GOING GREEN

A HANDBOOK OF SUSTAINABLE HOUSING PRACTICES IN DEVELOPING COUNTRIES

UN HABITAT
FOR A BETTER URBAN FUTURE

GOING GREEN: A HANDBOOK OF SUSTAINABLE HOUSING PRACTICES

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CONTENTS

LIST OF BOXES

LIST OF FIGURES

ACRONYMS

CEB	Compressed Earth Block
C&D	Construction and Demolition waste
GDHS	Geothermal district heating systems
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
ISSB	Interlocking Stabilized Soil Blocks
LEED	Leadership in Energy and Environmental Design
MDG	Millennium development goal
BREEAM	Building Research Establishment Environmental Assessment Method
SBAM	Sustainable Building Assessment Methodology

EXECUTIVE SUMMARY

This handbook introduces the linkages between current urbanization in the developing world, the housing sector and global warming. The housing sector is in a key position to mitigate climate change making environmentally friendly affordable housing strategies opportune and crucial. The housing sector is the single most efficient sector that can, without extra costs, address the issue of climate change. Scaling up efforts of making the housing stock of developingcountries more environmentally friendly can make a great difference in terms of climate change mitigation and adaptation as well as improve quality of life and human wellbeing.

In order to achieve sustainable housing a comprehensive approach is needed that includes not only environmental but also social, economic, cultural, and institutional sustainability dimensions. In order to make housing sustainable it needs to be connected to sustainable settlement planning strategies including specific urban forms such as compact city and mixed land use, infrastructure networks, services, employment possibilities, connectivity, environmental matters, disaster risk reduction strategies and tenure security. Building according to the prevailing climatic conditions is crucial in terms of saving energy and improved environmental conditions. Traditional and recycled construction materials are in general more environmentally friendly than contemporary materials such as concrete and burnt bricks but sometimes combining both can increase the life-span of the building. Energy efficiency of new buildings and environmental retrofitting of old buildings are both of great importance and should be connected to strategies of using renewable energy and saving water in housing.

Governmental incentives are crucial in order to support the sustainable housing sector. Low-income communities should be supported to access the initial investment needed to pay for sustainable housing. Communities should be helped to be involved in housing planning, design and management and the construction processes used to build up the skills of people. The specific needs of different groups such as different gender, ages and indigenous/cultural groups need to be taken into account. Pilot projects addressing sustainable housing are important but it is crucial to scale up sustainable housing practices beyond pilot level. In these efforts the institutional and regulatory environment, monitoring and evaluation, capacity development/ building, communication and governmental incentives are important.

01 HOUSING AND SUSTAINABILITY

KEY MESSAGES

In this chapter the purpose and structure of the handbook is outlined and the underpinnings of sustainable housing presented. The importance of an integrated comprehensive approach to sustainable housing is highlighted alongside the need to scale up sustainable housing supply in developing countries.

Sustainable housing: why is it important?

- The housing sector plays a noteworthy role in the current global environmental crisis but it also offers one of the largest possibilities of any sector to mitigate global climate change.
- Global urbanization is fastest in the developing countries and slums and informal settlements are rapidly growing making affordable sustainable housing strategies crucial in this context.
- Sustainable housing practices are still weak in developing countries and need support to bring sustainable housing solutions to scale.

Taking a comprehensive approach to sustainable housing

- Sustainable housing should be seen as a comprehensive process taking into account environmental, social, cultural, economic and institutional matters.
- The whole life-span of a house needs to be considered from the very beginning.
- Demonstration projects concerning affordable sustainable housing are important to test, influence and inspire, but scaling up sustainable housing practices is fundamental and should be the main goal.

Social sustainability

- In practice, social sustainability has many dimensions with various strategies, for example the empowerment of poor communities; inclusion of all groups in planning, design and governance decisions; building the skills of people; and creating training and employment opportunities through construction processes.
- Inclusion of low-income groups in housing strategies can increase security and decrease social tensions in cities.
- Particular urban forms and approaches such as mixed land use and density can promote social integration and equity.

Economic sustainability

- Housing policies, design, and construction processes should be connected to micro- and macro-economic development, and employment and income generation.
- Governmental incentives to support the development of a sustainable housing sector is crucial, as is increasing the means to help poor communities access initial, up-front costs needed for building sustainable housing.
- Macro-economic development in developing countries needs to be connected to sustainable housing in order to create long-term economically-viable solutions.

Cultural sustainability

- Cultural heritage is important for people's identity and should be maintained for future generations.
- Protecting traditional housing forms, patterns and domestic ways of living is historically is historically important, and can also have economic value in terms of tourism.
- Culturally appropriate and responsive built environments (including their form, design, spatial layout, and materials, etc.) are an important dimension of sustainable housing and is indeed one of the seven criteria of 'adequate housing' as prescribed in international instruments.

Institutional sustainability

- Governments are the key housing sector stakeholder that can guide the sustainable development of a country and are therefore in a crucial position to support sustainable housing development.
- Sustainable housing is not a 'one-off' task; it is a continual process that requires a robust and transparent institutional setting where each stakeholder can play their part. Where fundamental institutions exist they should be strengthened; where they do not exist they must be created.
- Institutions should work to improve economic support for low-income households and groups to access sustainable housing and reform unsustainable policies, building codes and regulations that constrain the provision of sustainable housing.

Vulnerable and special needs groups

- Housing for indigenous peoples needs to derive from the specific culture of the indigenous-groups.
- Minorities need to be included in housing strategies in order to facilitate inclusive sustainable development.
- A range of housing options should be provided to reflect occupant demographics such as age and gender. Rental housing may be more appropriate for young people compared with homeownership for middle-aged working people; safe and accessible housing is essential for the elderly, whereas a small apartment on the periphery may suit a young person living alone. Different sizes, forms, tenure types, etc., of houses should be promoted.

- In the developing world women spend much more of their lives in housing compared with men, juggling their many roles as mothers, daughters, careers, sisters, usually in addition to the daily 'operation' of the house and household. Particular attention should be paid to women's relationship with housing, and they should be involved in housing design, selection and implementation processes and their individual security of tenure promoted.

Scaling up sustainable housing practices

- Demonstration and pilot projects addressing sustainable housing, such as the case studies presented in this guide, are important examples that can inspire, influence, and guide other projects. However, it is crucial to scale up sustainable housing practices to meet the massive housing demand that exists, and that is forecast developing countries over the coming decades.
- Scaling up requires three key ingredients: a supportive institutional and regulatory environment, timely monitoring and evaluation mechanisms, and appropriate capacity development of the housing sector and capacity building of housing sector actors.

A young girl pauses from brick-making, Dhaka, Bangladesh, July 2007. ***© Manoocher Deghati / IRIN.***

Community members involved in construction in Myanmar. ***© UN-Habitat.***

1.1 PURPOSE OF THE HANDBOOK

This handbook is intended for housing sector stakeholders working in the context of housing in developing countries in the areas of new 'social' housing provision, slum upgrading, disaster/conflict reconstruction and housing environmental retrofitting. The target group includes professional such as architects and engineers; government officials, policy makers and local authorities; humanitarian/development organisations and practitioners; and NGOs, urban poor federations, and community based organisations.

The purpose of the handbook is to present sustainable housing as a comprehensive process /product and to connect best practice principles of sustainable housing with best practice case studies from different parts of the world and from different contexts. Although the emphasis is largely on environmentally-sound construction, the goal of the handbook is to broaden the concept of sustainable housing from solely environmental dimensions to a comprehensive process that balances the environmental alongside social, economic and cultural dimensions.

The comprehensive approach is important because improving the sustainability of housing in developing countries is not only a technical environmental challenge. Time and time again, 'appropriate' construction materials, technologies, and building approaches that are environmentally sustainable are not adopted at scale, often because they do not account for the nuanced but important social, economic and cultural dimensions of the context in which they are applied. The conceptual underpinning of this handbook, then, is that environmental aspects must be interwoven with the social, cultural and economic milieu in which they are proposed, adopted and, ideally, scaled-up to meet the massive housing demand in developing countries.

1.2 STRUCTURE OF THE HANDBOOK

In Chapter One the purpose and structure of the handbook are clarified and the context of sustainable housing presented. The importance of an integrated comprehensive approach to sustainable housing is highlighted. This chapter, therefore, provides the conceptual setting of what is meant by sustainable housing to guide subsequent chapters and to select and analyse the case studies presented in Chapter Five.

In Chapter Two sustainable housing is connected to the broader context of urban planning, settlement planning and methodologies to achieve long term housing sustainability such as building according to the climatic conditions and mitigating local disaster risks. The chapter highlights how sustainable housing must take account of aspects beyond the houses themselves to the settlement and city level which shape the overall sustainability of particular housing forms and approaches.

In Chapter Three different sustainable construction materials and their benefits, challenges and application possibilities are presented. The emphasis of the chapter is on natural materials such as wood and straw-based materials and earth and stone based materials as well as on recycled materials. Possibilities to use concrete in a more sustainable way are also presented.

In Chapter Four different sustainable technologies that can support sustainable housing are presented. Ecological retrofitting, green roofs, different renewable energy forms and ways of saving water in housing are introduced.

In Chapter Five ten comprehensively sustainable best practice case studies are presented representing different countries, climates and thematic areas of the content of the handbook. The case studies follow a common template giving information about the project and the organization in charge of it; the context in which the project has been implemented; the innovative aspects and the challenges of the project; and how the different sides of sustainability have been incorporated. The goal of presenting the case studies is to give examples of good projects in order to influence and inspire practitioners.

Chapter Six draws together conclusions and recommendations. The links of climate change, housing sector and population growth in the developing countries are presented, the need for an affordable sustainable housing stock with a comprehensive approach including principles of environmental, social, economic and cultural sustainability is discussed; ways of providing environmentally-sound housing are summarized and the importance of scaling up sustainable housing practices from pilot projects is emphasized.

1.3 SUSTAINABLE HOUSING: WHY IS IT IMPORTANT?

The environmental crisis and the building sector

Ecologically speaking, the global environmental development is alarming: human activities such as fossil fuels use and deforestation are producing greenhouse gases that have resulted in global warming and climate change. Dramatic measures for mitigation are needed putting the building and housing sectors in focus as currently 40 percent of all energy consumption and greenhouse gas emissions in the world are created by construction building and housing sectors.[1]

Buildings and housing account for a considerable share of the world's resources: 12 percent of global fresh water used by the building sector, 40 percent of all waste and a major amount of pollution is generated by the building sector;[2] and approximately 60 percent of world's electricity is used for residential and commercial buildings.[3] Compared with other sectors, the housing sector has the most potential for improvement without extra cost in the near future: according to the Intergovernmental Panel on Climate Change (IPCC), 29 percent of its energy consumption can be reduced by the year 2020.[4]

Urbanization in developing countries

Urbanization puts pressure on the building industry. At the moment, developed countries are responsible for most building sector-related energy and CO_2 emissions globally. However, this is changing fast: developing countries are urbanizing at a rate two to three times faster than developed countries[5] and the majority of the future population growth is predicted to happen in urban areas of the developing countries[6].

Urbanization is most rapid in the slums and informal settlements that proliferate in most cities of the developing world: every third urban dweller in the developing world lives in slums.[7] In order to mitigate climate change globally a major focus needs to be shifted to the housing practices in developing countries: 90 percent of the world's slum dweller population is predicted to still live in inadequate houses in the end of the timeframe for the Millennium development goals (MDGs) in 2020[8]. It is thus crucial that governments invest in pro-poor slum upgrading and prevention as obligated by the MDGs[9] in a manner that is environmentally responsible as obligated by international declarations such as the Rio declaration (Box 1) in order to facilitate future generations in the frame of earth's carrying capacity.[10] [11] Sustainable housing strategies need to be affordable in order to make them a realistic option for the poor and to ensure their implementation in developing countries.

Gaps in the current development of the sustainable housing sector

The Habitat Agenda, among other policy instruments and documents, calls for comprehensive methods to promote sustainable housing.[12] The construction sector/ private sector have a major role in the efforts

BOX 1: THE RIO DECLARATION ON ENVIRONMENT AND DEVELOPMENT

The Rio declaration seeks to protect the global environment. International agreements on environmental issues and new environmental legislation at the state level are encouraged. The declaration states: "Human beings are at the centre of concerns for sustainable development"... and states have the responsibility to "...ensure that activities within their jurisdiction or control do not cause damage to the environment...". "... The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations..." Poverty reduction is declared to be "... an indispensable requirement for sustainable development". Participation of all citizens including women, young people and indigenous people in environmental matters is concerned important. Both developing and developed countries are seen to have responsibilities related to sustainable development: "the global south needs to escape from poverty and the global north needs to adapt its energy consumption".

Source: United Nations (1992), Rio Declaration on Environment and Development; The United Nations Conference on Environment and Development; Rio de Janeiro 3- 14 June 1992.

to provide new technologies and options for comprehensive sustainable housing as household choices are restricted by the products and services available.[13] [14] Currently low-income housing is often not technically, socially, environmentally and culturally appropriate.[15] Additionally there are not enough affordable housing options available especially in developing countries, which concerns the poorest and most vulnerable slum dwellers but even the former middle class that have faced economic constraints due to the global economic crisis.[16]

New and upgraded sustainable low-income housing in the urban areas of developing countries are needed. In economic transition countries energy efficiency is an issue together with inadequate and/or unclear property rights and a lack of effective housing policies /legislation.[17] While urbanization and population growth are continuing rapidly in Africa and Asia; the need to retrofit housing stock in Latin America and Eastern Europe is becoming more evident. Comprehensive visions for sustainable affordable housing development are crucial and they should be realistically scheduled, based on best practices and derive from specific locations and contexts analysed together with regional, national and global development patterns.

1.4 TAKING A COMPREHENSIVE APPROACH TO SUSTAINABLE HOUSING

Sustainable housing: more than environmental efficiency

Sustainable housing means housing that takes into account the long-term environmental, social, cultural and economic balance of the housing stock and its occupants. Sustainable housing is connected to economic development of all income groups and to inclusive institutions. Sustainable housing should be affordable and the planning and building process should be harnesses to empower communities and build people's skills and capacities.

A comprehensive approach is extremely important. Even if it uses the most environmentally sustainable materials and construction methods a house is not sustainable if it is not culturally and socially appropriate; affordable; located near to employment and services; and connected to a well functioning infrastructure and service network. Sustainable urban planning (density, ecological transportation, etc.) good governance, as well as the micro- and macro-economy should be connected to housing strategies.[18]

Integrated development goals aiming towards the environmental, economic, cultural, social and physical sustainability of settlements need to be connected to housing with considerations for indigenous methods, accessibility to the least empowered and disaster risk reduction.[19] [20] Traditionally, it could be argued, sustainability has become a synonym for environmental matters in the developed countries, and economic matters in developing countries.[21] However, the different areas of sustainability should not be seen as separate entities but as interconnected layers of the same matter: greening buildings can for example improve the productivity and health of people supporting economic growth.[22] [23] Seeing the opportunities of environmental sustainability to increase economic and social sustainability is especially crucial for rapidly growing developing countries.

Long-term holistic building process

The whole process of building should be thought of from a sustainability point of view: planning, implementation, operation and maintenance, demolition, disposal and recycling of materials should be considered already when designing housing. Architectural interventions such as location, orientation, size and form of the building and choice of material are as important as environmentally sustainable engineering.[24]

It is especially important for developing countries to connect building processes with strategies of economic development, cultural preservation and social empowerment and participation of communities (Box2). Knowledge sharing, partnerships and cooperation between all actors working within the sustainable housing sector should be encouraged.[25] Building on demonstration projects of other agencies is recommendable[26] and scaling up sustainable housing practices of great importance.

1.5 ENVIRONMENTAL SUSTAINABILITY

Methods for achieving environmental affordable housing

Environmental sustainability means balancing multiple matters and choices. The choices should always be considered against the context, the local climate, material availability and environmental resources. Saving energy in construction, manufacturing and transportation of materials; designing and planning for energy efficiency; prioritizing natural and recycled materials; connecting housing with sustainable energy provision; and avoiding poisons and pollutants should be considered (Box 3). Renewable energy, rain water collection, passive design methods for solar gain and insulation for preserving warmth can be used.[27] [28] [29] Designing smaller buildings and preserving large parts of existing structures in renovations save energy.[30] The skills for designing environmentally sustainable housing should be developed already at the university level [31] as the lack of knowledge often prevents the use by professional.[32]

Affordable housing and energy

The major growth in slums of developing countries calls for sustainable energy strategies related to affordable housing. Finding alternative ways to produce energy for affordable housing is important[33] however these will possibly not be enough to completely replace the need for fossil fuel and not yet always affordable enough. Thus energy efficiency methods are crucial.[34]

The energy consumption of a building is measured in two ways; embodied energy (production, transportation, assembling of specific material and the technique used), and the energy used for maintenance (ventilation, heating, water and electricity). The climate zone affects both but both should be decreased as much as possible for the context.[35] The selection of building materials (with low carbon dioxide emissions throughout their life cycle: raw material extraction, transport, manufacturing, use, reuse, recycling and final disposal) and the construction technique are both crucial[36] and emphasized in several international declarations, for example the Habitat Agenda (Box 4).

Environmental aspects of building materials

Of the most used materials, wooden products have the lowest embodied energy compared with concrete and steel. Plastic production takes a lot of energy and creates permanent waste. In the production of glass harmful substances are created but glass can be recycled endless times. Metal materials are durable and recyclable but their production creates pollutions and requires a lot of energy.[37]

In addition to the embodied energy, harmful ingredients in materials should also be thought of including substances such as asbestos.[38] Minimizing the usage of energy-intensive materials/resources should be balanced with the long-term performance of the material: natural materials are energy efficient but modern materials often last longer and require less regular maintenance. The use of modern materials should thus be combined with natural materials.[39] It is important to remember that communities, especially in the developing countries, tend to stick to materials they are used to using[40] making techniques to improve the use of traditional materials important.

BOX 2: VERTICAL HOUSING IN BRAZIL

The Centre of Projects for the Built Environment facilitated a project of high-quality multi-story housing units for approximately 5000 low-income families in São Paulo, Brazil between years 1990-2007. The project has added density in an urban context; included people in all stages of the building process; given people skills; enhanced women's positions; and increased the knowledge of local governments about the importance of the social aspects in housing. Similar projects in Brazil have lead to an attitude change on the higher political levels: public funds are now used to support housing for low-income households. In 2001 'The city statute' was approved by the parliament followed by a Slum Action Plan by the Secretariat for Housing and Urban Development.

In São Paolo informal settlements are usually multi-story houses up to four floors built by households themselves, and they are sometimes located in high-risk areas. The USINA project introduced training for new technologies such as building steel stair towers and structural blocks that enabled people to build higher-quality multi-story housing without professional help. Locally-available materials were used. Employment, cultural activities and community facilities were integrated. The project was funded with government resources without any external aid money. There was a funding system introduced that gave credit according to household income with a low-interest rate. The construction work created employment such as small scale businesses and strengthened people's social networks.

Sources: http://www.worldhabitatawards.org and Enabling shelter strategies, Review of experience from two decades of implementation (2006), UN-Habitat

Traditional building methods in Nepal. ***© Matthew French, UN-Habitat.***

BOX 3: ECOLOGICAL HOUSING IN SETAGAYA-KU FUKASAWA, TOKYO, JAPAN

The project, realized in 1997, provided environmentally sustainable housing in one of the densest cities in the world with the normal public housing cost financed totally from the public sector funds. Five apartment buildings were constructed with 70 dwellings, 43 of which were for low income residents. High levels of thermal insulation and technologies saving energy such as a solar collector for heating and hot water; solar cells; and wind turbines were attached and water saving methods such as a permeable pavement and rain water collection were installed.

Various passive lighting, heating and cooling methods were applied and the design was made according to the local wind patterns to enable natural ventilation during the hot and humid summers. The building materials were selected to have minimal impacts on the environment and the health of the residents. Many trees were preserved and moved to the site; a garden established; and green rooftops installed, which is important in the context of low urban greenery and a major urban heat island effect. Thirty percent savings of the average household energy bills were achieved. Shared community facilities were constructed. The project had a social dimension resulting in a social mix that is very rare in Tokyo. The high level of social interaction achieved is not common in the communities of Tokyo. The residents actively participated in the different phases of project and have continued to cooperate.

Source: http://www.worldhabitatawards.org

1.6 SOCIAL SUSTAINABILITY

Empowerment and participation

Social sustainability has many dimensions. One of them is the empowerment of people from all income, age and ethnic groups, regardless of gender, to be a part of housing construction processes and the decision-making behind them. People should be involved in information gathering, planning, implementation, maintenance and monitoring processes related to housing[41] (Box 5).

It is important to build the capacity of economically and socially disadvantaged communities to understand laws, policies, and regulations; empower groups to influence city-building processes through democratic systems; and, where possible, give disadvantaged people the means to construct their own houses in the manner they see fit. Considering these social dimensions makes houses more responsive and appropriate. They can better reflect the needs of the users and occupants; and the building of skills and a feeling of ownership and responsibility are created.[42]

Especially in developing countries, a 'bottom-up' approach involving communities, local authorities and local stakeholders in planning and construction processes is extremely beneficial in contrast to a purely 'top-down' approach where large contractors and national governments are in charge of the process. By using decentralized strategies (in line with national strategies) long-term housing solutions can be achieved that are used and appreciated by the people whom the housing is supposed to seve.[43]

Social integration of different groups in housing production builds social capacity and strengthens social resiliency

Social sustainability means striving towards equal participation of different groups in the decision-making, planning, and production of housing.[44] It is important to avoid social exclusion of different gender, ethnic and low-income groups. This is especially important in developing countries where low-income groups are often excluded in official planning processes and resort to resolving their immediate housing needs through informal settlement approaches.

By increasing the opportunities for affordable housing for low-income groups social tensions can be decreased[45] and community stability, social interaction, and security increased. On the individual level quality of life, adequate housing standard, and access to a secure income, basic urban services, and infrastructure are important matters of social sustainability that should be facilitated through housing strategies. Additionally, housing construction can help in job-creation and building skills.[46] All the above mentioned matters can build the social capacity of vulnerable groups and communities of the developing world, which in turn can build their social resiliency to cope with changes, external shocks or socio-economic challenges.[47]

Links between urban forms and social sustainability

Specific urban forms such as a compact city and mixed land use can support socio-economic activities and social stability and equity if addressed together with the needs and preferences of different social groups. Density makes accessing facilities and services easier and cheaper and enables greater social interaction. Households' sense of security improves as isolated areas prone to crime and violence decrease. In dense settlements different groups are more likely to mix, which can decrease social segregation,[48] which is particularly important in the context of developing countries prone to high levels of social segregation of different groups.

1.7 ECONOMIC SUSTAINABILITY

Housing sector and income generation

It is crucial to link income generation (jobs, productivity) to housing policies for ensuring long-term solutions.[49] New employment can be created through the housing sector, which is especially important in the context of developing countries. Jobs can be created through new construction and retrofitting, production of energy efficient or recycled materials and though renewable energy and technologies related to it. The informal sector can, and should be engaged in developing countries, which increases the building sector's potential for poverty reduction by building on existing skills, networks and capabilities – even though they operate outside the formal construction sector.[50]

It is important to think about housing solutions that are grounded in their locales: construction and local material production by the community members can create local employment.[51] Workshops and training sessions during the planning and implementation of housing construction projects can build the capacity of local communities and professionals, as well as develop the capacity of the housing sector in general and therefore support the long-term economic sustainability of the specific area.[52] There have been many pilot and demonstration projects implemented in developing and transition countries where housing construction has generated job creation (Box 6). Scaling up from these experiences is important to address the massive housing demand in developing coutries.

Making an initial investment for long-term savings

Low-cost sustainable housing offers significant economic advantages in terms of energy-saving during use/occupation making sustainable housing cheaper in long-term compared to conventional housing.[53] However, the initial investment needed is usually higher than conventional housing and thus given the limited access to housing finance in developing countries, green building strategies are not currently widely adopted.[54] Tools such as governmental incentives to use renewable and secondary resources can be used to attract and motivate the private sector to 'build green'.[55] Low-income households, especially in developing countries, often do not have the initial capital needed for building sustainable housing or can face problems of paying back loans[56] making supportive financial support that provide cheap credit crucial.[57]

Means such as policy and regulatory changes, adjusting interest rates, providing benefits, or taxation on particular technologies and building approaches can be used to construct markets that induce green building practices.[58] Economic development in slum areas and micro-economic support to the poorest are important in order to facilitate economically sustainable slum upgrading programmes[59] whilst reducing the unwanted pressures of gentrification (households relocating after upgrading).[60]

BOX 4: THE HABITAT AGENDA

The Habitat Agenda adopted in the Istanbul Habitat conference of 1996 aims to reduce the negative environmental implications of building materials and construction technologies. The Habitat Agenda has its roots in the Brundtland commission's report "Our Common Future" 1987 addressing environmental sustainability, concerning the use of renewable materials and the reduction of greenhouse gas emissions.

Sources: UN-Habitat (1996), The Habitat Agenda Goals and Principles, Commitments and the Global Plan of Action; Brundtland Commission (1987), Our Common Future

1.8 CULTURAL SUSTAINABILITY

Cultural heritage

The most well-known and accepted meaning of cultural sustainability is protecting cultural built heritage. Housing can have a historic, aesthetic, spiritual or symbolic cultural heritage value even if it may not be economically valuable. Protecting cultural heritage can make people closer to their traditions and is a responsibility in terms of preserving history.[61]

Maintaining and protecting heritage of different groups in a society can enhance equity, create lively cities and help maintain peace and stability. Preservation of buildings should not only concern old buildings but also new culturally significant ones that have the potential of becoming heritage in the future. The traditional housing patterns and forms in developing countries should be considered as cultural heritage and preserved for future generations. The maintenance and protection of cultural heritage and traditional settlements can also help in sustaining economic activity in terms of tourism.

Culturally appropriate affordable housing

Just as important as cultural heritage is producing and maintaining housing that is culturally responsive and appropriate to the occupants who use it and the society in which it is located. This means aspects such as the form, design, spatial layout, materials, etc., must reflect the worldviews, values, ideals, lifestyles of its occupants and the cultural groups that it serves. The importance of cultural adequacy is highlighted by it being one of the seven criteria of 'adequate housing' as prescribed in the

BOX 5: UN-HABITAT PEOPLE'S PROCESS: ACEH NIAS SETTLEMENTS SUPPORT PROGRAMME ANSSP, INDONESIA

December 24th 2004 the Indian Ocean Tsunami hit the region of Aceh-Nias in Indonesia killing over 130,000 people and displacing half a million people. The tsunami was followed by a destructive earthquake three months later. UN-Habitat started in January 2005 to rebuild the houses of 3,450 families in six districts: altogether 4,492 houses were built. Social sustainability dimensions were taken into account: people were helped to return to their living environments if these were safe and involved in quickly starting a process of an inclusive and integrated reconstruction of permanent housing.

A strategy called the 'People's Process' put people's participation in the centre of decision making processes. Reconstruction was seen as a comprehensive settlement planning process combining housing reconstruction with the rebuilding of other sectors such as trunk infrastructure, services, employment, community facilities and risk mitigation. Social capital was built, which is especially crucial in the traumatizing environment of post-crisis where people have often lost all their assets.

The participatory reconstruction process resulted into higher quality buildings; higher satisfaction of the households; provided much needed work; and enabled rebuilding of social structures. Both women and men were involved in people's process developing their skills. People were involved in assigning priorities; making decisions; producing and implementing action plans; and reconstructing houses. Networks with institutions on higher levels and trust, unity, and capacities at the community level were built; and governance systems strengthened.

Source: UN-Habitat (2009), Anchoring Homes, UN-Habitat's people's process in Aceh and Nias after the tsunami, 2007, Post Tsunami Aceh-Nias Settlement and housing Recovery Review, UN-Habitat

International Right to Adequate Housing.[62]

Slum upgrading programmes in the developing countries should be culturally appropriate and reflect the context. Taking into account the ideas, beliefs and traditions of the specific cultural groups helps in providing housing that meets the needs of people, is appropriate in the specific context and thus can ensure the optimum use of housing and enhances occupants' feelings of belonging and wellbeing.[63]

It is valuable to start projects with a focus on local needs, allowing community-driven approaches instead of following misallocated alignments of the donor community or top-down approaches.[64] [65] Different cultures have different traditions according to settlement patterns, construction materials, design, shape, form and size of the buildings, which should be taken into account when designing housing together with local skills, techniques and building technology[66]. Likewise, much can be learned from traditional building methods and techniques. Sometimes it is however beneficial to adapt and refine traditional buildings approaches in a culturally appropriate way so that they meet modern standards and disaster risk reduction goals.

1.9 INSTITUTIONAL SUSTAINABILITY

Institutional responsibility to promote sustainable affordable housing

Governments and the laws, policies and institutions that they are in charge of greatly shape urban development, whether it is sustainable or not.[67] Local governments in particular should support the supply of low-cost housing development to meet demand.[68] Institutional sustainability – maintaining the presence, strengthening the abilities, and evolving the mandates of public institutions and private organizations - is a basis for any attempt to providing long term environmentally, culturally, economically and socially sustainable housing.[69]

Especially in developing countries where sustainable planning and building standards in housing are not yet common, institutional support for achieving sustainable housing practices is crucial and should be supported by capacity building and the development of the sector as a whole. However, financial resources are still often the dominant priority in the governmental programmes of developing countries: large numbers of low-cost housing units are often built instead of a smaller amount of sustainable units.[70] Social and ecological goals should be as important in the institutional agendas as the economic ones.

Integrating principles of sustainable housing, environmental protection and inclusion of different groups in decision making in national, municipal and local policies and laws is important for institutional sustainability.[71] Hidden costs and market failures can be avoided by efficient regulatory measures for sustainable housing.[72] For ensuring low-cost housing, regulatory frameworks of subsidized rates for renters or affordable prices for housing units can be used and paying of these ensured with affordable loans, subsidizes, long-term loans and mortgages which are given even towards informal income.[73] All members of a society including vulnerable groups, both men and women, and different ethnic groups and minorities should be included in democratic processes.

Inclusive building codes, standards and regulation

Building codes, standards and regulations should ensure social, environmental and economic goals and take into account even the limited resources of the most disadvantaged sectors of the population.[74] Often building codes and standards prevent the use of sustainable technologies/materials and often there is no viable quality control after the construction.[75] Additionally, housing policies are often detached from the practices of the building industry.[76] In many developing

BOX 6: MONTEAGUDO HOUSING PROJECT, BUENOS AIRES, ARGENTINA

After the 2001 economic collapse Argentina had an unemployment rate of 24 percent with half of the population living under the poverty line. Since then, the structural move away from poverty has been slow. In the community-led Complejo Monteagudo project formerly homeless unemployed people constructed 326 high quality multi-story houses for themselves at an equivalent cost of common social housing. The beneficiaries did not previously have access to credit and the project was realized with public funding. A zero-interest loan was given with a repayment time of 30 years.

