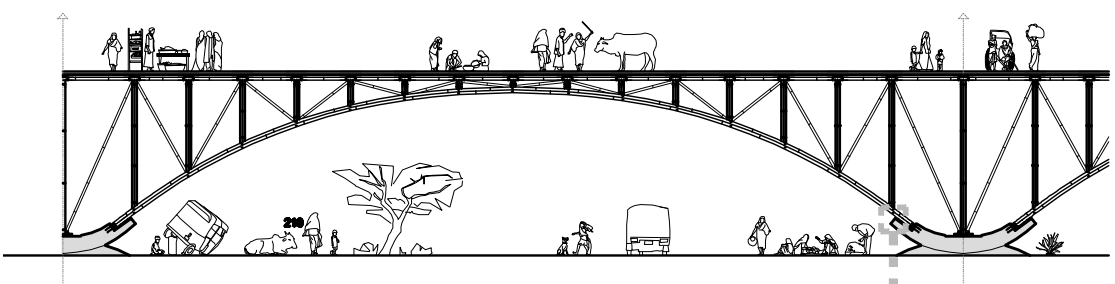
Figure 45: study images of the detail connection.



Top view sturcture



Front view



Section

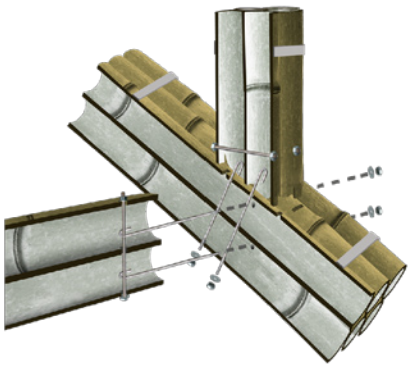


Figure 46: study images of the detail connection.
Scale of the bridge module: 1/300

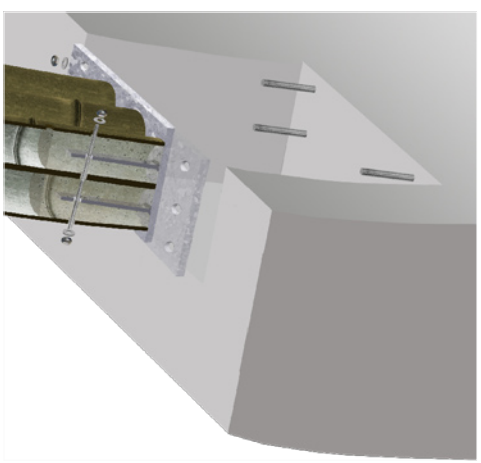


Figure 47: building the bamboo prototype scale 1:1

5. General conclusion of chapter four:

During the research we found that bamboo has properties that make of this material an interesting alternative that needs to be more included in the construction industry. One of the main advantages of bamboo is its abundance and easy reproduction, characteristics that makes it easy to be accessed by people of low incomes.

With respect to its economic feasibility, in 2006 a research was done by Van der Lugt, Van den Dobbelsteen en Janssen about the economic and practical assessments of bamboo. The research was focused in a bridge in the Amsterdam Woods in Amsterdam. The following figures are taken from this research.

Figure 31 shows that the costs to build a bridge in bamboo are relatively low compared to steel and hard-wood. The differences in costs will only increase when an example is taken in for instance India where bamboo is produced and thus more economic. Considering these costs it can be concluded that building with bamboo on the site of my final project is for sure more economic then steel. It is hard to say if other natural building materials are good enough competitors, but it is likely that bamboo is a good and cheap alternative.

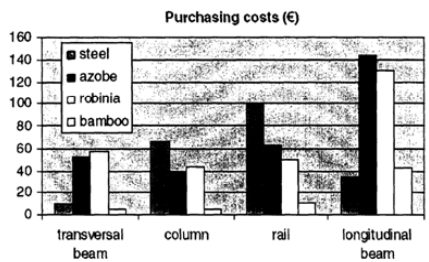


Figure 48: Comparison of costs

As can be seen in figure 32, the annual costs per element of bamboo are among the more expensive ones. The maintenance costs of bamboo are much higher than those of steel, because the lifespan of bamboo is much shorter.

The labor costs of bamboo are also higher, because a bamboo structure is more complicated to assembly than steel, due to the complicated connections and irregular dimensions. In India the labor costs are less high, so this factor is less important, but because of the high humidity, the lifespan of bamboo will be shorter.

Considering the low lifespan of bamboo of about 10 years, depending of the treatment, a combination of bamboo with steel should be well thought through, since the life span of for instance steel connections are much larger. Therefore it is wise to make the steel connections in such a way that they are easy to disconnect from the bamboo, so that only the bamboo has to be replaced**.**

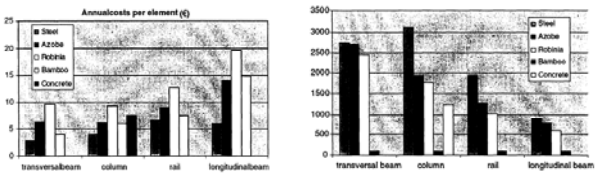


Figure 49: annual environmental costs of different materials

The above figure shows the annual environmental costs of different materials using an LCA analyses. Bamboo is clearly the most environmentally friendly product. Steel is about a hundred times less environmental friendly.

To build with bamboo in the location of my final project India, and in most other developing countries, good and reliable information is needed about the classification and usage of the material is needed, because of the uniqueness of each culm. The irregularity of the dimensions of the bamboo cane limits the industrial use of bamboo on large scale. International Network for Bamboo and Rattan (INBAR) has brought more knowledge and building codes for bamboo. In 2004 INBAR published several ISO-codes (ISO 22156:2004)(ISO 22157-1:2004).

From this research it can be concluded that it is possible to use bamboo as a design and construction material. Though the tensile strength of bamboo is about 1/3rd that of steel, this is normally sufficient for some types of structures such as houses or short-span bridges, and it provides a more economical and environment-friendly alternative that is accessible to every section of the society.

However, there is still ample scope for research on the subject, and it is important to put forward the existing uses of bamboo, and find new and creative applications of this giant grass, to generate more enthusiasm and to encourage students, builders, engineers and architects to include bamboo in their material list. As O. A. Arce Villalobos mentions in the book: Fundamentals of the design of bamboo structures, “structural materials have strengths and weakness, and it is up to the structural engineer to use them in the best possible way for the benefit not just of a specific client or idea, but for that of making as a whole”.

