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LOW COST SEISMIC CONSTRUCTIONS: DESIGN AND DISSEMINATION IN DEVELOPING SOCIO-ECONOMIC AREAS

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Substantial seismic risk to public buildings, such as schools and medical centres, affects a wide segment of the world's population: from the developing countries and those with considerable socio-economic diversity (Africa, Latin America), to those currently undergoing economic transformation and rapid demographic expansion (China, India, Southeast Asian). The direct exportation of modern technologies or know-how through simple economic aid programmes cannot alone solve the problem: local populations are often unable to handle the maintenance and management of modern buildings, whether it be for economic reasons, a lack of organizational support or simply a poor understanding of the materials, systems and construction techniques supplied them. The use of low-cost, easily available materials is a necessary, though insufficient, condition for balanced development in the field of earthquake-resistant structures. The goal, in this respect, is to improve existing local technologies by enhancing the peoples' understanding of the seismic behaviour of buildings, and by applying modern techniques to enhance traditional local materials and technologies. In doing so, all aspects relevant to structural stability (statics, energetics, systems, and sanitation) must be addressed. Another essential undertaking is to promulgate scientific knowledge: this involves understanding the linguistic and popular customs of local populations, their organizational structures and to implement means of language communication aimed at segments of the population or social structures able to receive such knowledge and render it operative.

In this regard, the case of the Republic of Malawi – the object of the present project – is emblematic. The project involves designing and constructing a simple school building with materials and techniques found in the area, by adopting some strategies to increase the structure's capacity to withstand seismic actions. The basic structural material to be used is bamboo, reinforced with timber, straw and mud, and masonry blocks. The seismic-resistant structure elements are fashioned of plywood and stainless-steel screws, easily assembled given suitable instructions. The construction methods are simple and can followed by locals with proper dissemination of the techniques throughout the community and organization of the building site. Three levels of communication are proposed:

a) technical dissemination through local institutions (local technical offices, Universities);

b) training work-site foremen in the local community;

c) support to and verification of the work progress.

Each of the three levels calls for specific communication methods for disseminating know-how, through documents, sketches, information boards and verbal explanations. In the first, typical western-culture technical and economic documents are used; in the second, a dissemination manual with simplified language, sketches and illustrations for assembly are adopted, using the communication techniques of "picture books" or "comic strips" typical of the educational brochures used in primary and secondary schools; lastly, in the third, descriptive charts will be drawn up to illustrate, through simple pictures and sketches, the various construction stages – a technique similar to the classical "story-board", which serves to bring to life the time sequence of the various stages and make them more easily understandable.

keywords: low cost constructions, socio-linguistics, developing country, seismic risk, communicative level.

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Abstract

The paper describes a procedure for establishing and disseminating a sustainable technique for the construction of low-cost seismic structures using reinforced bamboo elements. The procedure is illustrated via the example of a small public building, suitable for use as a primary school or health centre. From the technical perspective, innovative joints are proposed for erecting frames with roof trusses and bamboo columns and the addition of grass thatch and unbaked bricks. The simplicity of executing such a structure and its high mechanical performance have been demonstrated by a series of experimental tests conducted at the laboratory of the Polytechnic of Blantyre (Malawi). Lastly, we propose a multi-pronged strategy for disseminating the construction technique via various means of communication appropriate to the population's various socio-economic segments.

Keywords

Low cost constructions, socio-linguistics, developing country, seismic risk, communicative level.

