COMMUNITY BRIDGE: BUILDING RESILIENCE WITH BAMBOO

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Abstract: Situated on riverbanks, three communities of Matina Crossing Federation (*Matina Fed*) in Davao City, Mindanao have to rely on bamboo makeshift bridges for their access to the main street. The makeshift bridge is unsafe and flushed away each time the river floods. Nevertheless, the municipality was reluctant to replace the bridge due to the informal status of residents' land tenure. On November 2009 *Matina Fed* expressed their wish for a replacement bridge and started a savings group with guidance from the Homeless People's Federation Philippines Inc. (HPFPI). During a design workshop in January 2010 the challenge was shared with "community architects" from countries in the region. The replacement bridge will also be bamboo, but new technologies will be incorporated. Further, the Matina Crossing Federation took the lead in activities related to the project; on administration, materials procurement, mobilization for labor and food, and on hosting related workshops. In April 2011 two Indonesian bamboo carpenters stayed in the community and led the construction of the bridge. In one month the entire bamboo structure is completed. Another month was needed for roofing and mortar injection. Finally, three-inch thick concrete was poured for the floor. The 23 m span bamboo bridge was completed with cost of PHP 450.000 (around USD 10.000) that is paid by loans. In June 2011 a devastating flash-flood carried debris which battered the bridge. The bridge survived, and even served as a safety platform. The bridge continues to serve the communities for more than two years up to the time this is written.

Key words: bamboo, alternative, riverside, infrastructure, participation

1 THE PEOPLE'S PROCESS

1.1 A Community's Struggle

Situated behind the busy Matina Crossing in the southern part of Davao City, Philippines, is a 9.8 Ha parcel of land with an absentee landowner. Known as the Arroyo Compound, the land has been settled for around forty years and developed into an informal settlement. Crisscrossed by Matina River, some makeshift bridges serve as the main access to Arroyo Compound. Nevertheless, Arroyo Compound is home to, among others, four community associations, namely, *Saint Paul, Saint Benedict, Matina Balusong,* and *Shalom.* The four communities form the Matina Crossing Federation (*Matina Fed*). In late 2009, *Matina Fed* represents 488 families, which consist of food vendors, drivers, construction workers, masseurs, shop-keepers, security-staff, and other urban workers.

Since November 2009 *Matina Fed* is a member of the Homeless People's Federation Philippines, Inc. (HPFPI), a *people's organization* which aims to fulfill housing needs and tenure security of its members. *Matina Fed* took initiative to upgrade their access bridge; the need for which was expressed during a participatory design workshop hosted by the community in February 2010. Further, *Matina Fed* members take the lead in all activities related to their bridge project, including processing papers, permissions, and requests to the municipality; procuring materials; mobilizing community people to provide volunteers and food during preparation and construction; and undertaking workshop preparations in the community.

On December 2010 the community faced a demolition threat that was purported by a claimant of the land. The demolition did not occur and was dubbed as illegal. In fact, community members managed to respond quickly and halt the process. Despite the rising insecurity, the community was eager to carry on with the bamboo bridge project. Soon, the construction of the bridge's foundation began. The savings groups took an initial loan of PHP 300.000 (around USD 6.500) that was later re-negotiated to PHP 450.000 (around USD 10.000) along the course of the project. The loan is shouldered by 145 households, the active savings members within *Matina Fed* (Orendain and Co: 2011b).

1.2 The Civil Society Partnership

HPFPI is a network of 200 urban poor community associations and saving groups across the regions of Luzon, the Visayas, and Mindanao. Since its inception in 2002 until now HPFPI have spread to 14 cities and 16 municipalities country-wide. The NGO Philippine Action for Community-led Shelter Initiative (PACSII) is providing managerial and operational supports for HPFPI, while the Technical Assistance Movement for People and Environment, Inc. (TAMPEI) hosts young professionals and architects interested in HPFPI's housing initiatives. HPFPI, PACSII, and TAMPEI are collectively referred to as the *Philippine Alliance* (HPFPI-PACSII: 2010).

