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II level Master

WHAT'S BEHIND THE USE OF CONCRETE

Analysis of the dynamics that lead to the use of unsustainable materials, through a multidisciplinary comparison between Adobe Bricks, CSSBs and HCBs, in Ethiopia.

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KEY WORDS

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ABSTRACT

Climate change, and resource depletion, are the main challenges that mankind has to face in the 21st century. In order to avoid catastrophic consequences for the planet, it is essential to limit the greenhouse gas (GHG) emissions, of which the construction sector is the main producer. Encouraging the use of sustainable building materials and reduce energy consumption, therefore, is increasingly important, especially in developing countries, characterized by a large population growth and by a big construction-boom. Although the use of sustainable, natural and local materials is strongly recommended also by the United Nations and is planned as a target for the achievement of Sustainable Development Goal 11 "Sustainable cities and communities", the use of modern construction materials, generally imported and unsustainable, is increasing in most developing countries. The purposes of this paper are to investigate the most common reasons given when deciding to use an unsustainable building material like concrete, to analyze, in a more specific way, the dynamics that favor this process, and, finally, to outline a series of strategies to reverse the trend and spread the use of sustainable materials. Using as study-case the project of a school in Ethiopia, in which the author participated, and through the direct comparison of the economic, productive, performance and socio-cultural aspects of three building materials with different levels of sustainability (Adobe Bricks, Cement Stabilized Soil Blocks, Hollow Concrete Blocks), the objectives that had been set were achieved. As a result, it was noticed that, the main reasons leading to the choice of using ordinary construction techniques and unsustainable materials are: the efficiency of their production system; the habit and knowledge of local experts and workforce in using them; prejudices against alternative materials; and people's willingness to build according to a stereotyped idea of modernity. From the analysis, the CSSBs appear to be the best material overall, which combines sustainability and good technical properties. In order to spread its use, and encourage the progressive abandonment of unsustainable materials, it is essential to implement strategies that involve stakeholders belonging to all the areas related to the construction sector and at all levels of society, starting from artisans, workers, clients and final users, and then arriving at experts, architects, engineers, construction companies and government.

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Building site in Addis Ababa. https://www.azione.ch

"The cities, power plants and homes we build today will either lock society into damaging over-consumption beyond our lifetimes, or begin to propel this and future generations towards sustainable living."

(James Leape, Director General, World Wildlife Fund)

1. INTRODUCTION

1.1. CLIMATE CHANGE AND CHALLENGES OF 21st CENTURY

Climate change, with global warming, and resource depletion are the main problems and challenges that mankind has to face in the 21st century in order to save the Earth from progressive destruction (figure 1).

Global temperature has increased of 0.7°C from the beginning of the industrial era, and this process is increasingly speeding up, with an increase in temperatures of 0.2°C every ten years, causing the change of local rainfall patterns, the shift of ecological zones, the warming of the seas and the melting of the polar ice caps. (UN_Habitat, 2014)

Control the temperature rising is more than ever a priority, because, as stated in The Fourth Assessment Report of the Intergovernmental Panel on Climate Change[1] (IPCC), significant global impacts on ecosystems and water resources are likely at global temperature rises of between 1 and 2 °C, and negative impacts on global food production are likely to occur at temperature increases from 2-2.5 °C. An increase in temperature of a maximum of 2°C by 2050 has, therefore, been set as a limit which cannot be exceeded. In order not to trigger catastrophic consequences, and to respect the defined limit, it is essential to be able to control the greenhouse gas (GHG) emissions, which, having reached the level of 7tons Co_2eq per capita, must be reduced to 2tons Co_2eq per capita. According to the IPCC, by 2050, the amount of CO_2 emissions will have to be 85% lower than in the year 2000 and 50% lower than in 1990.

The progressive depletion of resources, both mineral (at our disposal for an estimated period of further 40 years) and biological, is another critical issue. As the human ecological footprint increases, the biological capacity of the planet decreases.

"Since the 1970s, humanity's annual demands on the natural world have exceeded what the Earth can renew in a year. This

1 - http://ipcc.ch

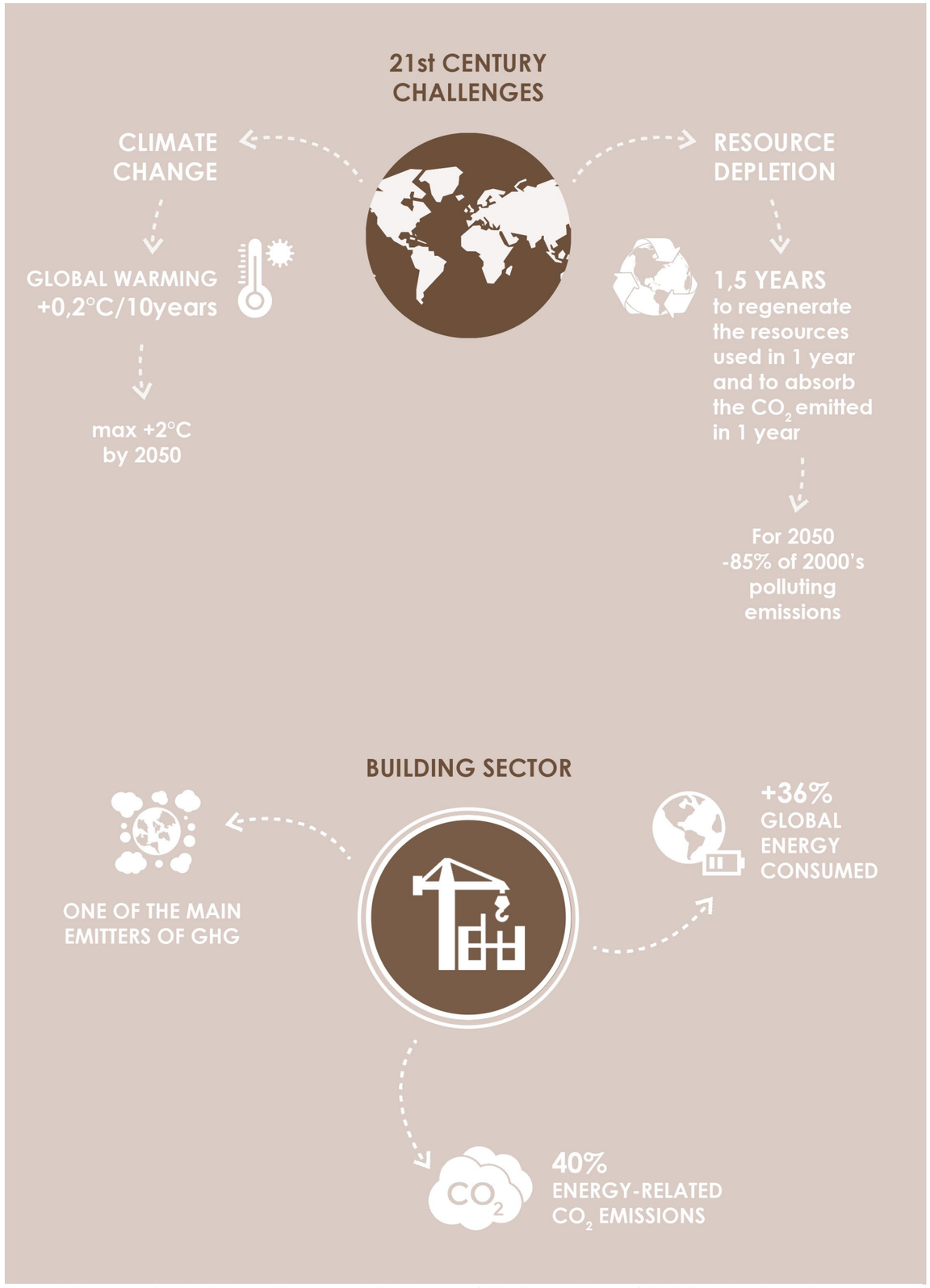


Figure 1: Scheme of *"1.1. Climate Change and Challenges of 21st Century"* and of *"1.2. Building Sector"*

ecological overshoot has continued to grow over the years, reaching a 50 per cent deficit in 2008. This means that it takes 1.5 years for the Earth to regenerate the renewable resources that people use, and to absorb the CO_2 waste they produce in one year." (UN-Habitat, 2014)

To face all these challenges, and avoid catastrophic scenarios, in 2015, all United Nations member states, decided to adopt 17 Sustainable Development Goals[2] as part of the *2030 Agenda for Sustainable Development*. SDGs are a set of objectives to be achieved, through precise actions, for a better and sustainable future. For the purposes of this study, it is important to mention SDG 11 "*Sustainable cities and communities*" with the 11.C target "*Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials*" and SDG12 "*Responsible consumption and production*", that together contribute to the achievement of SDG13 "Climate Action".

1.2. BUILDING SECTOR (figure 1)

In order to reach the 2°C target, it is essential to take into account the impact that the construction sector has on global pollution.

"The United Nations Environment Programme (UNEP) reported that buildings and construction are responsible for more than 36% of the global energy consumed, and as much as 40% of energy-related CO_2 emissions. According to the UNEP, the amount of total buildings-related CO_2 emissions (including energy-related emissions from buildings construction) in 2017 alone was more than 11 $GtCO_2$. Buildings and the construction sector have the largest shares of global energy and emissions compared to other sectors, such as industry and transport."(UNEP, 2018)

"In 2010 the worldwide building sector was responsible for 24% of the total GHG emissions deriving from fossil fuel combustion, second only to the industrial sector; but, if the embodied energy of construction materials is included, the share is far higher and the building sector becomes the prime CHG emitter." (UN-Habitat, 2014)

In fact, "a building's lifecycle energy comprises its embodied and operational energy. Embodied energy represents the total energy consumed during the lifecycle stages of buildings, and can be categorized into three components:

- Initial Embodied Energy (IEE): energy consumed in the production process of a product, from the extraction of raw materials and processing of natural resources to the manufacturing and transport of products to building construction sites. IEE is thus all the energy that is consumed in the pre-use phase of the building's lifecycle.

