Sustainable Housing for Himalayas: Adaptation of Traditional Construction Techniques Through Low-tech Innovations.

Eric Domon¹, Gianluca Paglia¹, Valentin Kunik², Guillaume de Morsier²  
¹Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland  
²Kunik de Morsier architectes, Lausanne, Switzerland

Presenting authors' email address: eric.domon@epfl.ch

Biography of Presenting Author:

Eric Domon is a recently graduated civil engineer of EPFL. Throughout his studies, he has been interested in cross-disciplinary projects related to sustainable housing and construction (eg. EPFL Solar Decathlon project, in which he is closely involved). With a group of EPFL graduate architects and engineers, he launched a project of sustainable housing for the Himalayas in order to apply his knowledge and his vision of sustainability in a concrete and original humanitarian project.

Abstract:

The reflection behind this project is based on the fact that emerging countries are generally already living with a small environmental footprint compared to our developed societies. Considering sustainability at a systemic level, this project aims to adapt traditional construction techniques to future challenges by using locally available and affordable technologies. The goal is to provide to the local population of the Himalayas tools to preserve their sustainable cultures while improving their level of comfort. Low-tech innovation is essential to address global challenges. In accordance with local tradition and customs, innovation in design and building techniques are collaboratively developed by an interdisciplinary group of Swiss engineers and architects with local architects and building companies. For ecological and economic reasons, the project proposes, for example, to use compressed earth blocks instead of concrete blocks or solar radiation instead of fossil fuels. To maximize the social anchorage, participative approaches are used at every step to confirm that the design choices correspond to the expectations and cultural habits of the future users. The first building will be built near a school and is supposed to be used as an example for the surrounding villages. To diffuse and raise awareness about building’s energy efficiency, several didactic activities for the children of the school and their parents will take place during the construction. The extended abstract details the main low-tech innovations that are implemented to improve traditional Zanskari housing.

Keywords: Himalaya, India, Sustainable housing, Low-tech architecture, Passive solar building design

Figure 1 - Site location, Stondgay, credits: E. Domon  
Figure 2 - Public presentation of the model, credits: E. Domon
Full paper

This paper presents the case study of a construction project developed by a group of engineers and architects from EPFL for a Swiss NGO, Association Rigzen Zanskar¹ (ARZ) that supports a school and others humanitarian projects in the Zanskar Valley (J&K, India).

Local Context, Issues and Opportunities

This project is located in Stongday, a small village in the Zanskar Valley, 3500m above sea level and 15km north of Padum, the main city of the region. About 20'000 Zanskarpas are living in the valley, which has an area similar to Switzerland. Because of the topography and snowfalls, the valley is reachable with motorized vehicles only 4-5 months per year. The climate in this high-altitude desert is very harsh: temperatures may fall to -30°C during winter and reach 25°C during summer. Furthermore the region is now facing climate change which induces a significant raise of rainfalls. The main advantage of the region is its important solar radiation, which opens great opportunities to develop alternative energy systems. Thanks to its low accessibility (about 5 months per year), the traditional Buddhist Tibetan culture is still well preserved and continues to rule social behavior. During the last decades however, the influence of the neighboring regions of India have become visible and initiated changes in the lifestyles of Zanskaris (e.g. the arrival of mobile phones, gas for heating and cooking, cement for construction).

The use of non-renewable energy sources and imported building materials are now expensive for the local population who wants to improve its quality of life. However the situation may change quickly. The Indian government is building heavy infrastructures to connect directly the valley to the Ladakh in the near future. This type of infrastructure will facilitate and reduce the cost of imported goods and so contribute to influence the lifestyle transition. This context is a unique opportunity to raise awareness within the population about sustainable housing and to adapt the actual traditional construction techniques to the near-future challenges. Nowadays, urban areas of India attract the young generation of educated Zanskaris. To counter this phenomenon, it's important to increase the comfort conditions and the quality of life by respecting the cultural heritage. The need of the ARZ to build a new staff-quarter for the teachers of the school site is a great chance to build a new and innovative house on a suitable place to diffuse new ideas, especially through the voice of the children who receive education there.

Objectives and project structure

In this context, the proposal is to adapt the traditional materials and know-how to the future challenges of the local population by using the potentials of the region. The main goal is to build a new staff quarter for the teachers of the Marpalling School in Stongday that includes the following objectives:

- Develop a type plan of a Solar Passive House adapted to the local conditions and easily reproducible by local people with local & affordable materials. This type of construction reduce the need of energy to heat the building with a better envelope, the goal is to get better thermal comfort conditions without using any kind of fuel.

