EARTHEN ARCHITECTURE AFTER DISASTER: INITIAL RISK-REDUCTION MEASURES IN KANJI VILLAGE FOR CONSERVING NON-ENGINEERED RURAL LADAKHI ARCHITECTURE

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Abstract
Ladakh (North of India) is characterized by an elevated level of seismic risk, being part of the Jammu and Kashmir state, very close to Pakistan, where in 2005, a terrible earthquake destroyed part of the building stock and killed thousands of people. Over the last decade in these areas, the climate has changed: the amount of rainfall has experienced an exponential increase. In particular, in August 2010, the unusual heavy rainfall resulted in various related physical phenomena, such as floods and landslides.

Since the summer of 2008, a team from the University of Udine's School of Architecture has supported the Achi Association's activities in Ladakh. The Udine team is carrying out architectural research and fieldwork in this area, aimed at producing a *conservation manual* for the community of Kanji, a small Ladakhi Himalayan village.
During the summer of 2010, the Udine Unit mission in the field was involved with the catastrophe that occurred in August. This climate-related as well as geo-environmental disaster produced more than one hundred civilian casualties and associated damage to the existing urban fabric in Leh (the capital of Ladakh), in addition to rural settlements.

This paper analyzes the damage to traditional earthen buildings in Kanji, linked to climate change, and appropriate solutions adopted in order to build new safe construction, and preserve the existing architectural heritage in a sustainable approach, respectful of traditional typologies and technologies.

1. INTRODUCTION

Kanji, a Himalayan village in the Leh district of Ladakh (Jammu & Kashmir State, India), is characterized by a fine earthen architectural heritage that is experiencing deterioration of some dwellings and religious buildings. Currently, typical architectural pathologies develop faster because of climate change, which has resulted in a much more humid temperature during the summer.

At one time, extremely cold winters and temperate dry summers characterized the climate of this region. Over the last decade, instead, the amount of rainfall has experienced an exponential increase, and as a result, the damage to Kanji earthen architecture has been widespread. In 2010, the heavy monsoon made the situation worse, destroying a part of the city of Leh and many dwellings of villages all over Ladakh (Fig. 1).

For the above-mentioned reasons, the main objective of our missions in Ladakh focuses on the conservation and maintenance of the traditional earthen buildings, as

well as the introduction of improved building-technology solutions aimed to enhance the stability of the non-engineered rural architecture, avoiding or reducing the risk of collapse due to seismic events or heavy monsoons. Therefore, this paper introduces the methodologies that the Udine Unit implemented in Kanji, to reduce climate-change impact on earthen buildings, which resulted in the appearance of severe damage to structures, and even their destruction. These methodologies follow the conservation approach promoted by the Achi Association, which is actively involved in the conservation of Buddhist temples in this area.

The Udine Unit is promoting three directions:

- **Conservation activities on site:** the team works in the field on preventive-maintenance activities aimed to reinforce the structure of traditional earthen buildings against any possible environmental risk.
- **Draft of a *conservation manual*:** the team is preparing a *conservation manual* for Kanji, which can also be useful for nearby villages. The *conservation manual* will be a review of the architecture of Kanji, and it will include an analysis and photographs of the variety of surviving architectural typologies, as well as all of the various building technologies and the vernacular architectural details employed.
- **Organization of workshops:** the team organizes workshops with the local population and a selected group of young people, including community leaders, artists and Buddhist monks, in order to improve their knowledge regarding new safer building-construction technologies, which should be adopted to face climate-change issues.

Fig. 1 – Leh, Ladakh: the destruction of the urban fabric after the heavy monsoon and related flood (credits: Désirée De Antoni, 2010)

2. KANJI'S TRADITIONAL EARTHEN HERITAGE AND RELATED PATHOLOGIES

2.1. Vernacular earthen typologies and building-construction materials

Ladakh is sometimes referred to as "Little Tibet", because it shares with Tibet various similarities, such as the Buddhist religion, partially-related ethnicity, language, and as well as vernacular architecture (building techniques and architectural typologies).

The architectural typologies of Kanji are characterized by the intensive use of earth, together with stone and wood, as basic building materials. The foundations of traditional buildings are built of stone; the load-bearing walls, as well as the internal framework, are executed with *pakbu*, the traditional earthen blocks. The floors and the roofs are constructed with poplar wood beams and willow sticks, vegetable fibers and a plaster mixture made of earth and water, called *markallak*.

