Pakistan Case Study
Bamboo Construction: Low Carbon and Disaster Resilient Alternative

Background and Context

Today, the construction industry is one of the major culprits behind the lack of environmental sustainability, particularly due to its excessive and irresponsible use of high carbon emitting material such as concrete, steel and brick. It is a well-known fact that the production of every ton of cement results in an emission of at least one ton of CO_2 and similarly, the production of every ton of steel releases over two tons of CO_2 in the atmosphere[1]. Other than the extremely high cost of emissions, there are several embedded costs of mining, which also present potential hazards to the environment[2]. Due to these grave issues, the status of public health, the quality of urban life and the services provided to the society are degrading day by day in Pakistan. This case study is a humble attempt in arousing people's interest in research and development of indigenous and traditional construction material, as an alternative to cement, steel and bricks. It will present bamboo as one versatile alternative to steel reinforcement, roofing etc, based on the work done by organizations in Pakistan.

This case study will illustrate the architectural, structural, environmental and technical performance of bamboo as a low carbon and disaster resilient alternative to conventionally used material such as steel, cement and bricks. It will present the construction process and discuss the various difficulties encountered during the building life cycle by Heritage Foundation - an organization pioneering the work on bamboo construction in Pakistan via their Green Karavan Ghar initiative.

The Heritage Foundation, based in Karachi, was founded in 1980 by Pakistan's first female licensed architect; Yasmeen Lari. Its mission is to document and preserve the historic built environment of Pakistan. They began the Green Karavan Ghar initiative in Swat constructing 270 units in 17 village clusters. This project entails the building of low cost, low carbon houses consisting of one room, a veranda, a kitchenette, W.C. and bath using sustainable materials i.e. bamboo, mud, lime and stone. With support from Architecture for Humanity, this programme was extended to Sindh, more specifically to a village called Darya Khan Shaikh in the district of Khairpur. There it was used as a demonstration project employing indigenous materials that are not only low carbon but also responsible for making structures more disaster resilient.

[1] Mahzuz et al. *Performance evaluation of bamboo with mortar and concrete.* Journal of Engineering and Technology Research Vol. 3(12), pp. 342 - 350. 2011

[2] Adhikari, Ervin and Bhupendra Chang. *Preparation of bamboo reinforced cement composite slab.* ABARI Adobe and Bamboo Research Institute. November 2012.

Heritage and the evolution of the Green Karavan Ghar

The first emergency shelters that became known as Karavan Ghar were designed by Yasmeen Lari for those affected by the Earthquake in 2005. During 2005-2006 over 1150 units were built in 75 hamlets in Hazara, and another 300 were built by a Japanese NGO called NICCO in Kashmir[3]. The design utilized material such as stone and wood from the debris of collapsed houses, along with the use of lime (instead of cement) in mortars, with provision for bond stones, galvanized iron sheets in corners and horizontal bracing in stone masonry walls[4]. Galvanized iron sheet roofs were used due to the terrible experience that people had had with mud roofs collapsing during the earthquake.

While HERITAGE was studying local techniques of construction, the value of *dhijji* (cross bracing) became clear as an effective seismic resistant structural technique. From 2007 onwards, Lari decided to test this technique in small structures such as bathrooms for executive accommodation at the Heritage Foundation Base Camp in Hazara, and later on extended it to household kitchens and almost 140 household bathrooms that were built in Kodar villages in the Siran Valley[5].

By 2007, it had also become clear to them that the galvanized iron sheets that were being used had been playing havoc with the environment and must be discouraged. The local technique of mud layers over wooden planks was considered to be far more suitable to the mountainous environment. Also, the application of lime and mud layers on roofs provided a weather resistant roof. From then on, all construction by Heritage Foundation began utilizing lime-mud roofs instead of the iron sheets and several structures were built with this technique at the base camp.[6]

With the mission of low cost, low carbon construction intact, eventually HERITAGE also tried to reduce the use of wood in construction. By 2009, sufficient research had been done on mud mortars and mixes to replace the high carbon emitting material. This was also around the same time that Yasmeen Lari designed the first bamboo structure for community kitchens. The speed (3 days of construction) and the insulation value of the combination of lime and mud (8-10 degree temperature difference) was extraordinary. Therefore, it was decided then to pursue the path of construction without any of the high carbon emitting material, such as wood, cement or steel.

This step by step reduction and replacement of high carbon emitting material with greener material is highly commendable in Pakistan, where the introduction of new, unconventional alternatives is faced with resistance. HERITAGE continued to better their plans, designs and material employed via experimentation and research till they arrived at the Green Karavan Ghar models of all-bamboo construction. This technique of construction was tried out when the 2010 floods struck Pakistan. The first project undertaken was in Swat where 300 Green Karavan Ghar were constructed in remote mountainous areas from October 2010 to February 2011. Also, over a 100 Green KaravanGhar were also built in the katcha area (the perennially flooded area) in Khairpur.