- Recurrent embodied energy (REE): Energy required to maintain, repair, and/or refurbish the buildings during their service life. REE is a function of how a building is used by its occupants, the maintenance demands of the occupants, the service life of the building, and the life span and quality of the

2 - https://www.un.org/sustainabledevelopment/

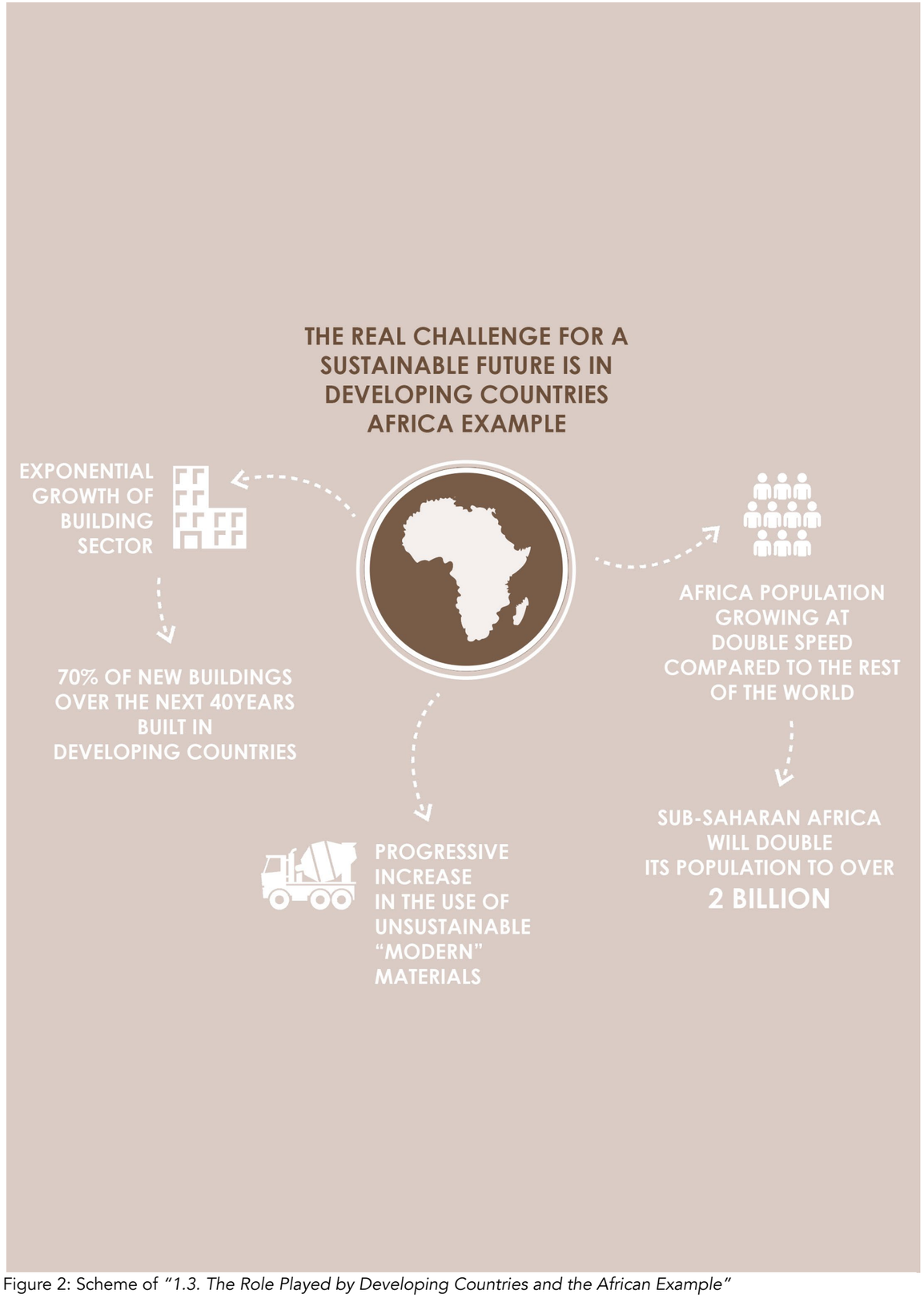


Figure 2: Scheme of *"1.3. The Role Played by Developing Countries and the African Example"*

materials and components.

- Demolition embodied energy (DEE): Energy consumed to destroy the building at the end of its lifecycle, recycle and re-use some components, and dispose of others by transporting the debris and waste to landfills or incinerators.

On the other hand, operational energy in buildings is the energy consumed mainly for space heating and cooling, lighting, and operating appliances and auxiliary systems." (Woubishet et al., 2019)

It is, therefore, essential that the construction sector does its part to reduce energy consumption, starting from a conscious design and the choice of sustainable and local materials (as stated in SDG11 target 11.C).

1.3. THE ROLE PLAYED BY DEVELOPING COUNTRIES and THE AFRICAN EXAMPLE (figure 2)

Although developed countries currently have the highest amount of GHG emissions, it is in developing countries that the real challenge for a sustainable future is at stake. In fact, "the exponential growth of the building sector due to rapid urban population increase is likely to cause the embodied energy and CO2 emissions to rise further in the future. According to the UNEP, the world is expected to construct 230 billion square meters of new buildings in the next 40 years, adding the equivalent of Paris every single week. More than 50% of the buildings expected by 2060 will be constructed in the coming 20 years, and two-thirds of them will be built in countries that lack mandatory building energy codes." (UNEP, 2017)

The demand for new buildings in these countries is progressively growing. Just think that, "while in Europe it is expected that, by the year 2050, some 25-30% of the building stock will have been built, in developing countries that figure can be estimated at close to 75%." (UN-Habitat, 2014)

In this scenario, where there is a lack of information and awareness on sustainability topics, lack of expertise, and absence of regulation, it is essential to learn from the mistakes of developed countries in order to take significant action towards a sustainable future as soon as possible. In order to achieve this goal, both architects and final users must deviate from pursuing the stereotyped idea of modernity, with the imitation of the architectures of developed countries and the use of materials that are unsustainable and unsuitable for local climates, starting from the appreciation and enhancement of the heritage of traditional architecture with the use of local materials and local construction techniques.

The data concerning Africa and, in particular, the Sub-Saharan territories are a great example of the dynamics described above. "Africa is not a significant source of greenhouse gas emissions and accounts for only 2–3 per cent of the world's carbon dioxide emissions from energy and industrial sources. According to the World Resources Institute, Africa's per capita emissions of carbon dioxide in the year 2000 were 0.8 metric tons per person,

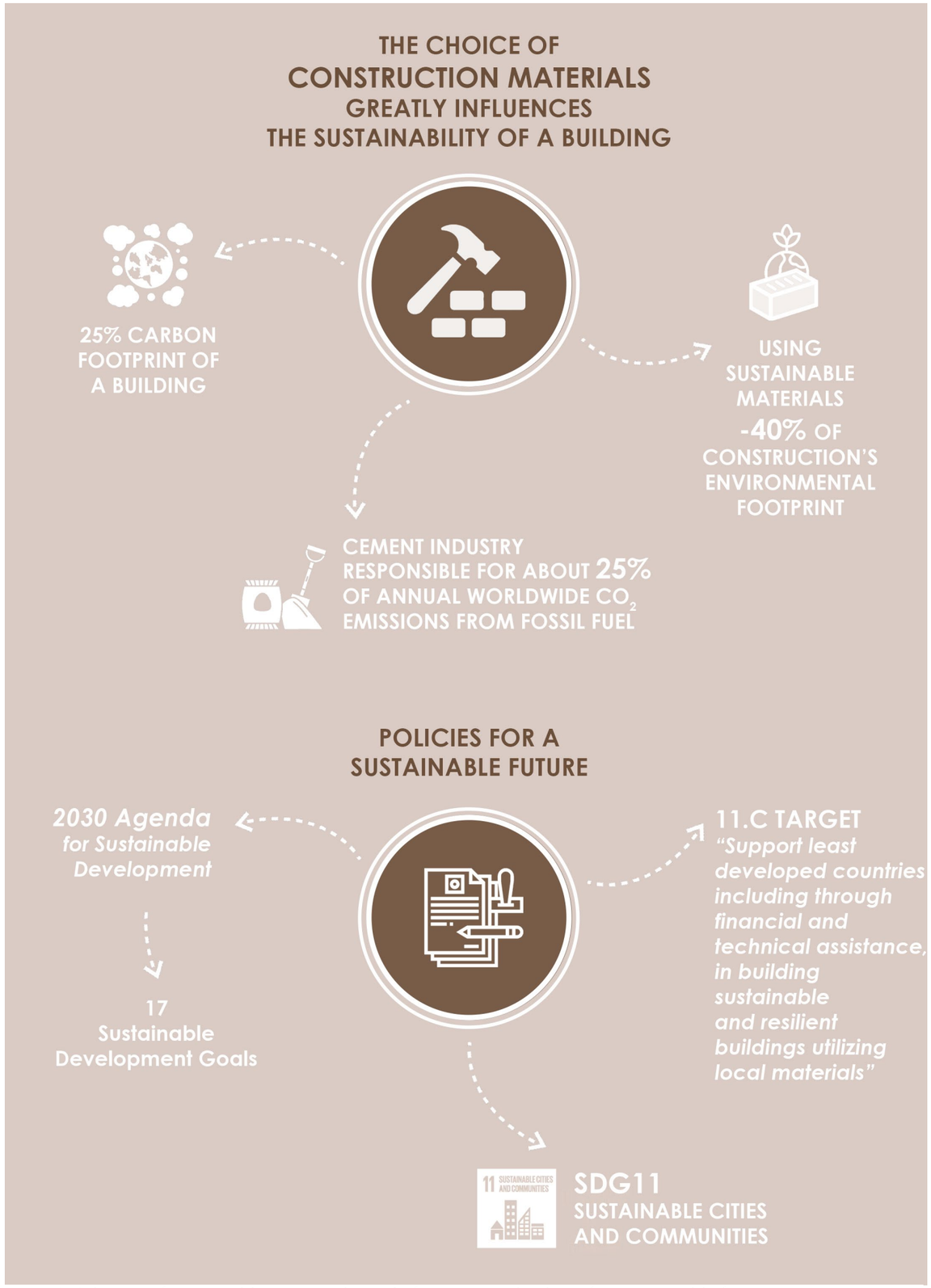


Figure 3: Schemes of *"1.4. Building Materials"* and of International Policies for a sustainable future

compared with a global figure of 3.9 tons per person."(United Nations, 2006)

Nevertheless, it is considered the continent most vulnerable to the impacts of climate change.