1. INTRODUCTION

Substantial seismic risk to public buildings, such as schools and health centres, affects a wide segment of the world's population: from the developing countries and those with considerable socio-economic diversity (Africa, Latin America), to those currently undergoing rapid economic and demographic expansion (China, India, Southeast Asian). The direct exportation of modern technologies or know-how through simple economic aid programmes cannot alone solve the problem: local populations are often unable to handle the maintenance and management of modern buildings, whether it be for economic reasons, a lack of organisational support or simply a poor understanding of the materials, systems and construction techniques supplied them.
The use of low-cost, easily available materials is a necessary, though insufficient, condition for balanced development in the field of earthquake-resistant structures. The goal, in this respect, is to improve existing local technologies by enhancing the populations' understanding of the seismic behaviour of buildings and applying modern techniques to enhance traditional local materials and technologies. In doing so, all aspects relevant to structural stability (statics, energetics, systems, and sanitation) must be addressed. In this regard, the World Housing Encyclopedia represents an invaluable resource, as it furnishes the results of a global survey of the vernacular construction techniques used in world areas subject to seismic risk.
Another essential undertaking is to promulgate scientific knowledge: this involves understanding the language and popular customs of local populations and their organisational structures, and to implementing means of communication aimed at segments of the population or social structures able to receive such knowledge and render it operative.
In this regard, the case of the Republic of Malawi – the object of the present project – is emblematic. The project involves designing and constructing a simple school building with materials and techniques found in the area, adopting some simple strategies to increase the structure's capacity to withstand seismic actions. The basic structural material to be used is bamboo, reinforced with timber, straw and mud, and masonry blocks. The seismic-resistant structural elements are fashioned from plywood and stainless-steel screws and are easily assembled given suitable instructions.
The construction methods are simple and can be followed by locals with proper dissemination of the techniques throughout the community and suitable organisation of the building site. Three levels of communication are proposed:

a) technical dissemination through local institutions (local technical offices, universities);

b) training work-site foremen in the local community;

c) support to and verification of the work progress.

Fig. 1: A traditional building in sub-Saharan Africa

Each of the three levels calls for specific communication methods for disseminating know-how, through documents, sketches, information boards and verbal explanations. In the first, typical western-culture technical and economic documents are used; in the second, a dissemination manual with simplified language, sketches and illustrations for assembly are adopted, using the communication techniques of “picture books” or “comic strips” typical of the educational brochures used in primary and secondary schools; lastly, in the third, descriptive charts will be drawn up to illustrate, through simple pictures and sketches, the various construction stages – a technique similar to the classic “storyboard”, which serves to bring to life the time sequence of the various stages and make them more easily understandable.

Fig.2 and 3: Photos illustrating the deforestation problem

2. THE TECHNICAL PROPOSAL

As in all regions of the developing world, a fundamental means to foster socio-economic growth in sub-Saharan Africa is to improve the quality of existing constructions. The term 'traditional housing' is used in this report to describe the types of homes constructed by exploiting the materials, unskilled labour and expertise available locally. Such housing is widespread in rural sub-Saharan Africa, for which the country of Malawi represents an exemplary case study. It has been found that cultural and social factors are similar throughout the region and have a bearing on traditional housing.
One essential prerequisite for any such undertaking is a thorough understanding of the construction techniques commonly applied in the area, as well as the level of the technology used by local construction companies and the know-how generally available to the local populations. To this end, the World Housing Encyclopedia represents a fundamental instrument for researching the vast number of different vernacular building techniques in widespread use throughout the world. A typical low-cost, yet high-performance construction material is bamboo: numerous building projects are by now under way in many areas of the globe, especially in Latin America and Southwest Asia, and have led to the development of a flourishing economic sector.