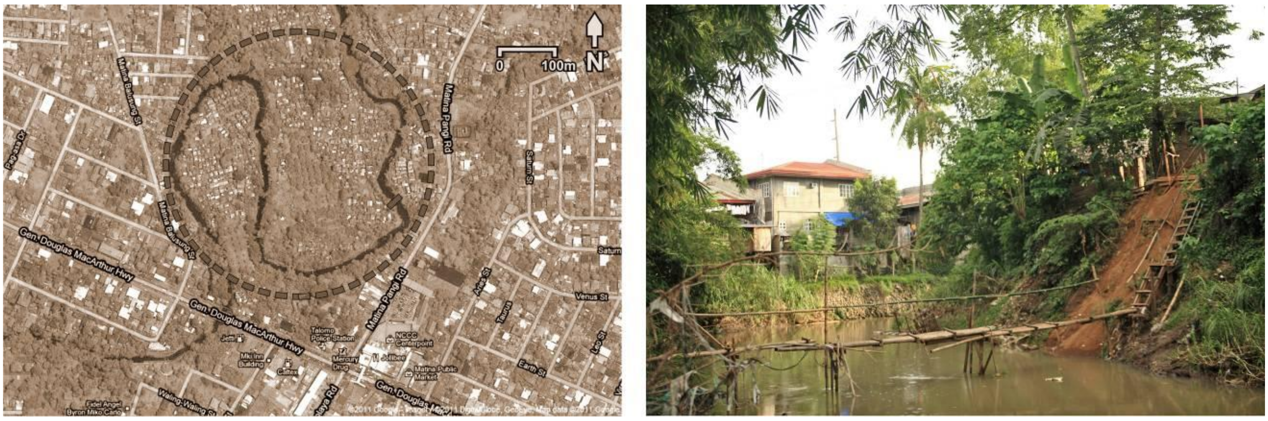

Figure 1 Map of the Matina River (left) and the makeshift bridge prior to development (right)

Local academic institutions also took part in the Matina bridge project. The Department of Engineering of the University of Mindanao provided technical engineering computations in load and structural analyses of bamboo bridge frames and assistance in foundation works. University of the Philippines Mindanao gave input in the bridge concept design, design properties and assistance in workshop preparation. Another link with the academic world is through a course paper submitted to HDM-Lund (Fitrianto: 2011). Actually, the work also caught the attention of a bamboo engineer-researcher in Coventry, UK but due to time constrains there was no academic research conducted in parallel with the project.

In the regional network, the *Philippine Alliance* is affiliated with the Asian Coalition for Housing Rights (ACHR). ACHR is founded on 1988 as a common platform for Asian housing activists and community workers to facilitate exchanges and collaboration (ACHR: 2010). ACHR provides financing and technical assistance through the program of Asian Coalition for Community Action (ACCA) that was first launched in 2009. The bamboo bridge project is part of ACCA, a community-driven upgrading based on women's savings groups, implemented across Asia through local organizations (Papeleras et al.: 2012).

Alongside ACHR's regional activities on housing with the urban poor communities in Asia there are architects and professionals that have been involved through provision of technical assistance. "Community architects" is a common denomination though the individuals vary from community builders, artisans, architecture students, professors, NGO professionals, architects, and other professionals (Luansang et al.: 2012). In June 2010 the Community Architects Network (CAN) was established in Chiang Mai, Thailand (CAN: 2013).

Through CAN, the bamboo advocates of *Sahabat Bambu* (SaBa) from Yogyakarta, Indonesia were invited to collaborate on the bridge project. SaBa mainly provided technical guidance in the design and construction of the Matina bridge and provided facilitation in the training workshops. The author was in charge of the project as a community architect on behalf of both CAN and SaBa.

Figure 2 The bamboo belt along the equator (left), the Filipino folklore of *si malakas at si maganda* (right)

2 BAMBOO: STRONG AND BEAUTIFUL

One of the *Philippine Alliance*'s efforts in its development initiatives is to explore alternative building technologies and materials that are low cost, community friendly, environmentally sound, and locally available; i.e. technologies that can easily be managed, handled-by, and transferred to the communities. Thus, bamboo came as one of the interests of the Alliance.