Already experiencing temperature increases of approximately 0.7°C and facing a wide range of impacts, African nations are at a critical point in their development. The urban population in Africa is projected to reach 1.23 billion people in 2050; nearly three times its 2010 level of 413 million, and the equivalent to 61.6 per cent of its actual total population (WWF et al., 2012).

Over the coming decades, also Sub-Saharan countries are projected to undergo an extensive demographic change. In the United Nations' (2013) medium projection, the population of SSA will grow at more than twice the rate of the rest of the world. By 2050, the region's population will double to over two billion. Consequently, the construction sector in Africa, that already accounts for over 54% of primary energy, is expected to have the second-highest growth rate globally (after emerging economies in Asia) by 2025 (Global Construction Perspectives & Oxford Economics, 2013). The current dynamism of the construction industry makes it particularly important to focus on low-carbon options, appropriate design and selection of proper materials.

1.4. BUILDING MATERIALS (figure 3)

As mentioned above, the type of construction materials has a great influence on the percentage of the environmental impact of a building. The GHGs emitted in the production of construction materials can, indeed, contribute up to 25% of a building's lifetime carbon footprint (Construction Industry Council, 2012).

"The use of appropriate building materials, instead, can reduce by 40% the environmental footprint of construction, provide more affordable shelter, create a healthier indoor environment, strengthen local culture by promoting traditional materials and promote the local economy through to the boost of local materials industry." (UN-Habitat)

Specifically, it should be noted that, every building material is characterized by a quantity of embodied energy or energy content that comprises all the energy consumed in acquiring and transforming the raw materials into finished products, and transporting them to the place of installation or the building site. The degree of sustainability of a material can be evaluated by means of the Life Cycle Assessment (LCA), a technique for assessing environmental impacts associated with all the stages of the product's life, giving to the designers and the constructor a system for comparing and selecting materials, and a comprehensive understanding of the environmental impact and the improvement that can be offered at each stage in the life cycle of a material. Other criteria to define the sustainability of a material on a wider level, going beyond the purely energy data, are defined by the *Urban Energy Technical Note 11 Building Materials*, according to which are preferable:

- raw materials locally available;

- natural materials (minimizing manufacturing process);

- source of extraction placed at less than 50 km from the place of construction;

- materials able to be manufactured and implemented with local labour;

- materials able to be reused and recycled;

- potential to be socially accepted and integrated;

- materials culturally adapted to the local needs;

- economically feasible materials.

As we can notice, use locally available materials and technologies, as well as locally made products, is very important. The place where materials are produced can have a big impact on lifecycle emissions of construction materials (Rauland, V., et al. 2015). Large-scale, centralised production of building materials necessitates transportation of raw materials and end products over potentially long distances, while, where there is potential to extract and manufacture building materials locally (more often the case with 'traditional' materials), there is a reduction of GHG emissions and an increase of positive impact of the construction sector on local economies. Local-level production of building materials can also facilitate a more balanced distribution of wealth and employment across regions (du Plessis, 2002).

Although the use of sustainable, natural and local materials is strongly recommended also by UN habitat (figure 3), in documents such as *"Key strategies for sustainable buildings"*, and is planned as a target for the achievement of SDG 11, the use of modern construction materials, generally imported and unsustainable, is increasing in most developing countries. The majority of people, blinded by a stereotyped idea of modernity, want to use building materials such as metal sheets as roofing material and cement blocks and cement plaster as wall building materials only but because they look "modern". (UN-Habitat, 2014) The problem is that the production of cement, steel, glass, aluminium and baked bricks, which are the basic building materials for most modern constructions, have very high environmental impacts, consume the most energy and cause the majority of the GHG emissions in the construction sector (UN-Habitat, 2014) because their production requires the processing of mined raw materials at a very high temperature. Specifically, cement, which is the most used building material in the world, has a carbon footprint of up to 5% of worldwide emissions; the cement industry is responsible for about 1/4 of the annual worldwide CO_2 emissions from fossil fuels; and the production of iron and steel, which are also used in reinforced concrete, is responsible for more than 4% of the total energy use worldwide and the related GHG emissions. (UN-Habitat, 2014)

1.5. ETHIOPIA FOCUS

Ethiopia, the country on which study analysis will focus more, is one of the developing countries in Sub-Saharan Africa characterized by rapid economic growth, building construction boom, poor management of building materials and a high percentage of wastes generated in building construction sites.

Despite being characterized by the presence and availability of numerous sustainable materials with low embodied energy, such as earth/clay bricks, Adobe Bricks, local eucalyptus timber, bamboo, straw, stone and thatch, which are the basis of ancient traditional construction techniques (*"chikka"* houses, *"tukul"*); despite the existence of innovative materials that reduce their environmental impact by combining natural elements with other industrialized (Compressed Stabilized Earth Blocks where traditional adobe bricks are mixed with small amounts of cement or limestone); and despite the 150billion USD invested for the full and effective implementation of the Green Economy Strategy and the reduction of net greenhouse gas (GHG) emissions by 2030; the country is seeing an increase in the demand and presence of industrial building materials. (African Development Bank, 2018)

The analysis described in *Embodied Energy and CO_2 Emissions of Widely Used Building Materials: The Ethiopian Context* (2019), shows that cement, sand, coarse aggregates, Hollow Concrete Blocks (HCB), and reinforcement bars are the top five most used building materials in Ethiopia, and that they are the prime consumers of energy, the biggest producers of CO_2 emissions and the main waste generators during construction Specifically, cement, HCBs, and rebars are responsible for 94% of the embodied energy and 98% of the CO_2 emissions during building construction, and exceed the national waste limits by 148%, 159%, and 157%, respectively.

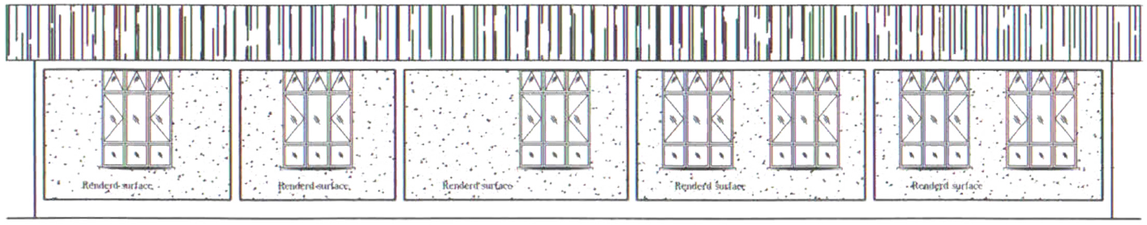
In Amhara region, northern Ethiopia, the design and the construction of buildings is based on rigid standards, which are rooted in the common mentality and from which it is difficult to depart. The structural system comprises a column–beam–slab frame and pad foundation of reinforced concrete, while the wall system consists of non-load bearing Hollow Concrete Blocks (HCBs) to fill the structural façade and all the internal partitions.

1.6. WORK EXPERIENCE IN AMHARA REGION AND OBJECTIVES OF THE STUDY

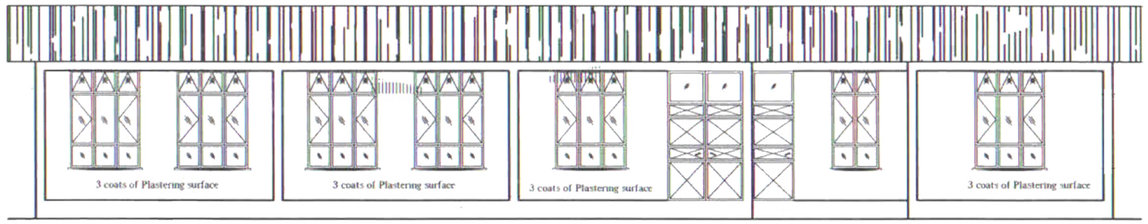
During the architectural design studio of the master, in the beginning, and during the period of the internship at *Arcò Architecture & Cooperation*, later, I had the opportunity to work on the design of an inclusive primary school in Kobo Robit (Amahra Region, Ethiopia).

The design and building materials' choices gradually changed in the various design phases, progressively clashing with local design standards, with the will of the clients, and the idea of architecture rooted in the mentality of local technicians.

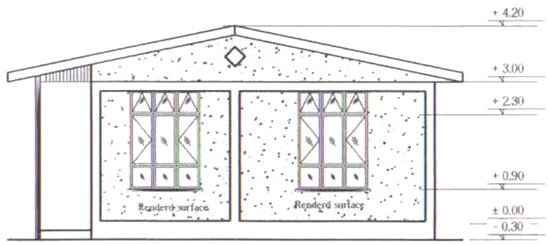
During the workshop, a phase of pure experimentation and design freedom, the will was to use materials as natural and sustainable as possible, such as adobe bricks and rammed earth, drawing with these, architectural forms appropriate to the climate of the place, aimed at improving the comfort of both indoor and outdoor environments.



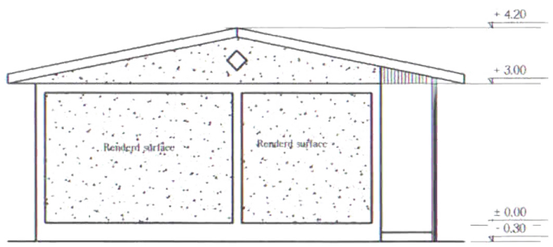
REAR ELEVATION



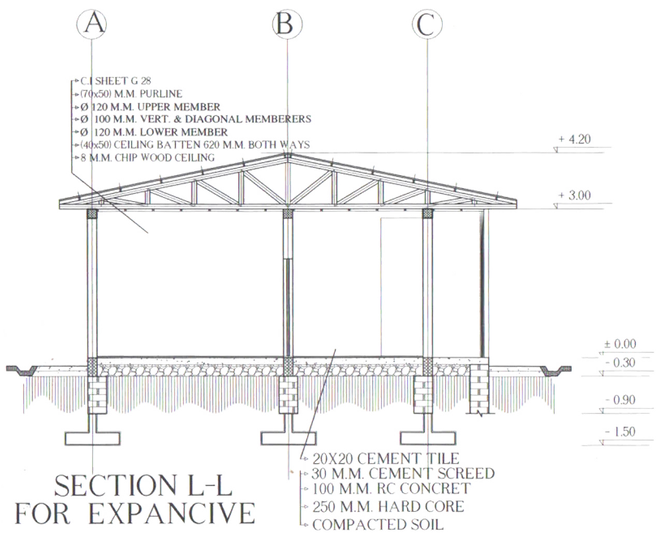
FRONT ELEVATION



R. SIDE ELEVATION



L. SIDE ELEVATION



SECTION L-L
FOR EXPANCIVE

Figure 4: Drawings of the Ethiopian Standards for schools' construction

Once approached the real project, during the internship at *Arcò*, the attempt was to meet the expectations of the clients, while safeguarding the environmental sustainability aspect and proposing a project based on the use of technologies that combined natural materials with industrial materials, such as locally produced CSSB (Cement Stabilized Soil Block).