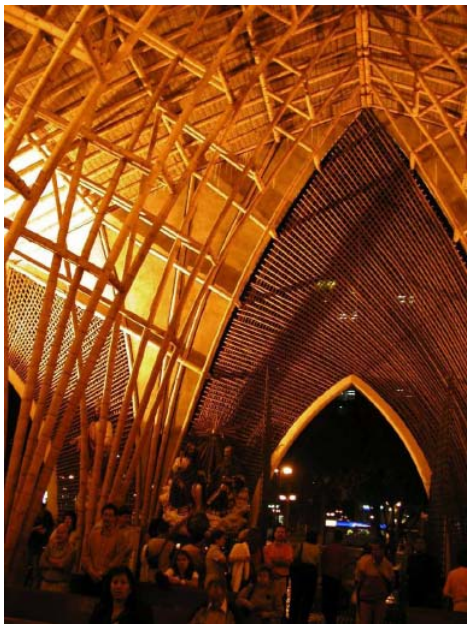

Fig. 4: A bamboo church in Latin America

Fig. 5: Bamboo vegetation

According to the 1998 Malawi Population and Housing Census, the proportion of houses in Malawi built with traditional materials and techniques exceeds 88%. The population living in rural areas was found to be 86%, which suggests that even people living in urban areas use traditional building materials. The use of bamboo as an easily availability building material may represent a strategic choice for improving structural quality, in terms of hygiene, comfort and safety, while maintaining conformity with local building traditions and enabling the construction of low-cost, low-maintenance buildings. Current improvements to traditional housing centre on heightening the efficiency of building materials utilisation. The use of grass thatch, for example, can be improved by applying plastic sheets to reduce the thatch thickness. The use of bamboo in truss construction can be improved by applying advanced analytical methods and more efficient joint designs. Lastly, quantification of the mechanical strength properties of traditional building materials can assist in economising cross-sections.
Although bamboo can be used in many building applications, the main focus of the current study is its application in truss buildings. Two types of trusses are commonly used in housing construction in Malawi: king post and Fink; these have therefore been analysed in detail. There are several methods of analyzing trusses to arrive at the appropriate design parameters. The analysis of bamboo trusses to determine bearing capacity was performed utilising SAP 2000 on various truss arrangements, including different spacings. The roof loads considered were those of the covering material, the self-weight of the roof structure and the maintenance load, whose values are as follows:

- Grass thatch: 243 kg/m^3 x 9.81 x 0.15m = 0.36 kN/m^2
- Roofing tiles: = 0.29kN/m^2
- Maintenance load = 0.50kN/m^2.

The material properties used in calculating the truss member loads are the following:

- External diameter – 60 mm, with 5 mm wall thickness
- Young's modulus of elasticity – 11,000 N/mm^2
- Density – 850 kg/m^3

Fig.6: Demonstrative pavillon with guada bamboo from Latin America

The strength of the trusses is also limited by the capacity of he joints. Jayanetti and Follet (1998) have provided a literature review of traditional bamboo joints. A large number of proposals have been advanced by several authors (Stulz, 1983; Hidalgo, 1992; Janssen, 1991, 1995; Arce, 1991, 1993; Mishra et al, 1991; Morisco et al, 1995). In particular, Stulz and Hidalgo introduced the technique of internally reinforcing the bamboo stalk, or culm, in linear (Fig.7) or plane-angled joints (Fig.8). Arce, instead, suggests the need for longitudinal slots in order to accommodate slight variations in the size of the internal wood reinforcement. Morisco et al. proposed the filled joint, fixed by means of bolts to ensure fastening of the inner wooden cylinder. With regards to angled joints, Mishra and Janssen developed the gusset plated joints (Fig. 9) and the Instituto Technologico of Costa Rica developed the ITCR joint, in which a plywood or steel plate is inserted into longitudinal slots to connect the extremities of the bamboo elements (Fig. 10).

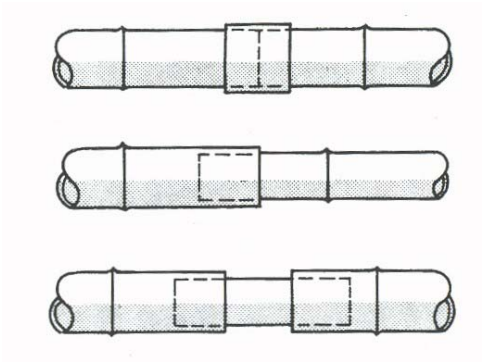

Fig. 7: Sleeves and inserts

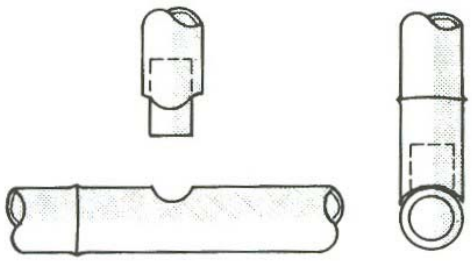

Fig. 8: Insert plane-angled joint

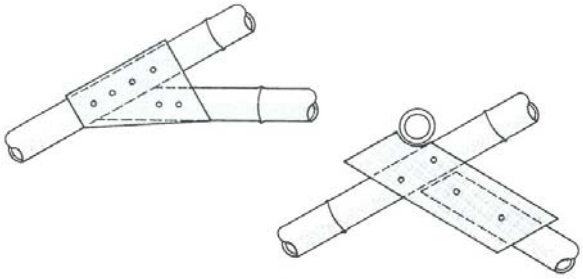

Fig. 9: Plywood side plates bolted to bamboo.