IMPRESSIONS

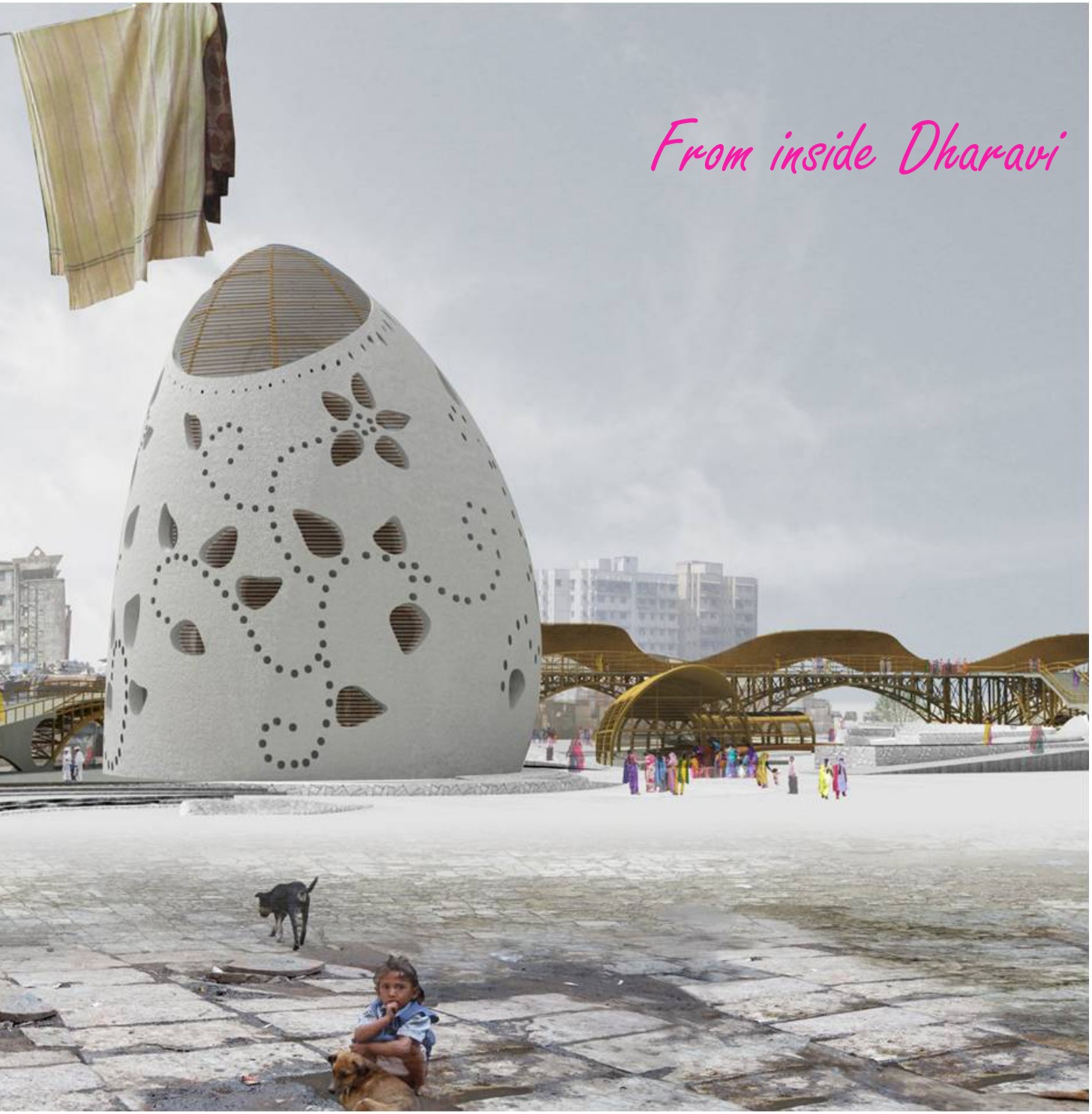
The overall design

Figure 50: view from the Living Bridge towards the Crafts Tower and towars the embattled ward of Dharavi-Mumbai India.

The new gateaway of Dharavi

The Community Centre

Figure 52: view from the embattled ward of Dharavi-Mumbai towards the Crafts Tower.


From inside Dharavi

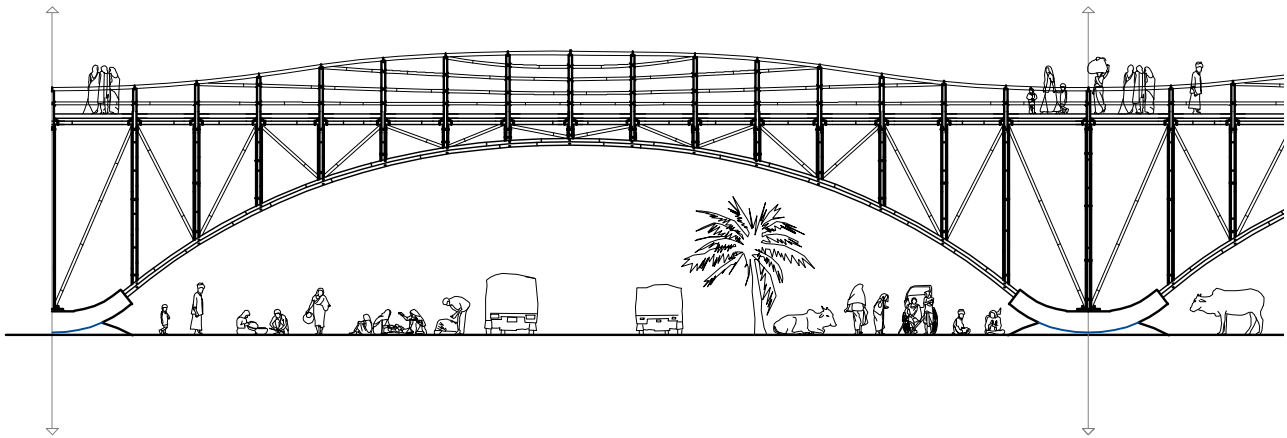
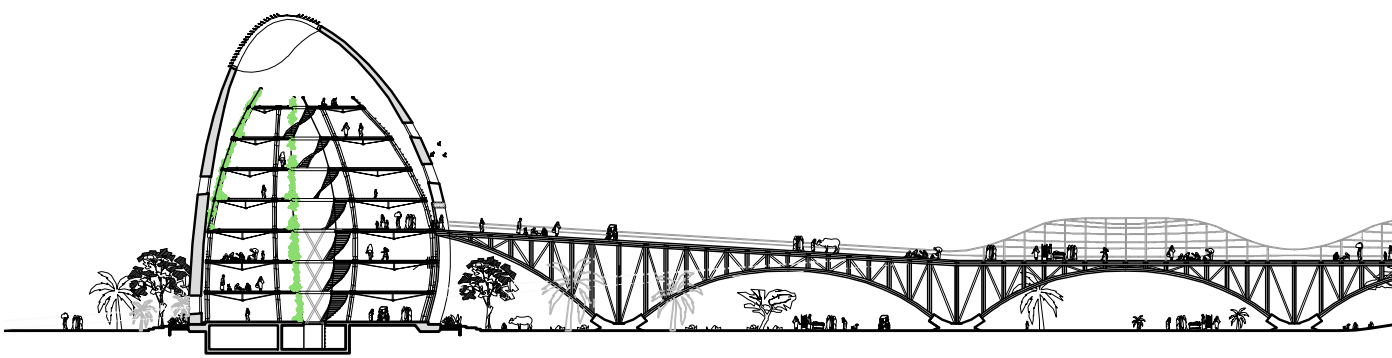