A technical training centre was established where the capacities and skills of both men and women were built in the areas of building construction, project planning, and self-management of resources. After the project a construction company was registered on commercial basis, which together with self-employment created 400 permanent formal jobs for structurally unemployed/former informal workers. The project was the first pilot for community-led and managed housing projects in Argentina to receive direct funding from the municipal government and has inspired other communities in Buenos Aires.

Source: World Habitat Awards, http://www.worldhabitatawards.org

countries exclusive urban planning, building regulations and codes; and lack of affordable land leave the urban poor outside the formal construction processes resulting in building on vulnerable disaster-prone land with inadequate materials without security of tenure. The lack of security of tenure often leads to forced evictions (Box 7). Inclusion of all income groups in regulatory frameworks is crucial for long-term sustainability[77] together with helping people to organize themselves to negotiate with the local governments.[78] Top-down regulations related to sustainable affordable housing are important but they need to be connected to bottom-up strategies in order to ensure implementation and adherence in the field.

1.10 VULNERABLE AND SPECIAL NEEDS GROUPS

Indigenous people and housing

According to the Rio Declaration on Environment and Development"… Indigenous people and their communities and other local communities have a vital role in environmental management and development because of their knowledge and traditional practices…"[79] As a part of cultural and social sustainability, heritage/housing traditions and adequate housing stock for indigenous people and minorities should be preserved and provided. This requires extra thought as the living traditions; traditional construction materials and techniques; size, form and design of the houses; settlement patterns; and cultural habits related to housing of indigenous groups and minorities can differ largely from that of the mainstream population (Box 8). Sometimes solutions suitable for the mainstream population might not be appropriate in an indigenous culture.

Preventing discrimination of minorities

Discrimination related to characteristics such as race, tribe, color, sex, language, religion, political or other opinion, national or social origin, property, birth or other status is prohibited in many international laws, internationally accepted policies, UN-resolutions, world conferences and declarations. For example the International Covenant on Economic, Social and Cultural Rights states that all human being should

A traditional ger in Mongolia. ***© Emma-Liisa Hannula, UN-Habitat.***

have freedom from fear and freely practice economic, social and cultural activities (including obtaining and maintaining housing) with equal rights.[80] Despite this, minorities are often excluded from housing and mortgage markets due to prejudices which leads to segregation. Problems of getting credit to buy a house keep minorities in marginal areas, which also have fewer education and employment opportunities. This in turn prevents minorities to improve their economic and social capabilities. Unstable economic situations in turn make minorities risky mortgage applicants, preventing them of getting credit for housing.[81] It is crucial for the overall stability, peace and development of a country to include minorities in housing strategies.

Including the specific needs of different groups into planning of affordable housing

It is important to think about all groups of users including different age groups and genders when designing housing and settlement patterns. Women and men, and adults and the youth use both private and public space differently and have different kinds of preferences and needs when it comes to housing. Planning and design that appears neutral often fails to accommodate the needs of women, youth and other vulnerable groups.

Housing options should be various including single apartments and shared apartments for collective use in addition to the houses for nuclear families.[82] It is crucial to promote affordable access and housing options for the disabled which include access ramps or low enough entrances; doors large enough for wheel chairs; and inside spaces that allowmovement with a wheel chair. For the elderly, extra handles can be installed and steep stairs should be avoided in the domestic environment. For children, providing safe spaces to play and move from one place to another is important in the public environment. Different kind of assessments, interviews, information and data gathering can help to identify the needs of different occupant groups. Employment opportunities presented by housing construction should be made available also for women and unemployed youth by trainings and information sharing.[83]

BOX 7: FORCED EVICTIONS

Under international human rights law, particularly the right to adequate housing, forced eviction is understood as the "permanent or temporary removal against their will of individuals, families and/or communities from the homes and/or land which they occupy, without the provision of, and access to, appropriate forms of legal or other protection". 1 Despite the fact that forced evictions constitute a gross violation of human rights 2, states are often sanctioning the practice of forced evictions 3. During forced evictions houses, property, social networks and livelihood strategies are destroyed.

Forced evictions are often justified by urban development projects (for example, infrastructure or regeneration projects) and usually disproportionately affect slum dwellers who, in addition to experiencing multiple human rights deprivations, do not have formal titles to their land and housing. Such practices run contrary to the principles and objectives of sustainable development as it leaves already poor and marginalized people in even more vulnerable situations, for example by leaving them but no choice to relocate to more peripheral locations that impede their access to affordable transportation and reduce their social networks that often generates possibilities for employment.

Forced evictions are counter-productive to any long-term strategy to solve urban informality as the poor people who have been forcibly evicted usually return to the city centers to live in search of employment and services. Preventing and proposing alternatives to forced evictions should be an integral part of institutional capacity and any affordable housing strategies. Urban planning interventions – such as land readjustment – can be used to develop alternative urban development schemes. The poor populations of cities must be included in the urban development in line with long-term sustainability goals. Communities should be consulted in processes that directly impact on their lives through participatory processes for urban planning interventions.

Sources: CESCR, general Comment No.7 on the Right to Adequate Housing, (E/C.12/1997/4), para 8.; 2 UN Commission on Human rights, Resolution 1993/77, para 1.; 3 UN-HABITAT (2007), Forced evictions-Towards solutions? Second report of the Advisory Group on Forced evictions to the Executive director of UN-HABITAT, Advisory group on Forced Evictions (AGFE)

Gender, housing and settlements

Gender matters should not be treated as a separate sector unlinked to the overall housing design and planning. Women often think of domestic security matters more than men in terms of urban space and use. Likewise often services and infrastructure are thought of differently than men, and women access employment through different routes than men. Women usually prioritize privacy and specific functions such as having cooking facilities and children's playing areas close to each other. For women and children increasing safety and security of settlements is especially important. Women should be included throughout the whole planning and implementation process of housing as equal participants and empowered to be involved in decision-making. When involving women in the communities it is, however, important to ensure that participation does not put women in dangerous positions: the involvement of women needs to be done in a culturally sensitive manner.[84]

1.11 SCALING UP SUSTAINABLE HOUSING PRACTICES

Institutional frameworks

The housing sector is a complex network of interlinked institutions, actors, laws, by-laws, policies and regulations. Additionally, multiple matters such as building materials, labor (including architects, engineers, and builders and masons), infrastructure, finance and land affect housing (Figure 1). In order to scale up sustainable housing it is important to influence the institutional framework of housing, which in turn influences the different components of the housing sector.

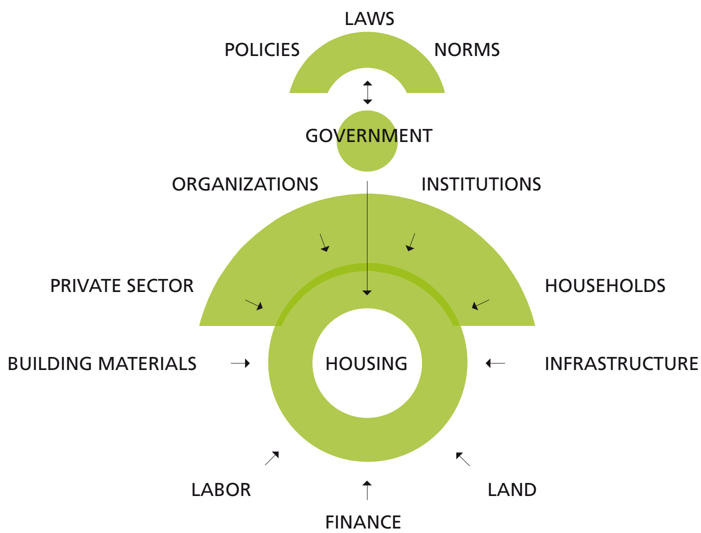
For example a lack of institutional support often results in a lack of finance for traditional materials/techniques as banks can refuse to finance construction processes utilizing such materials. Similarly, outdated/restrictive legal frameworks and building codes that do not enable the use of traditional materials, such as soil blocks, and sustainable construction techniques restrict the use of them.[85]

Institutional structures in charge of housing practices in a country include national ministries (such as the ministry of housing and urban development; ministry of environment; ministry of planning; the ministry of land; and the ministry of forestry), as well as state and municipal authorities. They operate in the regulatory framework of enforced laws, legislation and bi-laws of a country or an area and are shaped by policies, norms and standards. These feed into building codes, and infrastructure standards.

Governmental policies guide urban plans and norms, land use, and other regulations related to housing. Institutional decisions have also indirect consequences: for example if the ministry of forestry restricts logging, there will be lack of wood-based building materials, which results in a rise in the costs of wood and thus to decreased use of timber in construction.[86]

Institutions are linked with other actors including the private sector, households, and organizations, which also act inside the same regulatory framework than institutions but are also influenced by other factors

FIGURE 1: STAKEHOLDERS AND MATTERS AFFECTING HOUSING.



Source: UN-Habitat, 2012.

such as customary laws and the supply and demand chains of market forces (both formal and informal). Stakeholder analysis is an effective tool to understand what instances are influencing efforts to scale up sustainable housing in a country. Targeted efforts to promote sustainable housing to the most influential actors can then be done according to the stakeholder analysis.[87]

Monitoring and evaluation

Monitoring and evaluation of sustainable housing practices is an important tool to prove to various actors, including the political institutions and the national/international financial institutions, the benefits of sustainable housing. Monitoring and evaluation should feed into policies and help secure funding.

It is important to monitor and evaluate all aspects of sustainable housing: not only environmental but also social, economic and cultural. However, appropriate and contextspecific tools to conduct monitoring and evaluation of sustainable housing practices in developing countries are still weak. In developed countries tools such as LEED and BREEAM have been used but they cannot be directly implemented in all developing countries: intermediate tools need to be introduced.

One of the possible tools to be used is Sustainable Building Assessment Methodology (SBAM) developed by SKAT (Swiss Resource Centre and Consultancies for Development) and AD (Development Alternatives) between 2001-2005. SBAM is a participatory tool conducted through a workshop where stakeholders (30-35 participants including community members, private sector, public sector, donors, authorities and professionals) define context-specific qualitative and quantitative indicators for sustainable building practices based on experiences and needs of the specific community; assess already implemented building projects; and select solutions (such as sustainable technologies) for future interventions. Environmental, social, institutional, economic and cultural dimensions are considered and the life cycle of the building process looked into. A web-based software application is used to organize, present and store the information gathered.[88]

Capacity development and capacity building

Building capacities of institutions and actors is crucial for scaling up sustainable housing practices. Capacity development refers to the development of the whole housing sector whereas capacity building aims to improve skills of institutions and actors such as governments, households, organized community groups, housing cooperatives, and federation of building material industry.

It is important to build up capacities to recognize cultural and social needs and develop capacities to implement housing reflecting these needs. In many countries technical capacities to implement environmentally sustainable housing are stronger than the capacities to promote socially and culturally sustainable housing. In many developing countries there is still insufficient capacity to scale up sustainable housing practices and efforts to build up these capacities of institutions and actors are crucial.

Support for mainstreaming

Sustainable housing practices need to be supported by government interventions in order to scale them up and make the sector stronger and more affordable. Both the building sector including architects/engineers/ construction companies and the private households/consumers have a tendency to stick to the practices and habits they are used to, as they are the quickest, and/or the most cost effective in the short term.

BOX 8: HOUSING FOR INDIGENOUS PEOPLE IN AUSTRALIA

The housing conditions of indigenous Australians are very poor. There is a major over representation of homelessness and marginal housing among aboriginals. Access of indigenous people to public housing is worse than that of non-indigenous; aboriginal households are more likely to face forced evictions; and indigenous tenancies have much shorter durations than that of the non-indigenous. Larger dwellings should be constructed to indigenous people to avoid overcrowding 1: many indigenous people live in others' dwellings due to kinfolk visiting that sometimes becomes semi-permanent. The overcrowding can in turn lead to evictions. 2

A three-year research project "More than a Roof Overhead: Meeting the Need for a Sustainable Housing System in Remote Indigenous Communities" by the Charles Darwin University utilised an interdisciplinary approach to remote indigenous housing and aimed to ensure that future investments were targeted to increase functionality and the long-term character of indigenous housing and its connections to socio-economic development. The research material was gathered though field visits in communities; workshops; and consultations. Guidelines on how to best consult indigenous people; holistic housing strategies for indigenous settlements; guidelines to support housing related employment; design decision support tools; and review recommendations for policies and programmes were drafted and made available. 3

Sources: 1 AHURI Research & Policy Bulletin, ISSUE 65, 2005, Indigenous Access to Mainstream Public and Community Housing; AHURI Research & Policy Bulletin, 3 Issue 134, 2010, Indigenous homelessness; 4 RMIT University, Centre for design (2012), http://www.rmit.edu.au

In order to make sustainable housing practices a mainstream strategy for building housing knowledge sharing, advocacy, policy guidance and financial incentives can be used. Campaigns and promotion should also be used to present alternative ways of building and spread the knowledge of sustainable housing practices. Sustainable practices should be made part of governmental policy guidance and building codes in order to facilitate large scale use which in turn builds up market demand that results to more large scale research, product development and better affordability. Subsidies and economic incentives can be used to attract households to use sustainable ways of building. The private sector offering services, materials and products that are sustainable can be supported by subsidies and/or tax incentives.

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A woman constructing a mud house in Mahagi DRC. ***© Zahra Moloo, IRIN.***

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02 SUSTAINABLE DESIGN

KEY MESSAGES

In this chapter sustainable affordable housing is connected to the broader context of urban planning, settlement planning and methodologies to achieve long term housing sustainability through building in response to the climatic conditions and mitigating local disaster risks.

Settlement planning and urban design

- Housing is more than just houses. In order to make housing sustainable it needs to be connected to sustainable settlement planning strategies, infrastructure networks, services, employment structures, connectivity, environmental matters, disaster risk reduction strategies and legal and institutional matters.

- Sustainable settlement planning can increase economic development and the safety of areas; specific urban forms such as mixed use and increased density can help to achieve social and economic sustainability goals.

- Planning should be participatory whenever possible and derive from the specific context. Different planning scales should be used.

Introduction to building

- The different building parts define the structure: The walls, roof, floor and foundation are either monolithic or skeletal depending on the material and the construction method used.

- Tight connections between building parts and weather protection are important.

Building in clifferent climate zones

- Building according to the prevailing climatic conditions is crucial in terms of achieving sustainable housing and energy use reduction: passive solar gain and protection from the sun and wind can be achieved through bio-climatic design and climate specific settlement planning.

- The world climate is divided into five major climatic areas, which all have different conditions that should be taken into account in design and planning.

- Affordable housing projects and slum upgrading projects are too often planned/designed without climatic considerations with detrimental effects on energy use during occupation.

Panoramic view of a street in Seoul, Rep. of South Korea. ***© Madanmohan Rao, UN-Habitat.***

2.1 SETTLEMENT PLANNING AND URBAN DESIGN

Housing is more than just houses. It is connected to a larger network of urban design, settlement patterns, ecological structures as well as infrastructure and services of a city, region and country. Housing design that does not take into account these networks cannot be sustainable in the long-term as urban patterns and access to services and infrastructure affect the productivity, security, quality of life and development of communities.

It is important to use integrated environmental, economic, and physical planning to link livelihoods, infrastructure, settlements and surrounding natural resources. Participatory planning should be used especially in the developing countries as it can foster culturally responsive solutions due to the local knowledge of people; helps to build motivation for the maintenance of public spaces, services, and infrastructure; creates a sense of ownership; and reflects needs.[1] The current scale of urbanization in developing countries does not support the sole use of traditional architecture and design but traditional methods should be used more extensively and be tailored to the specific context and demands of contemporary urbanization.

Urban growth and population growth in the developing countries

The issues and opportunities of urban growth and population growth in the developing countries can be harnessed with good urban planning. In order to make urban development more inclusive, slum upgrading, legal instruments against forced eviction, supply of public housing and rental housing stock, land-sharing arrangements, and planning for affordable, well-located land with infrastructure and affordable housing should be facilitated with planning. The immediate and long-term needs and priorities of low-income households and marginalized communities should be considered and solutions found. City expansion areas for the next 20-30 years should be defined to facilitate the formal and efficient growth of cities in developing countries.[2]

Economy and livelihoods

The proximity of housing to employment determines people's livelihood strategies and thus planning should be used to connect economic opportunities, and locations for different types of employment with housing. Land use for employment that is accessible for low-income households such as small and informal businesses, home-enterprises, agriculture, tourism, and industrial activity should be connected with affordable housing options in developing countries.3 Too often slum resettlement projects are located outside the city centre on land far away from employment opportunities. This leads to situations where transportation becomes inadequately expensive and low-income families decide to move back to more central slums and informal settlements.

Infrastructure and services

Connections to basic infrastructure and services are crucial for sustainable housing. Waste management; water and sewage; roads; lightning and telecommunication are important as well as health and educational services; kindergartens; community centres; spaces for women and youth; and spaces for recreation. The quantity and diversity of services in a settlement should reflect the number of people living in the area.[4]

Planning scales

Housing should be linked to the overall strategic plans of a country and a region, to the city wide plans, sub-center plans and community plans. It is important to plan at different scales simultaneously and to note that unfortunately in many developing countries urban plans are not updated.

In regional plans the relationship of different cities, rural areas, and peri-urban areas and in mega-regional plans large metropolitan areas and mega-regions are addressed. In these scales matters such as access links, resource management, waste management, major infrastructure, manufacturing, economic development and environmental matters are planned.

City-wide plans address matters such as access and infrastructure routes, green areas, city-wide services, land use, industrial areas, business areas, housing areas, building codes, and building restrictions. Sub-center and community plans address local matters and land-use taking in more detailed urban design. Different functions, orientation and typologies of housing, public space and greenery are shown.[5] At the local level settlement patterns and urban design solutions should be adjusted to the prevailing climatic conditions including wind and sun light conditions: in hot climates winds are for example important for ventilation while sun need to be avoided[6] in cold climates it is important to protect houses from winds and allow sunlight exposure during winter months (Figure 4).[7] Placing of buildings, density of the settlement patterns, landscaping and locations of vegetation for example can be used both to direct and protect from winds and to shade or allow sun penetration.

Safety and peace

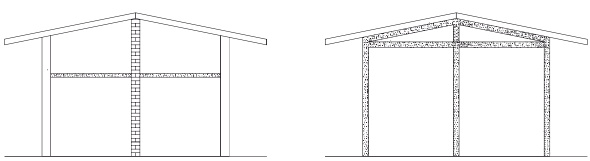
Planning can help in increasing safety, security, inclusiveness and conflict resolution between different groups in settlements: planning that seeks to uphold human rights and ensures the dignity of all groups of people is crucial for sustainability. Safety in settlements can be increased with well-maintained public spaces including adequate lighting, visibility, walkable streets and availability of well-maintained public services and infrastructure: good public space can increase movement, which in turn increases safety and decreases opportunities for violence. Mixed land-use is preferable over isolated mono-functional areas, which often contain safety risks.[8]

Disaster risk reduction

Disaster risk reduction can be facilitated with urban planning prior to the disasters saving a lot of suffering and resources and enabling a significantly more effective post-crisis planning process. Crucial mitigation methods include not building on vulnerable land and establishing resilient building codes, networks, and preparedness plans. In post-disaster the opportunity should be used to build settlements back better increasing resilience and not building them necessarily exactly as they were before.[9] Disaster risk reduction should always be a part of sustainable housing practices as it is connected to the long-term security and development of the communities and relevant in terms of saving human lives and money. The focus of disaster retrofitting should be on pre-disaster not on post-disaster. Reconstruction is a lengthy and expensive process, which gets more complicated with low economic levels and weak governance.

The local disaster risks should be mitigated in housing design and settlement planning: Not building on food plains, not changing natural storm drainage systems and flows of rivers for example help in avoiding flood disasters. Landscape can be shaped, storage dams and protective embankments constructed and

FIGURE 2: STABILIZING BUILDINGS MADE OF SOIL.



Left: stabilizing with buttresses, right: stabilizing with reinforced concrete.

Source: UN-Habitat, 2012. Based on Minke, 2001.

BOX 9: EARTHQUAKE MITIGATION

In many developing countries earthquake retrofitting is not yet wide-spread:[1] in the areas prone-to earthquakes 90% of the people still live in hazardous buildings.2a Wider use of retrofitting is crucial in terms of savings of lives and economic resources.

Earthquake retrofitting technique depends on the materials used. Massive heavy houses should be built on soft soil and light structures on rocky soil. Compact and symmetric house plan and elevations and small buildings rather than tall buildings have better earthquake resistance. Structures are mainly affected by horizontal forces creating falling of walls to outside when the roof collapses. Typical failures from earthquakes are diagonal cracks from window and wall bottom edges and destabilizion of a wall by the lintel. All building parts should be well connected with strong joists in order to stop deformation. A ring beam should be used on the top of the walls to help to stop bending. Gables are a weak point (Figure 2). A roof without gables with four inclined planes resting on a ring beam is the best roof construction.2b,[3]. Stabilizing openings is important (Figure 3).

Strong and flexible materials are important.2c Retrofitting for timber structures include bracing corners and intermediate parts of the walls; strong connections of the walls to the foundation; diagonal braces, plywood sheeting, metal connectors; vertical clenching; connection of wood locks with vertical steel bars; and frames around openings.[4] Brick walls, concrete block constructions, and stone structures are usually weak in tension and shear and get cracks, separations of walls at corners, and collapse partially/completely. Seismic belts and bands as well as vertical reinforced concrete/vertical steel bars can be used in all external and internal walls with proper connections at the corners and T-junctions. Rubble masonry, lime or clay easily lose their cohesion in earthquakes. Earthen houses can be strengthened by using wooden lintel bands/roof bands and buttresses to stabilize corners and wall junctions.2d,[5] Sometimes mud walls are stabilized with bamboo culms.[6] External seismic belts made of ferro-cement plates directions can also be used.2e

1 *Miho Yoshimura, Kimiro Meguro (2004), Paper No. 927: Proposal of retrofitting promotion system for low earthquake-resistant structures in earthquake prone countries, 13th World Conference on Earthquake Engineering: Vancouver, B.C.*

2 *Anan S Arya (2000), Non-engineered construction in developing countries –An approach toward earthquake risk reduction, Paper No. 2824 prepared for the 12WCEE 2000 : 12th World Conference on Earthquake Engineering, in Auckland New Zealand, University of Roorkee, India*

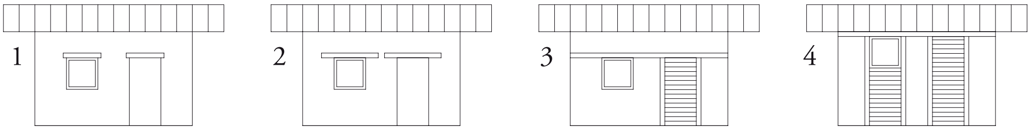
3 *Gernot Minke (2001), Construction manual for earthquake-resistant houses build on earth, GATE - BASIN (Building Advisory Service and Information Network) at GTZ GmbH), http://www2.gtz.de/dokumente/bib/04-5789.pdf*

4 *Chris Arnold, Timber construction, (date unknown), Building Systems Development, USA*

5 *B. V. Venkatarama Reddy (2004), Sustainable building technologies, Special section: application of S&T to rural areas, Current Science, vol. 87, No. 7*

6 *Jules J.A. Janssen (2000), Designing And Building with Bamboo, TECHNICAL REPORT NO. 20, International Network for Bamboo and Rattan*

FIGURE 3: WAYS OF STABILIZING OPENINGS.



1-Openings without stabilizing: dangerous, 2-Using at least 40cm lintels: acceptable,
3-Ring beam stabilization: a good option, 4-Structure resting on the ringbeam and the part below windows built as a light flexible structure: the best option.

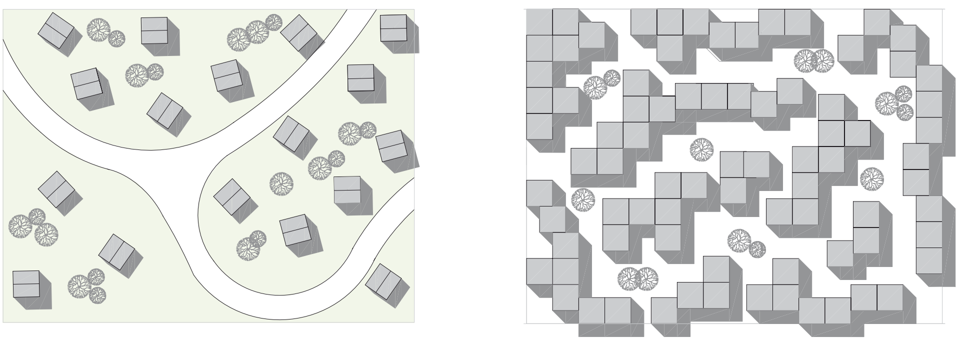
Source: UN-Habitat, 2012. Based on Minke, 2001.

BOX 10 : URBAN DENSITY IN SPRINGFIELD TERRACE, SOUTH AFRICA

Springfield terrace project was developed in 1992 as the first major non-racial lower-income inner city housing project with a purpose of filling in unused space such as small parcels of publicly owned land in the already built-up urban areas. The increased density provided large savings in transport and energy costs, enabled proximity to services and employment and created lively local markets. Public space surrounding the houses was well designed to serve for social purposes, and provide extended living space for households and privacy.

Source: Daniel Irurah et al. (2002); Towards sustainable settlements, Case studies from South Africa, Department of housing, Pretoria, South Africa

FIGURE 4: SETTLEMENT PATTERNS.



Left- looser patterns in hot/humid climate to maximize natural ventilation. Right- dense patterns in hot/dry climate to maximize shading and protect from hot and sandy winds.

Source: UN-Habitat, 2012.

buildings build on poles or robust foundations constructed that reach over the usual flood level of the area. Impacts of tsunami catastrophes can be decreased by building settlements on higher ground and by using anti-tsunami sea walls and effective early-warning systems. Not building on hillsides and protecting vegetation helps to mitigate towards avalanches and mud slides. For storms strong roof sheets can be used.[10 11]The mitigation method used for earthquakes is material specific but there are also general rules for increasing stability (Box9).

Building codes, policies and restrictions should address disaster mitigation and take into account the low-income part of the population.[12 13] It is important to ensure in post-crisis that the houses are not built exactly as they were before but that the disaster resilience is enhanced.[14]

Key principles for sustainable settlement planning:

Density: Mixed land-use settlement plans that combine employment, market related activities, services, and housing lead to significant reduction in greenhouse gas emissions as motor travel decreases[15]; and decrease distances, which save people's time and increase productivity. Means such as land readjustment; planning to utilize unused plots inside the city boundaries (Box10); sharing facilities; and planning secondary centers to complement city centers can be used.[16 17]

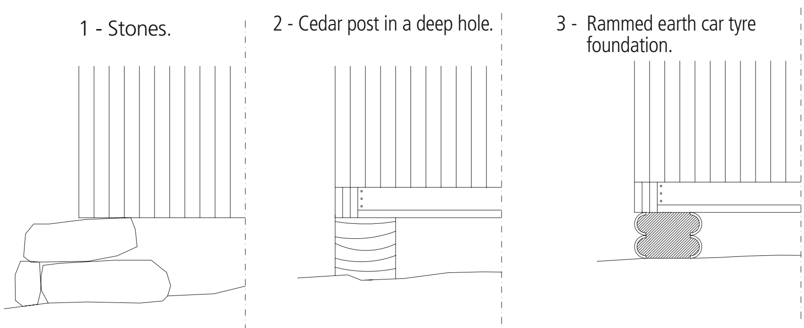
Locality: It is important to plan according to the prevailing local context. Local culture, livelihoods, local physical conditions, the political atmosphere and heritage should be taken into consideration. Human scale design and a sense of place should be promoted by introducing good quality urban design.[18]

Connectivity: The structure of roads is a crucial factor in climate change mitigation. Public transportation should be promoted over private motor travel and varying transport options introduced. Different hierarchies of roads are important. Good internal and external connectivity of housing is crucial for socio-economic sustainability.[19]

Environment: Sustainable management of resources such as water, fuel and forests is crucial for sustainability and peace. Sustainable resource management and ecosystem protection can be taken into planning by addressing protection areas for rare flora and fauna; and leaving space for green areas, wetlands, and ecological corridors in land-use plans.[20]

Legal and institutional: Measures for securing tenure rights for vulnerable groups and promoting sustainable land-use in the legaland institutional frameworks should be taken. Sustainable urban planning needs to be linked to capacity building of institutions and other actors as only implemented planning has real value.[21]

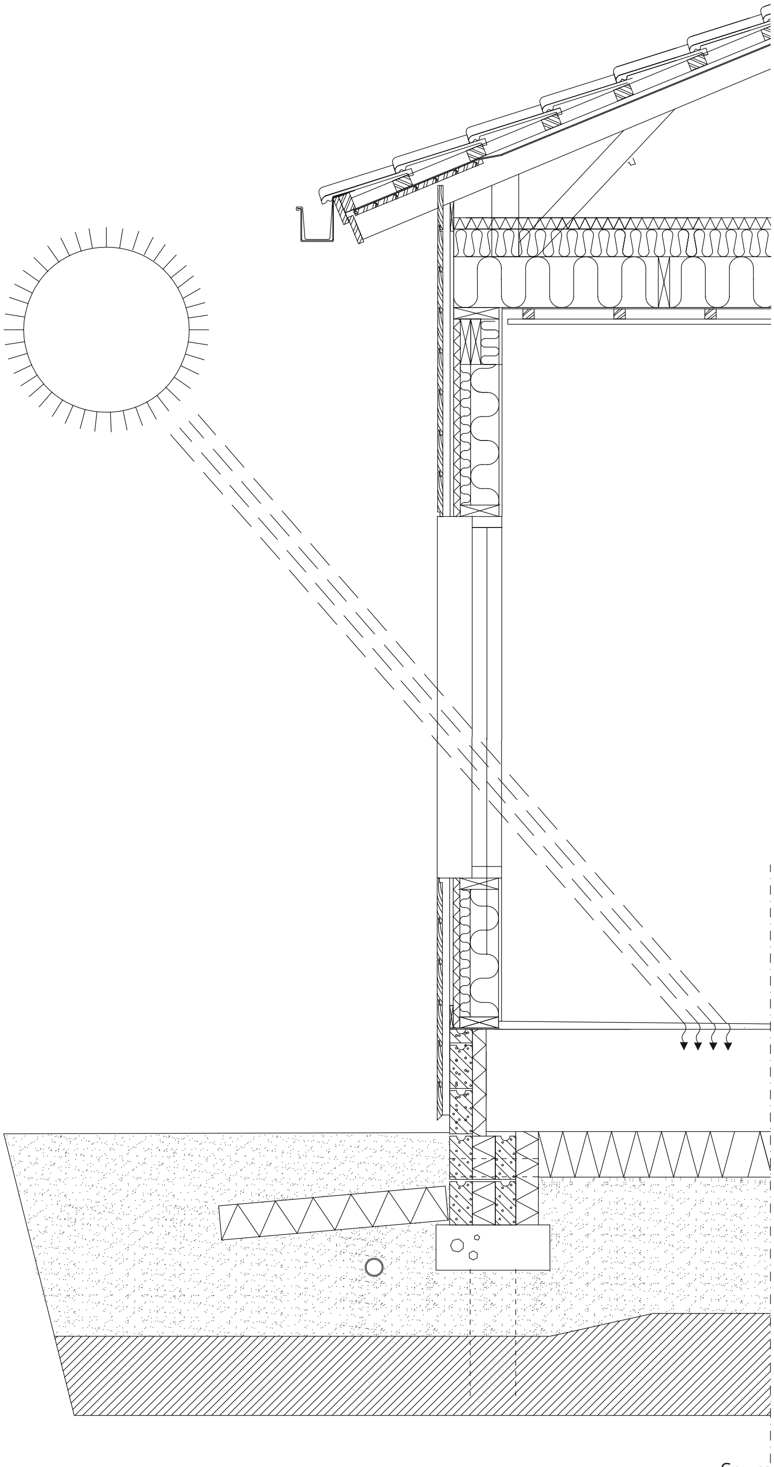
FIGURE 5: FOUNDATIONS FOR RAISED FLOORS.