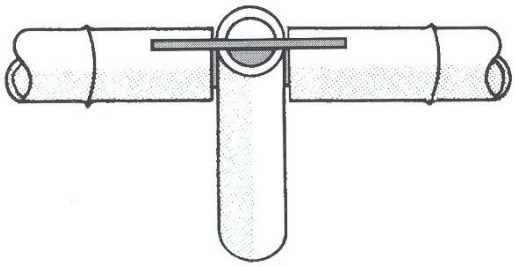

Fig. 10: Plywood insert glued into slots.

The joint proposed here may be regarded as a combination of the foregoing techniques: a bamboo rod is reinforced by a cylindrical wooden element, and a longitudinal slot is then made at its extremity. The connection between the reinforcement and the inner part of the bamboo is provided, in one case by a layer of vinyl glue alone, and in the other, by a set of screw nails in addition to the glue. A plywood plate or disc is then inserted into the slot and bolted to the bamboo-wood composite to execute the truss as in figures 11 and 12

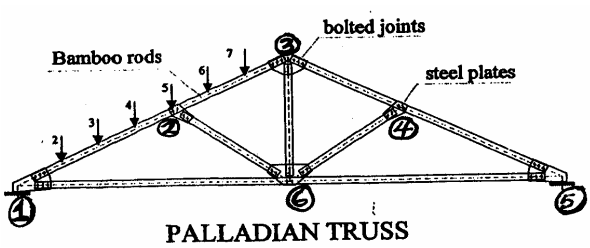

Fig. 11: King Post Truss

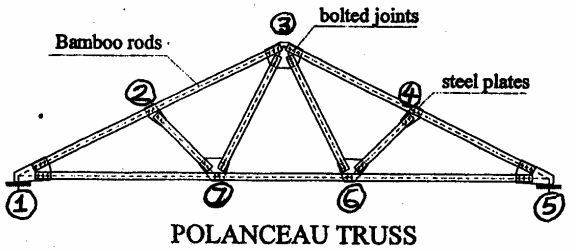

Fig. 12: Fink Truss

Tests were conducted at the Structural Engineering Laboratory at the University of Pisa and the Laboratory of the Polytechnic of Blantyre to determine the strength of several joint types. Bamboo proved to exhibit excellent mechanical properties. Moreover, it is easy to use and grows spontaneously and rampantly, given the proper climatic conditions. Therefore, the aim of the tests has been to modify the traditional techniques used for the connections between the bamboo stalks, which though easy for local populations to perform, are statically ineffective. Such modifications must however avoid high-tech solutions, which would be statically valid but difficult to implement in a poorly developed economy due to cost, complexity and difficult maintenance.

Experimental trials were conducted on single or paired bamboo culms (fig.13 and 14), connected by flat plywood discs. In the joint area the culm is strengthened by filling the hollow with solid wood elements and using glue and screw nails to fasten them together. The actual joint is executed with metal bolts extending throughout the full thickness of the culm, the reinforcement and the plywood discs.

In contrast to a first pilot trial, which was performed using a steel disc for the connection, the use of the plywood has led to decidedly more ductile fracture of the joint, in which the bamboo stalk loses little of its original bearing capacity. Such ductility is an extremely desirable property, as it allows for the possibility of adapting the joint before failure and, in seismic areas, energy dissipation during the vibrations of an earthquake.

Fig. 13: mechanical test on single joint

Fig. 14: mechanical test on double joint

The walls can conveniently designed using adobe or unburnt clay units, reflecting traditional techniques adopted to erect housing in rural villages, a recent example of which are the Stabilised Soil Blocks shown in figure 15.