Figure 53: Back side of the base module.
scale 1 /400



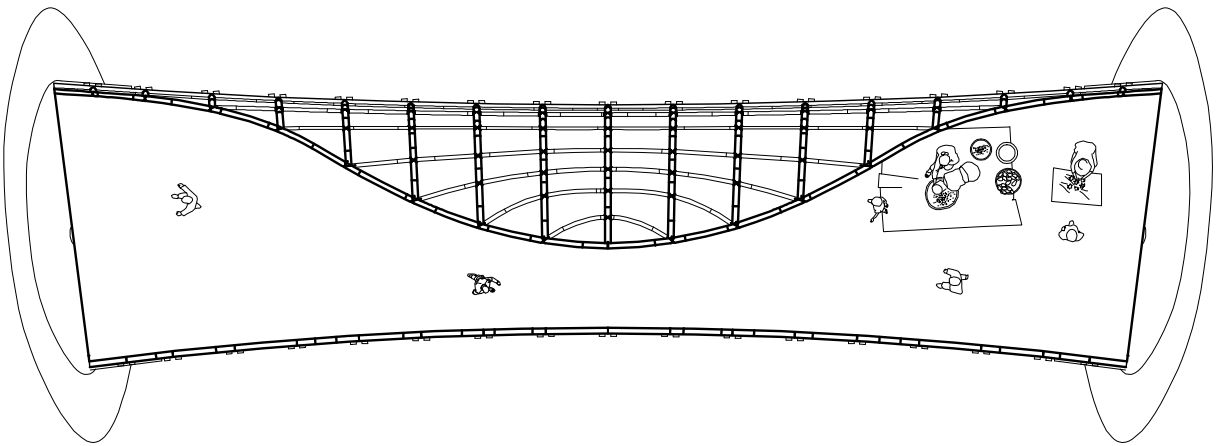


Figure 54: Top view of the base module
scale 1 /400

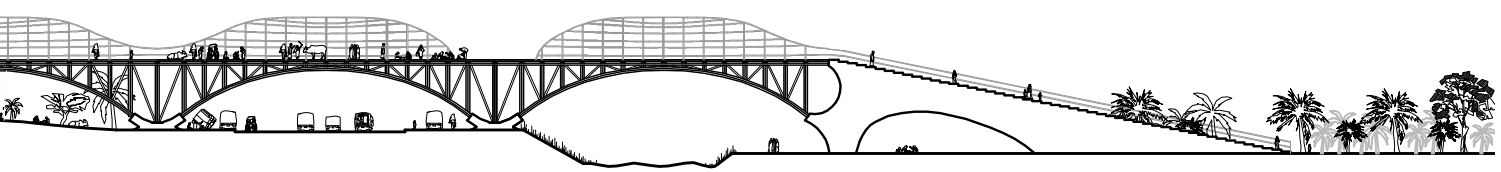


Figure 55: Section of the Living Bridge
scale 1 /800

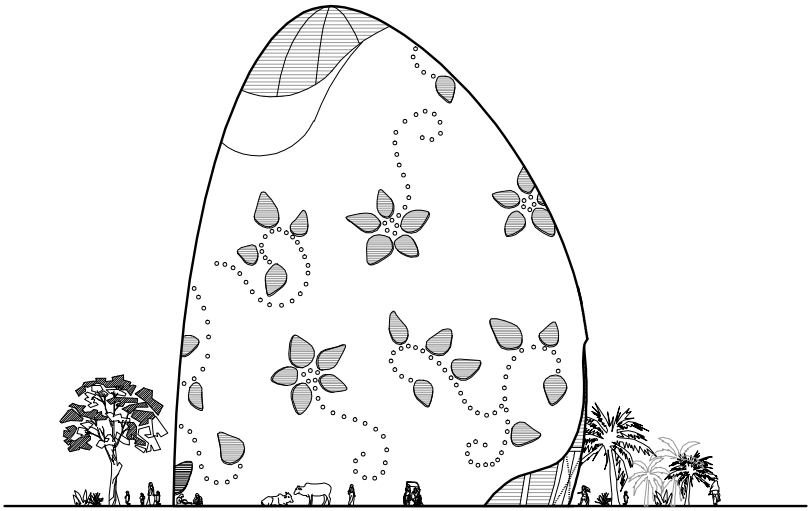


Figure 56: Facacde of the Craft tower
scale 1 /500

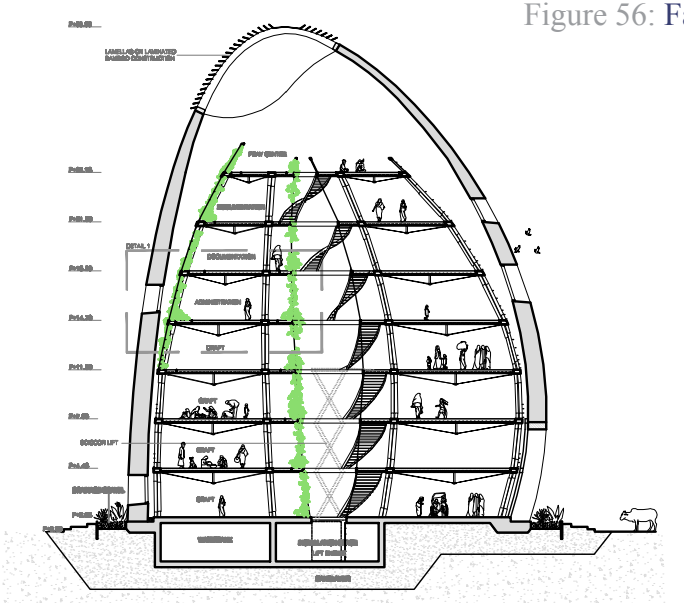


Figure 57: Section of the Craft tower
scale 1 /500

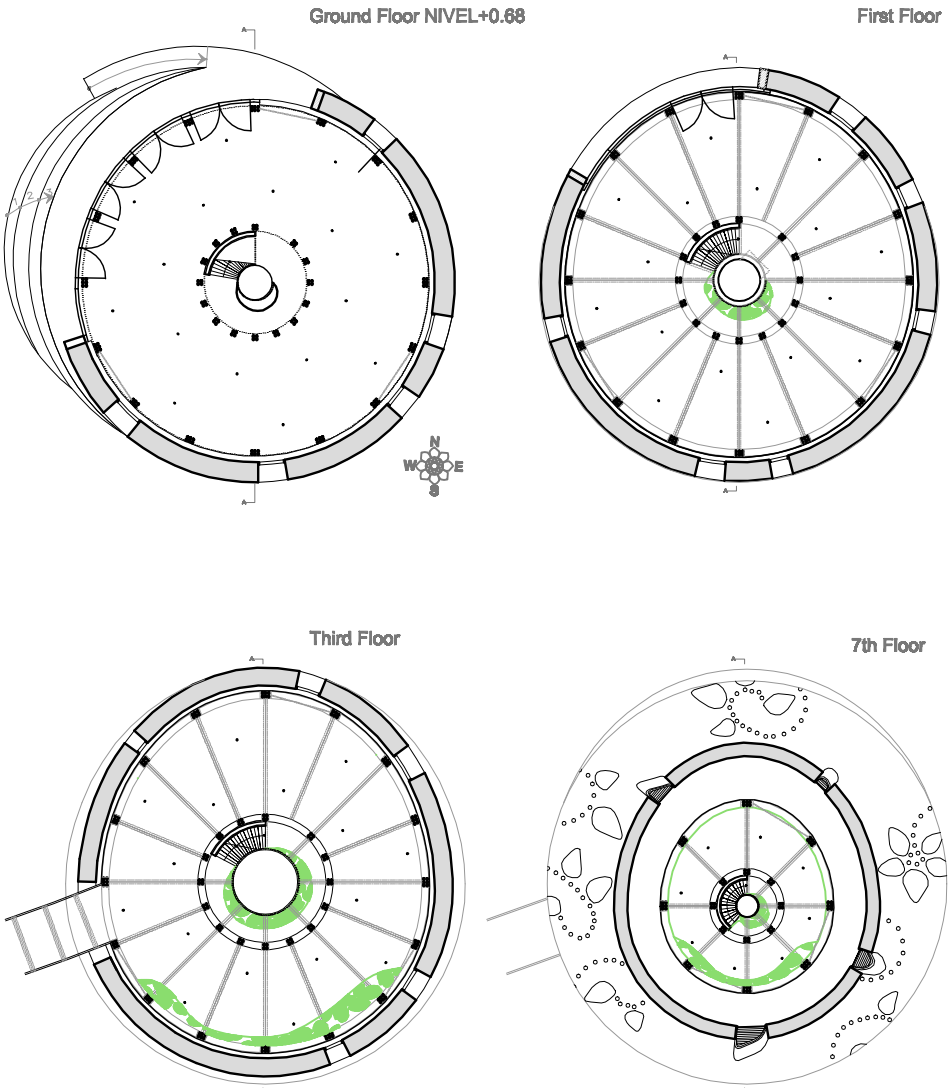


Figure 58: Floor plans of the Craft tower
scale 1 /500

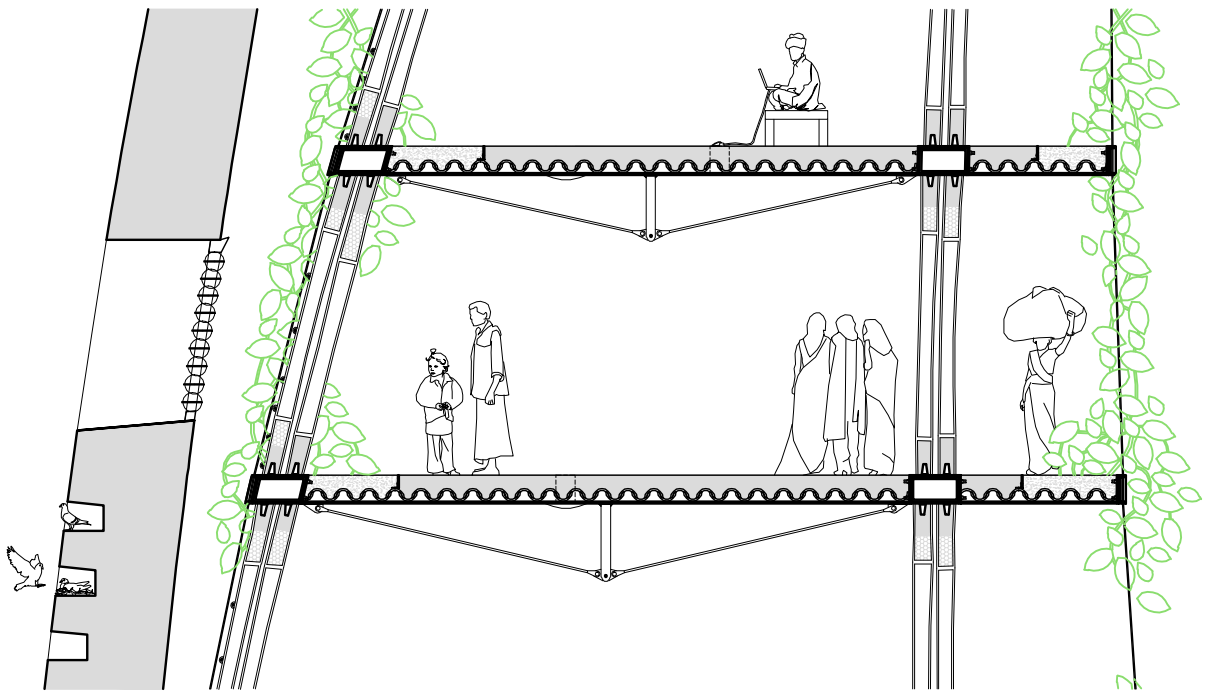


Figure 59: Detail section of the Craft tower
scale 1 /75

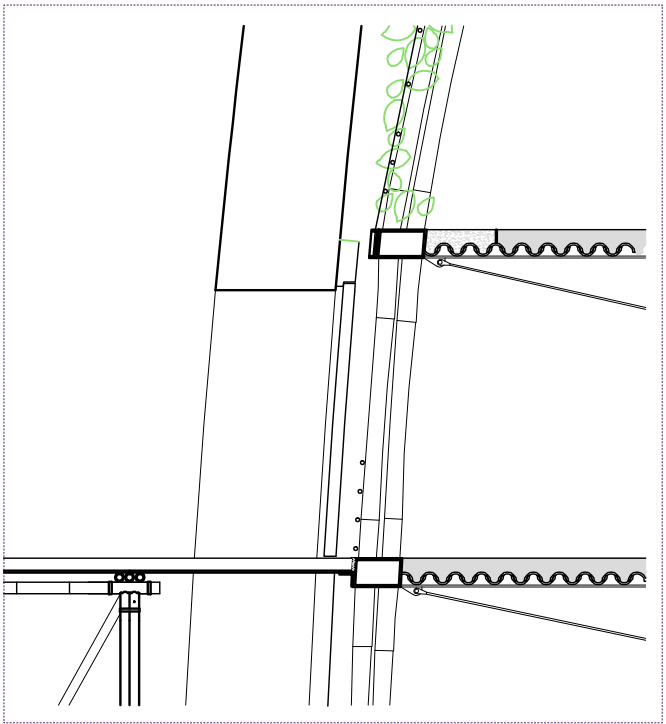


Figure 60: Detail A-A of the Craft tower scale 1 /75

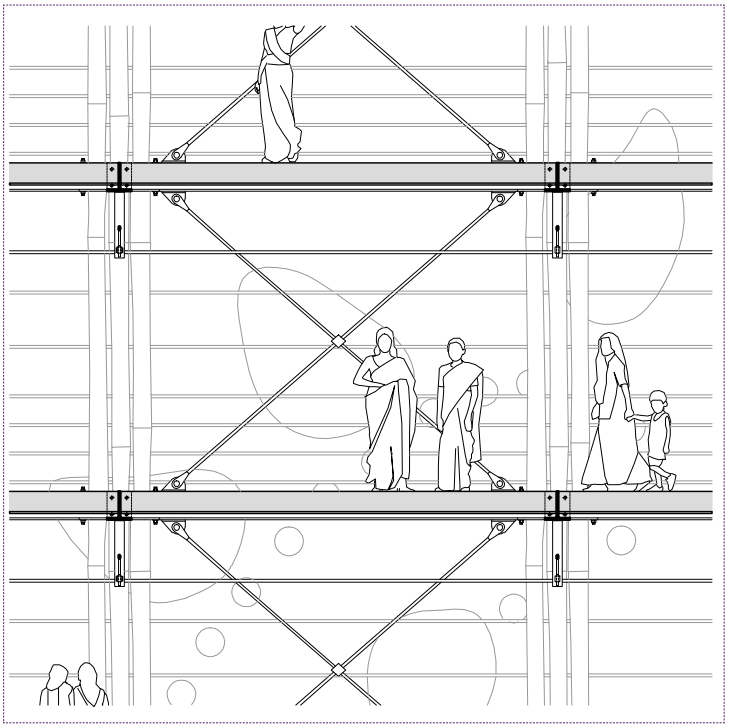
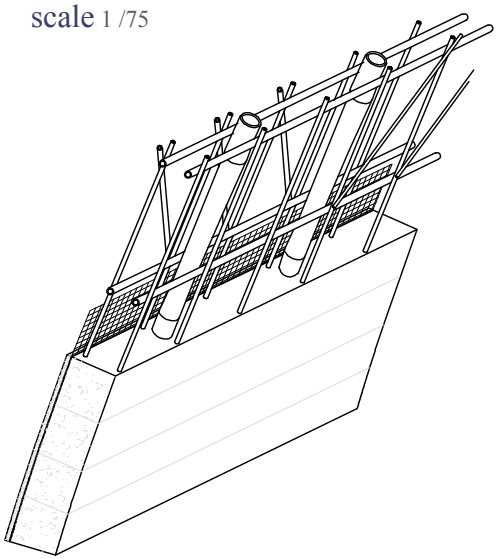


Figure 61: Detail B-B of the Craft tower scale 1 /75



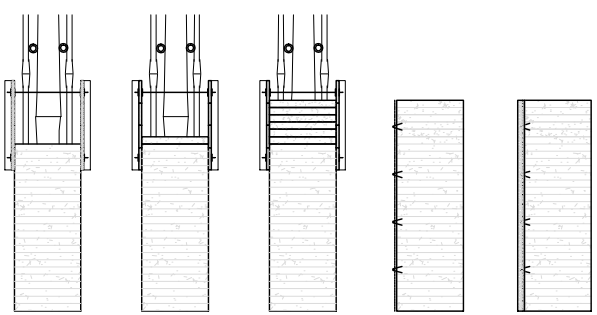


Figure 62: Detail construction of the facade . Rammed earth with bamboo.

Picture courtesy of flick.com

Design evaluation

The graduation project gives an alternative overall method for the upgrading process of Dharavi. The method proposed is called urban acupuncture; and shows another way to face the challenge of a sustainable, slum free Dharavi of middle class people.
A negative side of this method it is the somewhat long project time needed. Actually there exists a tremendous pressure for housing in Mumbai, with this respect the government of India has urgent plans to transform Dharavi into a world class township, the existing redevelopment plan has an estimated period of approximate 8 years.