Unfortunately, although the benefits of using alternative construction techniques and materials were explained, the perplexities and the contrarieties of the local authorities and technicians have been so much to oblige us to follow of the local structural and architectonic standards for the construction of schools (figure 4). The strength with which sustainable design proposals have been contrasted, despite the obvious benefits and the many positive aspects, has raised in me one simple question: why?

Why, despite the presence of natural and local alternatives, has the least sustainable route been chosen?

Why has the opportunity to create new alternative and sustainable standards not been taken?

This paper aims to answer all these questions; aims to understand the real reasons that are behind the choice of using unsustainable and highly polluting materials, like concrete, in a world that really needs to overcome its challenges towards the achievement of a better future; to be able to outline some strategies/actions aimed at avoiding the creation and the repetition of these dynamics; and to unhinge the *forma mentis* that leads to the wrong choice, both in "Global South" countries and in developed ones.

2. MATERIALS AND METHODS (figure 5)

To address such a crucial issue in the debate on the sustainability of architecture, and to achieve the objectives that the paper proposes, the author has studied the problem from a multidisciplinary point of view, trying to investigate all its facets.

In particular, attention was focused on the primary school project in Kobo Robit (Ethiopia), choosing it as a study case. Taking advantage of having personally experienced the decision-making process, and of having available reality-based documents, on which to set the research, it was decided to use the Ethiopian case as a starting point, an example to analyse, to draw conclusions concerning both the countries of the global south and those already developed.

With the aim to discover the real reasons behind the choice of using unsustainable building materials, the author outlined a number of plausible factors, and then investigated them one at a time, ascertaining their veracity or not. Among these, there are technical-performance factors, economical factors, and socio-cultural factors.

A direct comparison, related to these factors, was made between the three main building materials used in the different phases of the project. Starting with the more sustainable one, the Adobe Bricks, continuing with the Cement Stabilized Soil

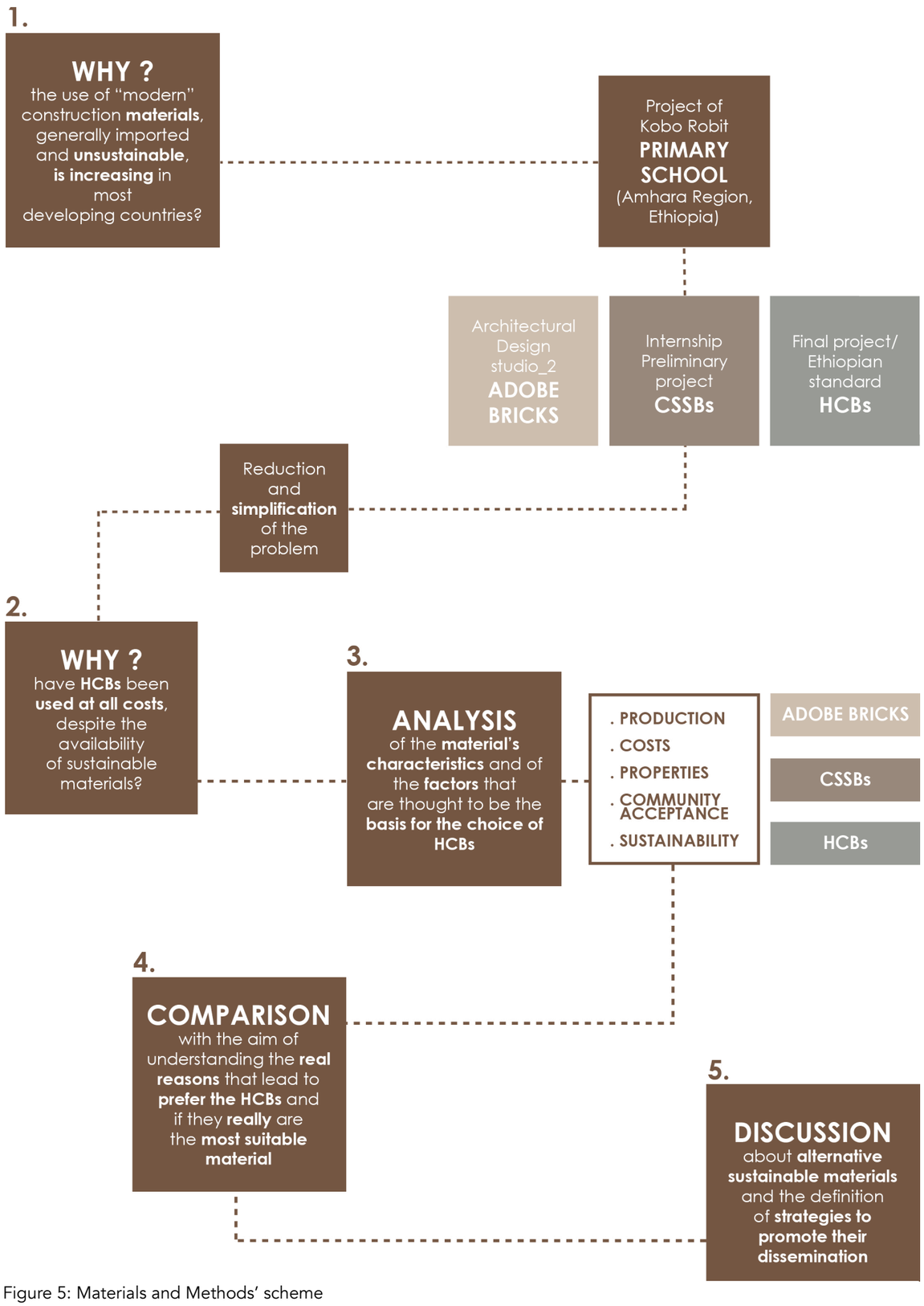


Figure 5: Materials and Methods' scheme

Blocks (CSSB), to then arrive at the final design choice of Hollow Concrete Blocks (HCB). The goal was to understand if cement was really the best alternative and if there was a sustainable material, with similar characteristics, that could replace it.

The study was made consulting books, official publications, scientific papers, articles from various scientific journals, technical documents, architectural texts, and through a dialogue with professionals in the sector (Alessio Battistella and Francesca Sammito - Arcò Architecture & Cooperation; Camillo Magni - Architects without Borders Italy; Uoldelul Cherati Dirar - Associate professor of History and Institutions of Africa, at the Department of Political Science, Communication and International Relations of the University of Macerata).

3. RESULTS

3.1. ADOBE BRICKS

Adobe Bricks, also called "Mud Bricks" or "Sundried Earth Blocks", are unbaked bricks produced manually by throwing wet earth info a formwork. These blocks are made out of soil and straw, that prevents cracking and adds strength. The soil grain size distribution appropriate for earth blocks is 14% clay, 22%silt, 62%sand and 2%gravel. (Minke, 2013)

3.1.1. PRODUCTION (figure 6)

Adobes are made either by filling moulds with a pasty loam mixture or by throwing moist lumps of earth into them. Different types of moulds can be used, but they are usually made from timber (figure 7). The throwing technique is commonly used in all developing countries. Here, a sandy loam is mixed with water, cut straw is usually added and the whole formed into a paste that is thrown into wooden moulds. The greater the force with which the loam is thrown, the better its compaction and dry strength. The surface is, then, smoothed by hand or by a timber piece, trowel or wire.

One person can produce about 300 blocks per day (including preparation of mix, transportation and stacking) using a single mould, and 500 blocks per day using a double mould. (Minke, 2013)

The mud mixture, once removed from the moulds, needs cures and to dry slow not directly exposed to the sunlight. The blocks must be protected by plastic sheets or leaves. To minimize cracks and to obtain high-quality blocks, usable even for two or three-storey buildings, the drying process is essential and lasts about one month. (Johansson A., et al. 2008)

Before starting the bricks production, some analysis and experiments have to be done to understand the soil composition in order to use it for construction purposes. Although the Adobe manufacturing process is very simple, and can be done by everyone after a small amount of training, loam is not a