Fig. 15: Stabilised Soil Block Teacher's House at Namadidi Primary School in Phalombe

Fig. 16: An example of traditional bamboo roof

Fig. 17: Demonstration of a bamboo framework for housing

The present technical proposal consists of a one-storey building sustained by a series of bamboo frameworks. A pair of bamboo pillars are fixed on a concrete base and their upper ends connected to a bamboo truss: the span of the roof is about 7.2 m with two symmetrical patios of about 2.2 m. The length of each module is 2.5 m to create a rectangular plan suitable, for example, for classrooms of a primary school or rooms for a medical centre. The walls can be constructed using Stabilized Soil Blocks or mud bricks.
The seismic performance of the proposed bamboo building is particularly noteworthy: the lightweight roof ensures low seismic actions while the bamboo rods with the plywood joints furnish ductility in case of transverse oscillations.

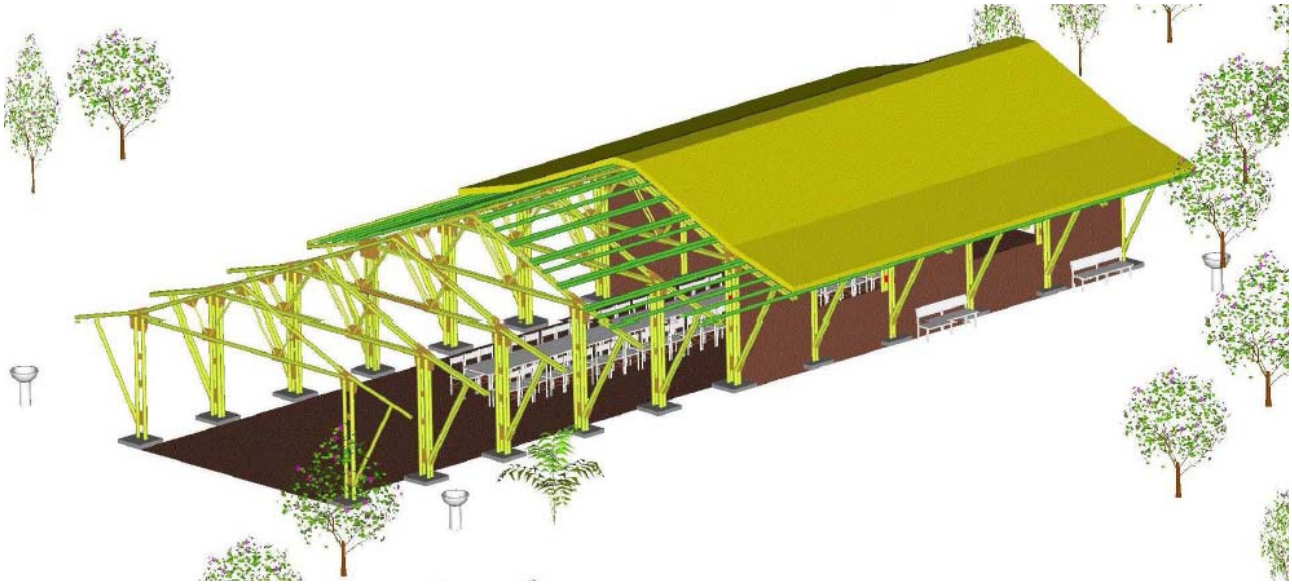

Fig. 18: 3D view of the proposed bamboo framework

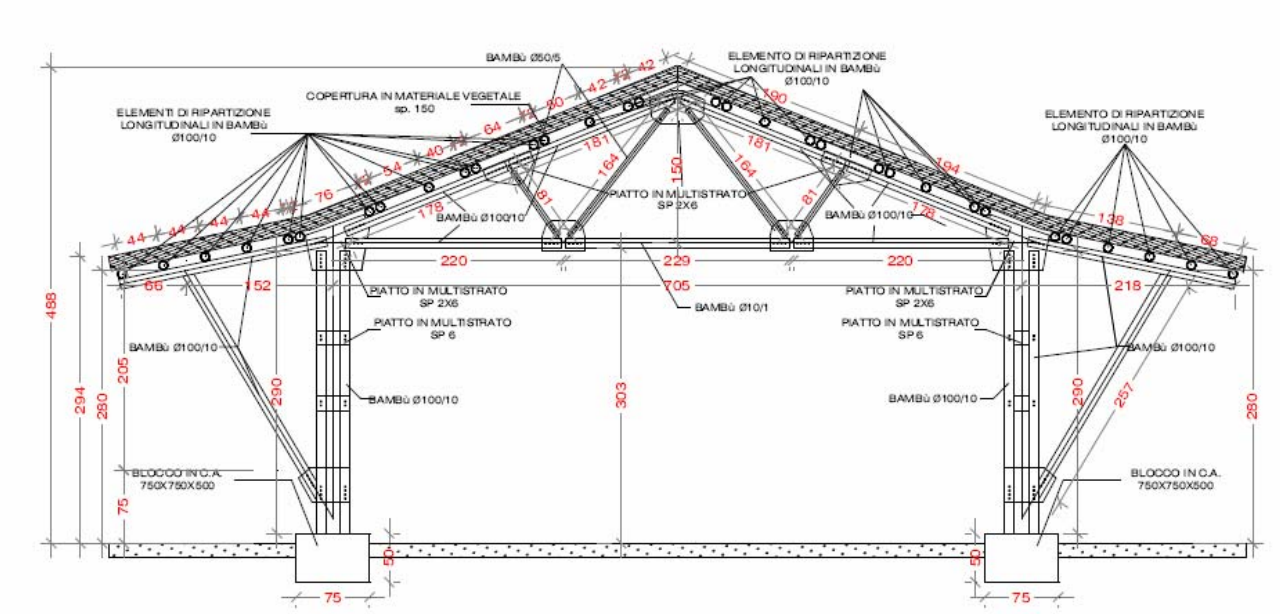

Fig. 19: Technical drawing of the proposed bamboo framework

The building afford a high degree of seismic resistance while calling for only modest additions in terms of modern technology, without the need to modify the traditional techniques and materials. The procedures for execution are moreover easily explained and disseminated throughout the various segments of the population, thereby simplifying maintenance and enabling replication of the techniques for other applications.

3. THE COMMUNICATIVE SIDE

3.1. Principles and tasks.

The first issue to address is the cultural differences between those explaining the structural projects and the local population.