Source: UN-Habitat 2012.

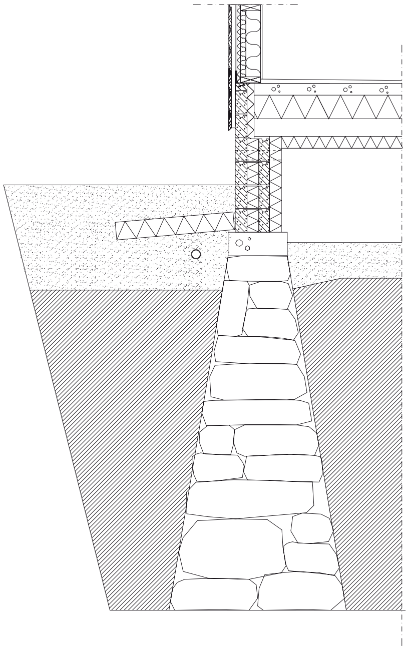
FIGURE 6: EXAMPLE OF A FOUNDATION RESTING ON THE GROUND.

The floor works as a thermal mass.



Source: UN-Habitat, 2012.

FIGURE 7: RUBBLE STONE MASONRY FOUNDATION WITH RAISED FLOOR.



Source: UN-Habitat, 2012,. Based on Skat 2006.

BOX 11: PASSIVE HOUSE

Passive houses do not need external space heating energy: they use passive solar energy and the energy emitted from people and household devices. Heat losses are reduced by post-heating and -cooling measures following the diurnal temperature change (ventilation system with high efficient heat recovery) preserving the temperature somewhat constant and resulting to halved total energy consumption. The windows of a passive house are four-glazed. There is a high level of air tigthness; a very good insulation of walls, roof, floor and other building parts; and windows that loose very little heat (superinsulating window frames; connections without thermal-bridges; directing and forming windows to optimize solar gain; and providing shading in the summer). Passive houses have been built in many developed countries. Currently the cost of a passive house may be too high to be used for affordable housing in developing countries but the principles are still relevant for developing countries in similar climates and strategies to decrease the costs should be sought.

Sources: Dr. Wolfgang Feist, Passive house institute; www.passivehouse.com; Jürgen Schnieders, CEPHEUS – measurement results from more than 100 dwelling units in passive houses, http://www.eceee.org, Markku Lappalainen, (2010), Energia ja ekologia kasikirja, suunnittelu ja rakentaminen, Rakennustieto Oy: Helsinki

2.2 INTRODUCTION TO BUILDING

Walls

In the vast majority of cases, every house has a foundation, walls and a roof. These building elements regulate temperature and protect from weather, insects and other outside forces. Walls bear loads from the roof and transfer them to foundation which transfers them to the ground.

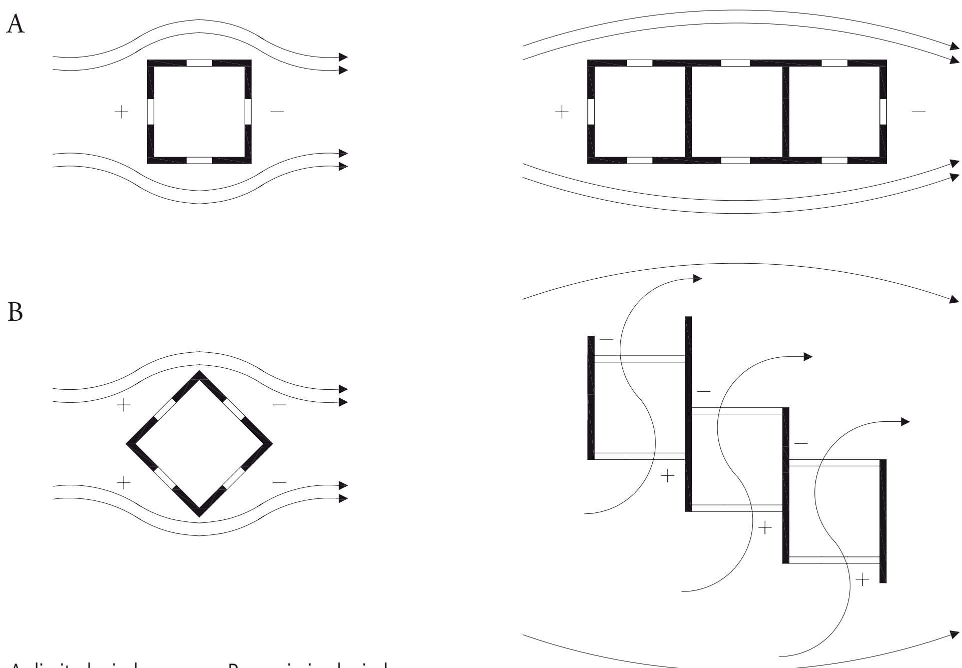
There are two main ways of building walls: skeletal where the bearing walls are made of separate parts (pilasters/columns) and a monolithic where the walls are a single mass.

In a skeletal structure door and window frames are not load bearing, in a monolith wall they bear loads. Walls made of organic or insulative materials need to be lifted from the ground to keep them from water penetration. Monolithic walls are usually more environmentally-sound as they are often made of local/recycled materials. Insulation can be difficult and they can have low thermal performance compared with skeletal walls where insulation is easy. Skeletal walls can be made for example of timber framing, masonry blocks or logs. The walls of a house need to be dense and able to keep dry.[22]

Foundation

Foundations can also be skeletal or monolithic. Massive walls need a strong and wide foundation such as a concrete foundation. Foundations can be made of different materials such as concrete; stones; debris, rubble or stones from demolished buildings; earth filled bags; or rammed earth tires (Figure 5 and 7).[23 24 25] Massive foundations should be built below the frost line in order to avoid water entering the underside, freezing, expanding and pushing the building up. If a skeletal foundation is used gravel trench is placed underneath with an open crawling space to suck water.[26]

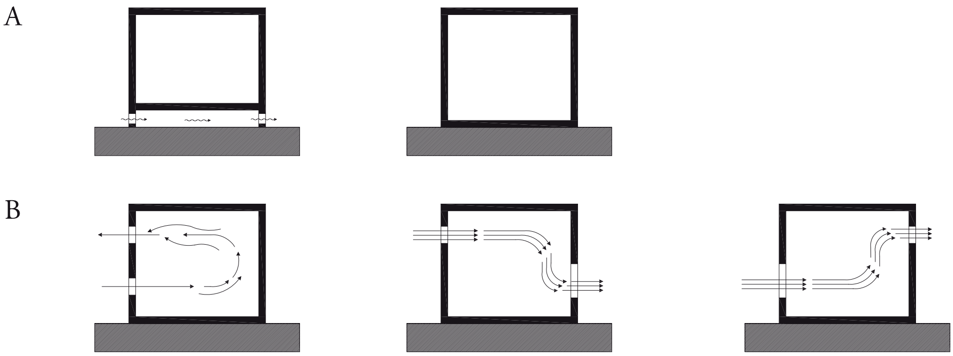
FIGURE 8: ORIENTING BUILDINGS TO MAXIMIZE AIR MOVEMENT.



A- limited wind exposure. B- maximized wind exposure.

Source: UN-Habitat, 2012. Based on Koch-Nielsen, 2002.

FIGURE 9: MAXIMIZING VENTILATION.



A- elevated floor allows ventilation. B- Placing windows to direct ventilation.

Source: UN-Habitat, 2012. Based on Koch-Nielsen, 2002.

Floor and roof

Floors can be either raised or on grade (floor/ foundation that rests on ground surface) depending on the foundation. A floor on grade can be used for heating in a suitable climate if made of a dense thermal mass (Figure 6).[27] The roof is crucial for weather protection making its form, construction technique and material choice important.[28]

Building considerations

It is important to direct rain water away from the building with landscaping and by using gravel, roof overhangs and a foundation drain[29 30]. If mixing different materials in a construction their connections with each other should be carefully thought of and optimal locations for the different materials found in the construction (in the northern hemisphere heat reserving material in south orientation, insulative material in the north orientation).[31]

BOX 12: PASSIVE SOLAR HOUSING IN THE INDIAN HIMALAYAS

GERES India implemented a programme providing passive solar housing technologies in cold desert areas of the Western Himalayas. Prior to the project traditional buildings were built of wood and stone with limited thermal resistance resulting in indoor temperatures below -10°C in the winter. With the new construction techniques the average indoor temperature remained above 5°C.

New houses and retrofits used solar gain, thermal mass and insulation methods. Direct solar gain, solar walls and attached greenhouse on the sun side were used. Insulation was made with local materials such as sawdust, straw and wild grass. As of 2011, 550 houses and community buildings had been constructed.

Positive achievements resulting from the programme included improved capacities of the community dwellers to influence authorities; economic independency; improved women's position; improved health; and increased winter income up to 50 percent. Additionally, a 50- 60 percent reduction in fuel consumption was achieved with major savings in heating costs.

Source: http://www.worldhabitatawards.org

Dense connections and insulation increase energy efficiency of buildings: with very high insulation value energy loss can even become negative (Box 11).

2.3 BUILDING IN DIFFERENT CLIMATE ZONES

The world climate is divided into five zones including several sub-zones:

A) *Tropical/equatorial climate zone:* an average temperature of over 18 Celsius all year, futher divided to three sub zones: tropical rainforest, tropical monsoon and savannah.

B) *Arid and semi arid climate zone:* major differences in night and day time temperaturesand a low precipitation level, further divided to desert and steppe zones.

C) *Temperate climatezone:* an average temperature over 10 Celsius in warm period and between -3 and 18 Celsius in the cold period, further divided to dry-summer subtropical zone, humid subtropical zone and a temperate zone with dry winters.

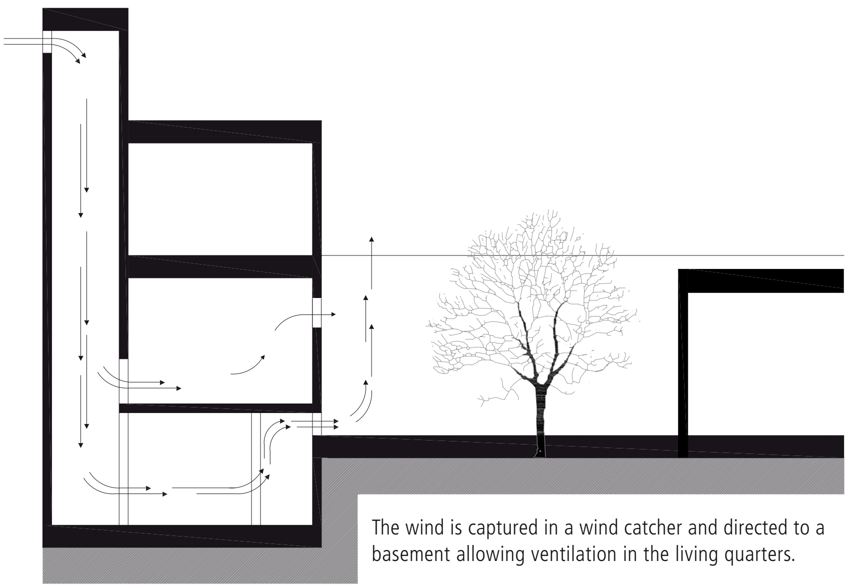
D) *Continental climate zone:* an average temperature above 10 Celsius in the warmest month, and below -3 Celsius in the coldest month, further divided to dry summerclimate, dry winter climate and fully humid climate.

E) *Polar climate:* an average temperature ofbelow 10 Celsius all year, further divided totundra and frost climate.[32]

Building houses with climatic considerations

Bio-climatic design (building houses with climatic considerations in mind), saves energy in terms of reduced heating and cooling costs. Passive solar design, and building orientation towards the prevailing sun and wind conditions are examples of bio-climatic design strategies (Figure 8). A right placement of openings and raised floors can be used to maximize ventilation. (Figure 9). The mass of the building together with height and surface area affects on the ability to store and release heat. The angle and direction of the sun changes during the diurnal cycle and the latitude and windows should be located accordingly.[33] [34] Sunlight coming within 20 degrees of perpendicular is transmitted while

FIGURE 10: A TYPICAL YADZ COURTYARD HOUSE.



Source: UN-Habitat, 2012. Based on May, 2010.

more than 35 degrees from perpendicular is reflected.[35]

Planning settlements with climatic considerations

The settlement pattern of any housing area should reflect the prevailing climate. Low-cost housing is often designed as rows of parallel buildings without climatic orientation consideration. The space between buildings direct wind and affects the quantity/reflection of sun light. Long and high buildings create wind tunnels that can help in ventilation in warm and hot climates[36] but are to be avoided in colder climates.[37] Other factors affecting heat transfer are temperature differences inside and outside, local wind patterns, and the characteristics of a specific wall material.[38]

Warm and humid: tropical/equatorial climate zone, parts of the temperate zone

In this tropical/equatorial climate protecting towards rain, internal heat gains and external solar radiation is important. Open houses and orientation outwards is important to take in all air movement. Shading of buildings and outdoor spaces with roofs, verandas and trees is important to avoid direct solar gain. Long eaves and a composite roof structure (ventilation effect) should be used to minimize heat gain and protect from rain.[39]

The settlement pattern should provide wide spaces between buildings with wide open streets. Buildings should be grouped freely and independently to maximize winds and enclosed walls avoided (Figure 4). High canopy trees should be used to provide shade but allow winds. In urban dense areas height should be prioritized over increased ground surface area as winds will increase with the height of the building. It is important to direct air movements through shaded areas. Wind breaks can be used to increase wind pressures around buildings.[40]

Internal air movements should be maximized by using open wall structures. The air temperature is quite constant during day and night and thus light weight construction should be used to reduce heat storage. Wood for example does not store much heat. Uplifted floor construction to allow maximum air ventilation and minimum heat storage should be used.[41]Large openings on opposite sides of a long and narrow room on body level for horizontal cross ventilation should be designed.[42] Insulated drapes, shutters and exterior roll-down shade screens can be used to shade.[43]

The form of the roof is important in order to directed air to it: a round form attracts air whereas a sharp roof will direct air away. Ventilation openings should be placed according to the angle of the roof and the roof oriented towards prevailing breezes of the hottest summer season.[44]

BOX 13: IRANIAN DESERT TOWNS

The city of Yadz in Iran is built out of adobe and wind catchers/air traps are widely used to mitigate the effects of strong sun, sandstorms, wind and dryness. In Iranian desert towns adobe structures are typically enclosed and interconnected to protect the settlements. Thick walls store heat and release it to the inside after hours. 1 A basement is located in the warmest quarter of a house as it is kept cool by the ground and a wind tower that it is connected to and releases cool air to the inside space (Figure 10). 2

Sources: 1 John May, (2010), Handmade houses and other buildings, The World of vernacular architecture, Thames&Hudson, 2 Shokrollah Manzoor (1989), Tradition and development an approach to vernacular architectural patterns in Iran, Chalmers university of architecture, School of architecture, Division for housing design, Gothenburg

Hot and dry: arid and semi arid climate zone

In this climate shading and reflection of indirect sunlight for minimizing heat gain and protection from stormy and sandy winds are important. There are big differences between day and night temperatures and thus thermal mass can be used to reduce heat gains (Box 12). Thermal mass stores heat during the hot day and releases it to the inside space during the colder night.[45]

Outside spaces and surfaces reflect heat to buildings and thus the lay out of a settlement should be compact with narrow streets. Houses should also be compact and inward facing and oriented so that minimum surface area is exposed to sun. Rectangular buildings should be placed along the average track of the sun with wide eaves. It is important to shade buildings with arcades, trees, pergolas and landscaping. Enclosed shaded courtyards have a cooling effect as they absorb heat from buildings in the night time.

Greenery has also a cooling/shading effect and it does not reflect heat as much as hard surfaces. Water motives can be used for evaporation effect as evaporation has a cooling effect for surfaces.[46 47]

Roofs get the most solar radiation during the day, heating up the inside. Composite roofs get hot in this climate: there is however a space between the roof and the ceiling which can be used to ventilate hot air away with ventilation openings. Flat roofs reserve most heat as the heat is absorbed from the whole surface: it is important to place low parapet walls on the roof to prevent cool night time air to flow of from the edge of the roof and instead cool down the inside space. Arched, domed or pitched roofs are good as they have always one part in shade: the slope of a roof should be directed towards breezes and/or a courtyard (cool night time air flows down towards the courtyard and can be directed inside with a parapet wall and a ventilation opening. The direct solar radiation to the east and west walls should be minimized and light colors used.[48]

Floor should be constructed with a maximum ground contact in order to provide thermal mass. Separate small windows for ventilation and sunlight should be used. Reflected light should be used for lighting by placing high level openings with white reflecting ceiling. Ventilation openings (small openings on windward side and larger openings on leeward side) should be placed in the walls on different heights as wind generated ventilation can be

A house adjusted to the tropical climate in Guatemala. ***© Emma-Liisa Hannula, UN-Habitat.***

assisted by stack effect where air goes up due to a pressure difference and is replaced by cool air coming from down. The rooms should be small and high to maximize ventilation. Cellars to cool inside spaces and wind towers/ wind catchers/air traps can be used (Box 13).[48]

Colder climates with winters: Parts of the temperate zone, continental climate, polar climate

In colder climates saving energy in space heating is important. The energy-efficiency of a building can be increased by making insulation better as well as regulating ventilation, cooling and heating. Passive methods of solar gain and wind protection should be maximized through location and design of the building. Insulation should be included at a level according to the prevailing climate and the minimum temperature.[49]

It is important to avoid thermal bridges (the different building parts have different R-values making one part to loose more heat).[50] The shape of the roof should be designed to protect from winds and roof overhangs made short for enabling solar radiation to enter the inside. In the Northern hemisphere in colder climates windows, glass verandas and greenhouses should be placed in the south side of the building for passive solar gain with summer shading. However, too much glass can create fast over heating/cooling.

Similarly the floor and the wall in the south side (opposite in the Southern hemisphere) of the building can be of thermal mass storing heat and partially buried inside a south facing hill making the structure access the massive thermal mass of the earth. However, too much mass result to a slow temperature changes.[51] [52] Dark colors can be used as they help in heat absorption.[53]

Solar gain, wind gain and position in altitude affect energy usage. Landscaping, fences, embankments, trees and cold storage buildings can be used to protect houses from winds. High and long buildings can create tunnels for winds which should be avoided. Building in valleys should also be avoided as the cold air moves down along the slopes. Coniferous trees on the Northern side (Northern hemisphere) for wind protection and deciduous trees in the southern side of a house should be used in climates with clear winter and summer seasons as they allow solar gain in winter (leaves drop in winter) but protect from excessive solar gain in summer. Houses should not be shaded by other houses.[54]

The form and size of the building determine the use of energy: a two-storey building uses 15 percent less energy than a one storey building and a 3-storey building 10 percent less energy than a 2-storey building but more stories do not save energy significantly. Larger buildings are more energy efficient per square meter. It is important to avoid unnecessary heated spaces and very high stud rooms. The rooms mostly used for living should be located in the south and the bedrooms in the north (Northern hemisphere). In two-storey buildings the living spaces should be located in the upper floor and spaces such as bathroom and storages downstairs as heat raises upwards.[55] The building should be made long and thin on the east-west axis to maximize exposure to the winter sun.[56]

CHAPTER TWO ENDNOTES:

1. UN-Habitat (forthcoming), A post-crisis urban planning quick guide: guidance for practitioners, UN-Habitat: Nairobi
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A house constructed by the Women Savings Group in Malawi Peoples Federation.
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Singapore. ***© Madanmohan Rao, UN-Habitat.***

The Government to replace the improvised homes in the foreground with better standard public housing in the background. Santo Domingo, Dominican Republic. ***© 1973, M Guthrie, UN Photo.***

03 SUSTAINABLE CONSTRUCTION MATERIALS

KEY MESSAGES

In this chapter different sustainable construction materials and their benefits, challenges, and application possibilities in construction are presented. The emphasis of the chapter is on natural materials such as wood and straw based materials and earth and stone based materials as well as on recycled materials. Possibilities to use concrete in a more sustainable way are also presented.

Wood and straw construction

- Wood and straw construction are easy to work with without a high level of required technical expertise or expensive tools and allow good insulation possibilities: straw has a good insulation value on its own and skeletal wood construction allows easy insulation in comparison monolithic constructions.
- Bamboo construction has a lot of potential in the affordable housing sector but the treatment and proper jointing of bamboo need to be ensured.

Earth and stone construction

- Earth and stone construction presents good thermal mass opportunities and a lot of potential in the affordable housing sector to produce comfortable housing interiors, especially in the hot and dry climate zone.
- New ways of producing and using mud bricks, for example through stabilized soil block technologies, has enhanced the abilities of traditional adobe bricks and made them more attractive as an affordable construction material and building system.

Ways of using concrete in a more sustainable manner

- Concrete is one of the most used construction materials in the world today.
- Concrete has many advantageous characteristics, which explains its wide use, but it also has a high embodied energy and its production can emits harmful substances. Additionally, the production of steel needed for reinforcement of concrete has a major environmental impact.
- New ways of producing more environmentally friendly concrete materials and construction systems should be developed and promoted.

Recycled materials

- Recycling materials is of high importance considering the current global environmental crisis.
- Recycling activities can create employment for the informal sector in developing countries.
- A vast amount of different materials from industrial waste, household waste and construction waste can be reused in building.

A boy making bricks at a kiln in Afghanistan. ***© Bethany Matta, IRIN.***

3.1 WOOD AND STRAW CONSTRUCTION

Benefits and challenges of wood and straw construction

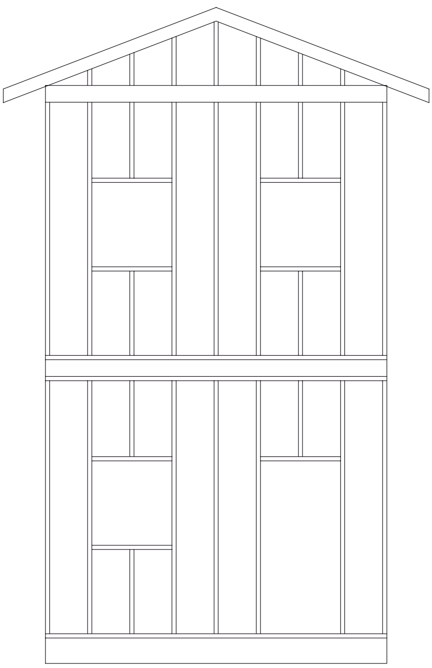
Wood and straw based materials are flexible for different kinds of constructions; easily workable without professionalism and high level of technical expertise; and allow light constructions. One of major common problems related to these materials is fire proofing.

3.1.1 TIMBER

Timber construction

There are six main types of wood construction with considerable variation between: thatch type; post-and-beam frame construction (diagonal members are used to create shear walls) (Figure 11); walls with bamboo/reed mesh and post (waffle and daub); wooden frames with or without infill; monolithic stud-wall frames/stick framing where columns are attached to top and bottom plates with plywood/gypsum board sheathing/diagonal bracing; wood panel construction (walls and floors of layered wood members); and log construction (horizontal timber logs with cross sections and without fasteners).[1]

FIGURE 11: A TYPICAL WOODEN POST-AND-BEAM STRUCTURE.



Source: UN-Habitat, 2012.

Skeletal post-beam structures are the most common ones.[2] A typical wood frame house is constructed on a concrete foundation that is anchored with bolts/joists to a platform on top of it and covered with plywood. On this platform interior and exterior walls are built using vertical timber studs connected with cross-sectional members and panels/horizontal members on which the façade material is fastened. A secondary floor can be constructed on the vertical members similarly to the first floor platform acting as a foundation to the second story walls.[3]

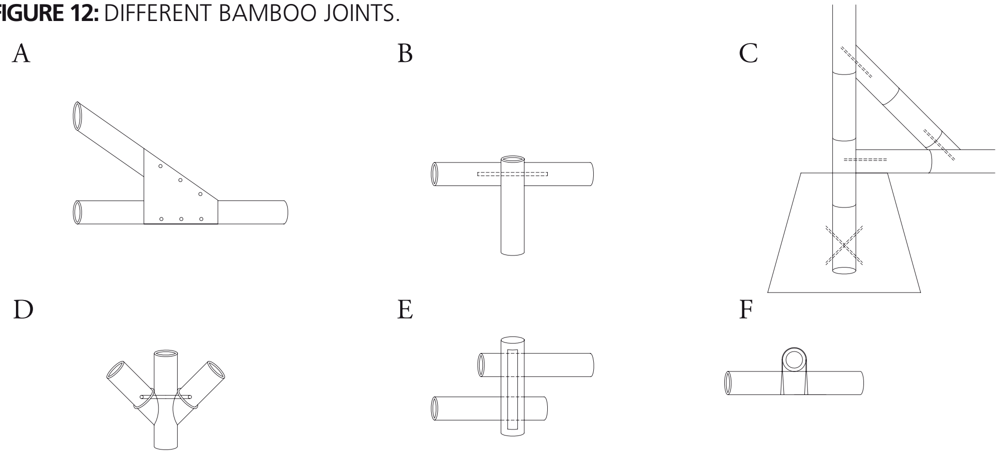
Benefits and challenges of timber

Wood is a renewable resource. There are many different wood species used for construction depending on the country and the area.[4] Legally and sustainably produced wood is the most environmentally friendly of the conventional building materials: it emits the lowest amount of greenhouse gases and requires the least energy during the production process; and it has the ability to store carbon during the life-cycle of buildings and other constructions.[5]

Wood is a strong and flexible material suitable for earthquake areas with reinforcement.[6] It is easy to work with even without professionalism and the design is easy to repair and change.[7] The use of wood should be balanced with the amount of local forest resources: deforestation is a major problem in some areas. It is crucial to know the origin of the wood used and avoid using rare wood species.

The quality of timber affects the quality of the construction: size, amount, location and form of branches affect the strength of wood.[8] The use of wood in construction has some

FIGURE 12: DIFFERENT BAMBOO JOINTS.



Gusset plated joints. B- ITCR joint. C- preformed concrete footing. D, F: Traditional joints made by tying. E: Through joint.

Source: UN-Habitat, 2012. Based on Jayanetti and Follet, 1998.

problems such as that wood burns easily; stick framing constructions do not offer much space to insulate;[9] and that the treatment against humidity and sun can be poisonous to occupants.[10] Additionally, wooden houses often have a major amount of other materials attached such as metal products and insulations materials that affect the overall environmental profile of the house[11].

3.1.2 BAMBOO

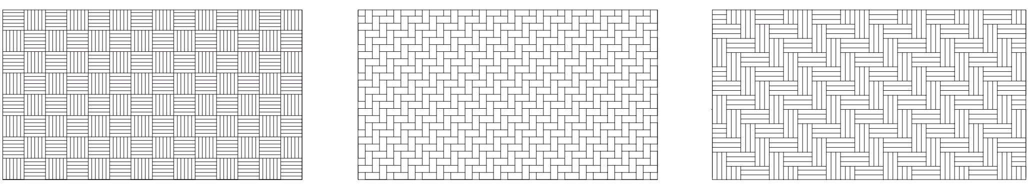
Bamboo construction

The structural frame of a bamboo construction is similar to traditional timber frame.[12] Thicker bamboo culms are good for vertical compression but the thinner ones are stronger in horizontal tension.[13] Floors are usually beams with floor decking of small bamboo culms; split or flattened bamboo; bamboo mats; panels; or parquettes. Walls are usually made of whole of halved vertical bamboo culms covered with different techniques. Bamboo roof trusses are often used as they enable large spans. Roof covering can be made of overlapping halved culms, tiles, shingles, or mats (Figure 13). It is important for earthquake, wind and hurricane resistance to have permeable walls, roof and floors; strong jointing; resistance to in-plane shear and to anchor bamboo columns properly to the foundation.[14 15]

Benefits and challenges of bamboo

Bamboo is easy and rapid to cultivate[16] and can be used without complicated techniques or tools. It is strong and light and has a good resistance to wind, earthquakes and hurricanes.[17 18] Bamboo is especially good for subtropical and tropical regions and can be used in different terrains.[19] It has a good tensile strength and good dimensions meaning that it can often be used in construction without sawing or cutting.[20] Low initial investment makes bamboo an opportune choice for low-income households and communities if training is in place.[21]

FIGURE 13: EXAMPLES OF WOVEN BAMBOO MATS.



Source: UN-Habitat, 2012. Based on Jayanetti and Follet, 1998.