2.1 Bamboo in Nature

Bamboo belongs to the family of grass (*Gramineae*) that grows around the equator belt both in the tropics and the sub-tropics. Geographically, bamboo is found in areas up to 47^{o} north in the island of Sakhalin and 46^{o} south in Argentinean Andes (Ohrnberger: 1999). There are more than 1.200 *species* of bamboo that have been identified and categorized into 90 *genera* (INBAR-FAO: 2007). In common among the family of grasses, bamboo sustains adverse soil. In nature, bamboo stands can be found from coastal land up to altitudes of 4.200 m in northern Yunnan and 4.500 m in the Andes of Chile.

Bamboo is also recognized by its type of root systems called *rhizome*. In this regard, there are three kinds of bamboo. *First*, the *monopodial* bamboo where shoots grow distanced from one to another, which is also called *running bamboo*. *Running bamboo* is found in the sub-tropics and they are expansive if given a sympathetic environment; e.g. *Phyllostachys pubescens* that is native to Japan and China. *Second*, the *sympodial* bamboo where shoots appear adjacent to each other thus configures a clump; *clumping bamboo*. Clumping bamboo accounts for the most of the tropical woody bamboo. *Third*, often a combination of both root formations is the *climbing bamboo*, which commonly appears as herbaceous bamboo.

In 4-6 months a bamboo shoot reaches its full height. In a year, branches develop and in another year, leaves completed. From two years on, branchelets develop and leaves are renewed. In three years of age a culm reaches maturity and the peak of its strength; the wall densifies, its silica-rich skin hardens, and its specific gravity increases. A culm remains strong until five years old when strength gradually decreases. As bamboo is vastly diverse in shape and characters, it is advisable to refer to local experience i.e. the local community, when it comes to the question of best use and potentials of each species.

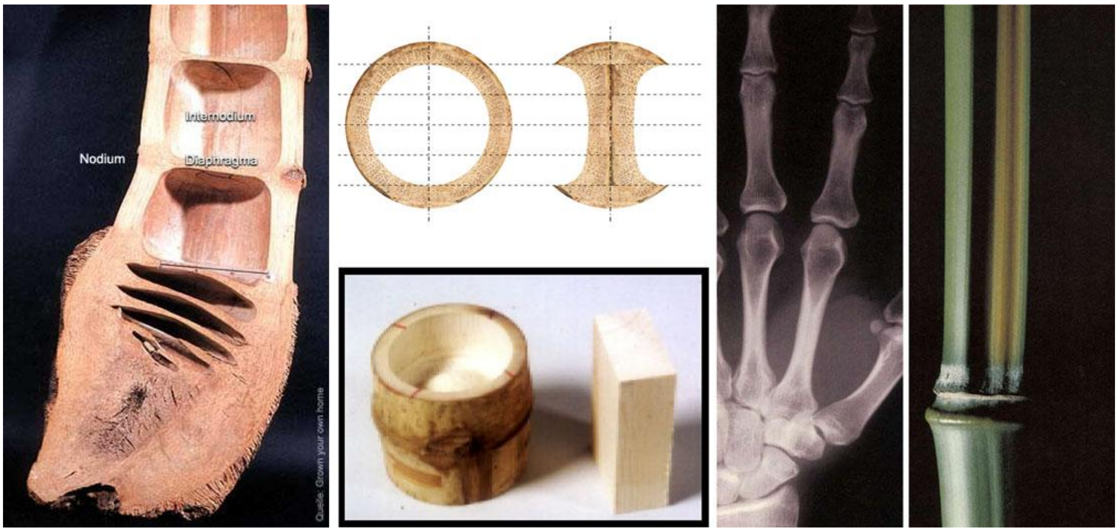

Figure 3 Section of root stem shows telescopic growth of bamboo (left), surface area of bamboo section (bottom center), recomposition of surface area shows how bamboo acts like an I-beam to all directions (top center), identical forms; between bamboo node and human skeleton (right).
Photos from (Janssen: 2000) and (Vélez et al.: 2000)