Kanji architectural typologies are basically three: buildings used as housing, buildings used for worship (temples and monastery), and public buildings (schools and meeting halls) (Fig. 2). These structures, within the framework of the *conservation manual*, have been evaluated for their state of conservation (good, sufficient, poor, or totally insufficient, which equates to a serious state of decay).

Fig. 2 – Kanji, Ladakh: the vernacular earthen architecture and the monastery (credits: Désirée De Antoni, 2010)

2.2. Pathologies and damage to earthen structures in Kanji

In the village of Kanji, earthen structures are really affected by several pathologies due to the inadequate choice of building materials, their implementation, and climatic factors such as rain, snow and ice. These three factors are related to each other and responsible for the decay of these buildings.

Field research demonstrates that sometimes the preparation of the *pakbu*, is approximate and realized very quickly without taking care if, during the production, the earth fills entirely the mould and, above all, its angles. Lack of earthen mortar between *pakbu* laid horizontally, or the absence of joints among the horizontal and vertical elements of the structure also has been observed (Fig. 3a). Furthermore, traditional *pakbu* masonry results in additional problems that can remarkably reduce the stability of earth construction. The first case concerns a low resistance of the wall itself, because the earthen blocks are not well connected to each other, and for this reason, they cannot resist together against a wall oscillation due to a seismic event or a flood. In the second case, instead, the loss of resistance is related to the reaction of the whole building: it is extremely necessary, in fact, that the connections among walls, floors, foundations and roof are assured in order to have a ”box-type” structure in which all the architectural elements can act together against any kind of external stress, like deformations due to the earthquake vibration (*box effect*).

Another very recurrent problem is due to the absence of periodic maintenance of the roof drainage system (Fig. 3b). Rain can infiltrate from the roof, and the resulting dampness and the freeze/thaw phenomena can create serious problems for the buildings, eroding structures and joints at the walls, till separation occurs.

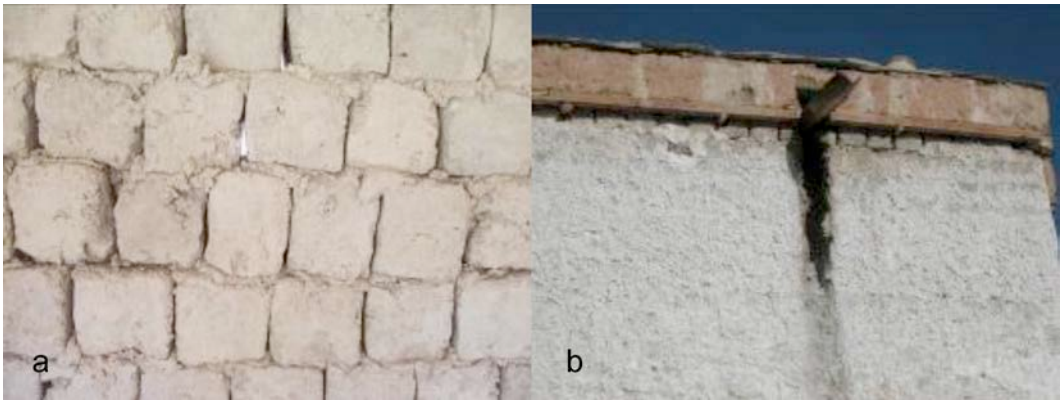

Fig. 3 - Kanji, Ladakh: (a) the lack of earthen mortar between the *pakbu* laid horizontally with incorrect *pakbu* vertical-joint design and; (b) a roof-drainage system, which does not work correctly, damaging the wall surface (credits: Désirée De Antoni, 2010 (a) and 2009 (b))

3. MEASURES FOR RISK REDUCTION: THREE MAIN ACTIONS

The Udine Unit, within the framework of the Achi Association's activities, contributes to climate-risk reduction in these areas, following an approach based on three main actions, which involve conservation activities to the site, drafting of a *conservation manual* of Kanji, and organization of workshops for selected groups of young community leaders, artists and monks.

3.1. Preventive-conservation activities on site

The Udine Unit with the Achi Association set up some conservation missions in order to preserve temples and monasteries of Kanji, Wanla and other rural villages of Ladakh. The approach was aimed at reducing damage due to climatic impact on local traditional architecture made of *pakbu*, the traditional earthen block.