Problems of bamboo include biodegradation; rot, pest, fungi and insect attacks; flammability; short service life; and connections that can make the structure weak if not made carefully.[22] [23] [24] Structural design, jointing,preservation and codification are not as developed as with wooden constructions.[25] [26] There can be challenges to get good quality bamboo and variations in size and diameter can present problems.[27] Additionally, bamboo has a tendency to crush and split.[28]

Matters affecting durability

The durability of bamboo varies between species, length of the culm and thickness of the wall. Lower parts of the culm and outer part of the wall are harder. The way of harvesting, storing and transporting affect the durability. Only locally suitable species should be used and aired during construction as bamboo needs to be dried before use. Protection towards water by ducting away from the roof, using eaves and gable overhangs, and building on stilts or raised foundations is of crucial importance. Careful detailing can prevent vermins. Jointing and treatment are the most crucial factors affecting durability of bamboo.[29] [30]

Treatment of bamboo

Without treatment bamboo has a life of l-5 years, with protection from rain 4-7 years, and as internal rafters framing 10-15 years.[31] Traditional ways of treatment include smoking by placing bamboo culms above fire; whitewashing where bamboo culms and mats are painted with slaked lime; a combination of tarring, sanding and whitewashing mats; plastering; curing (culms are left in the open leading to starch fall); soaking; and seasoning (imposing to water for weeks and later air dried in shade).[32] Traditional treatments can be applied almost for free with low skills but there is no real proof of increased durability.[33] Chemical treatments can increase the service life of bamboo by 15 years in the open and 25 years under cover. Chemical treatments include butt treatment; cold soaking; Boucherie; pressure treatment; I-lot, cold bath process; and glue line treatment.[34]

Jointing of bamboo

Jointing of bamboo differs from timber due to the round form. In traditional jointing lashing or tying is used with spliced joints (culms are joined to form longer members); orthogonal joints (including butt joints and cross over joints); angled joints; and through joints (smaller culm going through a larger). Modern jointing techniques are stronger but more expensive and complicated. The techniques include gusset plates (plywood or solid timber side plates); ITCR joints (plywood glued into wholes in the joined elements); arce joint (wooden inserts in the ends); das clamp (sections bolted with steel bands); Gutierrez joint (a welding steel bar is passed through the element); steel or plastic insert connectors and nails and screws (Figure 12).[35]

Engineered bamboo

Engineered bamboo can be a way to scale up the use of bamboo in construction. The amount of industrialized bamboo products available is still not very wide. [36] There are, however, already 28 types of bamboo composites lumber/ bamboo panel products (BCL) available for non-structural construction purposes including products such as bamboo strip boards (BSB) and laminated bamboo floor boards. Some of the bamboo products can be even better for certain usages than wood in addition to the fact that bamboo is more easily and faster cultivated than wood. When the research and industries on providing structural load-bearing bamboo products will develop the potential of using bamboo in various constructions will become great supporting the wider use of bamboo as a material for green architecture.[37]

3.1.3 STRAW-BALE

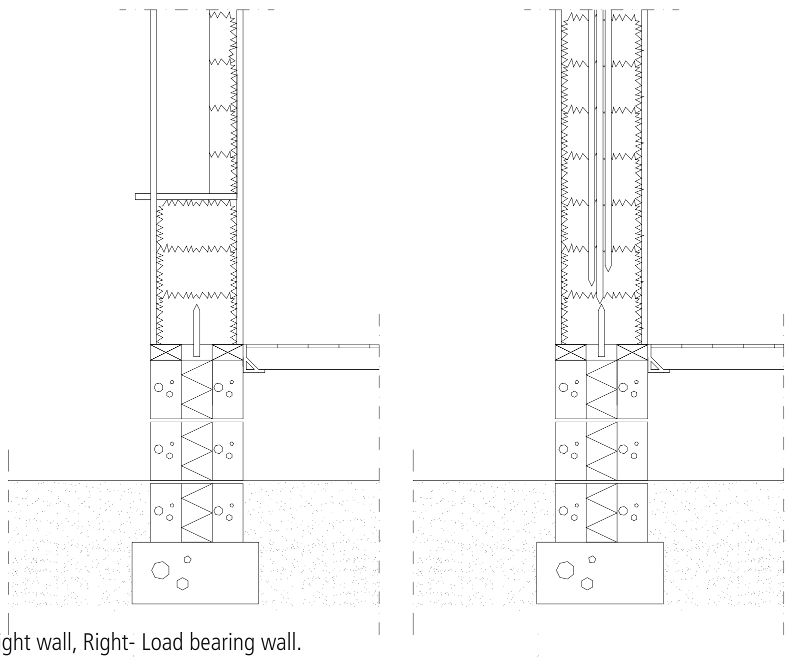
Straw-bale construction uses

Straw-bales can be used as an infill in a wooden structure or load bearing without any skeletal structure (Figure 14): if used as bricks they need to be pre-compressed before plastering to avoid later compression by the roof. Load bearing straw-bale construction suits drier climates. It is important to use straw not hay as straw is hollow, hard and decays slowly compared with hay that does not have these characteristics.[38] Bales of straw without seed-heads should be 16 - 30 kg; uniform in size being approximately twice as long as wide; and as densely compacted as possible with tight strings/wire/twine at the maximum compression strength of a baling machine possible. The bales should be kept dry during the whole building process. The design of other building elements should be made according to the dimension of the bales.[39] Bales should be laid on edges not flat for better R-value*. Straw bales can be tied together and plastered after trimming.[40] Load bearing straw-bale walls can be built up to three stories; infill straw bale walls have no limitation of height as long as they are adequately braced.[41] Materials similar to straw can be used as roof material (Box 14).

Benefits and challenges of straw-bale

Straw-bale is an energy efficient recycled material that does not generate pollution. Straw is a by-product of food production and thus a resource that can easily be renewed. Burning rice straw causes health risks and severe pollution, which can be avoided by using rice straw in construction. Straw-bale can be used as structural construction material, thermal insulation (very good insulative abilities, reduces thermal bridging) or acoustic absorption.[42 43 44] The U-value* of straw-bale is 0.13 W/m2K which is 2/3 lower than that of conventional materials.[45] Straw-bales are healthy as they do not include paints, chemicals, glues or toxins. Straw-bale

FIGURE 14: SECTION OF A STRAW BALE WALL.



Left- Lightweight wall, Right- Load bearing wall.

Source: UN-Habitat, 2012. Based on Amazon nails, 2001.

BOX 14: REED ROOF

Lake reed is similar to straw-bale. It has been used for building walls and roofs in many parts of the world for centuries. A lake reed roof is made manually. It has a long lifespan for approximately 40-60 years (sometimes even over 100 years); it resists rain, wind and snow well; and it is fireproof due to the minerals in reed. It does not cost more than the conventional roofs. A reed roof does not require energy or create pollution and it has good insulative and acoustic abilities. Reed collection from lakes has positive effects on the lakes as the old reed is removed before molding. Reed roofs are coming back to mainstream use. For example in Salo in Finland a large part of a new settlement is currently being built with lake reed roofs.

Source: Maria Nordin et al. (date unknown), Rauvolanniitty, modernia runkorakentamista uudella asuinalueella Varsinais-Suomen ELY-keskus ja Salon kaupunki.

can reduce the construction budget by 5 to 10 percent and heating costs per up to 75 percent when compared with conventional materials.[46] [47]

Straw-bales are easy to use without highly developed skills or machinery. The tight structure allows less pest attacks than timber.

Problems with straw-bale include moisture damages; fire hazards (which can be made better by using cement rendering); problems with getting building permits due to regulatory frameworks not including straw construction; and low compressive strength (but it can be strengthened using composite materials). The moisture content of the straw-bales should be kept under 15 percent with the help of an adequate foundation, long roof overhangs, directing guttering away from the walls, by choosing appropriate rendering materials,[48] [49] and using high foundations. Straw-bales need to be made before using them in the construction, they need to be uniform in size and cannot be adjusted afterwards. Thus windows and doors can be complicated to construct.[50]

- R-value= Thermal resistance. Measure of resistance of a heat loss through a material: how much energy is needed to keep the other side of the material i different temperature. The r-value of a wall is the sum of its parts.
- U-value= Measures the ability of a building component such as a wall to keep heat inside the building in colder climates or respectively cold air inside the building in warmer climates. The value measures how much warmth goes through a building element. The smaller the value is, the better.

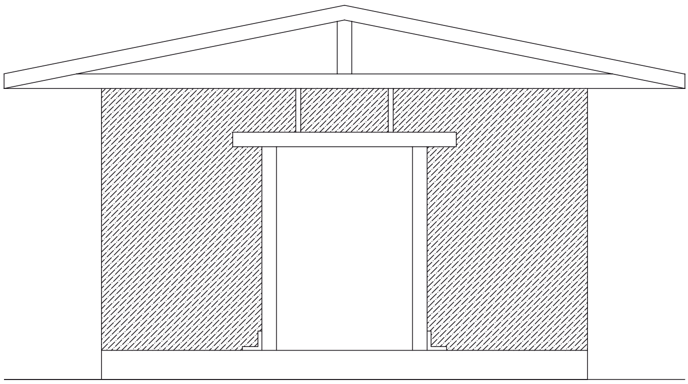
3.2 EARTH AND STONE CONSTRUCTION

Benefits and challenges of earth and stone constructions

Approximately one fifth of world's population lives in adobe/rammed earth constructions.[51] Earth and stone-based materials in general are recyclable materials with low environmental impact, a very low embodied energy compared with concrete, and have good heat and sound insulation capacities.[52] They are fast and economic to build,[53] natural, healthy, and non-flammable.[54]

Earth floor, roof and walls can absorb and store heat,[55] which can be beneficial especially in the hot and dry climates. Some stone materials need a lot of energy to be extracted and refined and this process can also damage the landscape[56] but rubble stone and earth materials are, in general, environmentally friendly. Other challenges of stone and earth based materials include an inadequate tensile strength that results to bad earthquake and hurricane resilience. The resilience can however be increased by seismic-resistant design and engineering methods.[57]

FIGURE 15: COB WALL.



Doors can be installed to cob walls with stable self-supporting bucks that will retain their shapes.

Source: UN-Habitat, 2012. Based on Snell and Callahan, 2005.

3.2.1 COB

Cob construction

Cob is formed by hand as a monolithic mass.[58] [59] [60] There should be earth quality control of strength and the connections between ingredients in the mix before using soil in cob construction.[61] Local mineralogical composition, grain shape and particle-size distribution affect to the quality of earth.[62]

When starting with cob construction clay particles need to be first suspended in water for breaking down or mechanically separated. After that the clay is mixed with sand to a homogenous mix by hands and feet or with a mixer. After that straw is added. Walking and jumping on the mass tightens the consistence.

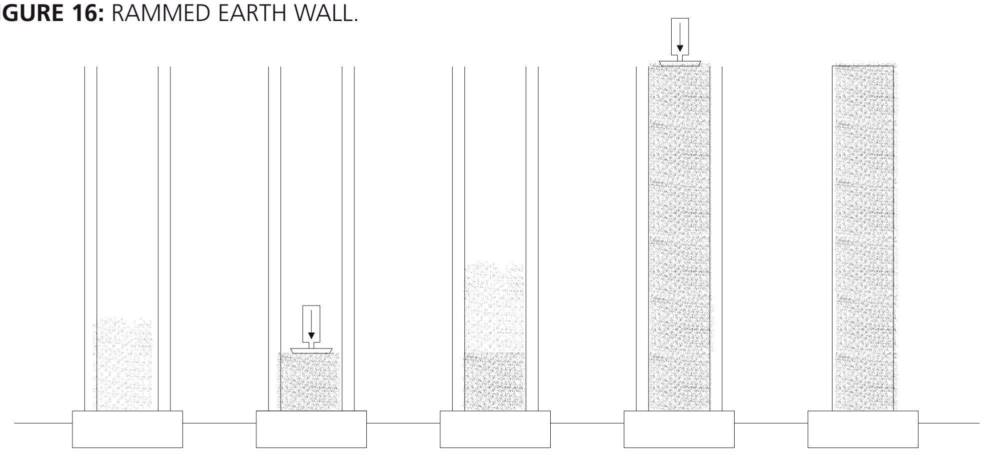
The ready mix is placed in small masses on a stone foundation (which prevents rising damp) framing the wall contours. Later the contours are filled integrating the masses to a uniform layer. This is redone layer by layer after the drying of each layer below. The layers are made approximately 60cm high and 60-90cm thick and it takes several days for them to dry. Walls should be protected from rain during the construction with a temporary roof. It takes 6-9 months for thick walls to dry completely and they will shrink in the process. After this doors and windows can be added (Figure 15). Permeable lime based renders or paint can be used to allow the surface to breathe. When having more straw than clay a lighter non-bearing mix called clay-strip is formed that has a better R-value and thus works better as insulation.[63]

Benefits and challenges of cob

Cob combines straw and earth which makes it an optimal material for hot and dry climate as it has good insulative characteristics (straw) and a thermal mass (earth). It can even be used in a wet climate if covered with roof overhangs, protected with plaster and raised from the ground with an adequate foundation.[64] [65] [66]

Other positive aspects of cob are good load-bearing ability; inexpensiveness; availability on site; need for very few tools and no form work; strong and durable walls; minimal mold growth; a good indoor environment; fire proofness; and flexibility. Cob is a low-impact, energy efficient building material that can create interiors that are warm in winter and cool in summer. It is strong in compression, very durable and it can be molded to different shapes. Construction is usually time consuming and labor intensive. Cob has also a low tension strength.[67]

FIGURE 16: RAMMED EARTH WALL.



Moist soil mix is compressed layer by layer between two panels molding a rammed earth wall.

Source: UN-Habitat, 2012. Based on www.iagram.com.

3.2.2 RAMMED EARTH

Rammed earth construction

Rammed earth is a structural wall system.[68] Rammed earth is made of a damp mixture of earth (sand, gravel and clay and sometimes stabilizer). Sandy sub-soil is usually used. Sand and gravel work as aggregates and silt and clay as binders similarly to concrete.[69] Cement can be added to stabilize the walls, which increases durability and thus the walls can be left without plastering.[70 71] It is important to make a quality test for the soil before building rammed earth walls.[72] The mass is compressed/rammed with hand or a tool such as pneumatic tamper in layers of 10-15cm inside a frame of two parallel panels molding the shape of a monolithic, thick (60-100cm) and not too high wall (Figure 16). After compaction the material is allowed to dry.[73 74 75]

Benefits and challenges of rammed earth construction

Rammed earth walls have potential for recycling; a long life span; good suction qualities resulting to high strength; and a good tolerance for humidity and short rainfalls.[76] However stand alone rammed earth construction is not tensile such as cob because of the lack of straw.[77] Rammed earth walls are more stable than adobe walls due to the monolithic form. They can somewhat withstand seismic shocks. However, thinner rammed earth walls can be stabilized by using different shapes that have angles able to absorb perpendicular forces. Also vertical wood or bamboo rods in the structure that is fixed to a ring beam and the foundation can be used.[78]

3.2.3 ADOBE

Adobe construction

Adobe bricks are made by mixing sand (used as aggregate, 75 percent of the content filling the volume. Silt or rocks are not to be used), clay (as binder, 25 percent, holds the mass together) and water (the mix is often wetter than in cob) and sometimes fibrous organic material such as sticks, straw or dung (to improve the R-value). These materials are shaped into bricks by using frames (formwork) which are removed at once, and used for new bricks. After this, the bricks are dried in the sun. Sometimes skeletal walls can be used where bricks are therefore infill, not structural. Earth plaster can be used to protect bricks.[79 80] Particle size and quality of the earth affect the quality of mud bricks.[81]

Benefits and challenges of rammed earth construction

Adobe bricks have the same benefits as mud construction in general: the bricks are recyclable with low environmental impact and low embodied energy, and good heat and sound insulation capacities[82] and they are fast and economic to build.[83] Adobe houses can be damaged in earthquakes mainly due to shearing stresses in the wall plane and bending stresses perpendicular to the wall.[84] Poor connections can lead to wall separation at corners/walls falling outwards and out-of-plane loads destroying walls and gables, which can lead to roof collapse.[85]

Adobe walls can be retrofitted with wooden frames and elements; vertical bamboo rods fitted in 5cm holes in the corners and intermediate buttresses; or with reinforced concrete at the corners stabilized with steel bars. Wire mesh covered with lime based mortar[86] and spiral-cuts from used car tyres can also be used for reinforcement.[87] Cement, latherine soil, asphalt or waste engine oil can be added to make the bricks more stable.[88]

3.2.4 COMPRESSED EARTH BLOCKS (CEBS); STABILIZED SOIL BLOCKS (SSB)

CEB construction

When producing CEBs moistured raw or stabilized soil is poured into steel press, compressed and cured for 28 days (Figure 17). Standard sizes of the blocks are 305 × 143 × 100 mm and 230 × 190 × 100 mm. Cement or lime stabilizer can be used and possibly waterproofing agents.[89] The amount of mortar is less than in a normal brick or cement construction. It is possible to produce 250- 350 CEBs a day using a simple press.[90] CINVA-RAM was the first press to make CEBs and it was followed with multiple motor-driven and manual presses and mobile and industrial scale presses.

Benefits and challenges of CEBs

With the CEB technique higher and thinner walls with better compressive strength and water resistance than with adobe bricks can be built. Advantages of CEBs when compared to fired bricks are 70 percent better energy efficiency; 20-40 percent economic savings; and savings of fire wood. Other good qualities include the ability for local production; flexible sizing; labor intensiveness that can create jobs; good stability and strength (can be improved by using high density and high percentage of stabilizers); thermal insulation; regular shape and size; easy transportation; good earthquake, typhoon, rain and insect resistance; and suitability for all climates except very wet climates. The soil used needs to be of good quality (clay content 10-25 percent).

Disadvantages of CEBs include the need for specific tools (block press, masonry tools and quality control devices) and that the bricks cannot be used in high-rise buildings, with big loads, in wet conditions or under water.[92 93]

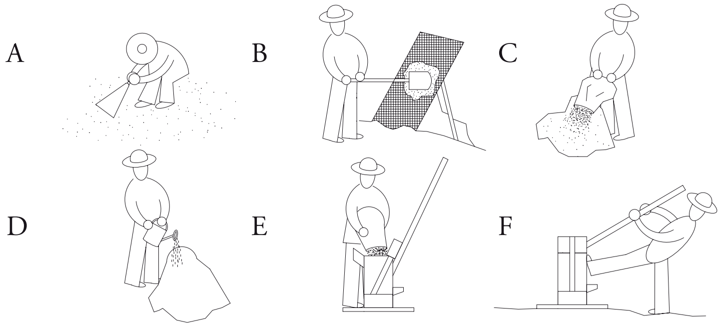
3.2.5 INTERLOCKING BRICKS, ISSB BLOCKS

ISSB Construction

Interlocking bricks are made from stone dust/ lateritic soil and a stabilizer which makes the soil more waterproof and stronger. The stabilizer can be chemical or natural, most commonly Portland cement. Interlocking bricks are typically fabricated in a manual steel brick press. A handle is pulled 1.5 meters downwards molding the bricks with the top and bottom plates. By tightening and loosing the bolts on the bottom plate the height of the bricks can be changed. Bricks are laid dry and locked into place.

Single brick walls are used for double story construction and multi-brick thickness for multiple story construction.[94 95] There are holes in the bricks for vertical steel/rod reinforcement that is fixed by cement. In this way the structure can be made flexible and earthquake/typhoon resistant.[96] The quality

FIGURE 17: PRODUCTION OF CEBS.



A- Select soil. B- Sieve out large particles. C- Mix soil and stabilizer. D- Moisten. E- Pour into steel press.
F- Compress manually or motorized. Later stack the blocks for curing.

Source: UN-Habitat, 2012.

of blocks depends on the mix of soil types, the compaction force and the stabilizers used. When using CINVA-RAM uniform rectangular blocks with a double interlock can be made. With other presses different forms can be achieved.

Benefits and challenges of ISSB blocks

The interlocking brick technique has drastically reduced the amount of cement and money needed when compared with CEBs and enhanced structural stability.[98] [99] Positive aspects of interlocking bricks include healthiness; environmentally friendliness; economic savings; easy workability; minimal requirement for skilled labor, no mortar is necessary; and it is a faster building process than conventional bricks.[100] The challenges are similar to those of CEBs.

3.3 WAYS OF USING CONCRETE IN A MORE SUSTAINABLE MANNER

3.3.1 CONCRETE

Concrete is a product of combining cement, sand/gravel, and water, and allowing to cure until it is set. Concrete is strongest in compression, and so steel reinforcing is typically embedded inside concrete to improve its tension resistance.

Strong concrete products can be made on-site with low-cost methods using one skilled worker and small scale equipment in local workshops. This can create small scale economic activity. Such products include micro-concrete roof tiles (lighter than pressed concrete tiles and more environmentally friendly than metal sheeting, possible for recycling), roosters/ventilation blocks, and concrete blocks (can be used instead fire bricks with reduced construction cost). Concrete blocks can have holes, which make them lighter; decrease the use of mortar; increase their thermal insulation ability; and allow the use of steel bars for earthquake retrofitting.[101] [102] Different roofs can be made of concrete.[103] Beam blocks are used for reinforced ground beams, lintels and ring beams[104]. Roof tiles[105]; concrete joists[106]; well rings; concrete door and window frames; concrete beams; concrete floor tiles; and prefabricated concrete footings can be used for example in areas with high deforestation or high disaster risks for typhoons or earthquakes (as reinforcement).[107]

Benefits and challenges of concrete

Concrete is not commonly seen as an environmentally-sound material and there is some truth to this, and so it should not be as widely used as it currently is. Concrete's use should not be abandoned but restricted: it has been noted above how cement is appropriate as a stabilizer. Also, using concrete can sometimes be an environmentally advantageous as it can prolong the life-span of a building.[108] Concrete buildings typically last much longer (often decades) and require less maintenance that earth or bamboo buildings.

Concrete can be used for different sizes and shapes of buildings; it has a strong and durable character; it is easy to use; and it has good weather, fire and insect resistance[109]; it can be used in all climates; can be load bearing; and recycled. The negative environmental characteristics of concrete result from cement not from water and the other ingredients used. The negative characteristics include concrete's high embodied energy from its production, transport and use; and minimal insulation value (needs to use rigid insulation).[110] The production of steel needed for reinforcement of concrete has a major environmental impact. Additionally, recycling steel reinforced concrete takes a lot of energy and the chemicals used in concrete production can create emissions of harmful substances such as sulfur dioxide and chrome.[11]

3.3.2 FERRO-CEMENT CONSTRUCTION

In ferro-cement production three centimeter thick elements are made of high performance micro-concrete (vibrated or self-compacted) with wire mesh reinforcement. They are placed on top of a concrete foundation and tied together on the top with horizontal tie-beams of steel reinforced concrete forming a highly earthquake and hurricane resistant structure. Panels for multi-story ceiling slabs and roofs have different mould and size according to the flexural strength needed.[112] Ferro-cement roof tiles can also be made.[113]

Benefits and challenges of ferro-cement

The ferro-cement technique allows thinner walls and a shorter construction time than conventional concrete. The elements can be lifted and placed by two people without mechanical help, and produced in formal or informal local workshops, even inside slums. Ferro-cement is cost-effective; walls need only some days to erect (possibility to use as a start for transitional shelter after a disaster with an income-generating factor), and reduces the need for steel and concrete.[114] Accessing building permits and using the still not commonly known construction methods may be challenges related to the use of ferro-cement in construction. Additionally, using ferro-cement tanks for water collection has been discussed for the possibility of dissolution of radioactive heavy-metals in fly-ash to the drinking water. However, the concentrations of radioactive materials should not be a source of alarm.[115]

3.3.3 LIME-POZZOLANA CEMENT, CP 40

CP 40 construction

Calcium hydroxide (lime or sometimes even secondary local lime) and pozzolana (industrial wastes or natural products such as volcanic sands, burnt clay pozzolana, fly ash, rice husk ash or combination of pozzolanas) in the ratio of 1:1.5 or 1:2 are mixed and ground to a powder in a ball mill. 1:3 or 1:4 ratio for Lime-pozzolana cement and sand can be used.[116 117] Challenges related to using lime-pozzolana cement in construction may include: few production lines for lime-pozzolana cement in cement factories, problems of accessing pozzolanic materials, and problems of achieving the high temperature needed for production.[118]

Benefits and challenges of CP 40

Up to 40 percent Portland cement can be replaced when using CP 40. Lime-pozzolana cement has less than half of the embodied energy of Portland cement. Money is saved in producing end products compared with Portland cement (up to 20 percent cheaper without affecting quality). Production of lime-pozzolana cement results to fewer emissions of CO2 and sulfur dioxide than production of Portland cement; the strength of the mortar mix is easily manipulated; lime-pozzolana cement works as a hydraulic binder; it is good for small-scale production; and the market price of the binder is up to 40 percent lower than that of Portland cement. Lime-puzzolana cement can be made in small scale workshops (micro business level) or connected with the production of concrete elements like hollow blocks or bricks.[119] [120]

3.3.4 REPLACING INGREDIENTS IN CONCRETE

Fly ash

Fly ash is a waste product that is generated when burning pulverized coal in electric power generating plants.[121] Fly ash can be used to replace Portland cement in the concrete mix. Up to 25 percent replacement suits all climates. Fly ash increases the tensile and compressive strength and durability of concrete[122] and decreases concrete's water permeability. Additionally the embodied energy of fly ash is smaller than that of Portland cement.[123]

Ingredients to replace sand in concrete

Recycled coal-combustion bottom ash and foundry sand can be used to replace sand in the concrete mix. Up to 25 percent sand in blocks can be replaced in cold regions and up to 35 percent in warm regions.[124]

3.4 RECYCLED MATERIALS

Context and the benefits of recycling

In contemporary times natural resources are used faster than ever before and we are witnessing the limits of our environment: recycling is necessary in the context of higher housing demand due to the future population growth.[125] [126] Rapid urban and economic growth together with inadequate governance capacity and a lack of knowledge or limited capacity of communities to manage waste has resulted in more waste that needs to be disposed of.[127] The construction and building industry is responsible for a considerable amount of waste. Reuse of materials can decrease the amount of waste and the embodied energy of buildings; save virgin materials; and decrease pollution.[128] Money can be saved as the cost of conventional building materials is increasing.[129] There are currently inadequate governmental incentives and too small markets in many countries to activate the private sector in recycling.[130] [131] However, there is a future possibility for material recycling from industrial, mining, municipal, agricultural processes.[132] Recycling

Much of the waste recycling in Phnom Penh Cambodia is done by the informal sector. ***© Mesi Koponen.***

of waste products is currently often done by the informal sector especially in developing countries, which should be supported by capacity building and training of the poor and by providing economic opportunities related to recycling of building materials as a part of poverty reduction strategies.[133]

Possible recyclable products

Large scale industries such as thermal plants, mining fields and aluminum industries provide considerable amounts of wastes such as red-mud, coal ash, slag, fly ash and mine tailings that could be significantly better utilized as construction materials. They can be used, for example, for bricks/blocks or substitutes for fine aggregates/partial replacement of cement in concrete or for lime–pozzolana cement. Similarly, demolished building waste and debris from disasters such as steel, stone, timber, bricks, concrete, aggregates and mortar can be reused.[134]

Materials from construction industry can be reused; for example, marble; many kinds of metals, metal doors and frames; structural steel; aluminum and glazed aluminum curtain walls; laminated wood chips, strands, wooden doors, lumber and other wood products; exterior glass and glazing; gypsum boards; ceiling panels and acoustic ceiling tiles; plastic electrical device wall plates; telecommunication cabling; rubber/wood/tile flooring; tiles and ceramic tiles; fiber glass; interior and exterior latex paints.[135] Newspapers for insulation[136]; paper; and; plastic from municipal waste management; fly ash; bottom ash; and exhausted sands from thermal treatment, as well as scrap tyres and sludges can also be recycled. Similarly coal ash, blast furnace slags, mining waste, marble and brick manufacturing residues can be reused.[137]

3.4.1 FINE CONCRETE BLOCKS AND HIGH DENSITY STEAM CURED BLOCKS

Fine concrete blocks

Fine concrete blocks can be made similarly to stabilized solid blocks using sand and cement/lime stabilizer, compacting with a machine and cured for 28 days. The difference is that ash, polished stone waste or mine wastes are added (20-25 percent of the weight of the sand) to the mix instead of soil. It is environmentally friendly to use these waste products as they would otherwise cause pollution. By adding 10 percent red soil a natural mud color can be achieved.[138]

High density steam cured blocks

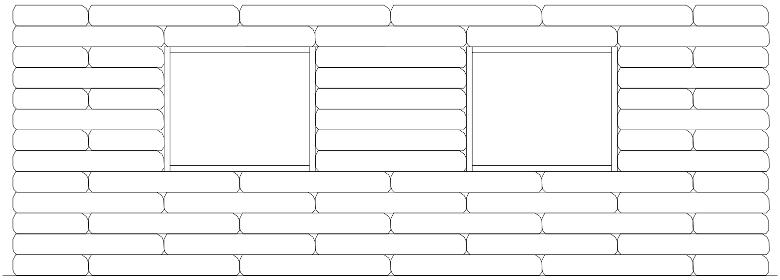
High-density steam cured blocks can be produced mixing industrial waste products such as fly ash with sand. A combination of 25 percent fly ash, 6 percent lime and 2 percent cement is optimal for strength but even higher strength can be achieved through adding stabilizers. The technique creates increased strength and is based on lime reacting with fly ash or clay minerals. The blocks are compacted with a machine and cured in 80 degree Celsius for 10 hours. The increased strength enables building 3-4 storey load bearing buildings with 3-4 meter spans. 2/3 of energy used for production can be saved when compared with burned bricks.[139]

3.4.2 EARTHSHIP

Earthship construction

Earthships use recycled steel belted car tyres that are filled with earth manually or with a pneumatic tamper. The tyre units are used like bricks, putting the next layer on top the one before. Earthships can be shaped in many ways and plastered so the tyres are not

FIGURE 18: EARTHBAG WALL.



Earthbags are laid in courses forming walls. Wood cleats along the sides of openings are for windows.

Source: UN-Habitat, 2012.

visible. Recycled bottles and cans are often used with cement as interior walls that are not load bearing.[140 141 142] Earthships are typically constructed in U-form so that a glazed opening faces to south. The thick U-shape walls are needed to carry the mass weight against the building. The roof is framed with beams.

When using other forms than the u-form of the structure, costs will be added. The structure will become weaker when cutting through the u-form to add other rooms[143]. The angle of the windows depends on the latitude and is chosen to capture a maximum amount of light. The walls on the north side protect from winds and are bermed to gain ground heat.[144] Passive solar energy, power from sun by solar panels and wind energy with small rotors are used resulting to an energy efficient low carbon construction.

Benefits and challenges of Earthship

Earthship is an energy efficient construction method and its maintenance saves also energy compared with conventional constructions. Earthships work as fireproof load bearing walls and foundations at the same time. The walls work as thermal mass, durable earthquake resistant structures due to their specific mix of rubber and earth.[145 146 147] Earthships use recycled tyres making the embodied energy of the construction very low and cheap to construct. Earthships should not be constructed in very wet climate as it is difficult to waterproof the construction. Water proofness can be improved by wrapping the tires in plastic sheeting before filling them with earth.[148]

3.4.3 EARTH BAG CONSTRUCTION

Earth bag construction

Sacks are filled with material found on-site and then laid in courses similarly to brick construction[149] and tamped in place before laying the next layer (Figure 18). Earth bags can be plastered. Superabobe construction can be achieved by adding barbed wire.[150] With earth bag technique dome roofs are typically built, which are good for earthquake resistance as they are monolith constructions that transfer stress to the foundation. The domes must be stabilized with a horizontal ring of reinforced concrete/steel/timber and connected with joists to the foundation/plinth. Lime paint can be used in covering to avoid material deterioration.[151]

Benefits and challenges of Earth bags

Earth bag construction is a very economic construction method that results in strong (more solid than adobe) structures that can be built fast (faster than cob), worked in many ways (more alternatives than with rammed earth).[152] High buildings cannot be built with earth bags and the construction is mainly limited to vaults and domes.[153]

3.4.4 PAPERCRETE

Papercrete construction

Papercrete mixes re-pulped paper fiber from, for example, newspapers with Portland cement, clay or dirt. The mixing is done with an electrical device in a tank with the help of water. After draining of the mix papercrete becomes soft and workable. Papercrete can be used for plastering both inside and outside walls or for making adobe brick sized blocks and mortaring them. It is important to add some material with the paper to make the material more fireproof and to stop reduce its sponging when it is exposed to water.[154]

Benefits and challenges of Papercrete

Papercrete has a good insulation value and it resists rodent and insects well. It must however be protected from continuous exposure to water such as from ground contact. Allowing effective drying is crucial in these constructions as the wall can otherwise mold.[155]

3.4.5 BOTTLES

Construction made of bottles

Bottles have been used in houses since the 1960's. A part or an entire house can be made of bottles.[156] One construction method is to use waste and bottles. Bottles are filled hard with, for example, plastic and loaded inside a chicken wire on both sides as bricks using plastic bags as infill in between. The structure is plastered from outside (Figure 19.[157]

Benefits and challenges of using bottles in constructions

The positive environmental aspects of recycling plastic inside a bottle structure are more significant than the negative aspects. Different plastics have, however, different environmental and health issues. Structures made of plastic bottles might be a risk in case of fire due to different harmful substances emitted from burning plastic. It is to be remembered that mixing, crushing and melting plastic can be environmentally harmful and dangerous for the health.[158]

3.4.6 OTHER WASTE PRODUCTS

There are several waste products that can be used as inputs to the production of materials and technologies even though they are not complete technologies themselves. Below examples of these materials are discussed.