With the proposed method for Dharavi a more long term project (50 years) is proposed. Long term projects always are not precise and are more risky than short-term projects, they lead to the possibility of delays in the case that the internal representatives of Dharavi or that external supports change. Also government decisions change over time and more drastic ideas can appear if the improvement of the zone is not appreciated in the short term view that the government in this regard has. Technology, economy, people wishes, etc continue changing in 50 years time.

According to Brundtland[26], three generations cover a period of 50 years. Fifty years is the time necessary to allow the adaptation process that the community of Dharavi needs to upgrade its existing social, economic and environmental conditions. This long period will be beneficial for the slumdwellers because, it will make it possible that each individual inside Dharavi forms part of the different steps that are going to take place in their community; they will control the change for themselves; they will lead their self development future.

The self development of a slum like Dharavi in my vision has a good chance of success, for the specific case of Dharavi a bottom-up approach is a good alternative. Bottom-up approaches are more self supporting in the future than top-down methods, because they come from inside out and a clever use of the local culture and local workmanships will keep the economy together, because it is based on what is already there and these are the foundations for the new development. A top down solution is forced onto the people and therefore in many cases lacks their support.

WHY I SUPPORT A BOTTOM-UP APPROACH FOR THE BIGGEST SLUM IN ASIA?

During the month that I spent in Dharavi, I discovered that besides the poor infrastructure, the prevailing context and the low quality services, Dharavi has a population determined to improve their living conditions, they work day and night to offer a better chance to their future generations, and they are decided to fight for their rights.

Nonetheless, Dharavi has a population proud of its background, they feel identification with the area in which they live and with the culture which they come from. A population that, without distinction of sex, religion, color or precedence, makes a communal celebration of any motive. Dharavi is one of the few places in the modern city of Mumbai that you can still get in touch with the rich diversity that the Indian culture possesses.

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27 Brundtland, Gro Harlem (chair) World Commission on Environment and DevelopTment, 1987, ‘Our common future’, Oxford University Press, Oxford-New York.

For the reasons previously listed I do not support the existing “Redevelopment Plan” for Dharavi. This type of massive urban redevelopment clears away all existing social, cultural and economic structure that Dharavi has strengthened during years. It is just necessary to see a picture of Dharavi to notice how the relocation of the slumdwellers in vertical accommodation is not a solution. It is true that the new infrastructures improve its housing conditions because they obtain a secure tenure with better sanitation, but many examples inside the slum show that this type of “solution” only give rise to a new concept, the “vertical slum”.