- Improve the performances of local bricks through low-tech means and promote the use of local materials in general. The main reason is economical, in order to provide an affordable solution to locals, the former reason is to minimize the grey energy of building materials related to their production and transportation.

The design process started in February 2015 and involved a group volunteers, engineers and architects from EPFL and representatives of the Association Rigzen Zanskar. The design is completed by projects of civil engineering students from EPFL interested in low-tech and sustainable construction. The initial model of the project was presented to its future users during the summer 2015; this contact was the opportunity to confirm assumptions and to refine some aspects of the architectural program. The final design will be delivered in May 2016 after a review from Swiss and Indian experts in seismic and solar passive house design. This way of working provides to the different stakeholders the opportunity to learn from different disciplines and cultures. The construction of the new staff-quarter will start in June 2016, when the road to the access the valley is suitable for vehicles again. A group of Nepalese builders and local employees of the association will do the construction with the supervision of Swiss technicians.

¹ http://www.rigzen-zanskar.org
**Design and Innovation to social impact**

As previously mentioned, the purpose of the project is to collaboratively develop and build a sustainable residential building in one of the most isolated Indian-Himalayan valley. This area is characterized by extreme climate conditions and low accessibility to technologies and imported goods. The presented construction project faces these challenges, by proposing solutions related to local tradition that are affordable to the local villagers while significantly improving their quality of life. The whole project respects that local knowledge in terms of construction and suggests smart improvements with low technologies (compressed earth bricks, plastic bottles for insulation, solar passive heating). The project also respects local architectural design related to customs and traditions (room distribution, social space and hygiene space). Design improvements are mainly oriented toward solar energy and global energy efficiency. Moreover, the didactic aspect of the building for the region is in the center of the designers' preoccupation as it supposed to be an exemplary in term of comfort and architecture. The floor plan of the building is the duplication of the floor plan of a single-family house. This concept allows the future visitors to visualize what could be their own solar passive house. All the design and innovation techniques are possibly reproducible by any local constructor. As we are working together with the local school, the building-yard will be a learning site where children can acquire knowledge of solar and passive housing. It is collaboratively developed as a place for exchange and mutual learning about low technologies and design. The learning goes both ways and implemented techniques can also be used in Switzerland and the global North to develop sustainable and ecological habitats.

The design plans to use mainly traditional materials and construction techniques. Raw earth will be the main material used for masonry, stones will be used for the foundations and the quantity of timber needed for the carpentry, the windows and the furniture will be reduced to a minimum because of its low availability.

The building includes 8 rooms for 2 people with a small kitchen, 2 bathrooms, 2 common spaces (one for leisure with a common kitchen and one for working / teaching), a temple and spaces for a water tank and food storage. Common spaces - used during the day - are situated on the South part of the building in order to benefit directly from the direct solar gains, rooms are located on two floors in the North and insulated part of the building. These rooms benefit from the diffusion of the heat accumulated during the day in a central thermal mass.

![Figure 3 - Floor plan of the proposed building (pre-design stage), credits: Kunik de Morsier arch.](image-url)
Areas of focus

The aim of the project is to improve the effectiveness of traditional Zanskar's buildings in terms of sustainability and comfort by focusing on three main areas of research: the production of an innovative type of mud brick, called compressed earth blocks, the energy efficiency of the solar passive design and the water & waste management.

Compressed earth block (CEB) technology

Traditionally, the most common construction material in the region is the sun-dried mud-brick, also called adobe. These bricks are made on-site with soil and water. The advantage of this type of bricks is its low cost and its intuitive production process. Nevertheless, because of the climate change and the rise of rainfalls these bricks are inclined to erosion. As a result, concrete blocks become an interesting and more durable materials, despite the fact it consumes a lot of grey-energy to produce and is much more expensive. In this project, we want to promote an alternative material, which combines the advantages of both techniques, called compressed earth blocks. The idea is to stabilize the soil with a small amount of cement and the compression of a manual press. The additional cement creates a micro-matrix in the material, this effect is combined with the press compression that decreases the porosity of the brick and increases its mechanical properties. As a result, the CEB made of locally available soil are more lasting and present interesting compression strength. The use of a press permits also to increase the productivity of the production in comparison with the other manually molded bricks.

A group of students from EPFL analyzed a sample of soil from the construction site and tested different blocks with different cement & water ratio. Based on their experiments, they found out a composition made of soil, cement (5% of the mass), water and gravels that can be reproducible on site. This research was made in collaboration with terrabloc sàrl, a swiss start-up, which develop this technology to recycle excavation waste. In a near future, the association will get a manual press and the production of CEB will start. Some local people will be trained to the technique in order to be able to manage the whole process of block production (from soil selection to storage). The added value to a local raw resource can potentially develop the interest of local contractor to develop this activity afterwards.