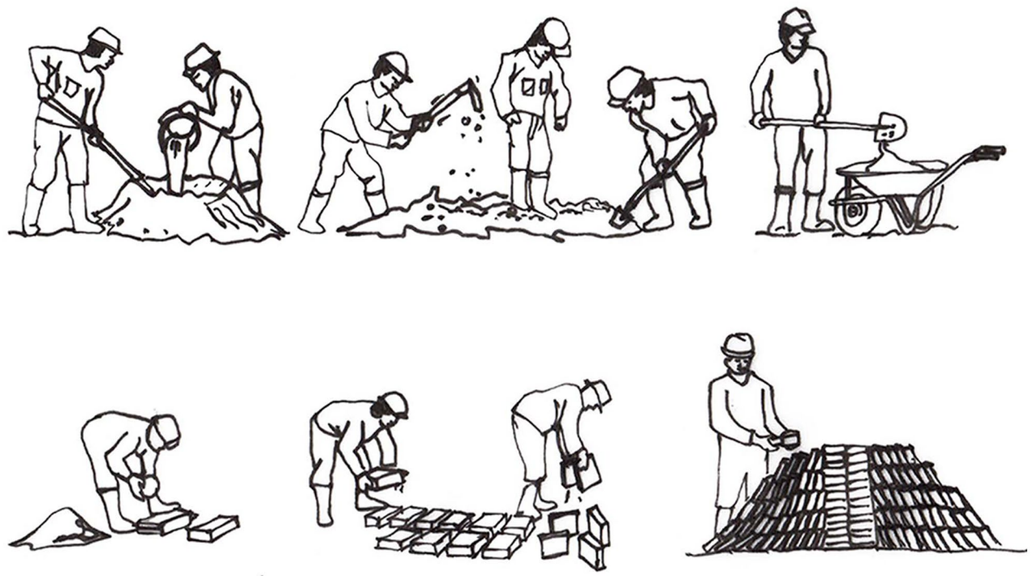


Figure 6

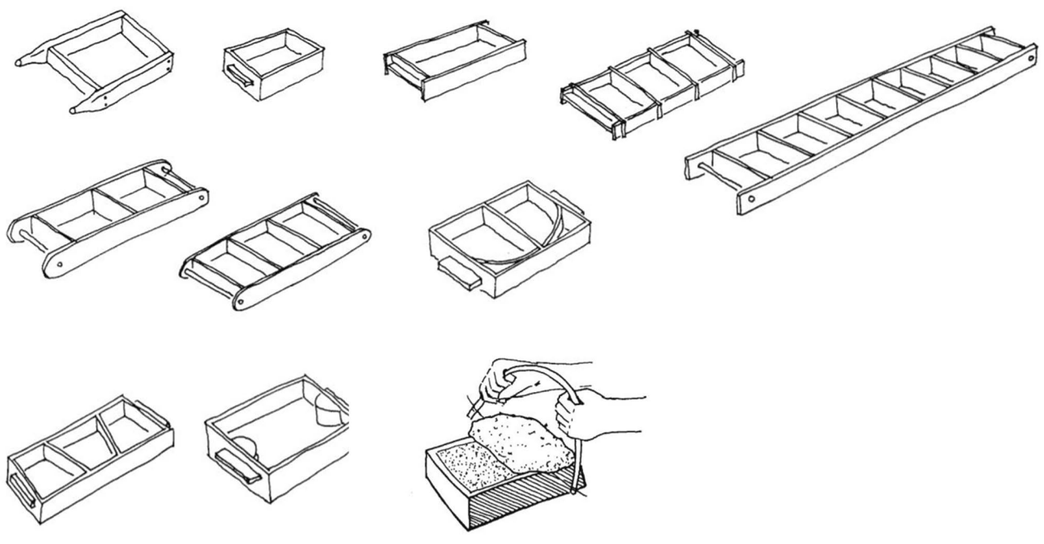


Figure 7

Figure 6: Adobe Briks production phases (Minke, 2013)
Figure 7: Timber moulds for Adobe Bricks production (Minke, 2013)

standardised building material, and an expert who is able to distinguish and understand the soil specific composition is needed. Especially in countries like Ethiopia where there are soils high vulnerable to shrinkage and expansion (black cotton soil). (Gutiérrez E. S., et al. 2018)

The earth bricks production process, being completely non-industrialized, is characterized by low energy consumption and has a positive impact on the environment.

3.1.2. COSTS

Adobe bricks are a very low-costs building material for several reasons.

The first is that mud bricks are produced using raw and local materials such as soil, straw and water. Soil is free of charge, often found on site. The soil excavated for foundations can be used for the construction, with no need for transport. If the local soil hasn't an adequate composition, clay or sand can be added in order to reach the right one. If there is the real need to use a different soil, coming from other construction sites, the transport is still economic. (Minke, 2013)

Straw, as a binding material, is found to a reasonable price, like 80 ETB/m3 (Johansson A., et al. 2008); while the cost of water is variable depending on the supply and distance of transportation. To minimize costs, the construction should preferably be carried out straight after the rainy season when the access of water is good.

The second reason is that mud bricks production is a process completely non-industrialized. The equipment is few and basic, one mould costs about 75ETB, (Johansson A., et al. 2008), and there is no need for high-skilled labour (except for the soil composition expert). The involvement of local labour creates employment opportunities among the local population and the use of raw materials reduces the economic dependence of a community on the construction materials market, preventing indebtedness. (Gutiérrez E. S., et al. 2018)

Finally, being earth a completely recyclable material, it has practically no disposal costs. Old dry loam can be reused after soaking in water, so it never becomes waste material. (Minke, 2013)

The average cost of one straw stabilized mud block is 3 birr (Birku Gobena D. 2019). The estimated overall cost of an adobe bricks wall is about 53 birr/m2. (Gutiérrez E. S., et al. 2018)

3.1.3. PROPERTIES

Good properties and performances of Adobe bricks depend on their loam composition and on how they are worked and cured in the drying phase.

The compressive strength (i.e. the amount of pressure they can resist without collapsing), that is one of the most important engineering properties of a block, depends upon the soil type, and the type and the amount of stabilizer used to form it.

Maximum strengths are obtained by proper mixing of suitable materials and good soil type. It's scientifically proved that the durability of mud blocks increases with an increase in its strength. (Birku Gobena D. 2019). Concerning Adobe bricks, they have a compressive strength that can vary from 0Mpa to 5Mpa (Minke, 2013; UNIDO, 2015). According to countries building authorities, values within 2-4Mpa are recommended in the construction of maximum one or two-storey buildings. (Birku Gobena, 2019)

Adobe bricks contribute to the improvement of indoor comfort, with their good thermal properties and their ability to regulate air-humidity (Johansson, et al. 2008). Mud bricks, in fact, being poor conductors of heat, have the capacity to absorb it very slowly in the hot afternoons, while the rooms' interior remains cool, and to dissipate it during the night, ensuring warm interiors, even in cold winters. (Adegun, et al., 2017). This is a very important property where it's necessary to store solar heat by passive means or in climatic zones with high diurnal temperature differences. The thermal conductivity of earth bricks is low and is about 0,4 – 0,8 W/m°C. (Minke, 2013; UNIDO, 2015).

The Adobe bricks ability to balance air-humidity is demonstrated by the experiments done at the *University of Kassel*, in Germany. It is able to absorb and to desorb humidity very fast. Even when standing in a climatic chamber at 95% humidity for 6 months, adobes do not become wet or lose their stability; nor do they exceed their equilibrium moisture content[3], which is about 5% to 7% by weight. Relative humidity in earth buildings is almost constant throughout the year, fluctuating only 5% to 10%, and producing healthy living conditions. (Minke, 2013)

The last positive aspect of Adobe bricks is that they are resistant to insects and termites (which are often a problem for Ethiopian eucalyptus wood).

Unfortunately, mud bricks don't have only good characteristics. One of their main problems is that they are not water-resistant. They must be sheltered against rain and frost in all the building phases and even after the construction. This aspect must be taken into account when designing an earth building. Walls must be protected by simple solutions: roof overhangs, damp-proof courses, appropriate surface coatings, etc...

Adobe bricks are also often subject to shrinkages (Minke, 2013), during the drying process; are brittle from a seismological point of view, a disadvantage that can be overcome through a proper design; and have poor abrasion resistance. (Johansson, et al., 2008)

3.1.4. COMMUNITY ACCEPTANCE

Despite the fact that, due to the lack of wood, the use of earth for construction is spreading in some areas of Ethiopia, the prejudice towards this material is always very high. In most countries, and in Ethiopia, building with clay and mud is associated with low status, and living in a house completely made of mud is closely related to poverty (Johansson, et al. 2008). For this reason, there are also problems in finding a market for adobe and in finding workers who are willing to work with mud (Hjort, et al., 2011). Furthermore, pre-convinced ideas have brought to the stigmatization of alternative soil-based construction methods. (Johansson A., et al. 2008)

3 - Maximum humidity a dry material can absorb

3.1.5. OVERVIEW

In conclusion, adobe bricks are a building material characterized by low costs, low environmental impact, and by non-industrialized production processes that favour the use of raw materials and local labour, also improving and helping the economy of low-income communities. Unfortunately, the production process takes quite a long time, the material is not readily available for construction and the presence of a technician expert in the composition of the soil is necessary. Its technical characteristics make it a good building material for low-rise buildings; its poor resistance to water and its tendency to brittleness during earthquakes, are problems that, to be overcome, require a lot of attention during the design. The prejudice of people against earthen constructions is still very high and greatly influences their diffusion.

3.2. CEMENT STABILIZED SOIL BLOCKS (CSSBs)

CSSBs are compressed earth bricks to which a variable percentage, between 4% and 8/10% (Johansson, et al.,2008; Minke, 2013), of cement has been added, as a stabilizer, to improve their properties. A CSSB is made from soil, cement and water.

3.2.1. PRODUCTION

Production of CSSB only takes three stages process which are: soil preparation, mix compression and curing (Riza, et al., 2010).

Before producing CSSB, it's very important to test and to select the adequate type of soil to determine if it is suitable for the construction, in order to get the best results and performances. Although the manufacture is very simple, and requires moderate to low skilled workers, some pre-knowledge about soil types, grain size and cement content are needed to attain a successful result. (Johansson, et al., 2008) Indeed, not every soil is suitable for cement stabilization. It is better to use it for sandy soils[4].

Once selected and prepared, the CSSB bricks mixture must be compressed with a manual or automatic pressing machine, with the advantage that loams with low water content can be used, making possible to stack blocks immediately after production (Minke, 2013).

Manually operated presses require three to five persons for optimum operation. The output per person per day is only 150 to 200 blocks (Minke, 2013), but, being manual, this type of procedure allows low-income users to produce bricks by themselves.

4 - http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php

Fully automatic block-making presses can produce 1500 to 4000 blocks daily (Minke, 2013). The manpower required is six to eight persons and the workers can be trained to operate the machines in 10-12 days. (Kebede, 2013). The automatic procedure is usually related to a large scale production aimed at sales.

The curing phase lasts, at least, four/five weeks. At first, they need to be regularly watered and protected from the sunlight for a week; then they must be kept stored for drying in a rain protected storage space. (Johansson, et al., 2008)

3.2.2. COSTS

The final cost of a Cement Stabilized Soil Block greatly varies according to the production system that is used. The initial investment in local and manual production is cheaper than in industrial production with automatic presses.

In the first case, costs are cut down significantly by the local labour, composed of semi-skilled people who have been given a short training, and by the use of on-site raw materials, that do not require transport. (Afkari, 2010) In this process, the only investment that needs to be done is the purchase of a pressing machine and of cement (197 ETB/quintal), which has to be bought and transported from the place of production to the project site. A heavy and good quality manual block press, although its relatively high initial costs, is the best investment that local communities can make in terms of optimisation for the investment/output/quality ratio, to produce good quality bricks and avoid machine failures. A manual press machine costs about 500/600 USD. This kind of production process is suitable for the population with a low income.