2.2 Bamboo in Culture

The Filipino folklore of *si malakas at si maganda,* which literally means the strong and the beauty, is about the first couple of human beings descent to the earth after a hummingbird pecked and cracked a giant bamboo. By being strong and beautiful, bamboo presents in many Asian cultures. Bamboo is used extensively from kitchen and household utensils to houses, fences, and bridges. Young bamboo shoot is a source of good nutrition, a common diet found in many Asian cuisines.

2.3 Bamboo in Architecture

Bamboo is among the oldest building materials known to the human race. Nevertheless, some significant achievements happened during the last three decades. This is associated with growing interest in alternative technologies which began in the 1960s. The same period when the urbanization rate was increasing, putting pressure on housing needs in urban areas of the Global South. Experiments in bamboo for building purposes took place in the Philippines (McClure: 1953), but nowhere else as intensely as in Colombia (Hidalgo-López: 2003). In 1999 an earthquake in the Colombian region of Armenia crippled modern structures but people's housing using the vernacular *bahareque* construction survives, hence bringing bamboo to the forefront as safe and reliable building material (Vélez et al.: 2000). However new techniques accumulated, there is still an age-old stigma on bamboo as the poor man's timber.

The equation is slowly changing around the beginning of 21th century when bamboo is used in luxurious projects as the new beauty along with the notion of *green architecture* and *sustainable design*. Among noteworthy projects is the *Greenschool* in Bali, Indonesia and *Ecolodge* resort in Guangdong, China (Meinhold: 2010) (Prince Claus Fund: 2009). From these projects, Colombia-based practitioners such as Jörg Stamm and Simón Vélez became known to the architecture and design community in Asia as leading bamboo innovators. The bamboo news arrived in the Matina community as well, through presentation slides by the community architects.

2.4 Some Technical Aspects

In terms of structural properties, bamboo has good strength in bending, in tension, and in compression if parallel to grain (Trujillo: 2009). It also has excellent strength to weight ratio. An experiment with vascular bundle, the tube-like element which transports moisture in living bamboo, reveals superiority in tension strength of bamboo over steel. However, it is difficult to draw the whole extent of this potential out of the laboratory and the biggest challenge lies around bamboo joinery methods (Arce-Villalobos: 1993). To overcome this, experienced bamboo architect like Simón Vélez lean towards compressive joints in his designs. Bamboo joinery and bamboo preservation have been the main topics which have long grabbed the attentions of many (Dunkelberg et al.: 1985, Janssen: 2000).

3 WORKSHOPS FOR CAPACITY BUILDING

3.1 Bridge Design Workshop

The February 2010 workshop held in Digos City and Davao City involved community leaders, builders, students, academes, and architects aligned with community efforts on housing. On a weekend, *Matina Fed* hosted a participatory design session where participants were divided in groups and asked to design a bridge. Beforehand, presentations on fundamentals or general aspects of bridges were given by engineers and architects from PACSII and SaBa. This was meant to break the norms that a bridge is solely an engineering product under authorship of professionals. The workshop resulted in six designs which were presented and discussed in the forum through modest and beautiful drawings and scale models. The one-and-half day workshop at the community was so lively, bringing a strong sense of ownership to the bridge project. Since then, the community architects maintain a close relationship with *Matina Fed*.

Figure 4 Participatory design workshop; democratizing design process and a medium for engagement

3.2 Subsequent Workshops

Between August 2010 and January 2011 there are mini-workshops on topics of (1) bamboo cultivation and clump management, (2) bamboo treatment, and (3) bamboo house construction held with community members. The series of workshops culminates at the regional workshop of *Bamboo for Sustainable Communities* which is held in January 2011 in Davao City. In the workshop examples of bamboo-based livelihood such as bamboo handicraft and furniture is presented and discussed (Orendain and Co: 2011a). Along with participants from the country-wide network of the *Philippine Alliance* there were community architects from Thailand, Cambodia, Vietnam, and an architect-volunteer from Colombia. The workshop facilitation is led by the Indonesia team, which includes two experienced traditional bamboo carpenters.