[3] http://www.heritagefoundationpak.org/mi/7/Sustainable-Green-Construction

[4] http://www.heritagefoundationpak.org/mi/7/Sustainable-Green-Construction

[5] http://www.heritagefoundationpak.org/mi/7/Sustainable-Green-Construction

[6] http://www.heritagefoundationpak.org/mi/7/Sustainable-Green-Construction

HERITAGE Foundation has not shied away from innovating with green construction. They constructed a two-storey floating bamboo structure on stilts, as women centres and eventually even as schools and health facilities. These structures have endured the 2011 floods, providing refuge to the community on the upper level while the waters flowed through the stilts - proving that such green structures are not only environmentally friendly, but disaster resilient as well.

Advantages

Other than the fact that HERITAGE has been pushing for the use of renewable, low carbon and sustainable material, there are also several other advantages of such green construction. The project managers and field officers attest to the fact that because such initiatives are encouraging the streamlining of indigenous, locally produced material, there has been a significant economic regeneration within the select communities. Some projects have assigned duties and responsibilities to specific trained members of the community, who are then given an adequate compensation. This aids individuals in earning their livelihoods, along with promoting green construction and building shelters.

Furthermore, with the use of mud and bamboo, people are able to construct their own houses and produce the material that is used, incurring little or no labour cost considerably bringing down the cost of construction. The main material i.e. the clay soil, is available in abundance and free of any cost what so ever. It can either be used as layers of mud or sun dried brick, both of which can be made by families themselves. In the same way, the bamboo used in the Green Karavan Ghar is also a fast growing reed, and is widely available in the country at a reasonable cost.

Also, such low carbon construction employing indigenous material actively involves the people and ensures that the women are able to continue to contribute in home-making, making each structure personalized. Other than the ownership and pride that this system flourishes, it also trains the community and makes them aware of the different ways various materials are employed in construction, and teaches them the best methods for achieving low carbon, green construction. This is probably the most long term benefit that comes out of such an endeavor - the education of the people with regard to low cost, low carbon construction.

Bamboo: Structural design and environmental assessments

In Pakistan building materials are commonly selected purely for their functional and financial requirements, paying absolutely no heed to the issue of sustainability or the environmental load of building materials. This is a rather grim scenario because the building industry is causing a considerable amount of the annual environmental damage. According to the World Bank, the CO^2 emissions from manufacturing industries and construction in Pakistan was reported at 43.35 (million metric tons) in 2008.[7]

Therefore it becomes absolutely necessary to look for and encourage environmentally benign materials such as bamboo. Bamboo is a fast growing renewable material with a simple production process. Also, as this study highlights, it has also proven to be a sustainable and strong alternative for more traditional

[7] http://www.tradingeconomics.com/pakistan/co2-emissions-kt-wb-data.html

structural materials, such as concrete, steel and timber[3] [4] [5]. P. Van der Lugt writes, in his environmental assessment of bamboo:

> *"Bamboo has a very efficient natural structural design; because of the hollowness and the fibers in longitudinal direction, less material mass is needed than in case of materials with a massive section, e.g., timber. In terms of load-bearing mass, as with all tubular elements, bamboo functions as an I-shaped cross-section, in each direction it is loaded, whereas other cross-sections are most efficient in one or two directions"*

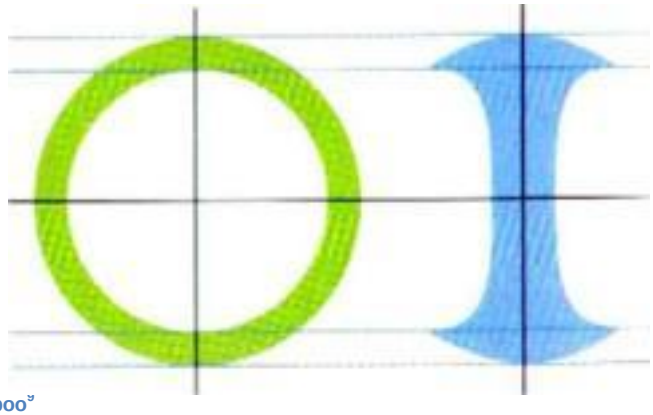

Figure 1 Cross Section of Bamboo[7]

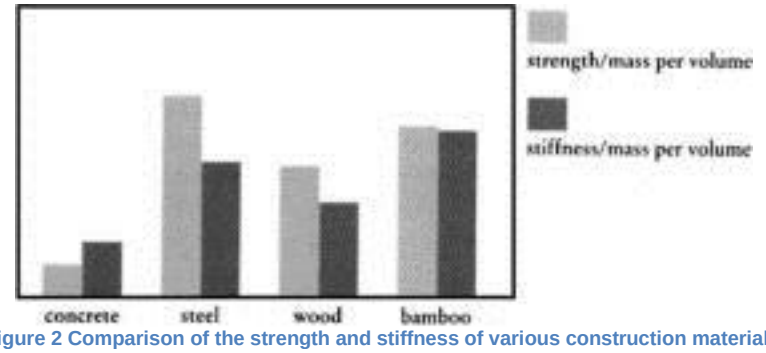

Figure 2 Comparison of the strength and stiffness of various construction material[10]