It is well known the conventions for verbal communication can vary substantially from one culture to another, even in the most fundamental ways (see, for example, Hymes, 1974). For instance, the so-called “no gap, no overlap” rule for conversational turn-taking of middle-class white Americans (Schegloff, 1972) contrasts with the rule of many native American Indians, for whom it is common for a person to wait several minutes in silence before answering a question or taking a speaking turn (Saville-Troike, 1982).
Therefore, as a first step, we are going to study the basic conversational rules of the local speech community with the aim of identifying those that work best for our intent.
Nevertheless, we are aware that a speech community is never homogeneous (see for example: Berruto, 1977, 1980; Fasold, 1990; Milroy, 1992; Labov, 1966; Romaine, 1982). Moreover, what may be considered a single language may in fact represent a diasystem, that is to say, several systems co-occuring in the competence of a speaker, which may emerge during speech acts in different ways.
The communication modes adopted must therefore vary depending on the socio-cultural level of the hearer, the speech situation and the communicative intent.

3.2. The three socio-linguistic levels.

We have identified three sociocultural layers into the local population. The first corresponds to literate city-dwellers, who conduct activities within an economic framework comparable to that of developed nations (office workers, civil servants, teachers, businesspersons, etc.), and are able to interpret linguistic codes analogous to those widespread in modern society. The project is therefore presented through written texts, technical drawings, architectural blueprints, descriptive reports of the techniques,