Using an automatic machine, instead, labour becomes more specialized and production becomes convenient only if done on a large scale, at an industrial level, with the purpose of selling bricks.

The parameters and factors influencing the cost of production of a material and its final cost are various.

Among these are the equipment costs, including the automatic press machine and all the accessories (around 25.000 USD), the daily maintenance of the machine and the yearly possible repairs, the daily labourers (90 ETB/day), the stabilizer content, and the soil supply (150 ETB/m3 including, excavation, loading-unloading, and transportation costs). (Tekle, 2018).

Taking all these factors into account, CSSB are sold in Ethiopia at a cost ranging between 4.23 birr and 6.59 birr. (Tekle, 2018). Specifically, they are sold from the Selam Technical Vocational Center to 4.14brr. (Johansson, et al., 2008). When the bricks are bought, the cost of transport must be added to the price.

Another aspect to take into account is that, containing cement, CSSBs are a non-recyclable material. As such, they expect disposal costs, and are not fully sustainable, especially if industrially produced.

Finally, the fact that the CSSB walls do not need plaster as protection from atmospheric agents (see paragraph 3.2.3.), means that the overall cost of the walls is lower. (Tekle, 2018)

3.2.3. PROPERTIES

CSSBs, having the soil as main component, retain some of the positive characteristics of adobe bricks and earthen buildings (see paragraph 3.1.3), while, the addition of cement improves some and worsens others.

Stabilization through cement is done for some important reasons: make the material resistant to water and atmospheric agents, increase its compressive strength and, therefore, durability, make them less brittle, and reduce shrinkage. (Riza, et al., 2010)

All this is possible thanks to the chemical reactions taking place between the cement and the soil. (Afkari, 2010)

The choice of the right type of soil, and the addition of an adequate amount of cement, are essential to obtain good quality and performing bricks. (Johansson, et al., 2008)

If the percentage of cement added is too low, the bricks' compressive strength worsens drastically (Minke, 2013). It's demonstrated that, even an addition above 10%, affects the strength of the bricks in a negative way. (Riza, et al., 2010)

A CSSB with an optimal composition, and with the right addition of cement (around 8%), has a dry compressive strength of 4-6 Mpa[5]. CRATerre, the *International Centre for Earth Construction* in France, recommends a sufficient dry compressive strength of 2-2.4 MPa for blocks used in one or two-storey buildings (Afkari, 2010). The CSSB can, therefore, safely be used for load bearing construction up to three-storey. (Kebede, 2013).

Unfortunately, the stabilisation process does not only have positive effects. The addition of cement, in fact, increases the thermal conductivity of the material, making it less insulating.

Although the CSSBs, thanks to their soil content, maintain the ability to regulate the indoor climate, their thermal conductivity rises to 0,8 – 1,4 W/m°C. (UNIDO, 2015).

3.2.4. COMMUNITY ACCEPTANCE

CSSBs are already part of the building industry of Ethiopia. Despite being composed of a high percentage of mud, they are considered as modern and are widely used in buildings also for high-income people. (Gutiérrez, et al., 2018)

This technology has spread in some urban areas, mainly in Addis Ababa, both for smaller and larger buildings, as well as fencing material. (Johansson, et al., 2008)

In Addis Ababa there is also a specialized centre, *"Selam Technical Vocational Center"* born in 1997, that deals with the production of CSSB bricks, teaching it to young and unemployed people.

5 - http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php

3.2.5. OVERVIEW

In conclusion, Cement Stabilized Soil Blocks are a material with many facets. When produced at a small scale, using manual machines and local labourer, they are sustainable and suitable for the low-income population, because their prices are not high; but, production times are long and the lack of skilled labour leads to a slightly lower quality product. When industrially produced, they are convenient only at a large scale and become a less sustainable material, due to the transportation costs and to the industrialized process, but the production is faster and allows to have a large amount of a quality product immediately available. The industrialized production is more convenient and suitable for big construction sites in the city, generally close to factories (lower transport costs) and with medium/high-income. By analyzing the positive and negative aspects of both processes, the best way forward could be the semi-industrialization of production. This offers the advantage to be more flexible and easily adapted to a local context, increasing the quality of the blocks without rising their costs.[6]

Properties related to its loam component, make CSSB a good regulator of humidity and indoor climate. The percentage of concrete, instead, while improving its compressive strength, durability, and water resistance, makes it less thermally insulating, less sustainable and non-recyclable.

CSSBs are a material well accepted by the population for several factors: the presence of concrete gives it a sense of reliability; thanks to its properties and its versatility, multi-storey buildings with different functions can be constructed, from low-cost homes to office buildings; it has an aesthetically pleasing appearance even without finishes.

Summing up, Cement Stabilized Soil Blocks represent a perfect synthesis between traditional practices and modern technologies, with good technical characteristics and affordable costs.

3.3. HOLLOW CONCRETE BLOCKS (HCB)

Hollow Concrete Blocks (HCB) are a building material produced by a mixture of powdered cement, water, sand, and gravel. These bricks are characterized by one or more large holes with the solid material between 50% and 75% of the total volume of the block calculated from the overall dimension. (Getachew, et al., 2017)

3.3.1. PRODUCTION

The production of HCBs is usually an industrialized process, which needs skilled labour, and specific equipment. The main Hollow Concrete Blocks fabrics are located in the main cities, like Addis Ababa, and produce intensively in order to sell the bricks and to meet the building market demand.

The main problems that characterize the production of this material are two. The first concerns the lack of availability, in Ethiopia, of raw materials to produce it. The shortage of cement, in fact, means that this must be imported from abroad, leading to an increase in timing and delays in production. The second deals with the low quality of workmanship of the country. Although HCBs are one of the most widely used construction materials in Ethiopia, it is difficult to find suitably qualified professionals for the production of bricks that meet the standards of the country (El-hadj M. Bah, et al., 2018). The speed of work and the large number of bricks produced (1200 pcs/day by only one machine) are the positive aspects of the industrialized process, which allow the reduction of the costs of the final product.

The small-scale production of HCBs, on the other hand, is characterized by longer timing and a finished product of lower quality. It is a complex process with different phases and, In order to achieve the best possible result, a specific group of workers should be trained. Even the production yard must have specific characteristics, such as adequate space for all equipment and all different types of storages, and proximity to the construction site. (Geschke, M.)

Firstly, all the aggregates must be cleaned, stored separately and approved by an independent concrete laboratory, the water must be free of all impurities, cement must be stored in a dry and moisture-free place, and all the machinery and equipment must be checked and in good conditions. Then, all the components are mixed and the ready mortar is poured and compressed into the moulds of the block making machine. Finally, the HCBs obtained must be laid on the floor for curing (Geschke, M.). After 10/15 days the bricks are ready for use.

The industrialization of the production process, the raw materials needed, and the pressing demand from the construction industry, make HCBs a material absolutely unsustainable. Cement and sand, in fact, given their great demand, are often extracted, even illegally, from banks of rivers and lakes, causing enormous environmental damage. (Gutiérrez, et al., 2018)

3.3.2. COSTS

The elements that raise the production cost of Hollow Concrete Blocks are mainly the investments that must be made to buy and maintain the machinery, and the high costs of the raw materials needed. Materials such as cement and sand, in fact, are often lacking in countries such as Ethiopia and there is a tendency to import them from abroad. The scarcity of raw materials and import costs lead to a general price increase (Hjort, et al., 2011).

The high initial investments, make HCBs convenient if produced industrially, through high production capacity processes and large-scale construction interventions. The high cost of raw materials and the difficulty in finding them, make unadvisable and almost inaccessible the local production process with a limited production capacity, increasing the total cost of the finished material. (El-hadj M. Bah, et al., 2018)

Buy a single HCB brick has a price ranging from 9 to 12 birr, to which must be added any transport costs from the factory to

6 - http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php

the construction site. The production sites of HCBs, in fact, are mainly located in large urban centres, such as Addis Ababa, very far from some areas of the country. As they are not recyclable, HCB Bricks are also subject to disposal costs.

Finally, the import of raw materials, and the fact that very often cement companies on African soil are not local, but Asian or European multinationals, in addition to increasing the prices of products related to these materials in countries with an existent budget deficit, doesn't make the direct proceeds of production and sale go into the coffers of the local state. (El-hadj M. Bah, et al., 2018).

3.3.3. PROPERTIES

To obtain a durable product, with good technical characteristics, that meets the Ethiopian national standards, must be used the right mixtures of components, quality raw materials, skilled labour and quality production processes.

The HCB bricks, being composed mainly of cement, have good durability, relative to their compressive strength, and high resistance to water, floods and atmospheric agents (Gutiérrez, et al., 2018). Ethiopian national standards define the minimum compressive strength of different types of HCBs. Specifically, 5MPa for class A load-bearing walls, 4MPa for class B walls and 3MPa for class C walls. Non-load-bearing walls can have a minimum compressive strength of about 2MPa (Getachew, et al., 2017). Often, because of the poor quality of the local labour, one of the most frequent wastage in the yards, and in the production phases, is due to the scrap of bricks that do not reach the standards defined by the government (El-hadj M., et al., 2018). Hollow Concrete Blocks, when steel-reinforced, can be used for the construction of multi-story buildings.

Finally, cement bricks don't have good insulation characteristics, their thermal conductivity is, in fact, is variable between 1W/m°C and 1,7W/m°C.

3.3.4. COMMUNITY ACCEPTANCE

The use of reinforced concrete and hollow concrete blocks are the main construction system in Ethiopia. Used mainly in the big cities, it has spread more and more also in the rural areas (Hjort, et al., 2011).

Field surveys show that, almost all of the engineers, project managers, professional experts, contractors, and construction workers, have only worked with these types of materials during their careers (Kebede, 2013).

The aftermath of the colonial-era construction techniques, and the tendency to follow and reproduce the developed countries architecture, lead to a stereotyped idea of the concept of "modern". A material like concrete, considered a symbol of modernity, is then used by most people to show off a "status" (El-hadj M. Bah, et al., 2018).