Concrete and lime production/ demolition wastes

Studies suggest that concrete and lime production/demolition wastes in different mixes can be used resulting to good finish products. A mix of 40 percent of lime waste and 60 percent concrete waste result to the best mechanical properties. Different mixes can be used for different construction goals.[159]

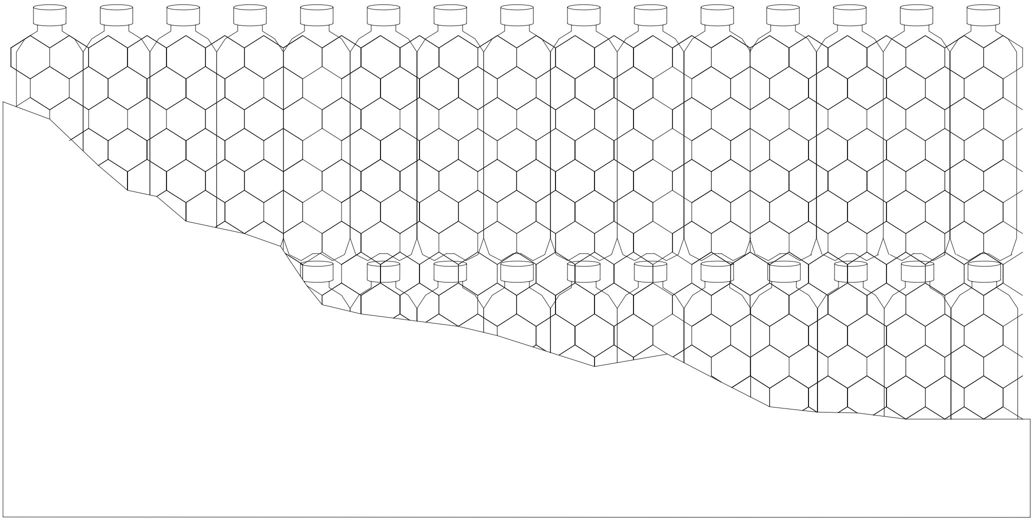
Rubcrete

Recycled tyre rubber can be used with Portland cement concrete resulting to a product called rubcrete. Rubcrete is easy to work with. It has high flexibility and tensile strength; ductility; toughness; resistibility to impacts, sound and weather; and insulative advantages. However the compressive strength is reduced when compared with normal concrete. The strength can be made better by using magnesium oxychloride cement.[160] Rubcrete can be used for example to repair concrete surfaces and precast panels and to smooth concrete block walls.[161]

Insulation panels made from waste products

Rice straw and waste tyre particles can be used to make insulation boards similar to wood panels/plywood with better water proofing abilities and flexibility. These panels are inexpensive; easy to modify; do not rot easily; have good sound insulation qualities; and can be used to prevent impact damage.[162]

FIGURE 19: WALLS BUILT WITH STUFFED BOTTLES BETWEEN CHICKEN WIRE. CONCRETE MIX IS APPLIED ON THE SURFACE.



Source: UN-Habitat, 2012. Based on Pura Vida 2012.

Structural composites made from waste products

Wood waste and high-density polyethylene (gives impact strength and tensile strength) manufactured from bottles and containers can be formed into composites that can be used for example as roofing. The composites have better mechanical abilities than conventional materials.163

Sludge products

Wastewater treatment creates sludge that is problematic to discharge in urban areas making its use as a building material highly recommendable. Waste water sludge and sludge ash that is created when incinerating sludge, can both be used in brick production. Sludge ash can also be used as a filler in concrete and pelletized sludge ash-water-liquor mixture as lightweight aggregate for concrete resulting to strong lightweight concrete. [164]

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04 SUSTAINABLE CONSTRUCTION TECHNOLOGIES

KEY MESSAGES

In this chapter different sustainable technologies that can support sustainable housing are presented. Environmental retrofitting, green roofs, different renewable energy forms and ways of saving water related to housing are introduced.

Environmental retrofitting

- Environmental retrofitting should be considered when the old building stock can be made more energy efficient and functional with a reasonable cost compared with demolition.
- Environmental retrofitting has several benefits including energy savings, financial savings, healthaspects, prolonged life-span of buildings and better serviced and more functional settlements.

Sustainable energy

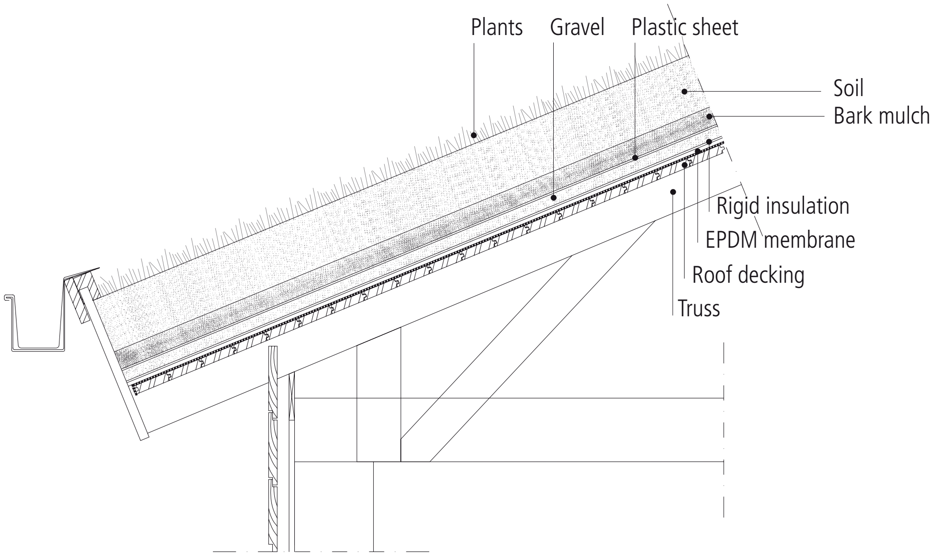
- Finding replacements for fossil fuels is crucial in the global context of ending natural resources, pollution and climate change.
- Energy efficiency methods and finding replacement for fire wood in deforestation areas are of similar importance.

Saving water in housing

- Global urban growth and development trends put pressure on water resources, which affects the environment worldwide.
- In order to meet increasing water needs new water sources, and water saving methods should be attached to housing.

Post-war multi-storied housing in the Czech Republic under environmental retrofitting.
© Matthew French, UN-Habitat.

FIGURE 20: EXAMPLE OF A LIVING ROOF POSSIBLE TO CONSTRUCT BY COMMUNITY MEMBERS.



Source: UN-Habitat, 2012. Based on: Snell and Callahan, 2005.

BOX 15: RETROFITTING SOVIET ERA HOUSING STOCK IN LITHUANIA

The project, led by the Central Project Management Agency Lithuania, has retrofitted urban low-cost housing stock that was constructed in the Soviet era in Lithuania with a low-energy efficiency focus. The project was crucial in terms of the long-term sustainability in a low-income country dependent on imported fuel in the context of rising global energy costs. The project was participatory involving low-income residents in decision making. 25,000 apartments were upgraded by building wall and roof insulation; placing better windows and doors; and building new heating systems. 25 percent better energy efficiency per apartment was achieved.

A 10 million USD loan agreement between the World Bank and the Lithuanian government (2006) helped to build affordable financing schemes. To get loans for upgrading, households needed to be a part of a household association. This resulted to over 1,100 associations for individual homeowners and thus to more inclusive social networks.

After the upgrading the maintenance of most of the blocks was transferred to the household associations which resulted to far better neighborhoods in comparison to the previous non-managed arrangement. The project has encouraged different income/ social groups to stay in the area. The economic situation of people has been made more sustainable as over 50 percent of the households had reduced energy bills after the project. Savings in heating costs were 20-30 percent and a major decrease in greenhouse gas emissions and pollution emissions was achieved. Additionally, asbestos was removed from buildings.

Source: http://www.worldhabitatawards.org

4.1 ENVIRONMENTAL RETROFITTING

Why and how to retrofit?

Environmental retrofitting means renovating buildings in order to increase the energy efficiency and environmental friendliness of buildings and in order to decrease CO2 emissions. Retrofitting improves physical and mental health[1] mainly due to better indoor environment[2] In some countries where new buildings are not rapidly constructed retrofitting can be used to enhance environmental friendliness of the building stock.[3]

Environmental retrofitting should be considered if the building stock has the potential to be changed to more energy efficient and functional in terms of infrastructure, heating and the overall condition with reasonable costs compared to demolition.[4] The order of retrofitting depends on the condition of the buildings and the building environments and the strategic plan for the city.[5] Retrofitting is especially important in developing/transitional countries with energy inefficient building stock in the context of rising fuel prices in the world (Box 15).

What does environmental retrofitting mean at the building/settlement level?

Reconstruction of local heating units, renovation and regulation of heating systems, fixing wall slab joints/sewage pipes/electric equipment, insulation of walls, replacement of windows/ doors and renovation of balconies and roofs (structure, waterproofing, and insulation) can be considered to achieve reduced energy costs. Side effects of environmental retrofitting are the improvement of the condition, humidity levels and life-span of the building (with 30–40 years); improvement of the urban planning aspects; links to social and physical infrastructure; and reduced maintenance and repair costs. The initial cost is large compared to the repayment that comes over the life of the building's use. But the increased market value can also be considered when deciding whether to retrofit buildings or not.[6]

4.2 GREEN ROOFS

Preventing storm water run off

Introducing green areas in city planning and green roofs in housing design has important benefits especially in urban areas (Box 16). Urban areas generate more storm water run-off than natural areas due to a high percentage of impermeable surfaces. Green roofs especially together with reduced roof slopes and deep vegetation reduce flooding caused by storms[7]: 45-70 percent of rain falls can be evaporated from the roof top yearly, which reduces the need for urban rain water management processes that are usually expensive.[8]

Preventing urban heat island effect

Another major advantage of introducing green roofs is the decreased urban heat island effect. Urban heat island effect means that there are extensive impervious surfaces in urban areas instead of greenery which prevents solar radiation to evaporate water. This means that the solar energy goes to heating building surfaces instead. The heat further increases at night as building surfaces radiate heat to the colder night air. Urban heat island effect is dangerous to health and increases energy usage for space cooling and ventilation.[9]

Reducing energy consumption

Energy consumption of buildings can be reduced by green roofs as they reduce temperature differences on building surfaces due to direct shading; and evaporate cooling.[10] The difference between minimum and maximum daily temperatures of the roof membrane is decreased, which keeps the inside temperature more constant decreasing the need for mechanical heating and cooling.[11] [12]The reduced temperature is especially important in hot and dry climates.[13] Green roof results to 1 percent energy saving annually, 6 percent saving in cooling costs during summer months and 25 percent saving during peak cooling hours. In winter the extra insulation layer of soil compensates the lost of solar gain though the roof.[14]

BOX 16: GREEN URBAN STRUCTURES IN TAMPINES, SINGAPORE

The Concept plan of Singapore (initially launched in 1971) proposed a development strategy of decentralization of the very dense capital population to four regional centres of Woodlands, Jurong East, Seletar and Tampines. In Tampines high-rise, high-density residential areas were constructed. Some 30–40 percent of land was provided for housing, one-third for industrial and commercial developments, and the rest for public facilities and public space including an extensive amount of green space. Green areas were provided according to the population size. Low buildings and open spaces were planned amongst the high-rise buildings. Green connectors meaning buffer planting, pocket gardens and networks of pedestrian walkways that link the different facilities and areas of the settlement structure were introduced increasing social interaction. A neighborhood park in every neighborhood was established and extensive roof-top gardens introduced in many high-rise buildings.

Source: Foo Tuan Seik (2001), Planning and design of Tampines, an award-winning high-rise, high density township in Singapore, Elsevier Science Ltd

Other benefits of green roofs

Green roofs also have other benefits: Environmental impacts are reduced as for example roof material transportation, material production impacts and electricity needed are decreased.[15] Green roofs have better durability than conventional roofs[16]: the lifespan of the roof can be extended by 10-40 years.[17] Green roofs decrease the amount of contaminants in urban water spaces[18]; increase mental wellbeing; and provide recreation space[19] (however, hotness and humidity can reduce the use of high rise roof top gardens in the tropical climate[20]). The air quality and sound insulation abilities can be improved and the amount of urban animal species increased by using green roofs.[21] [22] There is a potential for urban agriculture with green roofs[23] increasing possibilities for urban food production, job creation and saving of energy.[24] [25]

Use of green roofs in construction

A green roof needs a very strong supporting system. The structure in a one family house that can be constructed without highly skilled labor can be made of a box of heavy metal grating that is fixed through a membrane on a wooden structure framing the roof. The membrane is covered with water proof insulation plates, which are covered with plastic sheeting (root barrier). The whole structure is covered with pea gravel (drainage layer that directs water from the roof), a filter fabric keeping material from the drainage layer and an optional water retentation fabric on which the vegetation layer is placed (Figure 20).[26] [27] There are two types of green roofs. An intensive green roof needs high maintenance, has many plant types and a deeper soil layer (more than 15 cm). This kind of roof is usually flat and can be used for recreation. An extensive green roof in comparison needs low maintenance, cannot be accessed, is less than 15 cm deep, can be flat or sloped and can grow herbs, grasses or mosses. The plant selection should be made thinking of the climate and the microclimate.[28] In earthquake areas maximum 20cm thickness (required to keep thermal comfort during winter) of the soil is advised reducing the horizontal forces affecting the roof.[29]

4.3 SUSTAINABLE ENERGY

Why finding alternatives for fossil fuel is crucial

It is important to think of alternatives to fossil fuels in the contemporary global context: key fossil fuels will become increasingly more expensive as they become increasing unavailable. Coal resources will last longer than oil, natural gas and uranium but the use of coal should be restricted due to its strong effect on Co2 emissions and climate change.[30] Approximately 60 percent of world's electricity is used for residential and commercial buildings. Space heating accounts for 60 percent of residential energy consumption and water heating for 18 percent in developed countries.[31]

The number of inhabitants, their living habits and economic means; scale of technological development; and the policies, restrictions and changes concerning the country specific and global energy market affect the energy use patterns. The use of non-renewable energy sources have negative side effects such as global warming; air pollution; acid precipitation; ozone depletion; and emission of radioactive substances.[32] Additionally deforestation is a major issue in some areas where wood is used widely. In the context of the rapid urbanization in the developing countries finding alternatives to fossil fuels becomes crucial for the global environmental development.

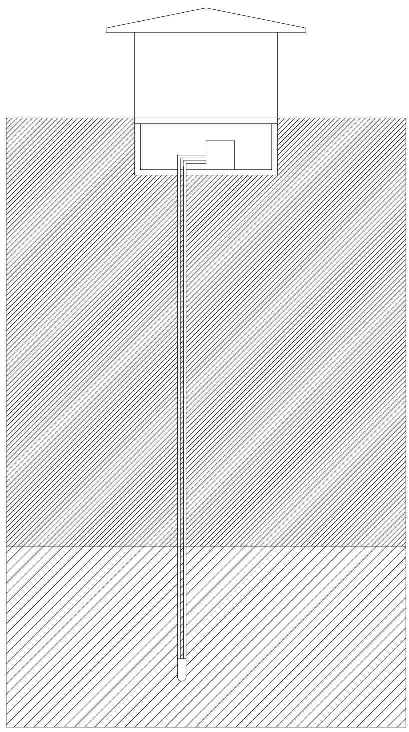
Existing sustainable energy

Existing sustainable energy resources include measures such as geothermal energy, water, wind and solar energy.[33] Hybrid energy systems combine several renewable energy sources depending on the availability and may have conventional generators for backup, which ensures constant energy availability.[34] Photovoltaic and Wind Generator is a well functioning combination due to the almost complementary power production characteristics,[35] but there are also combinations such as heat pump water heaters with solar energy assistance.[36] Just as important as finding alternatives for fossil fuels is improving the energy efficiency of buildings as well as finding fire wood replacements in deforestation areas (Box 17).

Depending on the climatic zone geothermal energy can be used to ventilate and/or heat spaces of one house or several houses with a district heating system (Box 18). In a one house mechanism the geothermal heat 15-20 meters underground can be used by using extraction of groundwater or by artificially circulating water with the help of a heat pump (Figure 21).[37]

A heat pump can be connected to a central heating system of a house. It works with electricity but uses only a minimum amount of electricity when compared to conventional electric heating. The technique is based on a

FIGURE 21: GEOTHERMAL ENERGY SYSTEM FOR A HOUSEHOLD.



Source: UN-Habitat, 2012. Based on: Rybach, Sanner, 2000.

BOX 17: IMPROVED COOK STOVES IN NIGERIA

Nigeria has among the highest deforestation in Sub-Saharan Africa: forests will be cleared by 2020 if nothing is done as there are few laws or regulations related to forest protection. The use of fuel wood is the main reason for deforestation and Co2 emissions in the area. The local cook stoves are inefficient and demand a lot of fire wood. German NGOs Atmosfair gGmbH and Lernen-Helfen-Leben together with the Nigerian Developmental Association for Renewable Energies started a project in 2011 to provide cost-effective efficient cook stoves in Nigeria.

Up to 100,000 different types of cook stoves will be disseminated within the next 5 years. The stoves save up to 80 percent of fuel wood, which will result to Co2 emission reduction of 250,000 tonnes annually. The recovery of natural forests will indirectly protect water resources, decrease soil erosion and increase biodiversity. Decreased indoor air pollution will lead to increased health. Economic savings will be achieved through decreased use of fire wood. During the project stove assemblers will be trained which creates local employment and income.

Source: UN-Habitat (2011)

BOX 18: GEOTHERMAL HEATING IN TURKEY

In Turkey geothermal heating is used for district heating, thermal facilities, greenhouse heating and spas. Over 300,000 residences were using geothermal heating in 2004: 13 cities were heated partially with geothermal district heating. Geothermal electricity has a low installation and operational cost (1500-2000 USD per residence in the year 2004 in Turkey); it is more environmentally friendly than the conventional heating methods; it is 65 percent cheaper than natural gas heating in the context of Turkey; and its price does not change according to the international markets such as that of coal, fuel and oil. Geothermal district heating systems (GDHS) have seen an annual growth 23 percent in Turkey since 1983. GDHS pay back investments in 5-8 years. The transition from brown lignite stove heating to GDHS has increased the standard of living in Turkey and is thus also socially important.

Sources: Orhan Mertoglu (2005), Geothermal Applications in Turkey, Proceedings World Geothermal Congress Antalya, Turkey, 24-29 April 2005 and Orhan Mertoglu (2001), Geothermal district heating experience in Turkey, GHC Bulletin machinery where a cold substance evaporates in a cold temperature (such as in underground pipes) from where it is pressed to a higher pressure with a compressor when it warms. The high pressure steam is calmed down when it liquefies loosing energy. The energy heats water/air that streams though the steam condenser and this water/air is directed to heat the living spaces through a pipe system. With a similar mechanism heat can be taken from a bottom of a lake or from cold air by cooling it with a couple of degrees (cold air heat pump).[38]

Solar energy is environmentally friendly despite the backup system as major amount of energy is saved and pollution avoided when compared to the use of fossil fuels.[39] When producing solar electricity solar radiation is collected and converted to electricity. Solar thermal power has a great potential but incentive programmes and political and financial support are needed for large scale application.[40] By using solar energy for domestic water heating savings in green gas emissions are 75-80 percent (Box 19). The energy used in manufacturing and installation of the solar systems is recouped in 1 or 2 years and the emissions from the embodied energy are repaid in a few months to 3.7 years.[41] The initial investment of photovoltaic (PV) technology is still relatively high but it will become cheaper with wider production and use.[42] There are various solar water heaters available such as flat plate type, vacuum tube type, a heat pipe and hybrid systems of solar powered water heaters.[43] The flat type is relatively inexpensive and the most effective and simplest of solar panels.[44]

Wind energy

Large wind power farms are already used in many countries but a larger utilization of micro-wind turbines and small-power wind turbines are recommendable as a complement energy source for households in all countries.[45] In small scale wind turbines electricity is produced by wind rotating turbine blades. There is a controller that stops overflow electricity and an inverter that turns the direct current electricity produced into altering current energy suitable for home use.[46] It is important to study the wind patterns especially when the wind turbines are used in urban areas as buildings, affect wind flows.[47]

4.4 SAVING WATER IN HOUSING

Stressed global water resources

Safe water provision is crucial for sustainable housing. In the context of stressed global water resources, urban growth, rising standards of living in developing countries, and climate change water demands are rising.[48] According to estimations 2/3 of the global population will face water shortage by 2025.[49]

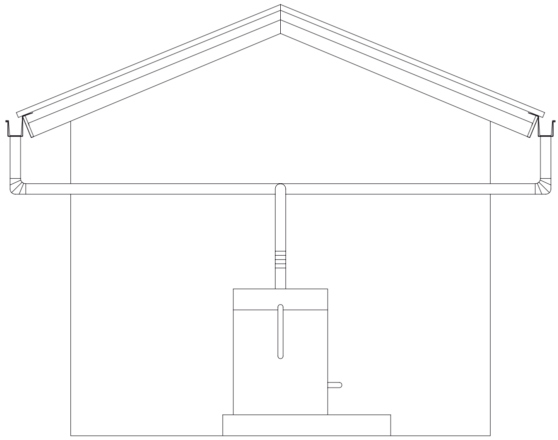
Means of saving water

Especially in water stressed areas rain water collection from roofs is important (Box 20, figure 22).[50] It is important to ensure that nothing leaks to the water incase it is used for drinking.[51] Water use can be made smaller by landscaping gardens in ways that save water used for gardening, grey water can be used for irrigation, and compositing toilets, non-water urinals and low-flow toilets can be used to save water going for flushing.[52] It is important not to mix different waters and water with contaminating matter: urine and faeces, excreta and water, black water and grey water and waste water and rain water should not be mixed in order to allow maximum use of water sources.[53]

Dry sanitation toilets

Flush and discharge toilets contaminate large amounts of water with human faeces: 15,000 liters of water is flushed away every year/person. 95% of sewage ends up in surface waters in the developing world causing water borne diseases that kill over three million people in the developing word every year.[54] Dehydration and decomposition dry toilets can be used for recycling urine and excreta. (Figure 23).

FIGURE 22: SIMPLE RAIN CATCHMENT SYSTEM.



Source: UN-Habitat, 2012. Based on: Snell and Callahan, 2005.

In a dehydration toilet urine and faeces are separated (the urine is either collected or flows into a soak-pit) and faces mixed with lime, ash or earth in a chamber under the toilet seat. Once the chamber is full it is sealed and left drying for a certain time to kill pathogens. Later the content can be used as fertilizer.[55 56] When urine and faeces are not mixed the urine keeps quite sterile and can be used for example for plants (when diluted with water).[57]

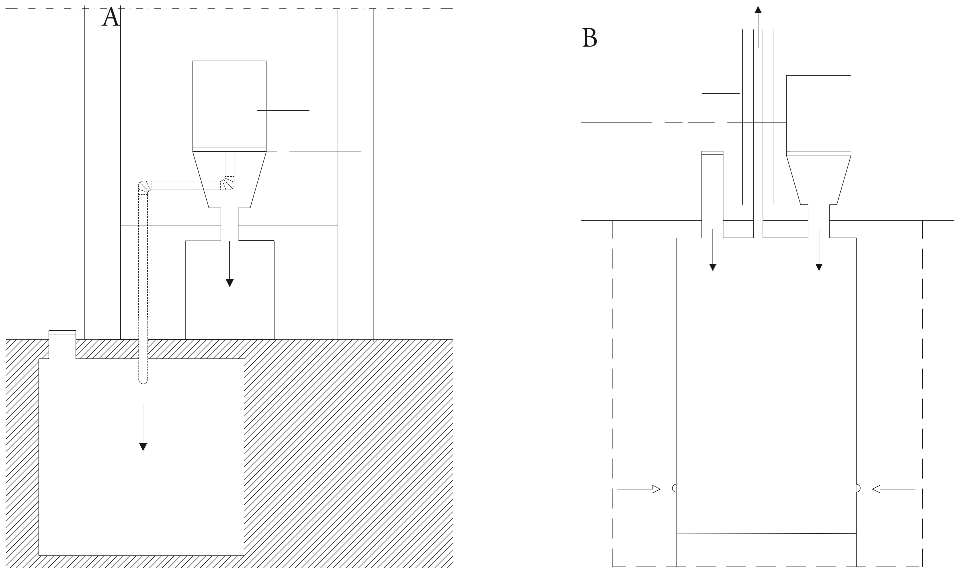
In decomposition toilets bacteria, worms, or other organisms break organic matter and diverting urine is not necessary. Other organic household waste can be added to speed the process. The content can be used as a soil fertilizer when the organic matter is ready (even 1 year for many designs). Isolating the chambers from ground/ground water is important as well as to construct, use and maintain the toilet well and storage the faeces long enough in order to avoid pathogens surviving and spreading diseases to the environment.[58]

BOX 19: SOLAR WATER HEATING IN JORDAN AND CYPRUS

In Jordan approximately 12% of dwellings use solar water heating. According to estimations made in Jordan solar water heating is the best option for energy production when reflected against the availability of fuel, national economy, social benefits and safety even if it is unreliable in terms of efficiency. Additionally it is the cheapest energy form in the long run. 1 In Cyprus 93% of residences use solar water heaters (the world record), which results to a major reduction in the environmental pollution each year. 2 The experiences from these countries can encourage other countries with a major solar potential to utilize solar water heaters.

Sources: 1 Mousa S. Mohsen and Bilal A. Akash (1997), Evaluation of domestic solar water heating system in Jordan using analytic hierarchy process, Energy Conrrrs. Mgntt Vol. 38; Issue 2, p. 18l5~l822. Soteris A. Kalogirou, Environmental Benefits of Domestic Solar Water Heating Systems, Higher Technical Institute, Cyprus

FIGURE 23: DRY SANITATION TOILETS.



A- Dehydrating with urine separation.
B- Composting without urine separation.

Source: UN-Habitat, 2012. Based on: Based on: Esrey, 1998.

BOX 20: WATER TOWERS IN BRAZIL

In Brazil water resources are concentrated in Amazonas and parts of the country suffer from poor distribution infrastructure. Thus many households construct self-made water collection tanks that collapse easily and in which safe water can not be guaranteed. In semiarid Sertao in the North-East of Brazil the government-led program "One million water tanks" was established in 2003 to alleviate water shortage. By 2009 250,000 water tanks of 16,000 litres costing 400 USD each have been built to harvest rain water. As apart of this programme LabEEE (laboratory of the Federal University of Santa Catarina) created a concept of a combined water tower and a solar water heater to be attached to low-income housing (developed for standard COHAB-SC low-income house but can be installed to any type of new or existing house).

The structure is made of prefabricated rings of ferro-cement. It has a rainwater collection in a lower tank (water collected from the roof); potable water of capacity of 1000 litres in an upper tank (double daily household demand); and a solar collector that is located between the two tanks that can be directed towards the prevailing angle of solar radiation. The rain water harvested can be used for washing and toilet flushing. In case there is no town water supply both tanks can be used for rain water harvesting and a rain water purification device can be added to the upper tank.

Source: Holcim Foundation for Sustainable Construction (2009), Second Holcim Award, Sustainable construction 2008/2009, Staubli Verlag AG: Zurich

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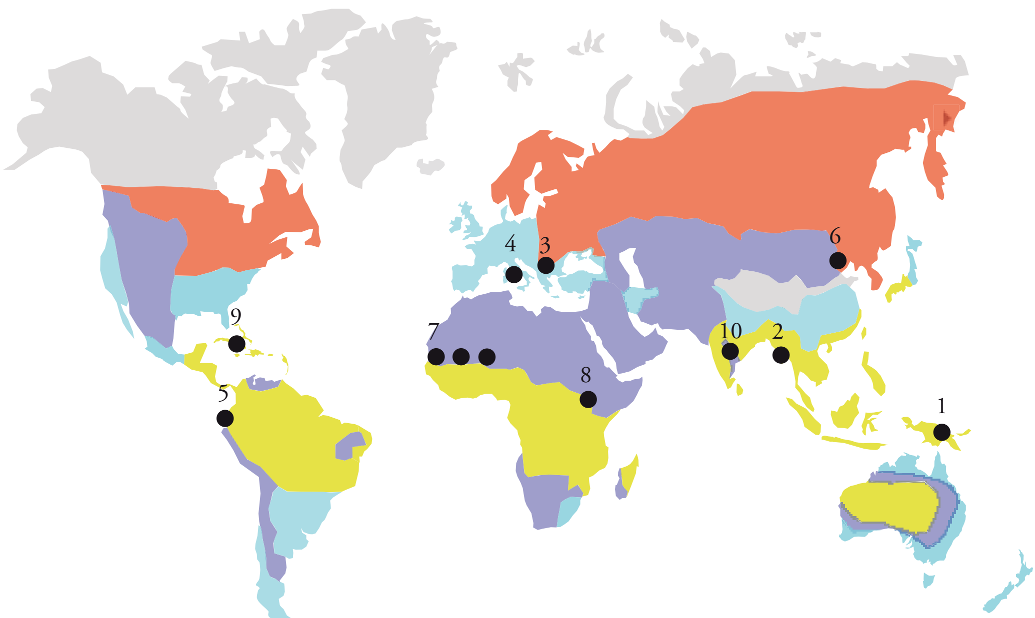
05 CASE STUDIES

In this chapter ten holistically sustainable 'good practice' case studies are presented representing different countries, climates and thematic areas of the content of the handbook. The case studies follow a common template giving information about the project and the organization in charge of it; the context in which the project has been implemented; the innovative aspects and the challenges of the project; and how the different sides of sustainability have been incorporated in the project. The goal of presenting these case studies is to give examples of good projects in order to influence and inspire practitioners.