materials and manufactured articles to be used, as well as estimates of the materials and work necessary for completion. This level is presumably aimed particularly at technicians who will be involved in the execution and co-ordination of the project and the final inspection and certification of the completed work, as well as at political officials and administrators representing the territorial authorities responsible for the planning and oversight of public works.
A second population segment consists of individuals with only basic reading skills (primary school level), coming from socio-cultural contexts typical of agrarian societies. They live for the most part in small rural communities along main roads (linear villages) and work in the local economies based on plantation farming, lumbering and livestock raising. The project is therefore presented through brochures and booklets with rather simple, very explicit drawings, accompanied by simple captions and explanations. The presentation follows the style of comic strips or picture books to provide the high degree of communication, typical of advertising or educational materials and reduce the level of conceptual abstraction of both imagery and words. This level is aimed at groups of workers, foremen and heads of families who have a stake in the decision process and must therefore be kept aware of and involved in the design choices and be able "to read" the project, put it into practice and check its correct execution, while also receiving information on the building's constituent components, their quantities and the costs involved.
The third and last segment consists of non-readers living mainly in tribal communities and involved in the so-called subsistence economies based on trade and barter. Their main links to so-called civil society are through the heads of families or tribes and their "elders" or via the mediation of the staff of religious missions or ONLUS personnel. In this case, the project will be explained verbally, by educated locals who have been expressly prepared beforehand. Their work will be facilitated by printed presentations with various series of highly graphic images (without text) to illustrate the main stages of the work of constructing the building. Such illustrations can be likened to classic "storyboards", and may be supplemented by scale model buildings with removable roofs, to show the interior, and which can also be at least partially disassembled to illustrate the main stages of construction. The communication strategies to be adopted here can be likened to children's building sets and the aim is to make the project easier to assimilate by the builder/end-user of the building via the familiar setting of "talks around the fire". As the community is unable to hire outside contractors, building will be made by the inhabitants themselves, by organising a work force selected from within the community itself. Respect for already existing hierarchies should be able to ensure that the social dynamics active within the community naturally lead to the choice of who supervises and illustrates the project, who does the actual building and who is responsible for checking the work.

* * *

At a first glance, the latter two communicative levels may seem simpler. On the contrary, they call for important subtle refinements. Languages work as filters or guides to external reality, not only as means of communication: they do not convey a fixed reality but encode an interpreted reality. Thus, in the latter two communicative levels, where the support of language systems is greatly reduced, the issue of the differences in the cognitive representation of events and things emerges most substantially. The cognitive representation of such tools, objects and actions called for in the project may vary substantially from one culture to another and among communities within the same cultural frame. It is very difficult to avoid interpreting other community representation of the world in terms of their own cultural images. Our aim is to investigate the main ways in which the concepts and notions we need to communicate are represented, with the aim of creating short texts, drawings and pictures that work best for our intent. To this end, we plan to study local languages and dialects (at the most basic level possible) and to stand side by side with the locals to understand their experience of the events and situations as they unfold.

3.3. Strategies for a linguistic approach.

The World Housing Encyclopedia, with its vast repertory of traditional constructions in seismic areas, contains a number of reports on similar experiences. From these it emerges that populations with similar climatic, cultural and materials provisioning conditions, also show a tendency to adopt similar building systems, despite never having had any cultural exchanges at all. Thus, more "evolved" societies in similar climates can serve as guides to their less evolved counterparts elsewhere. One noteworthy example is Latin America, where bamboo technology (in particular, Guadua) is particularly well developed and could be exported to the countries of sub-Saharan Africa. Also in Latin America there are cases of popular manuals on techniques for making and using Adobe, that is, sun-baked clay and straw blocks. These represent invaluable examples for promoting the spread of some

construction techniques already present in Africa (Stabilized Soil Blocks), which have to date been hindered, probably not by cost, but by the lack of strategies for training local populations in their use.

* * *

Another issue to be considered is the likelihood that during execution of the project situations will arise in which it will be necessary to give orders and advice or make suggestions. The norms of such speech acts vary from community to community. Therefore, we intend to investigate the language and cultural conventions for giving orders/advice and making requests that are most widespread in the communities where we are disseminating the project. The ultimate aim is to optimize communications in order to guarantee the greatest benefit for the local populations.

4. PERSPECTIVES

By combining the results of technical studies on low-cost constructions with well deliberated communicative strategies for involving and informing the various segments of the population (political decision-making circles, local economic community, rural and tribal communities), we hope to promote lasting improvements in the housing and social conditions of developing populations. In this sense, the methods illustrated here may constitute a first step, not only to the building of further, sorely needed structures (school, health centre, homes), but to providing a developing community with a valuable store of technical and cultural know-how to make their own.

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