One of the main conservation activities took place in 2005 and involved the maintenance of *Tsuglag-Khang*, the small Buddhist temple in Kanji, which consists of a unique room in which there are three Buddha statues and wonderful paintings on the walls. Intense rainfall and freeze/thaw cycles resulted in severe damage to the structure: multiple cracks were present along the walls, the earthen roof was in a serious state of decay, and one of the four load-bearing walls exhibited movement towards overturning. For these reasons during the 2005 campaign, the Udine Unit experts, along with other members of Achi Association, implemented protective interventions able to conserve the roof of the temple, and the underlying structure. The methods carried out to rehabilitate the temple took inspiration from local vernacular building technologies.

For the repair of cracks, the team decided provisionary to fill these with *markallak* instead of reconstructing parts of the masonry, in order to preserve the decorations on the walls (Fig. 4a). The restoration of the interior paintings is still ongoing. Degradation action on the earthen-wall decorations was due to infiltration of water or melted snow through the roof. These phenomena were tied to the presence of several deep cracks in the connection joint between the roof and the upper walls, and the inadequate maintenance of drainage system, which lacked a sufficient number of water evacuation points (scuppers).

Regarding the penetration of damp and scouring water along the joint line between the two perpendicular planes, the conservation activity focused on the creation of an "improved roof plane-wall joint". First of all, the Udine Unit decided to prepare a specific mixture of *markallak*, containing finely-cut straw, which was subsequently spread at the joint line. On top of this first layer of *markallak,* another layer of flat stones was created

and then covered with earthen mortar. This improved joint was designed to resist the phenomena of contraction-expansion due to the frequent freeze/thaw cycles impacting earthen roofs.

A second intervention involved the perimeter walls of the roof-terrace, and was related to the upper profile of these walls, which provided an improvement in defence against erosion caused by rain and wind. The intervention focused on the addition of a "*sacrificial layer*", creating a first level of protection during the winter period for the upper edge of the joints. This *sacrificial layer* was made by adding slivers of flat stone and an additional layer made of earth with a curved section. Unfortunately, these experimental conservation techniques could not totally solve water infiltration issues, because of the lack of maintenance of the evacuation points, which allowed water to accumulate, generating a "roof-pond" effect.

For this reason, the team decided to build a second protective roof. This choice certainly limits the possibility of obtaining "authenticity of form" related to traditional conservation interventions. On the other hand, this intervention presents a character of "reversibility", providing additional protection. This second roof, even in the absence of ordinary maintenance, can guarantee complete safeguarding of the structure.

For the load-bearing wall that presented movements of overturning, the team took the decision to maintain the two existing buttresses, made with stone and clay-based mortar, and to enlarge the foundations. These interventions allowed distribution of the load of the wall on a lager surface, avoiding a possible overturning of this part of the structure, as well as the destruction of the interior paintings (Fig. 4b).

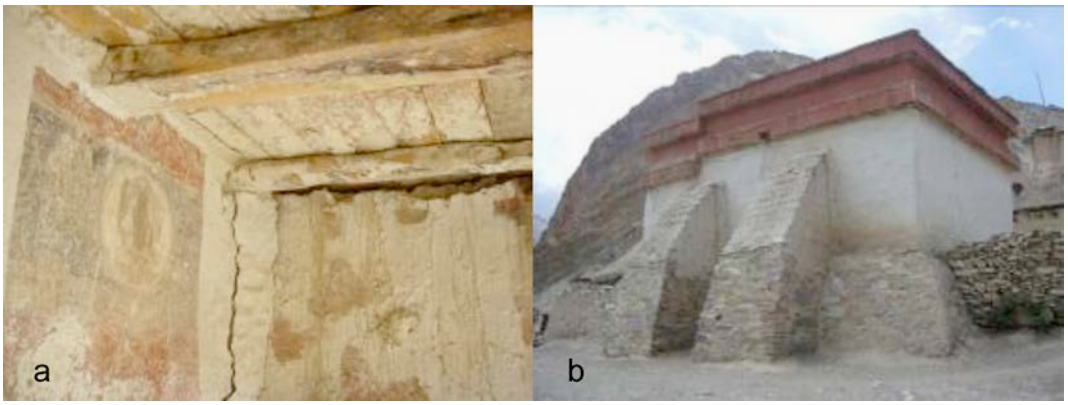

Fig. 4 – Kanji, Ladakh: conservation of the *Tsuglag-Khang*; (a) the interior damaged paintings; (b) the second roof, the stone buttress and the new foundations (credits: Mauro Bertagnin, 2007 (a); Giulia Bravo, 2008 (b))

3.2. Draft of the *Conservation Manual* of Kanji

The 2010 floods produced related damage to the vernacular architecture of several small villages like Kanji. For this reason it became important to draft a *conservation manual* for Kanji, which can be promoted in other similar areas. The *conservation manual* can explain how to build new buildings and conserve the existing architectural heritage, and in particular, how to maintain traditional construction that may be increasingly exposed to serious environmental risk.