Figure 4 - Production of experimental CEB samples (Vivant & Zanchetta (2016))

Table 1: Composition of experimental bricks (Vivant & Zanchetta(2016))

<table>
<thead>
<tr>
<th>Brick n°</th>
<th>Sample volume V (cm³)</th>
<th>Soil mₚ (g)</th>
<th>Water mₚ (g)</th>
<th>Gravel mₚ (g)</th>
<th>Cement mₚ (g)</th>
<th>Curing period (d)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1700</td>
<td>2022.45</td>
<td>313.48</td>
<td>353.45</td>
<td>136.47</td>
<td>14/21</td>
<td>5% cement, 15.5% water, with gravel</td>
</tr>
<tr>
<td>2</td>
<td>1700</td>
<td>2410.37</td>
<td>373.61</td>
<td>0</td>
<td>120.52</td>
<td>14/21</td>
<td>Without gravel</td>
</tr>
<tr>
<td>3</td>
<td>850</td>
<td>1234.36</td>
<td>191.33</td>
<td>0</td>
<td>0</td>
<td>till dry</td>
<td>0% cement, 15.5% water, without gravel</td>
</tr>
<tr>
<td>4</td>
<td>1700</td>
<td>2067.95</td>
<td>310.19</td>
<td>361.40</td>
<td>55.82</td>
<td>14/21</td>
<td>2% cement, 15% water</td>
</tr>
<tr>
<td>5</td>
<td>1700</td>
<td>1975.45</td>
<td>345.70</td>
<td>345.24</td>
<td>133.30</td>
<td>14/21</td>
<td>17.5% water</td>
</tr>
<tr>
<td>6</td>
<td>850</td>
<td>1999.67</td>
<td>297.15</td>
<td>0</td>
<td>0</td>
<td>till dry</td>
<td>0% cement, without gravel, 14.86% water</td>
</tr>
</tbody>
</table>

2 www.terrabloc.ch
**Solar Passive Design**

Despite the low temperatures during the cold periods, sun radiations in these areas are a viable source of heat. Keeping as a starting point the traditional shapes of the buildings, several solutions for passive solar heating are suggested. The collection of solar energy is provided through properly oriented windows and adapted thermal masses. Thanks to the new designed walls, this energy may be stored and naturally diffused through convection and radiation mechanisms. A related challenge is to improve the efficiency of the thermal envelope, usually traditional buildings are not insulated. For the northern part of the building, it is planned to add a layer of insulation made of sawdust and empty plastic bottles. This choice is driven by the intention of using exclusively local and affordable materials. Plastic bottles encapsulate air and reduce the volume of sawdust needed to fill the layer between two walls. Plastic bottles are a waste that is not recycled yet and easy to collect, so it is environmentally interesting to store this waste while providing thermal benefits. In the long term, it will be possible to replace - and definitely recycle the bottles - with a better insulation material (when available). As a result, temperature fluctuations decrease, allowing warmer indoor temperature during the cold months. The energy concept of the building is simulated in a building physics software to refine the geometry and the thickness of the structural elements.

In addition, in order to guarantee a minimal electricity supply for lighting and the functioning of a simple pump system for water distribution, the project considers the possible installation of photovoltaic panels on the roof.

**Water & Waste management**

Water and Waste management solutions in such remote regions are scarce. In general, there are only elementary solutions for water access, sanitary facilities and disposal systems. Through the proposed project there is a strong interest in improving the actual conditions and in exploring the possible and most sustainable solutions. Firstly, there will be a study with the purpose to integrate better and healthier systems to insure drinking water access and hygienic conditions during the whole year. Effectively, because of freezing during the cold months it is not possible to guarantee neither running water nor a minimal storage. Water has then to be manually collected and transported.

Secondly, the project will explore alternative approaches to the wastewater management. These areas are mainly equipped with basic dry toilets. One generally observes a poor maintenance of such toilets and, because of the lack of technologies and of a strong cultural influence; there are no strategies for waste disposal and treatment.

Wastewater can be considered as a resource that, when managed correctly, can be reused. The poor soil fertility can be improved with organic matter produced by the villagers, the grey water, even in small quantities can be easily recycled and use for farming purposes.

**Future works and application in practice**

In the coming months, the final drawings and technical calculations will be achieved. A particular effort is made on the production of didactic technical notices to facilitate the transmission of information for the different aspects of the project. It also includes a list of activities for local stakeholders to raise awareness about sustainable housing and to transfer the fundamental skills necessary to reproduce this type of innovative construction.

**References**


Aguettant G. & Bernhard P. (2016). Humanitarian project to build a school in the Zanskar valley, Construction Project, EPFL