In this regard, urban acupuncture and the proposal pilot project (first node generator of quality), seem to be a more promised alternative.

Finally, it is important to mention that even if the “pilot project” has been conceived with a sustainable approach, because its intervention does not create a negative impact in the existing structure of Dharavi and because introduces small scale interventions that consider people’s needs such as water cleaning system, local food production, or transport connections, in general all urban areas are not sustainable due to the fact that stimulate greater consumption of goods and services which have a negative impact on the environment.

In order to start a more sustainable society in Dharavi, it is necessary to change some social attitudes that affect directly the environment. For example, the existing problem of pollution can be easily improved through organization and relocation of collection points. However, the community of Dharavi is not conscious about these problems because they are not directly affected by them, but if a sustainable goal needs to be reached these attitudes have to change.

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Appendices

Appendice one:
DHARAVI - LAND ENVIRONMENT

1.Topography

The topography of the land is flat with an average elevation of about 5m above mean sea level. The site is devoided of almost any kind of vegetation. The nearest water body is Mahim Creek and Mithi River.

2.Soil

The soils of this region are highly saline in the vicinity of creeks and non-saline at other places. They are calcareous, neutral to alkaline in reaction (pH 7.5 to 8.5), clayey, with high amount of bases and have high water holding capacity (200-250 mm/m). The soils located on moderately sloping residual hills are lateritic in nature and show intensively leached surfaces. They are loamy and slight to moderately acidic (pH 5-6.5) with moderate base status (< 75%).

The result of the soil analysis for 3 points of interest around the area to intervene (BKC, Kalanagar and Kapadia Nagar) , are discussed below:

- Bulk density varies between 0.428 to 0.831 gm/cc. Soil texture at BKC and Kalanagar is sandy caly loam where as at Kapadia nagar its silty clay.
- pH ranged between 6 to 11. At Site it's alkaline in nature. Water holding capacity of soil at BKC was recorded the lowest in the study area i.e. 42%.
- Zinc and Copper were much higher in soil sediments collected from Kalanagar and Kapadia nagar.
- Manganese, nickel was below detection level.
- In general, soil sediments collected from Mithi River at Kalanagar and Kapadia nagar point were much poor in quality. Heavy metals are high in both the samples. In comparison to other two samples site soil sample is better in quality.

The physical and chemical characteristics of the soil samples collected for the are shown in the Table 1.1 at the end of apeendice one.

3.Mithi River

The Mithi River is located on northwest of the project site. At Dharavi area it's known as "Mahim Creek". The riverbed is narrow in the initial stretch and is about 10 meters wide. Mithi River originates at Powai and meets Arabian Sea at Mahim Creek flowing through residential and industrial complexes over a distance of about 15 km.

The citizens who discharge raw sewage, industrial waste and garbage unchecked treat this river like an open drain. Besides this, illegal activities of washing of oily drums, discharge of unauthorized hazardous waste are also carried out along the course of this river. (Source: Pollution Quantification of Mithi River by Kleen Consultants Pvt. Ltd.)

4.Mangroves in study area

Mangroves are considered as the most significant part of coastal ecosystem that play a vital role in cleaning marine pollution and also act as breeding grounds for wide variety of fauna. Mangroves also help in flood control, prevent buffer soil erosion and act as pollutant sink.

Flora

The survey results show that in Mangrove habitat, only one species was recorded in the proposed alignment. In the surrounding area of Mahim creek the same species is also commonly distributed. The girth size of the Avicennia marina is maximum 47 cm and minimum 25 cm and average girth size is 35.20 cm (average of 10 plants). Average height of the plants is 2.75 m. See in the Appendix the floral checklist in Table 1.2.

Fauna

Mammals: Both the study areas are located in the highly developed zone. Only some small mammals like Rats and mouse are expected from the study area. Other than rats and mouse no important species were recoded during the study period.

Birds: In the Mangrove area (Mahim creek) 7 aquatic/shore bird species and 15 terrestrial bird species were recorded. Out of 22-recorded bird species 22 are common and 2 are sporadic distribution. No migratory species are recorded from the study area, only 2 species are residential migratory.

Herpeto Fauna : Only 3 species of reptiles and two species of amphibian are recorded from the study area. All the five recorded herpeto fauna are common to the area.

Fishes: The Mahin creek is highly polluted due to discharge of sewage water from the municipal area. No fish fauna was recorded from the study area.

5.Maharashtra Nature Park (MNP)

MNP Developed on a previous Mumbai Municipal Corporation's dumping ground, today it's a lush green urban forest located in Dharavi. The presence of more than 14,000 trees, a majority of which have known medicinal properties and variety of other vegetation such as climbers, herbs, shrubs and grasses give MNP the look of woodland. More than 80 species of birds and 34 butterflies' species have been sighted in MNP. Apart from this, an enormous number of insects, reptiles and all other life forms are supported and sheltered by the park.

DHARAVI-METEOROLOGICAL DATA

Latitude : 19°03′N Longitude : 72°52′E Height above MSL : 5 Meters

6.Surface Temperature

Mumbai city experiences tropical savanna climate. On an average, the temperature during summer months (April to June) varies from 270C to 350C, while in winter (November to February); it ranges from 170C to 190C. Relative humidity during June to October remains above 75% while it varies between 50% and 65% during November to February.

7.Wind

Winds are generally moderate but increase in force during monsoon months. For maximum duration of the year wind has been found to blow from the NW direction.

The wind speed for most of the time lies in the range of 1 to 5 m/s. Wind speeds greater than 5m/s increase in the months of March to August, thus, faster pollutant dispersion is expected to occur in this duration. Maximum numbers of calm days occur in the winter months of December to February.

8.Rainfall

Precipitation plays a role in the mitigation of pollutants from air to land, and can minimize or eliminate wind erosion. As shown in Table 2.1, an average annual total precipitation of 2422.1 mm occurs in the region. The maximum mean monthly rainfall of 868.3mm occurs in July, with mean minimum monthly rainfall at 0.6 mm in January and April.

9. Vulnerability to Flood

It is important to know that flooding is one of the greatest water-related environmental disasters known. Flood affects an estimated 520 million people across the world yearly, resulting in up to 25,000 deaths in a single year. 96 percent of deaths related to natural disaster in the past decade occurred in developing countries. Some studies indicate that even if the emission are reduce the level of see will continue rising for expansion several millenniums more.

Mumbai is particularly vulnerable to floods during the wet season. (June-September), Typical June–September wet-day average rainfall at Mumbai (Bombay) is around 18 mm day21 with a daily standard deviation of 28 mm day 21; hence, more than 400 mm of rain in one day represents an extreme event or outlier more than 10 standard deviations greater than the mean.