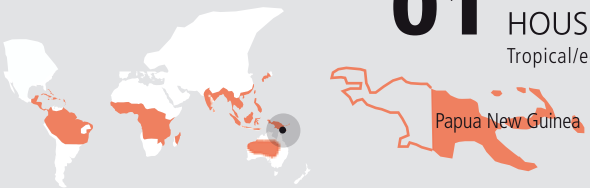
FIGURE 24: WORLD CLIMATE ZONES AND LOCATIONS OF THE CASE STUDIES.



Tropical/equatorial climate zone
Arid and semi arid climate zone
Temperate climate zone
Continental climate zone
Polar climate zone

1. Papua New Guinea
2. Myanmar
3. Serbia
4. Italy
5. Ecuador
6. China
7. Senegal, Mali, Burkina Faso
8. South Sudan
9. Cuba
10. India

Adobe construction in Guatemala. ***© Matthew French, UN-Habitat.***



01 AN EVOLUTION OF TRADITIONAL HOUSING INPAPUA NEW GUINEA

Tropical/equatorial climate zone

1. Brief project description

The project has built culturally sustainable timber housing in Papua New Guinea since 1979. Many versions, stages and buildings have been introduced. The original object was to create a new system of architecture and construction that drew on traditional architectural knowledge and local material culture, but at the same time was suited to modern uses and expectations.

2. Organization

In PNG: Community Based Building Program Ltd, SPK Projects, Niugini Works. In Australia: Assaí: Culture Driven Projects.

3. Target group

The target group includes households, government, schools, firms and NGOs requiring small buildings designed for local culture and climate, and contributing to the local economy and cultural identity.

4. Project goal and results

The goal of the project has been to build affordable, durable, and culturally, ecologically and economically sustainable building stock. 200 individual projects have been developed including village houses; rural and urban government owned houses; schools; community facilities; and tourism facilities.

Vuvumadaring House, Kokopo. ***© David Week, Assai.***

5. Brief country context

PNG is located in the Pacific Ocean. 17 per cent of its 7 million population lives in urban areas. It is renowned for having some 700 distinct language groups, and some of the most distinctive forest materials traditional building in the world, including the Haus Tambaran of the Sepik, the long houses of the highlands, and the yam houses of the Trobriands islands.

6. Local context

PNG is a rapidly growing economy, with a colonial past leading to independence in 1975; difficult transport and disconnected, isolated communities; rich and diverse cultures; and widespread poverty. The project has taken place in rural areas and provincial towns.

7. Climate zone and project's suitability to the climate

Tropical climate zone. The project responded with: single lined walls, large, open, screen-type windows; steep roofs with low overhangs to protect the interior and the walls.

8. Main material

Sustainably sourced timber has been used from local sawmills, which suits the climate well. It also fits the culture, construction skills and local economic systems well. Bamboo and rattan have been used for finishing. In many projects, village women were engaged to produce materials.

9. Construction and technical aspects

The traditional technique of building steep roofs that protect walls and ensure proper ventilation are used, but built materials such as treated timber roofings shakes instead of thatch for ensuring durability and for enabling water collection.

10. Innovative aspects

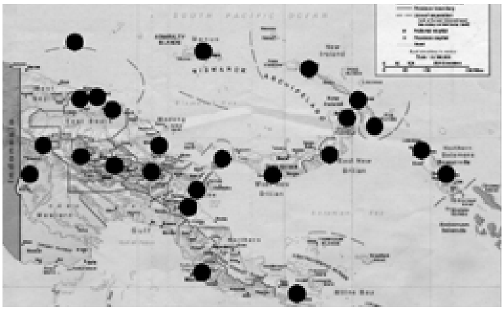
The locally sourced timber used in the project suits the climate, culture, construction skills and economic systems well. Traditional construction methods have been upgraded to modern context. Through the building process knowledge of the traditional architecture methods has been spread. The project used Christopher Alexander's ideas of "patterns" to analyse and update the traditional architecture. ('A Pattern language: Towns, Buildings and Construction', published1977, is an important work for architectural theory and has inspired architects worldwide).

11. Challenges

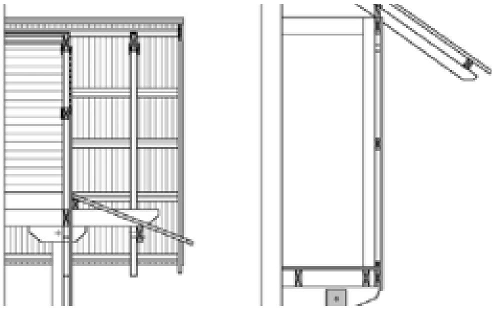
The system is still a "niche" system, running counter to the mainstream building culture that draws its models and materials from overseas. Ongoing development still depends on the vision, interests and energies of half dozen key individuals. However, there many cases in which the mainstream system has borrowed patterns and features from this niche system.

Ceiling, Sinai and Bungtabu Brown House, Kokopo.
© David Week, Assai.

Detail, Sinai and Bungtabu Brown House, Kokopo.
© David Week, Assai.



Black dots: project locations in PNG.
© David Week, Assai.



Standard details. ***© Assai.***

12. Holistic approach

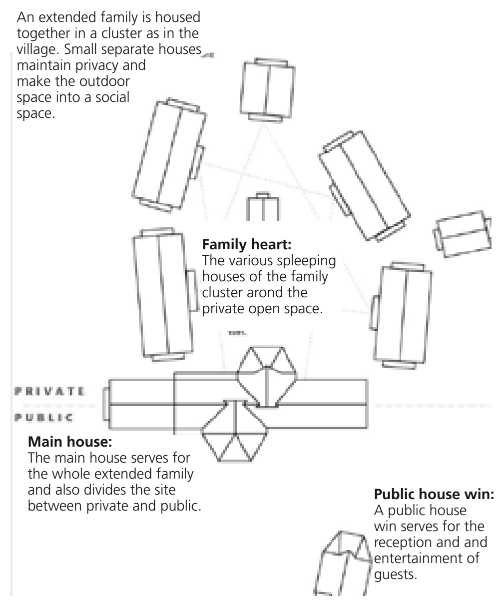
The approach covered the whole of the building, from site layout, to building configuration, to construction and materials; a multitude of factors, including climate, way of life, historic traditions, support for the local economy, and local human and material resources; not just product, but also the process of consultation, design, materials production and construction; and suitability for a range of community works: housing, schools, small commercial, public buildings, and tourism facilities.

13. Environmental sustainability

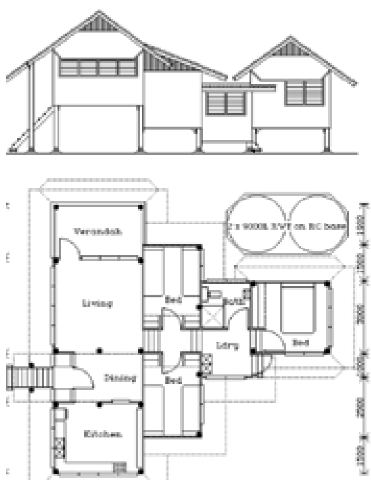
Local material has been used instead of imported materials decreasing the embodied energy of the buildings. The traditional building methods ensure natural ventilation leading to energy savings as mechanic ventilation and air-conditioning are not needed. Dry composing toilets, water collection from the roof and solar power systems are used wherever appropriate.

14. Economic sustainability

The construction process and material supply generate local income. Current construction costs are: USD400/m2-USD800/m2 for a low income house and USD1200/m2 for higher income house compared with the cost of a conventional construction US$1800/m2. The average income level/person/year in PNG is USD 1,300 (WB, 2010).



Examples of site lay out patterns. ***© Assai.***



Passam National high school: Teacher's house No.2.
© David Week, Assai.

Kokopo Beach Resort from air
© Kokopo Beach Resort

House in North Solomons Province ***© Assai***

15. Cultural sustainability

The traditional construction patterns are used instead of imported ways of building.

16. Social sustainability

The construction process has been participatory and building on people's capacities. The natural ventilation ensures a healthier living environment than an air-conditioned house. Over the course of the project, over 1000 workers have been employed and trained in the techniques.

17. Institutional sustainability

The project was started as an unincorporated activity. As offers of projects came in, it was incorporated as the not-for-profit Community Building Program Ltd. This ran into trouble in a large project in 1987, and was replaced by three private-sector firms: Assai, SPK Projects, and Niugini Works. This collaboration of private sector firms is more sustainable, but still faces challenges. The project has won many architectural awards.

Sources: *David Week; World Habitat Awards, http://www.worldhabitatawards.org/winners-and-finalists/project- details.cfm?lang=00&theProjectID=125); and http://pidp. eastwestcenter.org/pireport/2012/April/04-05-15.htm*

Lemban's house: a settler's house in East Sepik. The house was the first iteration of the system.
© David Week, Assai.

02 CYCLONE RESISTANT HOUSING IN MYANMAR

Tropical/equatorial climate zone

1. Brief project description

In response to the destruction caused by Cyclone Nargis, UN-Habitat has assisted affected communities in the Irrawaddy Delta with shelter recovery, water, sanitation & hygiene, and livelihoods. The Coastal Settlements Support Programme (CSSP) has helped 431 Internally Dispaced people (IDP) families from Kungyangone Township (Delta) to secure land tenure and build disaster resilient shelters with access to safe water and sanitation. Importantly, local community carpenters were trained in disaster resilient construction techniques, increasing their earning potential. Finally, cash for work opportunities for casual labourers were provided in the course of improving access infrastructure. The following is a list of the programme's components:

- Tenure security and voluntary return and resettlement for landless IDP survivors of the Cyclone.
- IDPs supported with new disaster resilient shelters with access to basic water and sanitation facilities for household and community consumption through provision of grants.
- Communities provided with the technical guidance to rebuild houses.
- Improved production and utilization of local building materials and generation of livelihood opportunities through build back techniques transferred to local entrepreneurs, carpenters and craftsmen.

Cyclone resistant housing for IDPs in Kungyangone Myanmar. ***© UN-Habitat.***

- Improved Access Infrastructure facilities through cash-for-work opportunities.
- Community capacity to plan and manage the recovery process enhanced, leading to sustained long-term development.

2. Organization

The Coastal Communities Support Programme (CSSP) was implemented by UN-Habitat with financial support from the New Zealand Government's International Aid and Development Programme (NZAID programme) within the Ministry of Foreign Affairs and Trade as well as the Ministry of Foreign Affairs in Norway.

3. Target group

431 IDP families across three areas of Kungyangone, who, two years after Nargis, had not received any sustainable shelter rehabilitation support. The families had been living in makeshift huts precariously constructed from weak, low quality and temporary materials. In some cases, multiple families were residing in a single dwelling.

4. Project goal and results

The goal of the programme was the holistic resettlement of IDP families who were victims of Cyclone Nargis, in new disaster resilient shelters with access to water and sanitation. In addition, communities were empowered through the formation of Village Recovery Committees, the transference of knowledge on disaster preparedness, and the transference of skills for disaster resilient construction.

5. Brief country context

Cyclone Nargis struck Myanmar in May 2008, resulting in 140,000 fatalities and massive damage to homes, livelihoods and infrastructure. The cyclone made landfall in Ayeyarwady Division, of which Kungyangone Township is a part. In total, of 2.5 million people were affected. UN-Habitat implemented several programmes in post-disaster Myanmar ranging from shelter to WASH to livelihoods to Disaster Risk Reduction.

6. Local context

IDP families came from three areas of Kyngyanon and were resettled at Pyi Taw

The People's Process was used when constructing housing for IDPs in Kungyangone Myanmar. ***© UN-Habitat.***

Thar village, in the Southern District of Yangon in Kungyangon Township, a village which was created by the Government to support UN-Habitat's resettlement of IDPs.

The intervention targeted a peri-urban area, thus helping to improve urban-rural linkages. Kungyangone is the main gateway between the Yangon, the country's industrial center, and the predominantly rural Delta area, which prior to the Cyclone was the "rice bowl" of Myanmar. The components of assistance to Kungyangone will help improve the flow of goods and services between two of the most economically important regions of the country.

7. Climate zone and project's suitability to the climate

The programme site is in a tropical climatic zone. Bamboo suits the climate well as it is light and good for ventilation. Ceilings have been built higher for better air circulation to account for the hot climate in Kungyangone. Disaster risk reduction (DRR) features such as cross-bracing and concrete footings were added due to the high risk of cyclones in the region.

8. Main material

Toddy palm timber was used for structural parts of the dwellings (purlins, rafters, beams), and bamboo was used for flooring and walls. Roofs are made of corrugated iron.

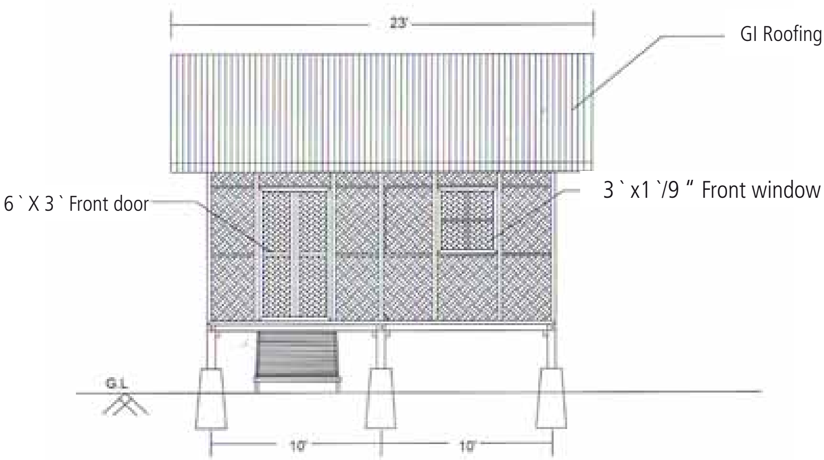
9. Construction and technical aspects

The design includes all disaster resilient features relevant to risks in the region. Larger shelter design takes into account hotter climate and accommodates larger families: some IDP families gained additional members after the Cyclone because they took in children or elderly members from families that had lost the head of household during the disaster.

10. Innovative aspects

The innovation here was the holistic and multi-pronged nature of the interventions: land tenure was secured, resettlement of IDPs facilitated, DRR shelters provided, water and sanitation provided, generation of livelihood opportunities through building techniques transferred to local carpenters/ craftsmen, improved access to infrastructure, and finally, communities were empowered throughbuilding communities' capacity to plan and manage the recovery process.

Additionally, traditional construction techniques were incorporated in the design, enabling cultural identification with the new dwellings.



Side elevation of a typical cyclone resistant house consructed during the reconstruction in Kungyangone.
© UN-Habitat.

11. Challenges

It took a long time to secure land tenure for the IDP families as UN Habitat had to consult with local, townships and regional authorities, and multiple departments/ministries. Further delay resulted from the change of government that occurred to elections in November of 2010.

12. Holistic approach

The intervention was multi-faceted and multi-sectoral: land tenure was secured, resettlement of IDPs facilitated, DRR shelters provided, water and sanitation provided, generation of livelihood opportunities through building techniques transferred to local carpenters/craftsmen, improved Access Infrastructure, and finally, communities were empowered through building communities' capacity to plan and manage the recovery process.

13. Environmental sustainability

Toddy palm and bamboo are natural products and are sustainable sources of timber (they grow locally and quickly).

14. Economic sustainability

The cost/square meter for the houses is USD 62,29/m2. The average income level/person/year in Myanmar is USD 2,989.

The community carpenters and other artisans trained in disaster resilient construction techniques, learn skills that increase their earning potential for years after the termination date of the programme. In addition, it is hoped they will share these new skills with other carpenters that they encounter on future job sites.

15. Cultural sustainability

Use of local building materials and integration of local building customs into shelter design: Programme housing is made of the same local materials and built in the same overall style indigenous to the region.

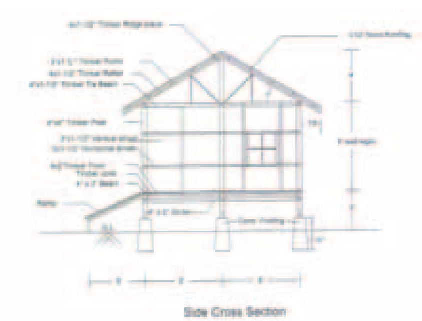
16. Social sustainability

The People's Process methodology has empowered these IDPs to build their own houses with financial and technical help from UN-Habitat which has led to increased social interaction, helped to attenuate feelings of hopelessness/powerlessness in the wake of the disaster, and brought about housing solutions that reflect needs. Capacities of local artisans and carpenters have been increased, improving their overall socio-economic situation.

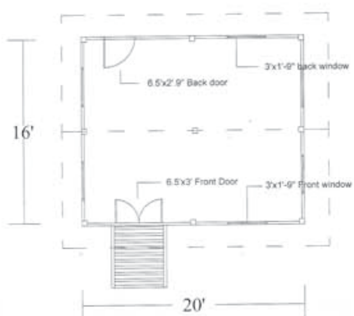
17. Institutional sustainability

The formation and capacity building of the Village Recovery Committees ensures that these committees will remain active long after the termination date of CSSP. VRC members have been trained in disaster preparedness, bookkeeping, and financial transparency.

Source: Eben Forbes (2012), UN-Habitat, Myanmar



Section of a typical cyclone resistant house in Kungyangone. ***© UN-Habitat.***



Plan of a typical cyclone resistant house in Kungyangone. ***© UN-Habitat.***

03 ROMA SETTLEMENTS IN VOJVODIAN SERBIA

Continental climate zone

1. Brief project description

The Roma settlements project has supported Municipal authorities in the upgrading of Roma settlements, and/or directly supported the settlement dwellers in building sanitation facilities; repairing their houses and getting skills. The project started in 2003 and implementation is still ongoing.

2. Organization

HEKS (a Swiss NGO); Swiss agency for development and cooperation; and the Norwegian Ministry of Foreign Affairs (through Norwegian Church Aid) have funded the project. Roma Resource Centre RRC, is responsible for the implementation. Skat Consulting is supporting RRC and HEKS in Technical and methodical matters.

3. Target group

The target group includes Roma families living in Roma settlements in selected Municipalities in Vojvodian; and Municipal officers in charge of infrastructure and social integration.

4. Project goal and results

The project goal has been to improve the social inclusion of the Roma population in Serbia and to increase sustainable livelihoods of the Roma population. The living conditions in seven Roma settlements and eight Roma neighborhoods have been improved by establishing sanitation facilities, house up-grading and infrastructure rehabilitation. All together 354 houses have been upgraded by December 2011 and 130 houses more are to be upgraded during 2012. Roma communities have been mobilized to upgrade their settlements and advocative measures have been taken to legalize settlements at municipality level. Tools to guide Municipal officers and Roma communities have been developed and social and employment access increased.

5. Brief country context

There are around 600 Roma settlements with estimated 300-500 000 inhabitants in Serbia. They live in very poor housing conditions: 30 per cent of the settlements have no water supply, 70 per cent no sewage system and 20 per cent no electricity.

Roma house in Djurdjevo before upgrading.
© Daniel Wyss, Skat Consulting Ltd.

Roma house in Djurdjevo after upgrading.
© Daniel Wyss, Skat Consulting Ltd.

Families with 3-8 members are often living in 1-2 rooms, without toilets or bathrooms. Roma returnees from Western Europe are putting additional pressure on the Roma settlements. The Republic of Serbia has produced several Strategy and Action Papers to support Roma inclusion but without much implementation.

6. Local context

Vojvodian is a major destination of re-immigrating Romas in Serbia (return from EU countries). They often end up in the houses of their relatives in already overcrowded settlements. The slum upgrading project was launched in Novi Sad in a peri-urban Roma settlement called Bangladesh. In the meantime the project has been replicated in six Roma settlements and seven Roma neighborhoods all over Vojvodian in rural and in urban context.

7. Climate zone and project's suitability to the climate

Vojvodian has a temperate continental climate, with four seasons. The houses are extended with bathrooms with thermal insulation. Repair of leaking roofs, broken window/doors increases weather protection.

8. Main material

The project offers new building material, while the beneficiaries contribute secondhand building material such as bricks, doors, windows, toilets, roofing and material. Many Roma in Vojvodina have good access to material from demolition sites.

9. Construction and technical aspects

The Roma families select a bathroom/septic tank solution and adapt it to their individual needs. They receive free of cost building material, but organize/pay construction labor by them self. Only electric and plumbing installations are organized by the project. With the leftover budget, each family can individually repair or upgrade their house by buying new materials or building a new room with reused materials. Technical help is provided by the project. The construction of settlement infrastructure is fully organized and funded through the Municipal authorities.

10. Innovative aspects

A participatory, comprehensive and cost-effective model to support Roma communities and Municipal authorities is developed. In 2012 this experience is being mainstreamed to municipal Administrations.

11. Challenges

Loose cooperation with Municipal authorities has been a challenge and more active cooperation is now being tested. Coordination of tasks and responsibilities in the implementation may present problems. It's also a challenge to get all Roma within the target communities to actively participate.

12. Holistic approach

The project intervenes at three different levels: at policy/authority level a guide for municipal officers is developed to enable local authoritiesto upgrade their Roma Settlements according to

House in the Roma Slum "Bangladesh" in Novi Sad before upgrading. ***© Daniel Wyss, Skat Consulting Ltd.***

House in the Roma Slum "Bangladesh" in Novi Sad after upgrading. ***© Daniel Wyss, Skat Consulting Ltd.***

Roma Slum "Bangladesh" in Novi Sad (above: before, below: after the upgrading.
© Daniel Wyss, Skat Consulting Ltd.

the National Action Plan on Roma Housing; at community level the capacities of the local community representatives are built in order to enable them to actively participate in the project's planning anddecision making; and at family level families are enabled to upgrade their houses accordingto their individual needs and their capacityto contribute work and building material. Livelihood and education aspects are integrated and legal counseling service offered particularly to Roma returning from EU countries.

13. Environmental sustainability

The Roma craftsmen are encouraged to repair and recycle secondhand building material reducing solid waste and saving natural resources.

14. Economic sustainability

Standard Project contribution for bathroom, septic tank and house upgrading is EUR 1,500 (USD2000) per family. The Romas contribute work and material of a value between EUR 500 (USD650) and EUR 1,500 (USD2000) per family. In few cases, where existing house cannot be upgraded, a core house including bathroom and septic tank are offered, costing EUR4,500 (USD5900). As a comparison if a Roma would build a new house (4mx4m) the cost would be approximately EUR 6.000 (USD 8000) for two rooms of 16 square meters. Additionally an average village house for Serbs costs between EUR 10,000- 40,000 (USD 13000-52400).The average income level per person per year in Serbia is USD 5,630 (WB,2010).

Skills have been built through the vocational trainings that generate a sustainable economic impact. The Roma have improved access to income due to improved education and skills; registration and access to state run employment programs have been provided; courses to support vocational, house repair and Roma language teacher skills have been facilitated. Additionally, the project offersa low cost solution to local authorities.

15. Cultural sustainability

The project brings the culture of the Roma community and the majority population (represented by the local authorities) at the same planning table. Applying participatory planning methods and placing the Roma families in the focus cultural sustainability of the project is guaranteed.

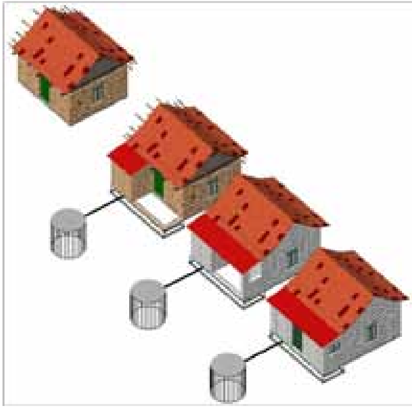


Illustration of different house upgradings, depending on the beneficiary involvement and material.
© Skat Consulting Ltd.

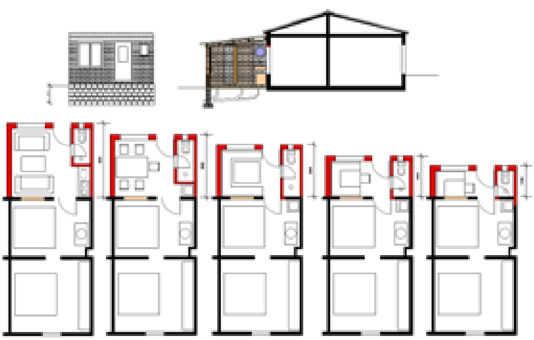
16. Social sustainability

Improved housing conditions and access to sanitation facilities have a major social impact. Electric lightning and warm rooms allow children to do their homework easing scholar integration. Enabling Romas to play an active role in the upgrading of their settlements empowers them. Sharing information to individuals and organizations on Roma rights in the fields of education, employment, health and social services and security improves Romas social position. Services such as legal support and counseling; information and advocacy; and access to obtaining personal documents have a great social impact. Socialinclusion of Roma has improved due to advocacy, information, dialogue and migration counseling activities.

17. Institutional sustainability

Preparation work and testing of institutionalizing the dweller driven house up-grading approach into Roma Decade Housing Action Plan has been facilitated; municipal authorities have been involved; and collaboration with the Central government for new projects have been sought.

Source: Daniel Wyss (2012), Skat Consulting Ltd, Switzerland; Robert Bu (2012), Roma Resource Centre Programme, Vojvodina, Serbia



Plans of house extension options for the Roma Slum "Bangladesh" in Novi Sad Serbia.
© Skat Consulting Ltd.

04 SEISMIC RESISTANT WOODEN MULTI-STORY HOUSING IN L´AQUILA, ITALY

Temperate climate zone

1. Brief project description

The project called C.A.S.E was developed after the 06 April 2009 earthquake in the L'Aquila region where thousands of people were left homeless. C.A.S.E. is spread on 19 areas and includes 185 buildings and approximately 4,500 apartments for 15 000 people. The buildings were designed with different technologies to withstand earthquakes and to meet sustainability criteria. A specific wood technology was used in 5 areas surrounding the city of Aquila, for a total of 12 buildings with 24 apartments in each, on seismically isolated concrete platforms. Each building was delivered in 78 days, including the start of production at the factory. The buildings were completed on 19 February, 2010.

2. Organization

The case-study shown in the document was developed in the context of the C.A.S.E. project. Contracting authority for the C.A.S.E. project: Civil Protection Department; Contracting authority (case-study): Civil Protection Department; Main Contractor (case-study): Log Engineering, Damiani Legnami; Architect (case-study): Lorenzo Perini, chief designer of the wooden buildings selected for this case study.

3. Target group

People left homeless by the earthquake in the L'Aquila region. The selection of persons was made based on various criteria, such as social and health conditions, among others. The selected people were then assigned the apartments on the basis of the availability of the needed size.

4. Project goal and results

C.A.S.E. project goal was to develop safe and sustainable districts surrounded by green areas capable to ensure a high standard of living. Goals included to avoid temporary shelters; to meet the tight time frame; to have the maximum seismic protection; and to reach high standards even in emergency housing. The houses were deliveredon time and tested along the construction process, showing a high grade of seismic safety as well as predicted energy performance.

The C.A.S.E. project: Multistorey buildings in Preturo. Installation of photovoltaic modules in combination with solar panels on south facing roofing. ***© by kind permission of Enerpoint S.P.A (www.enerpoint.it).***

5. Brief country context

Italy is a country with high seismic risk and the buildings are often inappropriate. In case of earthquakes, casualties are often high. Theaverage energy efficiency in buildings is quite low and there is an urgent need to improve the building stock. Some regions have implemented effective plans for energy recovery and recent regulations (implementing the EU Directive 91/2002 on energy efficiency) are trying to bridge the gap.

6. Local context

L'Aquila is a mountainous area in the Abruzzo region with high seismic risk and a critical economic situation. The housing stock is of poor quality and often presents critical structural issues. After the earthquake the economic situation has become critical. The areas for the new settlements were chosen close to the villages that had suffered the greatest damage. Secondly, the non-seismic safe areas were eliminated among those selected. The area counts about 300000 inhabitants and the population density is quite low depending on the urban or semi-urban position.

7. Climate zone and climatic suitability

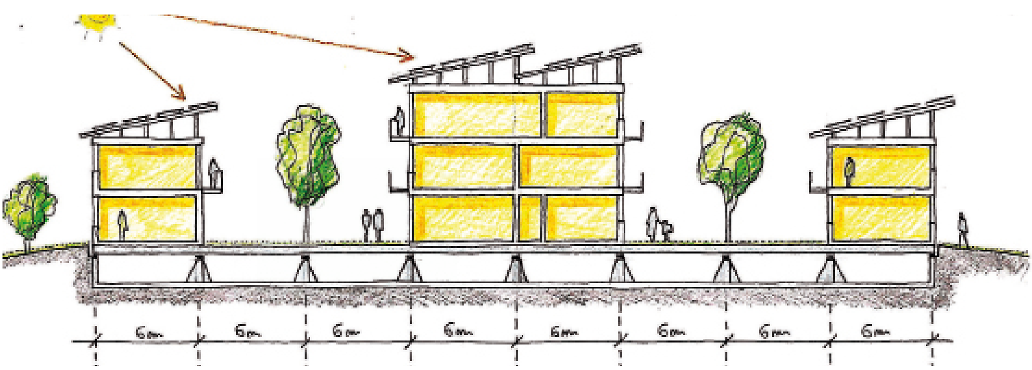
The province is located in the Apennine mountainous area and is thus characterized by a continental climate: winters are rigid and the summers very hot but quite dry. The project has been well developed in terms of energy efficiency: the external walls are well insulated enabling a good performance in winter while balconies and shutters control well the summer overheating.

8. Main material

The buildings were done with wood-technology, using a platform-frame-like system for the outside walls and spruce laminated wood beam ("lamellare sdraiato") for the floor slabs. The wood-frame of the outside wall is insulated with wood-fiber, closed with OSB (Oriented strand board) panels and finished outside with EPS (Expanded Polystyrene). The inside walls are made with gypsum board. The balconies are prefabricated wood while the stair are made of steel. The demand of crossed requirements like energy efficiency, construction time, cost control and seismic resistance were the key for selecting wood as building material. It was the first time wood was used so widely in a public construction tender.