First, the *conservation manual* should incorporate a study of the Kanji context, which means: study of geographical location, environmental characteristics, climate and its changes, etc. During the 2010 mission, it was also possible to improve the team's knowledge through research on village history and traditions, concerning also the first settlements, the roles of women and men in society, the socio-economic as well as

political activities, the building traditions (orientation, myths related to the house, etc.) The *conservation manual* should include the analysis of the architectural heritage as well, providing a distinction between houses, buildings for worship, public buildings and tourism facilities. The Udine Unit is also analyzing public buildings, just to make a comparison between the building technologies and materials used for these and those used for traditional structures.

During the final 2010 mission, an in-depth study of the vernacular building technologies used in Kanji was carried out, focusing on an analysis of the materials, their characteristics and function, and the methods used for their implementation. After this analysis, the architectural details related to some examples of roofs, windows, doors, capitals and columns will be included in the *conservation manual*. It is still necessary to study some of the main pathologies that affect the earthen vernacular architecture of Kanji, indentifying the causes, such as inappropriate choice of the materials, application defects, dampness, climate-related alterations, and human factors.

After analyzing pathologies, the *conservation manual* will provide some guidelines for the conservation of traditional buildings and for the construction of new dwellings. The challenge for the conservation of Ladakhi vernacular earthen heritage is to identify new criteria for preserving the local earthen-building culture, while simultaneously improving existing building technologies in order to strengthen new earthen buildings. There is, in fact, a serious risk of a progressive loss of vernacular building know-how in local communities, and one of the main causes is climate change, which is modifying the local building construction at the expense of using *pakbu*.

Public buildings, built thanks to public money, are mostly made with stone and cement, providing better durability against climatic phenomena, but they are, at the same time, totally unsuited for the local climate (Fig. 5a). In addition, the use of these more durable construction materials produces an “imitative process”, causing local people to privilege the use of stone, cement and concrete, instead of raw earth. Together with the new materials, a modification of the aspects of new buildings, as well as technical construction methods, is occurring. For example, the introduction of concrete curbs and beams are more evident, as well as concrete foundations in new construction (Fig. 5b).

For these reasons, it becomes important to provide a manual with visual guidelines illustrating appropriate construction technologies for building new structures in the surrounding landscape, and for the conservation and maintenance of existing traditional buildings. Therefore, the main purpose of the *conservation manual* is to contribute to village development, which combines respect for an important cultural heritage to be protected and maintained, the possibilities offered by modern building technology to make life more comfortable, and the respect for nature and vernacular architecture based on local building materials .

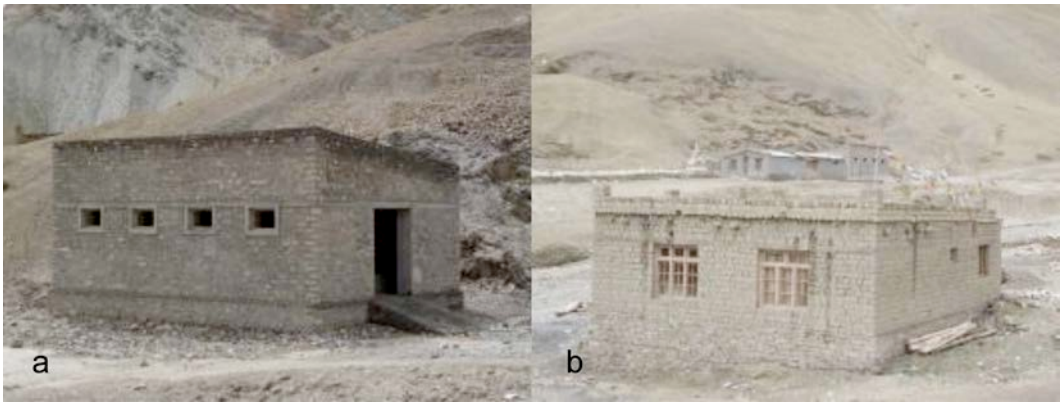

Fig. 5 – Kanji, Ladakh: (a) a rice store built of stone, cement and concrete; (b) a new earthen house with a concrete curb (credits: Désirée De Antoni, 2010)

3.3. Workshops for the local community and Ladakhi Buddhist monks aimed to improve traditional earthen-construction patterns and techniques

In order to increase the awareness of local population on the necessity of improving traditional earthen-construction patterns and techniques, in February 2011, a special winter workshop was organized in Dehradun, India for climatic reasons by the Udine Unit, within the framework of the Achi Association's educational program in Ladakh. The workshop was conceived for a selected team of community leaders, young Ladakhi artists and monks. After attending the workshop, the participants have the responsibility of spreading updated know-how to Ladakhi villages and communities.