One of the extreme daily rainfall events was the great flood of 2005, resulting in huge loss of lives and property. The rainfall recorded in different areas of Mumbai over the 24 h period was: Vihar104.5 cm., Santa Cruz: 94 cm, Bhandup: 81 cm, Dharavi: 49 cm, Vihar lake: 104 cm, Malabar Hill: 7 cm and Colaba: 7 cm (source: India Meteorological Department,IMD).

The different scenarios for 2070 consider Mumbai as a one of the top ten cities with more population exposure to coastal flooding. The studies predict that Mumbai will witness a curtailed monsoon and regular floods. But the reality is that the monsoon could disappear entirely (or it could double in intensity!). There's not much to say about this -- because no one really knows -- except that it reminds us how little we really know about what is happening.

10. Air Quality

Major source of air pollution within the impact zone is vehicular traffic. The other significant sources are the different industrial activities being conducted in the region and any other natural or anthropogenic source present in the vicinity.

11. Noise Environment

All cities in India are loud, but nothing matches the 24/7-decibel level of Mumbai.

The sound environment surrounding the design area is characterized by an urban hum, primarily due to traffic along the road and toloudspeakers and industries in the area. Overhead aircraft traffic is not a very significant noise source. Movement of local trains also contributes to the noise.

12. Water Quality

Water samples collected from 3 locations around the Mithi River, analyzed and compared with IS: 10500: 1991 standards. The monitoring results show that water quality of in general is very bad at Kalanagar and kapadia nagar. Overall, water is badly polluted with sewage.

DATA TABLES:

Sr.No.	Parameters	Near Bank of Baroda (BKC area)	Mithi River at Kalanagar	Mithi River at Kapadia Nagar
1	Bulk Density,gm/cc	0.824	0.831	0.428
2	Salinity,ppt	BDL	BDL	BDL
3	Porosity,%	48.7	26.7	37.2
4	Texture	Sandy clay loam	Sandy clay loam	Silt clay
5	Sand, %	72.8	71.3	14.9
6	Silt,%	11.6	12.5	40.8
7	Clay,%	15.6	16.2	44.3
8	pH (1:10 suspension)	11.4	8.22	6.01
9	Electric conductivity,ms/cm	4.26	1.074	1.647
10	Cation exchange capacity	BDL	BDL	BDL
11	Sodium (as Na),mg/gm	43	0.61	0.79
12	Potassium,(%)	0.17	0.17	0.26
13	Sodium Adsorption Ratio	0.67	1.22	2.27
14	Water Holding Capacity,(%)	42.1	56.7	94
15	Iron (as Fe),mg/gm	0.0356	5.4	20.7
16	Copper (as Cu),mg/gm	0.0098	94.2	808
17	Zinc (as Zn),mg/gm	0.0178	754	2361
18	Manganese,mg/gm	BDL	BDL	BDL

TABLE 1.1: soil characteristic in the study area

Month	Total rainfall (mm)	Predominant wind direction	Mean Temp. (°C)	Percentage of Calms (%)
January	0.6	NW	23.5	24.5
February	1.5	NW	24.7	24.5
March	0.1	NW	27.5	21.5
April	0 6	NW	29 5	17 5
May	13.2	W	30.5	12.5
June	574.1	W	29.0	6.5
July	868.3	W	27.5	6.0
August	553.0	W	27.0	6.0
September	306.4	W	27.3	17.5
October	62.9	NW	28.1	21.5
November	14.9	NW	27.3	16.5
December	5.6	NW	19.4	20.0
Annual Total or Average Mean	**2422.1**	**NW**	**27.3**	**16.0**

TABLE 1.2: climatological summary for the imd (1951-1980)

Sl. No.	Scientific Name	Common Name	Number of plants in the alignment	Local Status
A.	**Mangrove Habitat :**			
1.	*Avicennia marina*		50	Common mangrove in the creek area of the Mumbai
B.	**Urbanized/Disturbed Area**			
2.	*Hibiscus populneus*	Paras Pipul	13	Locally common
3.	*Ficus religiosa*	Aswatha	5	Sporadically distributed
4.	*Zizyphus jujube*	Ber	3	Common
5.	*Leucaena leucocephala*	Subabul	1	Common, exotic species
6.	*Ficuus lucicens*	Pakur	2	Sporadic
7.	*Peltophorum pterocarpum*	Yelow Gulmohor	1	Common, exotic species
8.	*Moringa oleifera*	Sajina	2	Common
9.	*Syzygium cumini*	Jam	6	Common
10.	*Cocus nucifera*	Narikel	1	Common
11.	*Casuarinas equisetifolia*	Jhau	1	Common, exotic species
12.	*Couroupita guianensis*	Naglingam	1	Sporadic
13.	*Ficus benghalensis*	Bat	2	Common
14.	*Annona squamosa*	Sitapalam	1	Common
15.	*Psidium guyava*	Peru	1	Common
16.	*Ficus glomerata*	Jagya	2	Common

TABLE 1.3: climatological summary for the imd (1951-1980)

APPENDICE TWO:

Green Facades

1.Clasification

Professionals involved in vegetated building envelope systems, such as the Vancouver landscape architect Randy Sharp defined this systems in two main categories:

.Green façades: are wall systems where climbing plants or cascading groundcovers are trained to cover specially designed supporting structures. Plant materials can be rooted at the base of the structures, in intermediate planters, or on rooftops. Green façades can be attached to existing walls or built as freestanding structures . These green facades by its way of being integrated in the building envelop can be classified in:

1.traditional system: consists in self climbing climbers that do not required supporting network of wires or trellis. In the south of Italy it is common to see vines attached directly the roughness of the wall, or Virginia creeper (Parthenocissus tricuspidata) attach to the walls of all houses in Germany or France.

2.modern system: a different of traditional systems, the modern ones prefer holding plants away from the surface, requiring for this new technology based on the use of steel cables or trellis. This new technology offers extensive surface covering and reduces the risk of damage for directly contact with the building.

Living walls: Living walls (also called biowalls, "mur" vegetal, or vertical gardens) are composed of pre-vegetated panels or integrated fabric systems that are affixed to a structural wall or frame. Modular panels can be comprised of polypropylene plastic containers, geotextiles, irrigation, and growing medium and vegetation. This system supports a great diversity of plant species, including a mixture of groundcovers, ferns, low shrubs, perennial flowers, and edible plants. Living walls perform well in full sun, shade, and interior applications, and can be used in both tropical and temperate locations.

Other experts of green walls add other category that is related to bioengineering and ecotechnology, both techniques are usually employed without strong esthetical parameters, where archive a specific job in the most efficient way is the goal, this category is:

Engineering walls: are engineered building envelope systems that are mainly employed in functional manner and that allow the growth of vegetation between or around the outside of its structure. These systems are normally part of the vernacular landscape, of different parts of the world, for example in the Netherlands, we can see that architect Louis G. Le Roy's has use for its Eco Cathedral waste brig and tile structures as a support of free growing vegetation.