As the figures, and earlier environmental assessments suggest, bamboo is a unique construction material - in that it is strong in both tension and compression. While tensile strength remains the same throughout the age of the bamboo plant, compressive strength increases as it gets older.[6]

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[3] P. van der Lugt, A.A.J.F. van den Dobbelsteen. *An environmental, economic and practical assessment of bamboo as a building material for supporting structures.* Construction and Building Materials. 2005.

[4] P. van der Lugt, A.A.J.F. van den Dobbelsteen. *An environmental, economic and practical assessment of bamboo as a building material for supporting structures.* Construction and Building Materials. 2005.

[5] P. van der Lugt, A.A.J.F. van den Dobbelsteen. *An environmental, economic and practical assessment of bamboo as a building material for supporting structures.* Construction and Building Materials. 2005.

[6] Cassandra Adams. *Bamboo Architecture and Construction with Oscar Hidalgo.* 1998

[7] http://www.tradingeconomics.com/pakistan/co2-emissions-kt-wb-data.html

Limitations: Material, Social and Institutional.

There are certain limitations of the use of bamboo in construction as well. The starchy interior is attractive to insects, therefore making it immune to fungus and insect infestations. Construction companies and organizations must be wary of this particular vulnerability, and it is imperative that bamboo roofs/walls are treated to extend their longevity. A boric acid/ borax solution is used to preclude such infestations and corrosion. HERITAGE Foundation uses lime for protection.

Many studies and researches have been done to determine the feasibility of using bamboo to reinforce concrete, and they emphasize its strength and resilience. The problem is, however, that bamboo soaks up the water in the concrete, causing it to swell then shrink, the process of which can break the concrete. In addition, adhesion between the bamboo and the concrete is poor. Though it has not yet been done in Pakistan, in some places of South East Asia, people have experimented with the material, using braided bamboo as reinforcement[11] [7]. Though this is extremely time consuming, it has been known to be an effective solution where employed.

Another major problem is that in many places bamboo is disappearing, just like our world forest resources. In Brazil there were 85,000 sq km of bamboo in 1976, while in 1983 there were only 32,000 sq km. It is feared that within a decade all bamboo in Brazil will be gone. In the same way, bamboo is not readily and easily available in Pakistan. If its usage increases considerably in the country, there will not be enough supply to cope with the demand.

The biggest problem affecting the adoption of bamboo architecture in the rural areas of Pakistan is the social and cultural associations with the material. There is a skewed perception in the minds of the people that bamboo is "poor people's" housing, and thus many are reluctant in using it in their homes - despite the several advantages.

Conclusion

As mentioned, construction in recent years has been challenging the sustainability of the natural environment. Due to the extensive use of material such as concrete and steel, the construction industry has developed several complex structures and industries that have made it impossible to cut down on or disband the usage of such material. Alternative construction technologies, material, energy efficiency, sustainable design concepts and even non technical aspects such as economics are totally lost from the horizon of the construction industry. In this context, there is urgent necessity for the development of alternative material technology ensuring durability and sustainability at the same time. Bamboo is one of the most popular indigenous and traditional building materials proven as a potential alternative, assuring quality, durability and spatial needs.

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[7] Cassandra Adams. *Bamboo Architecture and Construction with Oscar Hidalgo.* 1998
http://www.networkearth.org/naturalbuilding/bamboo.html

Many research and studies are being carried out to establish the durability of bamboo reinforcement with improved bonding capability of bamboo reinforcing bars. Several results around the world also show that bamboo can satisfactorily substitute steel structures. With reference to these types of studies there is also a need of updating national building codes especially in the case of developing countries like Nepal[13]

The same holds true for Pakistan as well. There is an urgent need for authorities to recognize the environmentally destructive monopoly of cement and brick in the construction industry, and actively work towards breaking this hold. Foundations such as HERITAGE, supported by donors such as UNHABITAT and DFID are making their own contribution in introducing these indigenous technologies to communities, making them aware of their advantages and using development forums to discuss these issues. However, there needs to be an institutionalized, collective effort made to bring these materials, technology into housing policies, instructional guidelines etc for mainstream and widespread usage. There is a glaring lack of any kind of academic and research work on low carbon construction in Pakistan. There needs to be a provision for instructional courses at different levels of university studies and technical schools about the use of prospective indigenous and traditional building materials and technology. This gives a genuine motivation to students and can lead to the enhancement of local conditions of living and a greener construction industry[14]

14 http://www.academia.edu/3719348/Bamboo Architecture
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