9. Construction and technical aspect

The buildings are marked by two main components: the seismic isolation platforms with standard size for all areas; and the prefabricated elements designed with wood technology. The whole construction process was set to the maximum standardization to meet the timing requirements. To speed up the assembly and finishing on site, the walls were designed using a frame structure in spruce (KVH) sandwiched between OSB panels, insulated with wood fiber and finished with gypsum board. Once positioned, the walls

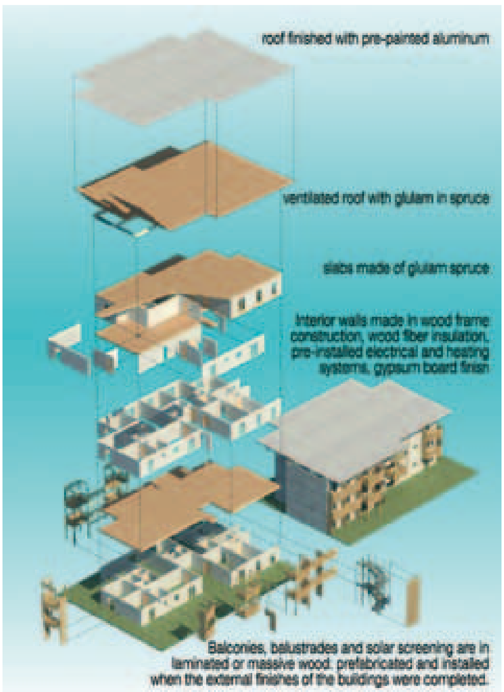


General scheme for the Urban block with a preliminary idea of the prototype building: in evidence the seismically- isolated plate and internal pedestrian streets. ***© Fondazione Eucentre.***

were assembled with "dry fixing". Afterwards, the electrical andplumbing structures were connected to the flooring. The interiors were completed with thescreeds and acoustic sheaths, while the outside insulation and the plaster were placed inthe meantime. The larch balconies, stairs and lifts were prefabricated in modular elements. In less than two and a half months from the start of production, 48 apartments were constructed.

10. Innovative aspects

The buildings lay on concrete seismic isolation platforms supported by columns that are isolated from the ground. The platforms are separated from the columns by "sliding isolation pendulums" that allow to separate the movement of the earth from that of the building andcan withstand a shift up to ± 260 mm and a vertical load of 3000kN. It was the first time in Italy when an anti-seismic device wasused so extensively (a total of 7368). The U value for the outside wall was estimated lessthan U<0,2 W/m2K. The average U value for the windows was about Uw 1,5 W/m2K and for the glass Ug 1 W/m2K, much better thanthe minimum requirements by the law. The overall performance of the building reached a value < 25 kWh/m2 per year. The heat from outside is transmitted inside gradually so to activate the "natural ventilation" during the night. Highly efficient heat generators; separate accounting system for cold and hot water; a heating system operating at low temperatures; and solar panels were obligatory. Hot water is partially powered by solar panels installed on the roof: about 50 m2 in each building, ensuring a supply of 68 per cent of the demand.



Case study: Exploded representation of structure and building componenets. ***© Log Engineering.***

11. Challenges

Building permanent buildings that were seismic risk-free and of high standards (energy efficiency, environmental, architectural details); and to build "communities of people" with social interaction equipped with all comforts and as challenging. During the construction phase the challenge was the logistics: at some point of the construction, up to 500 companies were co-working in an area covering less than some hundreds of square meters.

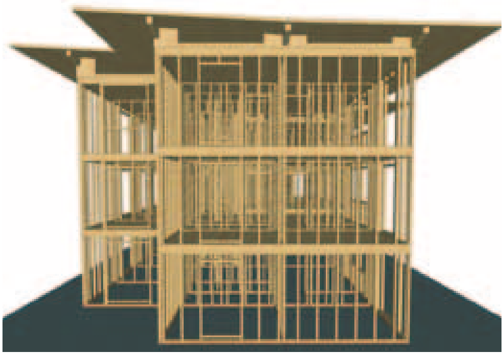
12. Holistic approach

The new settlements were chosen to be constructed due to the severity of the damage; fragile territory; harsh climate; and the shortage of receptive structures. Holistic approach was used from the beginning to build fast permanent homes in the urban context with consideration to the traumatized people. The local, environmental, landscape and technical needs were taken into account.

Functionality; livability and a good outdoor livability were thought of.

13. Environmental sustainability

Impervious areas were minimized; optimum exposure of the buildings to sun light though of; and rainwater used for irrigation of green spaces. Design solutions minimized resource consumption and environmental burden; and screening systems for the control



Structural perspective. ***© Log Engineering.***

Seismic isolation platform. ***© Fondazione Eucentre.***

of solar radiation were used. Solutions facilitated modularity, reuse and disassembly of components; provided good thermal transmittance values; and improved indoor air quality. Material choices used low energy and low emission of CO_2 equivalents. The environmental sustainability of the construction process and the buildings were assessed with the ITACA protocol.

14. Economic sustainability

The cost/square meter is 1,166 euros/m2. (~USD 1,500). The average income level/ person/year in Italy is USD 35,150 WB,2010). Given the emergency situation, the economic aspect was not the most sensitive one. The overall cost for the 13 buildings was 25,600.000 euros.

15. Cultural sustainability

Common areas, to be used to socialize like in a "piazza" (square) or a "cortile" (courtyard) were used. Careful assessments were made about the use of color and the control of indoor natural light. The project wanted to avoid the Civil Protection Department, building an efficient operative model. All the instances were able to fully cooperate.

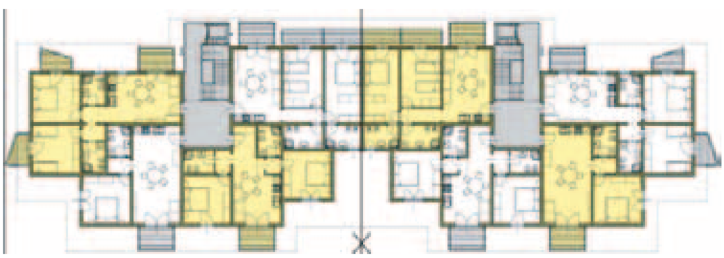
16. Social sustainability

The urgent social issue was to give an appropriate home to people who had lost everything in the earthquake. One of the criteria used was the principle of access to homes closest to people's original residence. Great effort was made to make the buildings recognizable in order to give a sense of belonging to people who had lost everything.

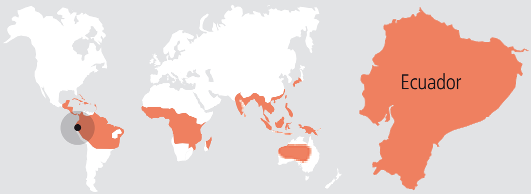
17. Institutional sustainability

The operation was widely and totally monitored all along its process, from the design to the construction sites: the database of the process is accessible to any institutional authority and the expenditures have been fully reported. The scientific community, universities and research institutes have supported the work of the Civil Protection Department, building an efficient operative model. All the instances were able to fully cooperate.

Source: Francesco Pontalti (2012), Consultant in the C.A.S.E



Case Study : floor plan; to speed up the design and construction phase the plant has been simplified; the balconies are prefabricated with laminated or massive wood: arrived in the building site almost ready to be placed alongside the facade. ***© Log Engineering.***



05 BAMBOO BASED HOUSES, GUAYAQUIL, ECUADOR

Tropical/equatorial climate zone

1. Brief project description

Climate change has increased the number of floods and landslides in the coastal regions of Ecuador. At present, Ecuadorians have limited opportunities to adapt to climate-related disaster risks. This project introduces an innovative technology to build flood-resistant elevated bamboo structures aimed at reducing the vulnerability of populations living along the coast. The programme is taking action in coastal regions of Ecuador and Northern Peru. One of the main areas for the project is Monte Sinai, a peri-urban zone surrounding the north of Guayaquil city.

2. Organization

International network of bamboo and rattan INBAR Latin America is implementing activities with different partners under one program: Economic Development and Adaptation to Climate Change. The subproject of bamboo housing in Guayaquil is a collaboration project between INBAR and Viviendas del Hogar de Cristo. The program is implemented with financial support from the World Bank, European Union and the Common Fund for Commodities (CFC).

Improved bamboo home prototype built in Olon community, Santa Elena province, Ecuador in 2011. © INBAR LAC.

3. Target group

Low-income homeless migrants living in slums in the outskirts of cities in Ecuador and Northern Peru.

4. Project goal and results

Hogar de Cristo has built and delivered around 265,000 traditional bamboo homes in Ecuador so far. INBAR and Hogar de Cristo have worked together since 2010 improving the existing initiative: proposal to a World bank competition "100 ideas to save the world" combined production of bamboo, sustainable forest management, reduction of the size of the distribution chain (retailers) and improvement of a prototype for bamboo homes. Temperature increase; raised sea levels; and floods, landslides and stronger winds due to the climate change were taken into account in the building design. After several analyses a new design for the bamboo homes was proposed though participatory approach and approved in 2010. During 2011 and 2012 around 15 prototypes are being built in Guayas and Santa Elena provinces of Ecuador.

5. Brief country context

Ecuador is among the world's most vulnerable countries to extreme hydro-meteorological events such as rainstorms, windstorms and subtropical and tropical cyclones. The effects of climate change are already being felt by millions in the coastal regions due to an increased number of floods and landslides, whose frequency and severity is projected to intensify in the future. The provinces of: Manabi, Santa Elena, Guayas, Los Ríos and El Oro are especially exposed. Heavy rains and storms coupled with ongoing melting of glaciers in the Andes, are predicted to amplify rates of upland soil erosion and frequency of flooding. In the January 2008 floods in Ecuador, 48,000 families were affected, and housing and infrastructure were severely damaged: 12 5000 houses were destroyed. The poorest population segment lives on the most disaster-prone land. Deforested hillside settlements are particularly dangerous for both those who live on them andbelow, due to high landslide and flood risk.

6. Local context

The project targeted rural and peri-urban areas. Local residents in the coastal regions of the country are aware of the potential dangers they face during the rainy seasons each year. The project works in the Guayas (Monte Sinai, el Empalme communities) and Santa Elena Provinces (Olon communities). In addition, the provinces have the lowest per capita GDP in the country, with local households earning about USD 100-150 per month on average. The provinces of Guayas and Santa Elena are Ecuador's most populous provinces, with more than 3 million people living in Guayas alone; over 17 per cent live in inadequate houses.

7. Climate zone and project's suitability to the climate

Tropical climate. Bamboo suits the climate well as it is light and good for ventilation. It is earthquake resistant due to the strong and flexible character.

8. Main material

Bamboo and wood.

9. Construction and technical aspects

- Use of a renewable locally available resource, for building flood-resistant elevated structures.
- Processing bamboo into bamboo-based panels will create local rural employment and can be highly energy, resource and water efficient.
- Use of a simple, energy-efficient, low-carbon technology for building bamboo homes, with easy transfer of skills to locals, which is replicable and scalable with the underlying economies of scale.
- Stronger, safer, flood-resistant homes with flood-resistant features, including raised elevation, increased durability, flood-resistant window fabric, rooftop access "escape hatches" or attic windows.

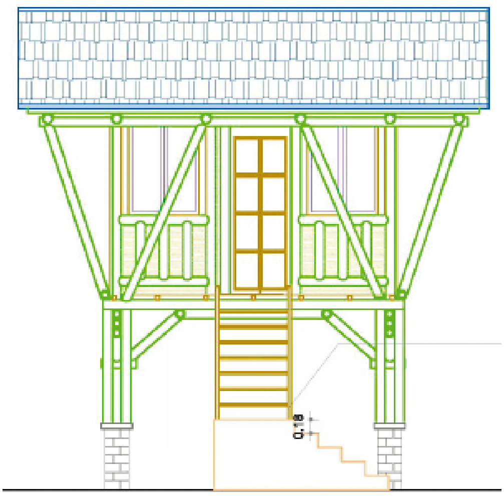
- Affordable yet environmentally sound housing at an estimated market price of USD5,000 for a 32 square meter house with a lifespan of up to thirty years.

10. Innovative aspects

INBAR project pioneers the use of innovative bamboo-based technology that will enable local community members to engage in the designand construction of flood-resistant, elevated and more permanent bamboo housing than current local traditional bamboo construction. Over 75 per cent of the houses are built using locally available bamboo resources. The project employs a new bamboo housing technology which builds on local knowledge, but differs from existing practices, in order to create long-term structures that will be more resilient to climate-related floods and be stronger and safer.

11. Challenges

Bamboo, without any treatment, needs to be replaced in 5-10 years. The bamboo houses of Hogar de Cristo are a usable answer for the poorest people in Ecuador, however they are far from being an integral solution for improving the overall quality of life of the beneficiaries. Furthermore, there is a problem



Original design of the improved bamboo home prototype. Arch. Jorge Moran, Arch. Saul Vera.
© INBAR LAC.

with the quality of materials and illegal logging of bamboo forests in the area. The INBAR project with the new technology has some minimal social risks, as it is attempting to change an established housing production system.

12. Holistic approach

The bamboo construction used is a safe and disaster resistant option suitable for the context.

13. Environmental sustainability

Bamboo is a good local option for materials such as plastic, wood and stone. The cultivation and use of bamboo will decrease the use of wood and thus decrease deforestation. The houses do not create pollution and creates minimal waste materials.

14. Economic sustainability

The cost/square meter for a Hogar de Cristo traditional home is USD 49/m2 and for a improved bamboo home (INBAR) USD 200.The average income level/person/year in Ecuador is USD 3,850 (WB, 2010).

Bamboo is an affordable material but needs to be replaced every 5-10 years. The project provided three year loans to cover the cost. Currently a bamboo home is sold for approximately USD 1,000 and the idea is that an improved bamboo home would be sold for approximately USD 5,000 in the future which will fit the current subsidy for homes promoted by the government of Ecuador.

15. Cultural sustainability

The bamboo house model is adapted andoptimized from the rural traditional bamboo house. Communities have a long term tradition of building with bamboo; over 75 per cent of the local houses in Monte Sinai used locally available bamboo resources.

16. Social sustainability

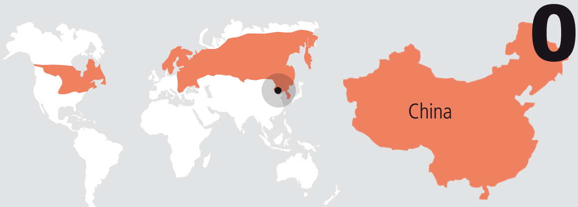
The cultivation, harvesting, manufacturing and distribution of bamboo as well as peasant splittering provide employment for non-skilled and semi-skilled people. Bamboo houses are quick to build and give people an adequate housing standard fast. People get building skills during the construction process, which can help in employment. To ensure commitment from local communities to new designs and technology, the project is focusing on adopting participatory approaches and raising local awareness through the structural demonstration sites in Olon and Monte Sinai.

17. Institutional sustainability

The project links to a long term program sponsored by the NGO Viviendas Hogar de Cristo (VHC). VHC's factory, located in the project site of Monte Sinai, turns out up to 50 prefabricated bamboo houses/day. The project is disseminating and promoting the new technology through the NGO's existing supply chain and consumer base, reaching a large number of beneficiaries.

Source: Alvaro Cabrera, INBAR Latin Amerca and Caribbean; INBAR, Ubidia J.M (2002): Low Cost Bamboo based houses: Viviendas Del Hogar de Cristo, Guayaquil, Ecuador. INBAR: Transfer of Technology Model (TOTEM)

Improved bamboo home prototype built in Monte Sinai, Guayaquil city, Ecuador, 2012. ***© INBAR LAC.***



06 STRAW-BALE HOUSING IN NORTH EASTERN CHINA

Continental climate zone

1. Brief project description

The project has built climate responsible and earthquake resistant low-cost housing stock with an alternative material -strawbales- sourced from local rice and wheat straw waste. Over 600 houses have been built in 59 villages and over 460 people received training as of 2005. During 2008-2009 a two-year training project took place in Heilongjiang. The project began in 1998 with construction of a school in Zhangbei and ended in 2009.

2. Organization

One World Design Architecture and Adventist Development and Relief Agency.

3. Target group

Both low- and middle-income families wereincluded in order to avoid stigmatization of the material as "poor people's construction material". The environmental refugees in the area were especially targeted.

4. Project goal and results

The goal of the project was to enable the Chinese people to build architecturally sound and energy efficient buidlings using straw bales. Houses and public buildings have been built with waste rice straw which is performs well thermally and disaster resistant building method instead of the traditionally used materials brick, mud, stone and rubble that do not protect people from the cold climate (up

Completed strawbale house in Heilongjiang, China. ***© Kelly Lerner, One World Design Architecture.***

to -40 degrees Celsius) and are not earthquake resilient.

5. Brief country context

China is a large diverse country with many socio-economic levels and development needs. It also has a huge diversity of climates.

6. Local context

The project targeted rural and sub-urban areas. There is a major desertification in the area that has resulted in many environmental refugees. The traditional building stock is not energy-efficient which leads to high heating costs and severe pollution.

7. Climate zone and project's suitability to the climate

The are has the continental, extreme cold-dry climate. Straw-bale construction is very well suited to this climate because it is highly insulated.

8. Main material

Straw-bale in-filled in a brick or concrete structural frame which is plastered over.

9. Construction and technical aspects

Straw-bales are dense and ductile and can thus absorb seismic energy through deformation, which resists earthquakes well.

10. Innovative aspects

Local waste product is used that has not been used before in the area. The straw-bale buildings have withstood all earthquakes in the area when many of the other buildings have collapsed. Straw-bale has a good thermal capacity, which is important in the harsh climate. Additional insulation has been added to ceiling and floor.

11. Challenges

Introducing a new building method was a challenge first but it was tackled by organized training as well financial and technical support. Efficient straw-bale manufacturing and supply system needed to be established as it did not exist previously. Ways to use energy efficient design needed to be balanced with the traditional aesthetics.

Strawbale house with brick frame under construction. ***© Kelly Lerner, One World Design Architecture.***

12. Holistic approach

Matters of safety, healthiness, energy-efficiency affordability and durability were integrated in project.

13. Environmental sustainability

The use of bricks in the construction is reduced by 2/3, which decreases environmental impacts and increases energy-efficiency. The use of waste rice straw has reduced the use of coal by 2/3 and thus CO_2 emissions. A straw-bale house is 68 per cent more energy-efficient than a brick house of same size due to straw's insulation value. When using an alternative construction method to locally produced bricks, top-soils are saved which decreases air pollution, slows down desertification process and increases resilience against earthquakes. Additionally, the project uses passive solar design.

14. Economic sustainability

The cost/square meter was USD 45 in 2000-2001 and USD 75 in 2010. The average income level/person/year in China is USD 4,270 (WB,2010).

During the first year direct subsidies for houses up to 40 per cent were given to the dwellers. The straw-bale construction reduces heating costs significantly in the context of a very cold climate and low-income levels.

15. Cultural sustainability

The construction method is new in the area. Thus homeowners are actively involved in the settlement planning and design in order to provide housing that is culturally appropriate.

16. Social sustainability

The project addresses the major issue of desertification refugees. The building process is participatory including people in consultation, materials acquisition, village education and planning of the housing design. The project provides local professionals and homeowners technical training and project managers with management experience. The easy construction technique allows using local construction teams. Additionally, the straw-bale construction has resulted to less respiratory disease among the residents because pollution caused by burning of coal for household use has decreased.

First strawbale school in China under construction, Hebei 1998. ***© Kelly Lerner, One World Design Architecture.***

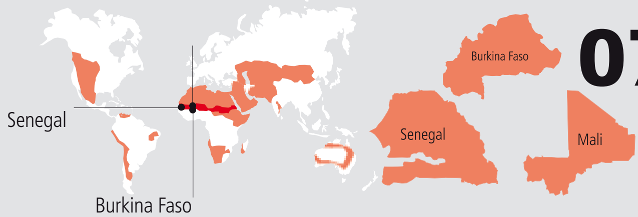
Stacking straw bales between brick columns, Heilongjiang, China. ***© Kelly Lerner, One World Design Architecture.***

17. Institutional sustainability

A network of architects and local technicians has been estabished to support international research and similar projects.

Sources: World Habitat awards, www.worldhabatawards.org; Kelly Lerner (2012), One World design Architecture

Stacking strawbale walls with earthen mortar, Jilin, China. ***© Kelly Lerner, One World Design Architecture.***



07 THE NUBIAN VAULT - EARTH ROOFS IN THE SAHEL

SAHEL/Arid and semi arid climate zone

1. Brief description

In the Sahel region of sub-Saharan Africa, bush timber and thatch has been used for roofing. However, climate change, deforestation, and increasing population growth mean that traditional building techniques are no longer feasible, and the struggle to obtain decent housing plunges millions of families into a vicious circle of poverty. Association la Voûte Nubienne (AVN) has worked with three integrated concepts: a Roof, a Skill, a Market.

The 'Earth Roofs in the Sahel' programme, implemented since 2000 in Burkina Faso, Mali, and Senegal, organises the training and support of local masons in the Nubian Vault (NV) technique, helping develop a sustainable market in affordable housing.

2. Organization

AVN is a networked transnational NGO, founded in 2000 by a French stone mason (Thomas Granier) and a Burkinabe farmer (Seri Youlou), with field staff based in Burkina Faso and Mali and head office (support, management, Liaison, fund-raising and promotion) in France.

3. Target group

The key target group is that of low-income rural and semi-rural families, predominantly subsistence farmers.

4. Project goal and results

Since the year 2000, AVN has seen an annual growth rate of 36 per cent in the numbers of masons trained/vaults built. By 2011:

Construction of a two-vault Nubian Vault house, Burkina Faso. ***© AVN.***

- Over 200 VN masons have been trained
- Over 1,300 vaults built, for some 800 buildings
- 10,000 people (client families, masons, apprentices, laborers...) have benefitted directly from NV buildings

AVN's work has achieved major international recognition (Semi-finalist Buckminster Fuller Challenge 2012, World Habitat Awards Finalist 2009, World Bank Development Marketplace Competition 2009, Tech Awards of Innovation 2007, Ashoka's Changemakers Prize for Affordable Housing 2006 ...).

5. Brief country context

The Sahel is a vast green belt, stretching from Mauritania to Sudan, threatened by desertification. AVN's programme is mainly active in Burkina Faso, Mali, and Senegal, with pilot projects in Benin and Togo.

6. Local context

The project targeted rural and semi-rural areas with fringes of urban areas. The future of rural families, and the ecosystems of the Sahel, are interconnected. Affordable housing that is based on local skills and materials, has low environmental impact, and is economically self-sustaining, is essential to the region's social and environmental restoration.

7. Climate zone and project's suitability to the climate

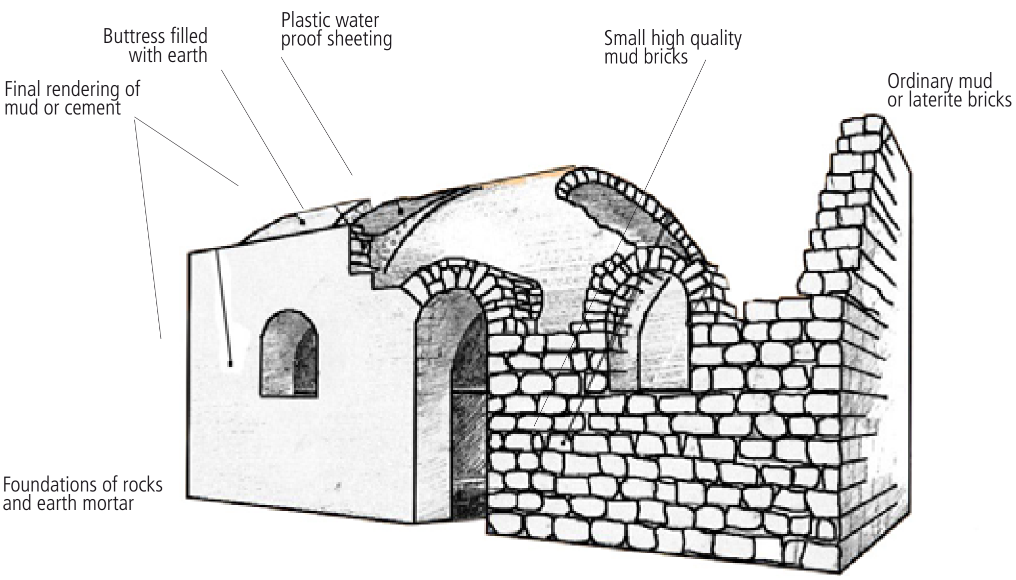
The Sahel has a semi arid climate. Mud brick construction, and solid vaulted adobe roofs, provide effective thermal insulation against extremes of heat and cold. AVN has developed techniques to protect the adobe vaults from damage during the short but intense rainy periods.

8. Main material

Earth bricks and mortar made of the same earth. The roof is water proofed using locally produced plastic sheeting, covered with a mud mortar containing water-repellent additives.

9. Construction and technical aspects

Timberless vaulted earth brick construction is used which is environmentally friendly, sustainable, affordable, and comfortable, using the Nubian Vault (NV) technique. Such houses can be built with locally sourced materials, are long-lasting (circa 50 years) and avoid the use of expensive, imported,



Nubian Vault - lateral cross-section. ***© AVN.***

manufactured building materials. In contrast, houses or shacks with tin roofs have no thermal or sound insulation properties, and roofs need replacing every 7-10 years - a major drain on family resources.

10. Innovative aspects

AVN has pioneered a profoundly new approach to the provision of shelter in environmentally and socially stressed situations. It has carefully developed a system whose growth can be sustained with modest and diminishing external resource inputs. Key features of the system are the simplicity of the technique, its standardisation and modularity, its affordability, and the on-site training of builders in the community. Local, generally illiterate, apprentices learn how to construct vaults in 2-6 months; after a few years' experience, they can become independent builders.

11. Challenges

The main challenge lies in the scaling-up of the programme in response to need, and its extension to other countries of the Sahel region. Scaling-up requires the acceleration of recruitment and training of apprentices, an increase in the productivity of qualified NV masons, and the deployment of larger numbers of AVN extension agents, working in collaboration with local and franchised partners on the ground.

12. Holistic approach

The AVN strategy results in systemic, holistic, change because it is completely integrated into local economic circuits, relies entirely on locally sourced, often freely available, raw materials, and is creating autonomous markets in NV housing through the activity of increasing numbers of trained NV builders and entrepreneurs.

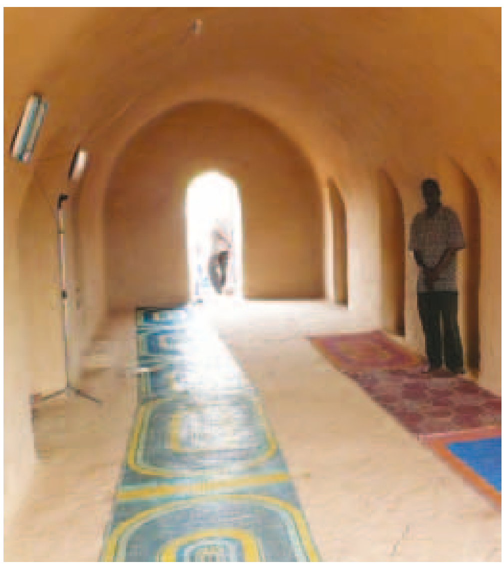
13. Environmental sustainability

Use of the NV method has saved the use of some 2000 trees, or 15,000 corrugated iron roofing sheets, representing carbon savings of 3,000 tons of CO_2-equivalent, compared to alternative methods.

14. Economic sustainability

The cost/square meter depends on location, proximity to water/materials and the involvement of the client. In Burkina Faso for example the cost was 8 USD/m2 if clients provide all un-skilled labor and 40 USD/m2 if all labor done by a mason. The average income level/person/year in Burkina Faso is USD 550,

Interior of a village house, Burkina Faso. ***© AVN.***



Interior of a village mosque, Dendjola, Mali. ***© AVN.***

in Mali USD 600, and in Senegal, USD1,090 (WB 2010). 750,000 Euros (USD930000) of local economic impacts have been generated through the AVN programme. Over one-third of the NV construction market is now completely autonomous and self-sustaining: 37 per cent of NV clients are found directly by NV builders/entrepreneurs. Of the remainder, 40 per cent come via a local intermediary, and only 23 per cent via AVN itself; in the regions where AVN is active, a growing and independent market in NV construction is rapidly developing.

15. Cultural sustainability

The NV technique is an evolution of vernacular adobe architectural traditions, and allows for the inclusion of a traditional flat-roof terrace.

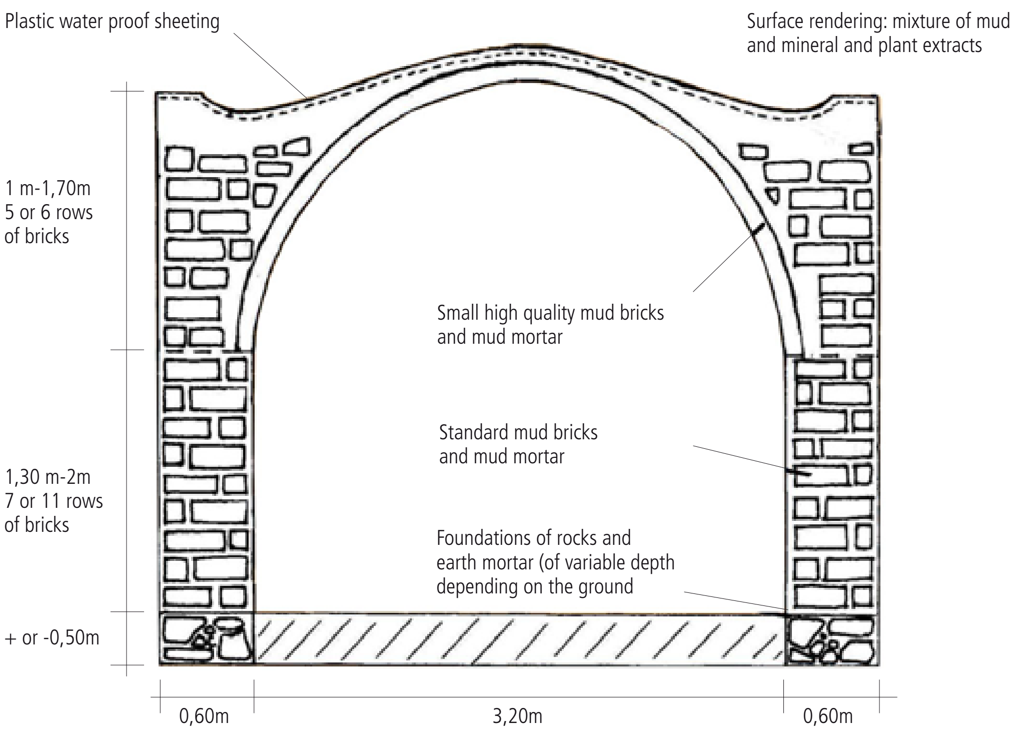
16. Social sustainability

214 trained NV masons and 296 apprentices in training in the 2011/12 construction season, and some 10,000 people living in or using NV buildings, are strong indicators of the programme's social sustainability.

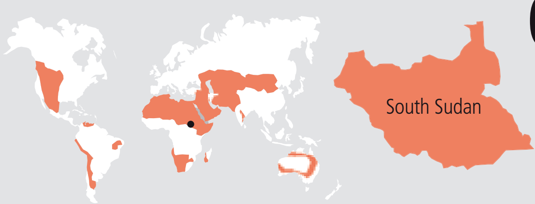
17. Institutional sustainability

AVN's social entrepreneurship model is a strong one, involving four principal groups of stakeholders: social investors who raise funds which can be used by AVN's local teams who, often with the help of technical partners, implement specific programs for end-user beneficiaries. As a result, the 'Earth Roofs in the Sahel' programme, started in 2000, has grown at an average rate of 36 per cent in recent years, and continues to attract significant levels of investment and sponsorship. AVN's operating budget in 2011/12 was 350,000 euros (USD435000).