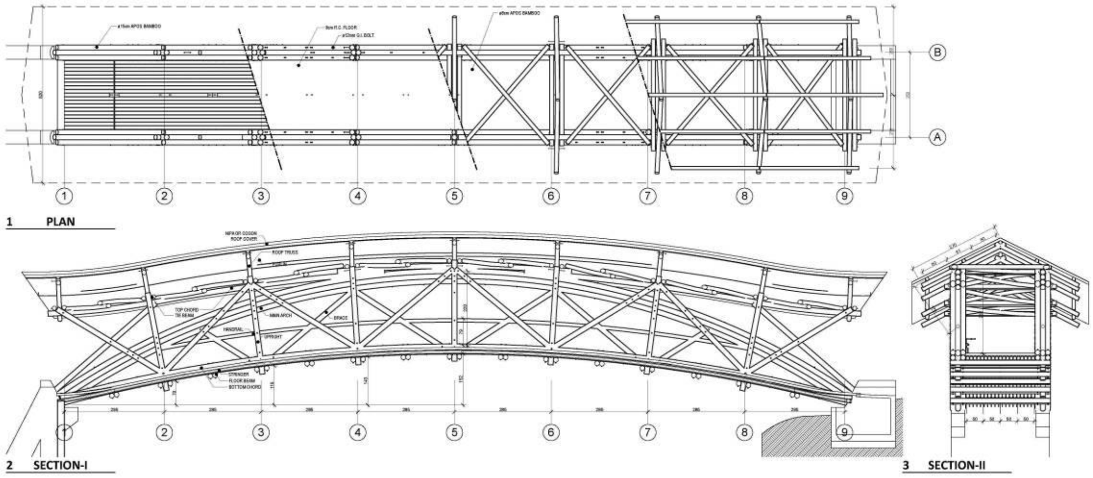

Figure 5 Technical drawings of the Matina community bamboo bridge

4 BRIDGE DESIGN AND BAMBOO TECHNOLOGIES

In October 2010 the architects consolidated the six designs from the community into one; a truss bridge with a center column. However, when the recurring threat of flash floods became apparent during construction of the center foundation in November 2010 the community insisted on a free-span bridge design. This put a fresh challenge to the architects. A new design is needed for the 23 m span between the banks. The first approach was by looking at precedents of modern bamboo bridges, then emailing other bamboo experts and friends. Through their generosity, opinions, suggestions, and help were obtained. It took three months to fully develop the design; a Howe truss pre-tensioned with arches that benefits from the natural curve of the bamboo (Stamm: 2009). A consultation with Jörg Stamm in Bali on March 2011 provides input to the design and concludes the design development.

4.1 Design Modeling

Modeling has long been part of architectural design work stream. Today, computer generated models are commonly used as they are fast and accurate. CAD software with 3D native such as ArchiCAD is very helpful for bamboo design, especially to mitigate collision in complex bamboo arrangements. In the field of engineering, STAAD is among the favorite software familiar to engineering students to analyze space-frame structures like the bridge's design in Matina community. However, since CAD models are merely virtual it needs to be complemented with physical scale models.

To make a scale model, bamboo skewers with section of ø3 mm are available in supermarkets. They are perfect to represent ø12 cm bamboo in 1:40 scale model (Tulay na Kawayan: 2011). Push pins from the stationeries section is used to join the skewers. To insert the pins, holes are made with help of mini-drill; commonly used for electronic chip boards. Indeed, the use of glue in the scale model is intentionally avoided. Thus, the scale model would mimic the steel bolts joinery in reality. When tested with loads the scale model is able to show deformations and failures; provides useful feedback for the design development. Steps of building a scale model are analogous with construction steps of the real bridge. At the end, the scale model is an excellent design communication tool.