3.3.5. OVERVIEW

In conclusion, hollow concrete blocks are a material characterized by good durability and technical performance, except for its poor insulating power. The difficulty in finding raw materials for production and the high investments needed to buy specific machinery make it more suitable for large-scale production and consumption. In fact, production costs are too high for small-scale local production and become less accessible for self-construction by the low-income population.

The industrialization of the productive system brings with its positive aspects, like the lowering of the product final costs and the uniformity of the materials, but it has a negative impact on the environment. HCBs are, in fact, an unsustainable material, also because of the type of raw materials used, such as sand, which is often extracted illegally from rivers or lakes to be sold on the market. The high import rate of cement, the centralization of production factories, the need for long transports to construction sites, and its impossibility to be recycled, make it a very polluting material.

The industrialized productive system, moreover, favouring the progressive replacement of manual labour with a mechanized one, is not a positive element in a country where the unemployment rate is very high.

Another critical aspect concerns the European and Asian multinationals present in Africa, which hold the primacy of cement production and derive most of the revenues from it, to the detriment of the host country, often already in a critical economic situation.

The desire to build in a "modern" way and the habit of local technicians to work with this material, make Hollow Concrete Blocks the main Ethiopian building material, especially used in urban areas. Despite this, sometimes, due to the unskilled workforce, the standards are not always met and the final product is rarely of high quality.

3.4. CONCLUSION

3.4.1. PRODUCTION

To evaluate the efficiency of a production process, several factors must be considered, such as the timing and type of production, the quality of the required labour and, finally, the purpose with which a material is produced.

The adobe bricks, without an industrial production and a presence on the market, and is characterized by a local, slow and manual production, are not competitive when compared to other types of materials, except in the case in which they are aimed at the self-construction of a few buildings. The lack of expert technicians in this type of technology, and the risk of obtaining final products of poor quality, are mitigated by the ease of the production process and the ability to learn it quickly.

Building materials	Unit	Energy (kWh)
Cement	Sack	50
Concrete	Cubic meter	400 - 500
Fired brick	Cubic meter	1000
Adobe	Cubic meter	5

Figure 8: Energy comparisons of different construction material. (AL-sakkaf, 2009)

On the exact opposite are the HCBs bricks. Widely used throughout the country, they are characterized by industrialized processes and production according to national standards. These two elements make it possible to produce large quantities of material quickly and efficiently, ensuring a quality finished product (Kebede, 2013). The presence of architects, engineers, and other professionals, accustomed and prepared to build with this type of material, is a reason for safety. On the other hand, the lack of an adequately qualified workforce, especially for the production of HCB on a local scale, often causes a lot of waste deriving from unsuitable finished bricks. The scarcity of the necessary raw materials present in the country and their high level of import, often cause delays in the production phases.

A middle ground between the two materials mentioned above, are CSSB bricks. The preparation of the finished material keeps the same long timing as Adobe bricks, but, at the same time, the bricks produced are much more, thanks to the use of automatic machines. Also in this case, the simplicity of the easily learned production process, can make up for the lack of technicians specialized in the use of this technology. A non-industrialized process and the use of unskilled local labor mean that the final product can vary and that it is not always of excellent quality. Thanks to ARSO (*African Organisation for Standardisation*) and to the drafting of the document "*Compressed stabilized earth blocks. Requirements, production and construction*", enormous progress has been made in the standardization of the production and of the properties regarding CSSBs.

The comparison shows that the most efficient and reliable production process is that of HCB, despite the fact that, a fully industrialized production, which eliminates the need for labour force, is not the best solution in a country with a very high unemployment rate (El-hadj M. Bah, et al., 2018).

3.4.2. SUSTAINABILITY

Adobe bricks are, among the three, the most sustainable material. Its components are natural, recyclable and locally available, without the need for transport (the soil used is often resulting from excavations for foundations). Its production process, completely manual, does not foresee polluting emissions.

CSSB bricks, despite the cement content, which implies the impossibility of recycling and the need for transport, and the more automated production processes, remain a material mostly sustainable.

HCB bricks, on the other hand, being composed mainly of cement, are a highly polluting material. The industrialized production process and raw materials, which are often imported or illegally sourced causing serious environmental damage, are the main factors that determine their unsustainability (Gutiérrez, et al., 2018).

In Figure 8 it's possible to see the comparison between the embodied Energies of the three materials analysed.

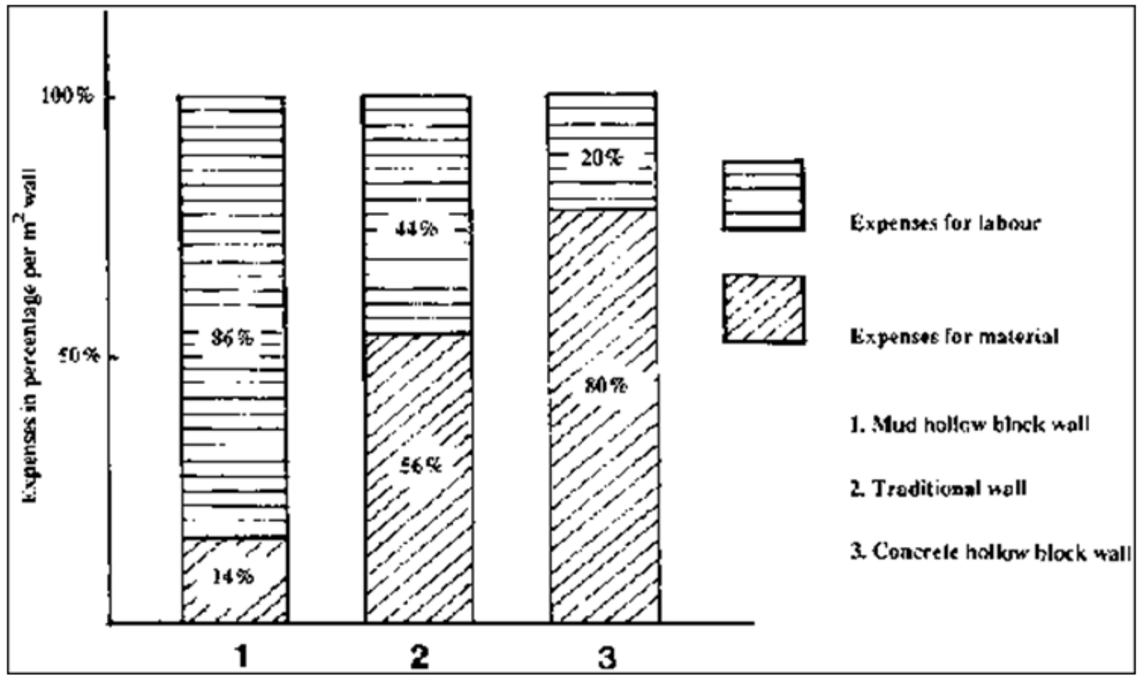


Figure 9

Comparison per m2 of wall (Birr)	HCB Hollow Concrete Blocks	Hydraform	CEB standard Compressed Earth Blocks	Adobe	Wood local house
Total cost	78,86	87,64	76,39	52,91	46,53
Cement cost included	22,87	24,31	12,70	4,05	4,05
Money locally invested	36,35	49,73	60,75	39,39	32,88
%	46%	57%	80%	74%	71%
Money going out of Ethiopia	42,52	37,9	15,63	13,52	13,65
%	54%	43%	20%	26%	29%

Figure 10

Block type	materials	Rate (birr)	Ratio	Weight	Cost	Remark
Mud block	Teff straw	20 per kg(approx.)	1:32	15kg	<3 ETB	labor force
	Soil					
Mud block	Cement	190 per bag (50 kg)	1:3	8.83 kg	10 ETB	labor force
	Soil					
Mud block	Cement	190 per bag (50 kg)	1:1:3	8.83 kg	12 ETB	labor force
	Sand	400 per m3				
	Soil					
Concrete block	Cement	190 per bag (50 kg)	1:2:3	7kg	20 ETB	
	Sand	400 per m3				
	Aggregate	400 per m3				

Figure 11

Figure 9: Percentages of expenses of three different types of walls. (Biering, M.,1991)
Figure 10: Comparison of different construction systems regarding cost, cement cost, money locally invested and money being invested outside Ethiopia. Case study for Awasa (Sidama Zone, SNNPR) in 2004. (Moles, O. 2004).
Figure 11: The costs of mud block and concrete block. (Birku Gobena, 2019)

3.4.3. COSTS

The final price of the three materials analysed, shows how, with the increase in production mechanized processes and the use of materials not locally available, there is a progressive increase in costs.

Adobe bricks are certainly the cheapest, being generally self-produced and composed of local raw materials. The estimated price is 3birr per piece.

With a more complex production process, and the use of a material not locally available as cement, CSSB bricks see an increase in price. They are sold in Addis Ababa at a cost ranging between 4 and 6 birrs.

Finally, although the industrialized process allows a significant decrease in production costs, HCB bricks are the ones that have the highest price in the Ethiopian market. A brick, in fact, has a price ranging between 9 and 12 birr. This, in large part, is due to the raw materials, mainly imported from abroad, which, as we can see in figure 9, affect 80% of total costs.

Furthermore, being Asian and European multinationals, the main producers of cement in Africa, the largest revenue from the sale of this product leaves the country, not entering the state coffers (figure 10). The HCBs and building technologies that involve the use of cement, in fact, are part of dynamics played by strong economic powers, including international ones. These take advantage of the construction-boom and the great demand for building materials in African countries, providing a ready-made and easy-to-use solution such as concrete, on which they have great interests and economic revenues (El-hadj M. Bah, et al., 2018).

As a consequence of these dynamics, revenues are concentrated only on a few category of people (Gutiérrez, et al., 2018). The use of low-priced alternative materials, which also include local players in their dynamics, and make the market accessible even to low-income people, is, therefore, more necessary than ever (Woundimagegnehu, 2014; Kebede, 2013). A direct comparison between the prices of the three materials, with reference to the raw materials used for their production, is shown in figure 11.

3.4.4. PROPERTIES

The use of only natural components makes Adobe bricks the material with the worst durability and compressive strength, compared to the other two. The high earth content, on the other hand, makes it the material with the best insulation and humidity regulation properties, ensuring high indoor comfort.