Other examples to mention are the walling units called gabions where the colonization of vegetation is spontaneously, or for example the use of rolls of coconut fibre combined with wetland vegetation, or willows as a structural components to stabilize water channels.

From the three categories mentioned, living walls require more intensive maintenance, due to its diversity and density of plant life aspect like water regulation, nutrients, fertilizer, etc, needs of care. Green facades and engineering

In accordance with its type of support green walls can be separated into a number of categories including:

- Supported by a wall – self-supporting climbers.
- Supported by a structure on a wall – trellis etc.
- Supported by a self-standing structure away from a wall – frameworks, etc.
- Hanging walls – allowing plants to hang from a height.
- Walls with plants growing within them.

2.Environmental benefits

1.Moderate temperature (lowering energy consumption): by the addition of thermal mass, the provision of shade and by the pillow generated between the wall and the plant (insulating dead space), green walls contribute to moderate indoor and outdoor building temperatures. We can add that vegetation also lowers adjacent air temperatures by evaporating enormous amounts of water from leaf surfaces.

Different studies have shown that the reduction of summer cooling load by living walls was even more dramatic than for green roofs, and if technology was used extensively a significant reduction in the urban hot island effect could be attained. The effectiveness of this cooling effect is related primarily to the total area shaded and evapotranspiration effects of the vegetation, rather than the thickness of the climber. Together with the insulation effect, diurnal temperature fluctuations at the wall surface can be reduced from between 10°C and 60°C to between 5°C and 30°C.

2.Winter insulation: the beneficial aspects of winter insulation of green walls are reached for the same properties explained in point one, however, the effectiveness of winter insulation is more related to the thickness of growth, and the reduction of wild child on the wall surface.

Research has demonstrated that by creating a zone of still air adjacent to the wall, evergreen plants can reduce convection at the wall surface by up to 75 per cent and heating demand by up to 25 per cent.11

3.Noise Reduction: Green walls can help reduce sound transmission into buildings due to the layer of plants, growing medium and, depending upon the design, the dead air space between the living and conventional walls.

4.Pollutant removal: on the plant surfaces off green walls a variety of pollutants are trapped, notably volatile organic compounds, and unburned hydrocarbons from vehicle exhausts. This pollutants are trapped in the tissues of the plants and the discarded. All green plants absorb CO2 emissions, thus climbers in urban areas help to reduce the contribution made to human-induced global warming.

5.Reduce the risk of flooding by absorbing or retaining temporarily water during rainstorms, in the same way that green roofs do.

6.Protect the surface of the building from ultraviolet light than can deteriorated more fast some types of material. Also a green wall creates a layer of protection against heavy rain fall or other elements that can damage the appearance of the building.

7.Psychological effects: vegetation always offers relaxing views that seem to exert effect in people that enjoy of that. According to Health Facilities Management, plants have positive psychological effects on people. For example, HFM mentions a study conducted by Texas A&M University, in which college students "exhibited less fear and anger and more positive feelings when plants were in full view."

8.Biodiversity: Plants on buildings can not only can provide a food source for fees invertebrates and birds, when the technology proceeds, green walls can also be used as a vertical agricultural system, where different types of nutritional herbs, fruit or vegetables can grow. It is difficult to find green walls for food growing, some proponents suggest homemade versions for greenhouse walls and vegetable gardens, have been elaborated.

9.Water conservation: the circulating water in a living wall evaporates less than in a horizontal garden so can work well in drier climates.12

10.Visual benefits: different designs related to green walls have gained a lot of attention not only for all the benefits mentioned, green walls also add an important esthetical value to the place where is built, most of this projects are designed by artistic effects that enhance public perception of urban environments or indoor spaces.

3.Contras of green walls:

1.Maintenance: in this respect we have two different points of view, some sources agree that indoor vegetated walls do not require more maintenance than horizontal indoor gardens, however, other groups suggest that green walls require a much higher level of maintenance, specially on living walls, the time/money spent in maintenance of this system is related to the fact that living wall is a new technique where no practical ideas has been put yet in practice.

2.Energy/Resource Use: green walls have attracted different interests, specially because its environmental benefits, however, the new technology of green walls seems to need more energy, pump water and nutrients than traditional ones. There does not exist any cost-benefit analysis that can assess to clarify how effectively living walls archive their goals.

3.Mould/Moisture Problems: Proper air flow and water movement must be established to help to ensure some moulds do not grow, particularly in indoor applications. In addition, the constant presence of moisture means that the walls must be well separated from the adjacent structure.

4.Attract unwanted: because its condition as a "living system" green wall can attract unwanted insects, birds or pests. For both green façades and living walls, climbing plants can be selected that do not bear fruit or provide a food source. Also, property managers prefer closely cropped vegetation to discourage shelter or nesting sites for birds. Any excessive growth or dead wood should be removed, and standing water should be avoided. A continuous gravel strip at the base of the building is recommended.

5.Pollens: Designers should consider pollen generation when choosing plants, especially for indoor applications or beside operating windows.

4.General cconsiderations :

•Protection of the structural support system's integrity, and waterproofing protection of that system.
•Positive drainage throughout the system so that plantings at the bottom will have optimal growing conditions without becoming oversaturated.
•A long-term, lightweight planting medium that isn't subject to deterioration through decomposition (normally, this is a synthetic product).
•Irrigation and fertilization for optimum plant growth and sustainability.
•Adaptation of the plantings to the environmental conditions.
•Provisions for maintenance.

•The most important element in the construction of a greenwall is protecting the integrity of the structural components that support the vertical garden. For this reason, there must be waterproofing of exceptional longevity to prevent damage and reduce the possibility of a long-term, expensive reconstruction.

Load-bearing capacity. It is important to consider that a greenwall can weigh anywhere from 25 to 40 pounds per square foot once they're fully saturated with water, reason why it is important to verify the load-bearing capacity of the wall that will support the system.

Root + waterproofing. To prevent damage in the building and in the green wall structure it is important to make the system water and root-proof. There exist in the market different products available such as powder-coated protection or polyester sheets, it is also possible to construct the structural members of waterproofing materials like stainless steel.

A more low-tech alternative is to protect the wall with asphalt or bitumen felt layer and then cover it with a protective mat (old carpet works well) to help support the materials placed above.

Type of plants. The selection of plants is other important factor to take into account, consider at first hand the native plants that are founded in the area; other no native plants can be also integrated into the green wall, the only requirement needed to be selected is that this plants can handle with the local conditions. For example, In an arid area, you should use plants that can withstand the dry conditions; in an interior greenwall, you need to select plants that can take the lighting levels offered by the space.