Source : Association la Voûte Nubienne (2012), www.lavoutenubienne.org



*Nubian vault, vertical cross-section.© **AVN.***



08 DARFUR, STABILIZED SOIL BLOCK CONSTRUCTION

Tropical/equatorial climate zone

1. Brief project description

The project targets vulnerable households who are trying to overcome the self-development limitations induced by their IDP status, using woodless technology to protect the fragile environment with Stabilised Soil Blocks (SSB). Self-help construction will be promoted to demonstrate the affordability of the proposed intervention, securing plot tenure, including contribution to public utilities development, on-the-job training and creation of income generation activities. The project has started early 2010 and concluded by the end of 2010.

2. Organization

Implemented by UN-Habitat in close collaboration with UNHCR which also funded the project.

3. Target group

a) Vulnerable households, still holding IDP status b) Community members, who will receive training in SSB and who can generate income by using the leased hand press machines, c) Government officials, especially in the SMPUD and HAC, who will be trained in low-cost housing construction and participatory planning, d) Donors and international partners that will participate in coordination and dissemination activities.

4. Project goal and results

The goal of the project has been a reconstruction process that decreases the number of slum dwellers; prevents new slums; empowers local communities/vulnerable groups/civil society organizations; reduces environmental

A house built by SSB for disabled headed IDP house-hold in Sakali Area - Southern Darfur in 2010. ***© UN-Habitat.***

degradation; builds the capacity of the private sector and public institutions; provides sustainable land management; and uses sustainable alternative housing technologies.

In the pilot project of Sakali in Nyala a housing model with common walls with other houses that is possible to expand with time was introduced. Shared WASH services by units of five homes where constructed.

5. Brief country context

The recent conflicts in Darfur displaced 2 million people (almost 1/3 of its population), mainly forced to flee to the major cities thus contributing to an accelerated urbanisation process. Additionally, the formation of IDP camps and the migrations to urban areas create huge environmental threats, particularly due to the growing need of wood for producing fired bricks which accelerates the deforestation process in an already fragile ecosystem.

Land issues are particularly complex to manage, and access to adequate shelter and basic services for the poor is among the most critical and urgent matters to be addressed. The government has a major pressure to provide serviced land with infrastructure as the absorptive capacity of the urban centres has been strained by massive migration of returnees, IDPs exiting the camps, and the rural exodus provoked by the on-going conflict. Failing to provide urgently solutions to such challenges, there is a considerable risk of creating social stress, new conflicts and instability in the region. The conditions of the urban centres in Darfur have been assessed in multiple studies, especially through the Joint Assessment Mission.

6. Local context

The project targeted urban areas. The local environment suffers from continuous degradation affected by high deforestation rate due to prevailing drought and cutting trees for building houses and other domestic uses.

7. Climate zone and project's suitability to the climate

Darfur falls within the tropical climate zone, with a poor savanna ecosystem unlike the overall Sudan climate which is Arid/semiarid. The Stabilized soil blocks suit the climate well.

A housing unit built by SSB for a vulnerable IDP family in Sakali - Southern Darfur in 2010. ***© UN-Habitat.***

8. Main material

Stabilized Soil Blocks (SSB); comprises of a mix between silt and clay soil with 5 per cent cement and 60per cent less use of water in comparison with any other blocks/bricks.

9. Construction and technical aspects

SSBs compressed/compacted with a stabilized soil block machines using binders such as cement, lime, volcanic ash or pozzolana.

10. Innovative aspects

The use of an alternative more cost-efficient material to fired bricks (high use of firewood) and timber in a context of high deforestation.

11. Challenges

Scaling up from pilot projects is a challenge as well as the effort to make the stabilized earth blocks a wide scale material that would replace the use of fired bricks.

12. Holistic approach

An incremental approach in construction has been used.

13. Environmental sustainability

The materials to produce blocks - clay, sandand water - are easily found in Darfur and have a smaller ecological impact than imported materials. The use of an alternative material to wood in the context of deforestation is environmentally important: stabilized soil blocks enables zero consumption of firewood and structural timber; and 60 per cent decrease in water usage (needed to produce fired bricks). Decreased energy consumption is achieved by means such as maximizing the use of land and using natural ventilation. Stabilized soil block machines help to avoid waste of material. The binder cement should be gradually replaced with binders such as lime, volcanic ash or pozzolana for smaller ecological impact: using lime is currently under investigation by UN-Habitat and the state authorities.

14. Economic sustainability

The cost/square meter is USD 230. The average income level/person/year in Darfur is USD4,270 (WB, 2010).Stabilized soil blocks are 30per cent more affordable than fired bricks and faster to build. Use of other binder than cement saves money as cement is expensive in Darfur. Support to access to machines and materials in form of tax exceptions and subsidies is being used.

Training of unemployed youth on production of SSB in Sakali Area - Southern Darfur in 2010. ***© UN-Habitat.***

15. Cultural sustainability

Tradition of building with bricks matches cultural values.

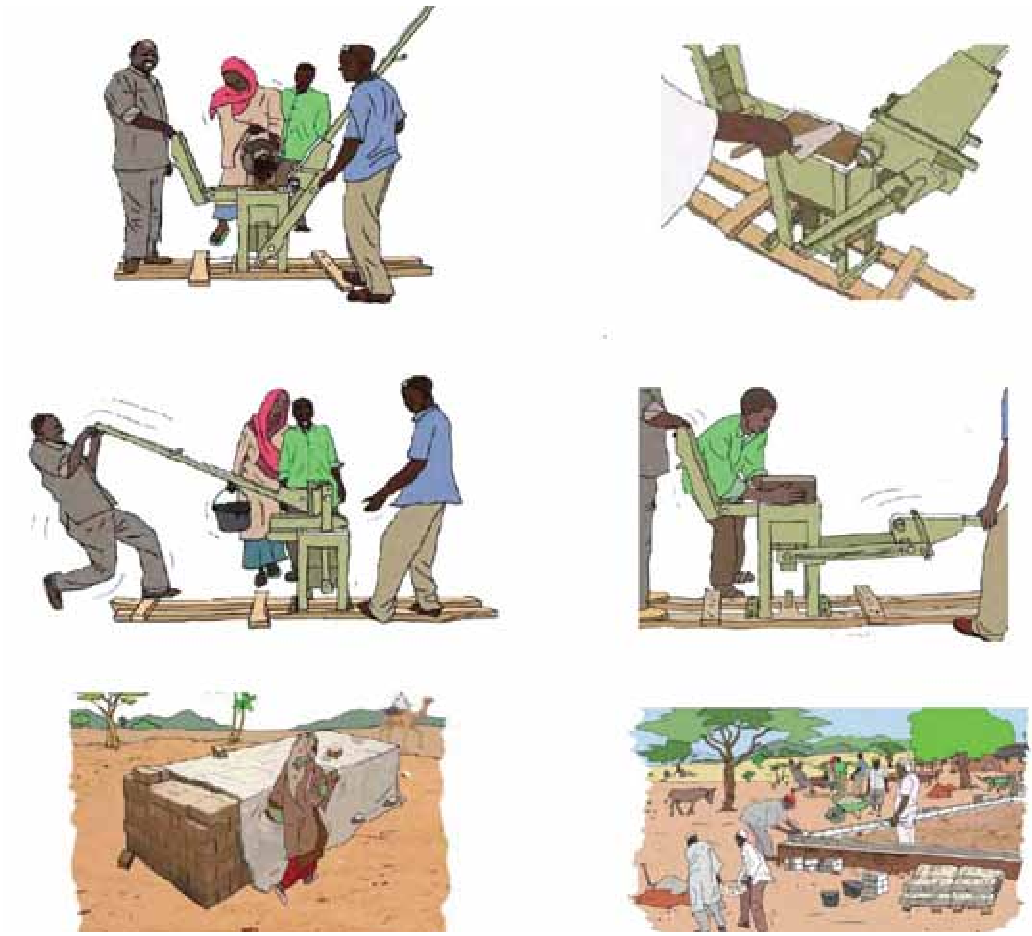
16. Social sustainability

Participatory planning approach including the vulnerable members of the community has been used. There has been training in place to train masons and technical schools to use stabilized soil blocks rather than fired bricks. The production of blocks is labor intensive and can generate income for low-income communities if sufficient micro-finance skills are introduced.

17. Institutional sustainability

UN-Habitat has been working closely with the local authorities and technical institutes/ schools to include the SSB in their training curriculum, and with the state ministries to introduce the SSB in their construction codes and standards.

Source: UN-HABITAT (2009), Darfur, Early recovery stabilized soil blocks for sustainable urban growth and email exchange with Wael Wainstock (February-March 2012)



Awaraness tools for production and application of SSB to replace burned bricks. ***© UN-Habitat.***

09 FERRO-CEMENT CONSTRUCTION IN CUBA

Tropical/equatorial climate zone

1. Brief project description

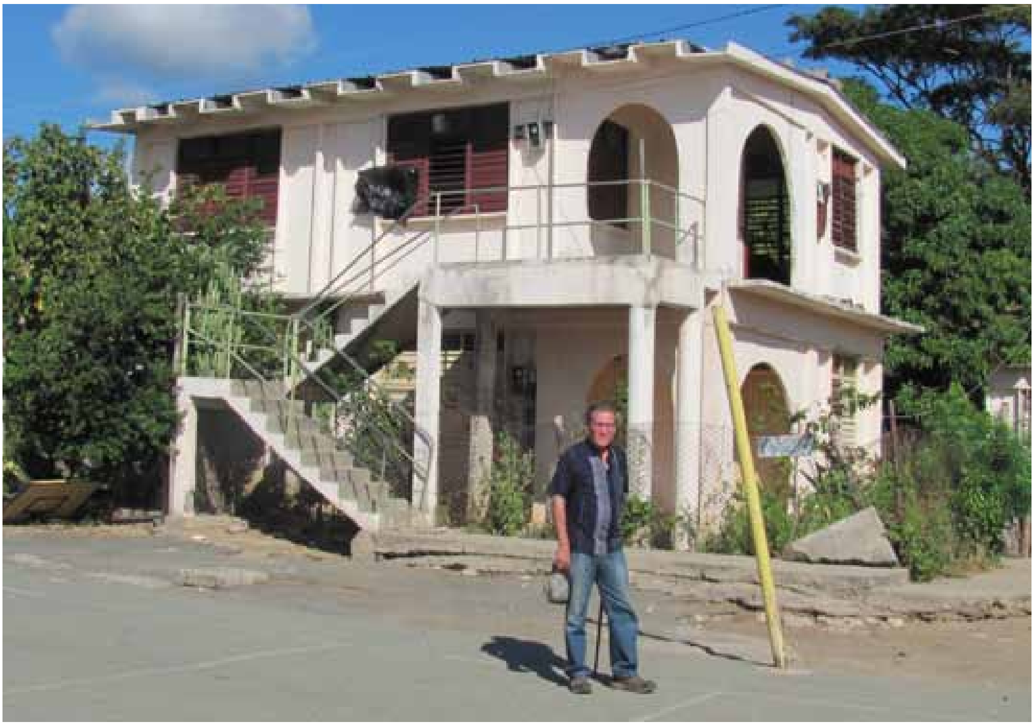
In the 20th Century concrete replaced timber as the principal construction material in Cuba. Structures of reinforced concrete with infill of cement blocks and burnt clay bricks are ideal materials for the rigorous weather with torrential rainfalls and frequent hurricanes. The revolutionary Government embarked after 1960 in large housing projects setting reinforced concrete panels as standard. The high cost of such structures animated Prof Hugo Wainshtok to apply his experience of building boats in ferrocement, to design a scaled down and more flexible panel system. Together with Prof Emilio Escobar he developed the system named SERF.

2. Organization

CREDEF, at the Polytechnic University of Havanna promotes the technology within Cuba and the EcoSur Network has exported it to several Latin American Nations.

3. Target group

The population in general.



SERF inventor Wainshtok in front of a 20 year-old ferro-cement building. ***© Ecosur.***

4. Project goal and results

Reducing the consumption of raw materials in construction, mainly cement and steel. The small scale local production also reduces transport. As a fact, the construction costs could be reduced by about 30 per cent as compared to the accustomed technologies. Since 1990 SERF has been used in Nicaragua, Dominican Republic, El Salvador and after the 2010 earthquake also in Haiti.

5. Brief country context

In Cuba, housing delivery is a responsibility of the state: the state builds apartments/houses or supplies materials/credit for self builders. The apartments are assigned to the owners who pay a mortgage calculated on the base of their income over a period of maximal 20 years. More than 80per cent of the housing stock is privately owned.In Cuba the situation is very different from most developing countries. In the rural areas and intermediate towns the housing stock is generally better than in the centers of the larger towns. The Government has made great efforts to upgrade housing outside of the cities and almost all Cuban households nationwide enjoy basic services like drinking water and electricity.

6. Local context

The National Housing Institute has an office in every Municipality and all buildings are registered. There exists clear information on the general state of the buildings and their potential degree of vulnerability. In the event of foreseeable hurricanes or inundations vulnerable locations are evacuated. While the owner of the house or apartment is responsible for its upkeep and minor renovations, the Municipality operates work brigades who undertake major repairs and new constructions, they also make minor repairs in the households of disabled people.

SERF is an ideal platform for extending houses /building new ones. Most of those units have been built by the Municipal brigades within the planned activities of the Housing Directorate.

A mobile vibrator forms the panels (above). Alternatively panels are produced by hand (below). ***© Ecosur.***

One mason and three helpers assemble the house. ***© Ecosur.***

7. Climate zone and project's suitability to the climate

The type of building is suited to the warm and humid climate. The frequent hurricanes demand solid construction. Cubans prefer concrete construction over all other options.

8. Main material

Ferrocement panels are made with microconcrete (cement and well graduated sand), some steel bars and a wire mesh. They are used for walls and ceilings, through their shape they are self-supporting and do not need additional reinforcement. Production is manual and does not need extensive areas nor power connection.

9. Construction and technical aspects

Foundations are made according to the situation, with a reinforced ringbeam that encloses the wall panels. The panels are topped with another reinforced ringbeam, which is the support for the horizontal panel forming the ceiling or roof. The same ringbeam encloses the wall panels of the next floor.

10. Innovative aspects

Ferrocement is well known from massive applications, mainly in roof structures (Nervi). The application as medium size self-supporting wall and roofing elements produced in small workshops for social housing is a novelty and it has proven extremely versatile in post disaster reconstruction where permanent shelters made with those panels are a viable fast alternative.

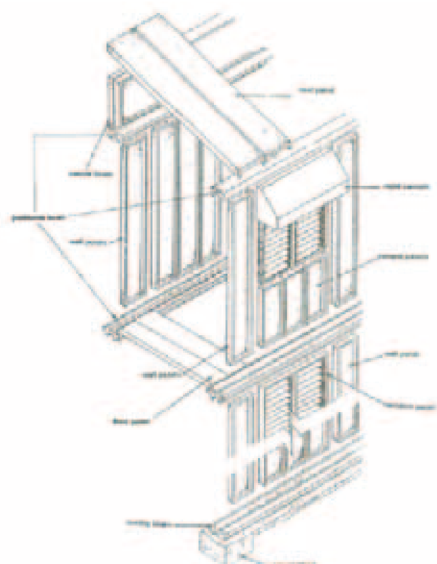
11. Challenges

Introducing a new technology generally encounters resistance from a large part of the professional establishment and the skepticism of the engineers responsible for construction permits.

12. Holistic approach

Local production with low or no consumption of energy (other than human) and the optimized use of cement, sand and steel produce a material that has a smaller ecological footprint than most durable housing solutions.

The panels are placed and then concreted into the ringbeam. ***© Ecosur.***



Construction scheme, taken from "Ferrocemento", book available at www.ecosur.org . ***© Ecosur.***

13. Environmental sustainability

The consumption of raw materials per square meter of construction is lower than most other walling or roofing systems. The elements are only 3 cm thick and due to careful curing of the concrete and ideal positioning of the steel rods, high efficiency of the materials are achieved, they are used close to their maximum capacity. Local production reduces transport emission.

14. Economic sustainability

The cost/square meter is complicated to indicate as materials assigned by the government are not accounted at market prices. However, it can be learned from the experiences from countries in the region that the real costs are approximately USD 150-200. The average income level/person/year in Cuba is USD 5,520 (WB 2010).

The low consumption of raw materials per produced unit combines with fast assembly of the panels, one qualified mason works with three helpers. Setting up local production of panels is fast and low cost, as the moulds can be moved from site to site. Total cost per built unit is lower than most alternatives.

15. Cultural sustainability

Cubans prefer concrete structures over other structures, and once the initial skepticism about a new technology is overcome, the technology is well accepted. The same has been experienced in several other countries where the system was introduced.

16. Social sustainability

Local production of the panels with a simple technology is a good base for social sustainability.

17. Institutional sustainability

The technology is being promoted internationally by the EcoSur network and used in several projects (including a UNDP sponsored action in Haiti).

Sources: Professor Hugo Wainstock CREDEF, at the Polytechnic University of Havanna; and Professor Kurt Rhyner, Ecosur

Using ferro-cement panels as floorslab in a conventional building. ***© Ecosur.***

*Placing the horizontal panels with the help of a chain-pulley .****© Ecosur.***

10 SLUM RESETTLEMENT IN JAUNAPUR INDIA

Arid and semi arid climate zone

1. Brief project description

The project has a holistic approach to the upgradation of low cost housing based on issues such as the choice of land, roads, water supply, drainage and appropriate building materials. Technologies that respond to the local climate are applied and the use of building waste is in focus, which makes the project cost efficient.

The project was initiated in 1996, with a Supreme Court directive, stating that 3600 illegal squatters in Delhi would be resettled on Delhi's outskirts. The project was meant to facilitate the resettlement of 4500 former slum households in Jaunapur, near Delhi on degraded highland previously classified unusable.

In May 1997, the Lt. Governor of Delhi gave the project a kick-start by ordering a pilot scheme comprising 52 units to be built to demonstrate its feasibility and efficiency. Construction started in July 1997 and by September 1997 these had been built. Currently since September 1997 the project has been on hold due to political objection and a court case now being addressed in the Supreme Court of India. The project has received strong support from the slum dwellers in question despite their initial objections and it is a very important project in terms of attempting to change the course of slum upgradation in India.

2. Organization

The project started by the Anangpur Building Centre, a private entrepreneurship headed by architect Prof. Anil Laul. The centre, which has been the forerunner of the Building Centre movement in India, has previously also worked on other low cost housing projects and developed structural systems and building systems such as A-frames, Cube-on-vertex, Funicular shells that are earthquake resistant and yet cost-effective.

3. Target group

The target group is the slum dwellers living in Delhi's ecologically sensitive Southern Ridge forest area. The inhabitants had been living there for approximately 40 years working in the nearby mining areas, until the Supreme Court ordered the resettlement. Under the

Jaunapur Slum Resettlement at Jaunapur. ***© Anangpur Building Centre.***

supervision of Prof. Anil Laul, the Anangpur Building Centre identified Jaunapur as an ideal site for rehabilitation.The engineers of the Slum Department were resistant to the unconventional approach to site development, building techniques and implementation system and the project met with stiff resistance from them.

4. Project goal and results

Today the forms of governance dictate the rules enforced by Laws and Governments in Human Settlements. The main goal of this project is to holistically design a settlement around the humans living in it. It facilitates a new perspective to sustainable affordable resettlement of slum dwellers and questions the fundamental approach of the governmental policies that are currently enforced. The pilot scheme of 52 dwelling units has been constructed during the project implementation with the density of 200 dwelling units per hectare, which is the maximum density of such clusters. The project proves that with adequate policies and efficient use of economic resources, a sustainable settlement scheme can be achieved.

5. Brief country context

India is one of the world's largest countries with the population of 1.2 billion people and it is currently witnessing a major economic growth of 8 percent for the fiscal year that ended in March 2012. However, the economic growth has not benefitted the whole population equally: 42 percent of people in rural areas and 26 percent of people in urban areas still lived below the poverty line in 2004-05 according to the official statistics. Governmental programs to increase access of the poor to education, employment, health care, services and infrastructure have been initiated. However, the slum upgrading policies in general are not sustainable.

6. Local context

Four million people from Delhi's 14 million population live in slums. Lack of funding, infrastructure and proper planning are common constraints. The project is located within the suburbs of Delhi bringing the slums seven kilometers closer to the city center.

7. Climate zone and project's suitability to the climate

Hot semi-arid climate zone. There is 706mm rainfall/year. The temperature varies from minimum 4 degrees Celsius to maximum 45 degrees Celsius. The construction techniques used suit well the local climatic conditions.

8. Main material

Waste materials such as broken bricks, PVC, broken tiles, stone and paper have been used. The walling material used is the hollow core interlocking block with an impermeable non-erodable diaphragm with required finish integrated during manufacturing. For the floor slabs and the roof funicular shells, which are compression structures, have been used. Both these technologies display an array of colour and texture.

9. Construction and technical aspects

Diverse materials, designs and construction methods have been used. The main interlocking brick with its impermeable external face prevents the use of paints which protects the soil from harmful chemicals that get washed off every year by rain. The use of lean backup materials such as fly ash, burnt rice husk, mud and even papercrete increases thermal insulation. The blocks are made by a simple hand mould and require curing for 48 hours. Waste polythene is stuffed inside the hollow of the blocks for further increasing the thermal insulation. Various patterns and textures are created on the external surface using PVC chips or waste products from former houses such as stone or broken ceramic tiles. Traditionally compression structures in the form of arches, vaults, domes, catenaries and doubly curved structures have been used extensively in temples and forts. These structures are an exemplary proof of the durable performance of such structures, having stood the test of time. The funicular shell roof is one such compression structure, which ensures conservation of natural resources by utilising waste materials effectively and minimizing the use of expensive steel and cement. Artistic patterns are created by placing waste materials such as marble/granite slab, bricks, stone tiles, mud blocks or broken tiles on top of the mould and fastened with cement slurry.

10. Innovative aspects

The innovativeness of the project lies in recreating the past and simplifying the construction process. Both the technologies utilize waste materials from old constructions. Diagonal bonding of the interlocking blocks creates earthquake and cyclone resistant structures. Funicular roofs optimize the use of steel and cement and thus making it more affordable. The roofs are easily adapted to different shapes and artistic expressions.

11. Challenges

There has been lack of political will to deal with the slum problem in the area even if funds and land are in place. Despite their initial objections the project received strong support from the slum dwellers in question but even this was not an incentive towards the completion of the project.

12. Holistic approach

A slum dweller community is resettled in a sustainable and affordable way in the context of choice of appropriate land and the settlements planned to ensure social sustainability. Due to the use of waste land the settlements can be located closer to the centre of the city, which makes access to employment easier. The land also makes for decentralized waste water disposal with the use twin leech pits, thereby dispensing the large cost of piping in the centralized disposal system. The tendency to encroach in the cluster planning scheme would be at the cost of inconvenience to the owner and his family. By building clusters together the residents cannot build outside the limits, which make consolidation of the property and speculation impossible. High income housing is mixed with low income housing, which makes the project socially more sustainable.

13. Environmental sustainability

The project implies minimized use of steel and cement and maximized use of recycled and local materials. Waste water is treated locally and used for fruit plantations on site. Kitchen-bath waste and sewage waste is separated and waste water is allowed to percolate into the soil through alternating twin leech pits. The absence of use of paint for exteriors keeps harmful chemicals from percolating into the soil and hence protecting the ground water.

14. Economic sustainability

The cost per dwelling is approximately 1100 US$ and the cost/square meter USD 35 (*Year 1997), which is less than half of the cost of municipal resettlement cost (2000USD) due to the use of appropriate technologies. The average income level/person/year in India is USD 1330 (WB 2010).

Income generation is taken into account in the settlement plans by providing small retail spaces and connecting the area to a

Bhoomiheen camp. A school project built with the same technologies. ***© Anangpur Building Centre.***

Furnicular shells as flooring and roofing constructed using waste stone. ***© Anangpur Building Centre.***

local transportation system. During the project people have been trained and they have become entrepreneurs in making the interlocking blocks which has helped in their social integration.

15. Cultural sustainability

Rich colours and textures used in the surfaces of the houses constructed during the project reflect the Indian cultural tradition. People's individual statements in terms of patterns, colors and texture marking their homes helps define each ones personality.

16. Social sustainability

Participatory approach has been used in the building process. Training has been provided for the dwellers by the Building centre to produce hollow concrete blocks for the walls. The clustered settlement plans are planned to increase security and interaction inside the community. Living conditions are improved by providing clean water, sanitation and cross ventilation.

17. Institutional sustainability

There have been bureaucratic and political problems for fear of exposure of inefficiency within the system which is now being addressed in the Supreme Court. This institutional atmosphere has been a major hindrance in the completion of the project.

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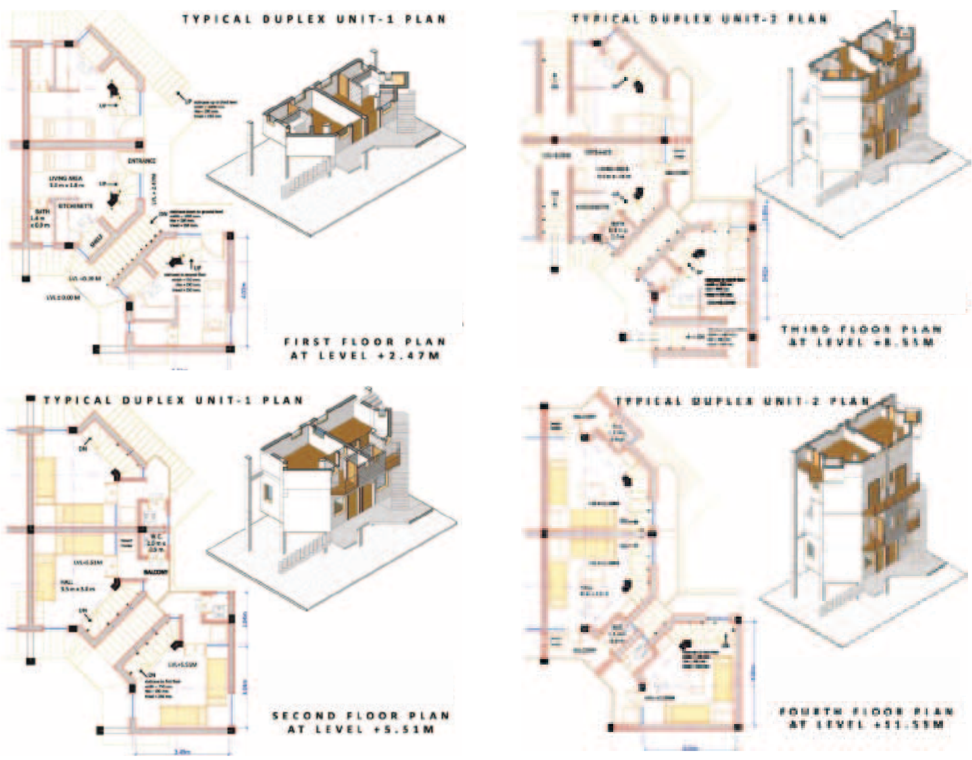

Typical floor plans and 3D views of the Jaunapur settlement houses. ***© Anangpur Building Centre.***

06 CONCLUSION

The construction sector has a large responsibility in reducing greenhouse gas emissions but also presents a major opportunity to contribute to mitigating the climate change. Environmentally sustainable housing practices are crucial for future housing practices and urban development in order to facilitate the future population growth in the limits of the world's carrying capacity. Most of population and urban growth is predicted to happen in developing countries where many of the currently used green building strategies are too expensive for wider use. In order to make the building stock more sustainable in developing countries the efforts of building sustainable housing stock need to be made affordable. Only affordable sustainable housing practices can have potential to be implemented in wider scale in the developing countries.

In order to provide sustainable affordable housing that has a long-term benefit a comprehensive approach is needed. This approach should include not only environmental but also social, economic, cultural, and institutional sustainability aspects. The choices made for design and planning need to always derive from the specific context and climate. Environmentally sustainable housing need to be culturally appropriate and located near employment and support the social networks of people. Poor communities should be helped to be involved in construction processes and decision making and the construction processes used to build up the skills of people. The specific needs of different groups such as different gender, ages and indigenous/cultural groups need to be taken into account. Specific urban forms such as compact city and mixed land use can help in these efforts.

It is important to connect housing to infrastructure networks, services and safe water provision. Likewise, disaster risk reduction and tenure security needs to be linked with sustainable affordable housing. Renewable energy and water saving in housing should be used in the context of affordable housing in developing countries. Ways of saving energy are important: bio-climatic design should be used in slum upgrading and affordable housing strategies as it helps to save energy and improve the environmental conditions. Material choice is of crucial importance for the energy used during the whole life cycle of the building: in general, traditional and recycled construction materials are more environmentally friendly than contemporary materials, such as concrete and burnt bricks, but sometimes combining both can increase the life-span of a building. In addition to improving the energy efficiency of new buildings ecological retrofitting of existing buildings can be used to increase the energy efficiency of the total building stock.

From the perspective of low-income communities being able to make the initial investment is crucial and can be supported, for example, by low-interest loans and the inclusion of even informal income. The institutional and regulatory environment should be build to support sustainable housing in terms of means such as policy reform to scale-up sustainable housing practices and building codes that allow and support the use of traditional and recycled materials and control the energy use of a building. Implemented sustainable housing projects should be monitored and evaluated. Building up the knowledge and skills of professionals and communities in sustainable housing practices is important and should be in line with the overall capacity development of the whole sustainable affordable housing sector.

Pilot projects using sustainable housing practices are valuable in order to influence other projects and solving context specific issues. However, scaling up sustainable housing practices at the country level and at the global level is the ultimate goal of any efforts of promoting sustainable affordable housing. Governments have a crucial role in supporting the efforts of scaling up sustainable affordable housing practices. Incentives for the private sector, for the practitioners and for the households are of great importance and can be facilitated though means such as policy reform, subsidies and tax-incentives.

Favela in Mata Machado, Rio de Janeiro, Brazil. ***© Claudio Acioly, UN-Habitat.***

GOING GREEN: A HANDBOOK OF SUSTAINABLE HOUSING PRACTICES IN DEVELOPING COUNTRIES

The housing sector is in a prime position to mitigate climate change and make environmentally-friendly cities. *Going Green* provides an overview of sustainable housing practices with a focus on 'green' building materials and construction technologies, and climate-responsive housing and settlement design. However, improving the sustainability of housing is not only a technical challenge and this book shows how environmental aspects can be successfully interwoven with the social, cultural and economic milieu in which they are proposed, adopted and, ideally, scaled-up to meet the massive housing demand in developing countries.

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