On the other hand, HCBs, thanks to the high cement content, have good durability and good compressive strength, but are poor insulators.

CSSB bricks, with an earth and cement content, take the best properties from both. Thanks to the soil component, they maintain the good insulation and internal comfort capabilities of Adobe bricks, while, thanks to stabilization with cement, they

COMPARATIVE ANALYSIS
AND ADVANTAGES
OF MUD STABILSED BLOCKS

PROPERTIES	INTERLOCKING STABILIZED SOIL BLOCK	SUN-DRIED MUD BLOCKS	BURNT CLAY BRICK	STABILIZED SOIL BLOCK	CONCRETE MASONRY UNIT
DIMENSION (LxWxH) (cm)	26.5x14x10	25x15x7-40x20x15	20x10x10	29x14x11.5	40x20x20
WEIGHT (kg)	8-10	5-18	4-5	8-10	12-14
TEXTURE	Smooth and flat	Rough and powdery	Rough and powdery	Smooth and flat	Coarse and flat
BLOCKS/m²	35	10 to 30	30	21	10
WET COMPRESSIVE STRENGHT (MPa)	1-4	0-5	0.5-6	1-4	0.7-5
THERMAL INSULATION (W/mC)	0.8-1.4	0.4-0.8	0.7-1.3	0.8-1.4	1-1.7
DENSITY (kg/m³)	1700-2200	1200-1700	1400-2400	1700-2200	1700-2200

Figure 12

Figure 12: Comparative Analysis and Advantages of Mud Stabilized Blocks. (UNIDO, 2015)

become more durable, resistant to atmospheric agents and water, and achieve good overall compressive strength.

Figure 12 shows the comparison between the properties of different materials, including the three ones analyzed in the study.

3.4.5. COMMUNITY ACCEPTANCE

Concrete is certainly the most used and requested building material by the Ethiopian population and beyond. This, in fact, for most people, represents an idea of modernity and progress. Even if the basic concept is incorrect and refers to a stereotyped and obsolete idea of the "modern", using the same building technologies as in developed countries becomes, in the common mentality, a status symbol.[7]

Automatically, this leads to the stigmatization of alternative materials such as Adobe bricks, which, due to their earth content, are often linked to an idea of poor durability, poor hygiene and poverty. It's just not wanting to be associated with belonging to poor social classes that makes the use of this material really limited, especially in urban centers. Very often, even workers do not want to handle this "poor" material as it is considered degrading and related to a low-status (Hjort, et al., 2011).

Resistance to the use of unconventional materials is also found between local experts, architects, engineers and project managers. The mistrust towards the use of different technologies is mainly due to a lack of knowledge about these, to a poor tolerance towards innovations in terms of design and creativity, and to the familiarity and dependence they have with conventional construction systems based on the use of concrete and HCBs (Kebede, 2013).

Finally, CSSBs, thanks to their pleasant appearance even without finishes, which gives the impression of being a high-quality material, are very well socially accepted. (Johansson, et al., 2008) These are, in fact, considered by the community a modern material, and their use is gradually growing, despite being composed mostly of earth (Gutiérrez, et al., 2018).

3.4.6. FINAL COMPARISON AND CONSIDERATIONS

The analysis carried out shows that (figure 13):

- HCBs are often chosen as building material because they have shorter production times, and are easily and quickly available in both large and medium-sized urban centres. In addition, most of the workforce and technicians are trained and accustomed to the use of this building material.

- The idea that HCBs are chosen because they are the cheapest material is wrong. The raw materials used to produce it, in fact, are less and less available, more and more imported and more expensive. The price analysis of the Addis Ababa market shows that, among the three materials, HCBs are the most expensive. Costs are further increased if the material is produced on a small scale.

7 - From the conversation with Uoldelul Cherati Dirar - Associate professor of History and Institutions of Africa, at the Department of Political Science, Communication and International Relations of the University of Macerata

Comparison factors / Materials	PRODUCTION EFFICIENCY	SUSTAINABILITY	COSTS	ECONOMIC DYNAMICS SUSTAINABILITY	PROPERTIES	COMMUNITY ACCEPTANCE
ADOBE	3	1°	1°	2°	3	3
CSSBs	2°	2°	2°	1°	1°	2°
HCBs	1°	3	3	3	2°	1°

- **Chosen** as building material for its **short production times**, and **easy availability** in both large and medium urban centres. In addition, most of the **workforce and technicians are trained and accustomed to the use of HCBs**.
- The **idea that HCBs are chosen because they are the cheapest material is wrong.** The **raw materials** used to produce it are **hardly available**, **expensive** and often **imported**. Costs further increase if the material is produced on a small scale.
- **Influence by strong economic powers** that, gaining from a material like cement, **push for its use**, **exploiting the high demand for building materials in developing countries** subject to construction-boom.
- The **idea that HCBs are chosen because they are the material with the best technical properties, is roughly wrong.** Although HCBs are undoubtedly a durable material with a good resistance, they are **lacking in terms of thermal insulation.**
- **Chosen** as building materials because they are considered a **symbol of modernity** and are **well accepted by local communities and technicians.**

Figure 13: Final comparison's tab

- Also the idea that HCBs, since they are composed of concrete, are the material with the best technical properties, is roughly wrong. In fact, although HCBs are undoubtedly a durable material with good resistance, it is lacking in terms of thermal insulation and conferment of good comfort to indoor environments. CSSBs, almost equal in terms of durability and resistance, are good insulators and passively guarantee a high level of indoor comfort.

- One of the main reasons why concrete is preferred over other materials is that it is a symbol of modernity and is therefore very well accepted by local communities and technicians. The tendency to build with this material, and the preparation and habit of technicians to use this type of construction technology, go hand in hand and influence each other.

- Finally, concrete and, therefore, Hollow Concrete Blocks, are not characterized by any kind of sustainability, neither environmental nor economic. They have a high embodied energy and the economic dynamics in which they are inserted create damage to the Ethiopian economy leading it to depend on that of other more developed countries.

It has, therefore, been demonstrated that, some of the factors considered decisive in the choice of the use of a material such as concrete, are myths to debunk, and that there are alternative materials, such as CSSBs, which, with the same performance, are more sustainable both from an environmental and a socio-economic point of view.

4. DISCUSSION

As it turns out from the analysis and comparison carried out, CSSBs are the best material, and, due to their environmental and economic sustainability, technical characteristics, costs and acceptance by local communities, they can be a valid substitute for HCBs in view of the sustainable development of the construction sector.

Taking note of the problems and the improvable characteristics of CSSBs, and being aware of their many positive aspects, in the following chapter the author analyzes a series of strategies and actions to be implemented in order to increase their diffusion, limiting the use of polluting materials, such as cement-based HCBs, and making people aware that a valid sustainable alternative is really possible.

4.1. IMPLEMENTATION STRATEGIES FOR DISSEMINATION OF ALTERNATIVE BUILDING MATERIALS (figure 14)

The analysis showed that the lack of professionals and craftsmen specialized in alternative construction technologies is one of the main reasons that lead to not using materials other than ordinary ones. Overcoming this lack is therefore essential to spread the use of sustainable materials such as CSSBs. The strategies to be implemented are:

- Develop and provide, to manufacturers, general contractors,

Figure 14: Implementation strategies' scheme for the dissemination of alternative sustainable materials' use

and designers, awareness training in the use of alternative construction technologies; (Kebede, 2013)

- Established adequate training facilities in all the country, at different levels; (Kebede, 2013)

- Promotion, by construction companies and building centres, of on-site training courses for their employees and workers;

- Teamwork between construction and design discipline, mature manufacturing companies and suppliers, to develop continuing education course to increase the awareness of professionals.

In order to disseminate, among the population, the existence and the positive aspects of alternative materials, and in order to eliminate people's prejudice, effective strategies can be:

- Incorporate earth construction techniques into the educational curricula; (Adegun, et al., 2017)

- Use public and social media as methods of dissemination and public awareness; (Adegun, et al., 2017)

- Design and construction of quality pilot projects that can demonstrate to people the positive characteristics of alternative materials, eliminate people's prejudices and serve as best practices for the implementation of future projects.

The strategies to be implemented, with the aim of making the production system more efficient, having a finished product with controlled quality, and regularizing soil-cement buildings, are:

- Increase the investments of companies and professional organizations in research and development in the area of design and production of alternative materials; (Kebede, 2013)

- Standardise materials and components, in line with global trends, and create national standards and other local institutional regulatory apparatus; (Adegun, et al., 2017)

- Adapt building codes to local realities (urban vs. rural), in order to promote housing affordability, and to favour quality local production of building materials. (El-hadj M. Bah, et al., 2018)

Finally, to change the dynamics on a broader level, it is necessary that the government itself implements strategies aimed at the enhancement and dissemination of the use of alternative construction technologies, such as:

- Creation of a national scheme of incentives and governmental assistance; (Kebede, 2013)

- Use of alternative materials in government construction themselves, especially in the social sector; (Kebede, 2013)

- Promotion of financial and fiscal incentives for the entrepreneurs who want to take up the production of alternative building materials, assuring the supply of raw materials at

reasonable prices and the marketing of the products; (Kebede, 2013)

- Organization, by the government, of experts, architects and civil engineers to exchange experiences in the field of development, production and application of alternative building materials and techniques; (Kebede, 2013)

- Establishment of research and development facilities, strengthening the existing ones, with a view to developing low-cost building materials; (Kebede, 2013)

- Translation of the researches' results into actions, through appropriate extension agencies with the adequate resources to give financial and technical support about the use of alternative technologies; (Kebede, 2013)

- Promotion of small-scale industrial specialization (in situ or off-site) in the production of earthen materials to make them available in the market, generating employment opportunities and boosting local economies; (Adegun, et al., 2017)

- Policy reforms of government's regulation, that often act as a barrier to the adoption of alternative building technologies; (El-hadj M. Bah, et al., 2018)

- Creation of national standards in order to better oversee alternative material production and building construction.

4.3. FINAL CONSIDERATION

It should be noted that these strategies, aimed at spreading the use of alternative and sustainable materials within the building industry, are applicable not only in Ethiopia and in the countries of the "Global South", but also in developed countries. In fact, even in the already developed part of the world, it is necessary to break down the same dynamics that lead to the choice of materials harmful to the environment.

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