The winter workshop was a first step for a more complex and detailed educational program, aimed to create awareness for the necessity of improving traditional earth construction know-how to face the increasing issues related to the impact of global change on small Ladakhi rural settlements. The workshop was organized around themes, such as "Basic Knowledge of Architectural Conservation Principles", "Earthen Architecture in Ladakh", "Earth Construction Technology", "Basic Notions of Earthquake Resistant Earth Construction Design" and "Earth Construction Practice".

The "Earth Construction Practice" theme's basic goal was to provide initial practical experience on earth construction through a brief field exercise of earth material-identification basic tests, production of traditional Ladakhi *pakbu*, and preparation of earth-based mortars and plasters according to the vernacular building culture, as well as improved mixture recipes. An awareness was also promoted on the importance of improving seismic strengthening of load-bearing walls, following the building technologies explained in the Indian Standards for earthen building. The Udine Unit, referring to the Indian Standards 13827/1993 - Improving Earthquake Resistance of Earthen Buildings, Guidelines, taught workshop participants, for instance, how to produce better quality *pakbu*, or how to create a correct *pakbu* masonry design, using appropriate improved mud-based mortars and plasters, and making sure of the correct distribution of the mortar in between two *pakbu* or in the laying of *pakbu* masonry (Fig. 6a). An improved corner joint for the walls, thanks to the introduction of a simple structure constituted by a band with two timbers in parallel and diagonal members for bracing at corners, was another important achievement of the "Earth Construction Practice" theme (Fig. 6b). This simple introduction to correct earthen-construction practices in seismic areas like Ladakh, supported by basic knowledge of architectural-conservation principles, will create a solid base for future improvements, included in the work-in-progress of the Udine Unit's action in Kanji.

Fig. 6 – Dehradun, India, the winter workshop: (a) the production of different *pakbu* and; (b) the improved corner joint of the walls due to a simple structure constituted by a band with two timbers in parallel and diagonal members for bracing at corners (credits: Mauro Bertagnin, 2011)

4. IMPLEMENTATION OF ACTIONS AGAINST CLIMATIC IMPACT ON EARTHEN STRUCTURES: EXPECTED OUTCOMES

The winter workshop in Dehradun is part of an ambitious program of activities promoted by the Achi Association over the past decade, in order to reduce the climatic impact on Ladakhi earthen architecture. For what concerns the Udine Unit's action, the Dehradun winter workshop completed the threefold conservation program, including the monitoring and conservation activities on site and the drafting of the *conservation manual* of Kanji. The expected outcomes of these coordinated efforts are strictly related to the capability of Kanji inhabitants to understand the importance of preserving their identity, maintaining and improving their vernacular architecture in an era of global change.

The purpose of these activities was to stimulate basic awareness of opportunities for an architectural-heritage conservation shared by the villagers, as a main goal for the reinforcement of community identity facing globalization, and the struggle against global change, affecting year after year, small rural Ladakhi settlements. The idea of targeting "young" representatives of Ladakhi communities helped also a new vision, improving the expected outcomes for a better preventive conservation of the refined Ladakhi earthen-architectural heritage.

Helping improve community awareness of vernacular architecture as a treasure to be protected, and rediscovering its value for contemporary life, requires providing basic technical knowledge and tools to allow villagers to be active in the protection of their heritage. Furthermore, to overcome various issues related to the impact of global change and to preserve the non-engineered earthen architecture of the region, the multidisciplinary approach provided by the Achi Association, should be improved and adapted to continuous variations related to climate change. An example of these unexpected variations was clearly displayed by the dramatic environmental emergency, occurring in the summer 2010, which deeply shocked Ladakh.

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Curriculum

Mauro Bertagnin, architect, professor of Architecture, University of Udine, Dean of School of Architecture. Member of CRATerre, he is actually involved in several conservation projects of earthen architectural heritage in Africa and Asia. He is also scientific counselor of the UNESCO-WHEAP-World Heritage Earthen Architecture Programme (2007-2017).

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