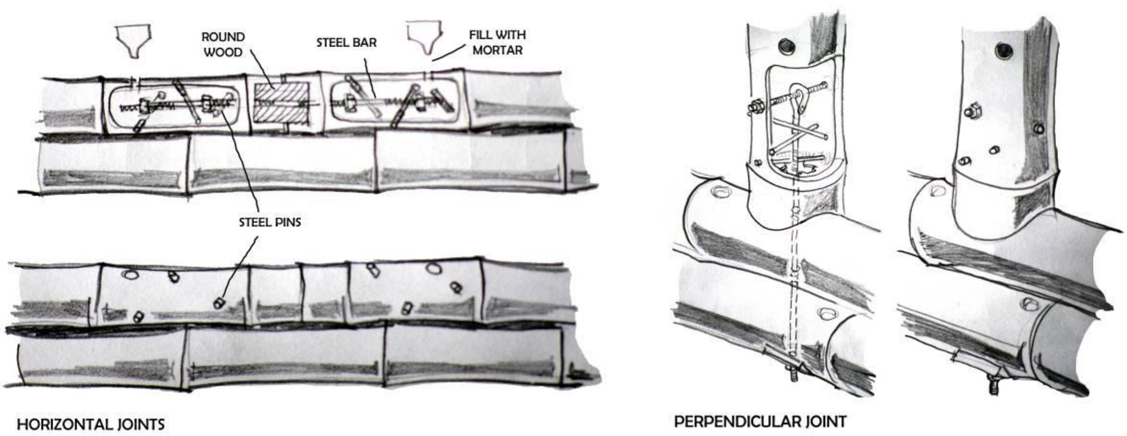

Figure 6 Example of main joineries incorporating steel bolts and pins with mortar filling

4.2 The Species of Bamboo

After a mistake in selection of bamboo, which causes delay in construction schedule, it is assured that the bamboo species to be used for the bridge is the giant bamboo of Southeast Asia that is locally known as *apos* (*Dendrocalamus asper*). The *apos* were purchased at PHP 90 (around USD 2) per culm from non-production clumps on a private mango farm in Serawan, around 10 km west of Toril district, on a moderate slope at the lower part of Mount Apo. While the “mistaken” stock of large but thin-walled *botong* (*Dendrocalamus latiflorus*) is used for the workshop in January 2011. Some remaining *botongs* were used for tertiary members in the bridge along with *tungkan* (*Bambusa blumeana*), another species that is common in the local bamboo market. The three bamboo species mentioned are natives (Roxas: 2010).

Figure 7 Vertical Soak Diffusion (VSD) plant adjacent to the bridge's site (left) and illustrations of the treatment process (right)

4.3 Treatment of Bamboo

If not properly treated, bamboo will not last more than four years. Treatment is imperative in having a permanent bamboo structure. A minimum 25 years lifetime is expected given the bamboo structure is well protected from rain and from humidity that may generate from contact with soil. A treatment facility is constructed at the vicinity of the bridge site consists of 4 m height concrete portals topped with 6 m bamboo cover structure high enough to treat 9 m poles. Through gravity, the Vertical Soak Diffusion (VSD) system is aimed to replace bamboo’s sugary sap with 7% solution of *borax* and *boric acid* (B+B), thus the bamboo is unattractive to pests known as *bukbok* (*Dinoderus minutus*). In Indonesia, VSD system is developed around 2000 by the Environmental Bamboo Foundation (EBF: 2005) and further improvised by SaBa. While there is a general acceptance to B+B as the “least poisonous” substances, a report says prolonged contact and inhalation may harm fertility. Therefore, the use of rubber gloves and masks for workers is suggested.

4.4 The Foundation

In parallel with bridge’s design development and bamboo treatment was the construction of the foundation. The new bridge is located at the same spot with the old one, in a river section with sufficient distance from bends and protected from erosion. A pair of reinforced concrete foundations compensates the 5 m height difference between the banks which is separated by 23 m. The foundation that is designed by Eng. Joeffry Camarista from PACSII would transfer lateral forces from the arched bridge to the ground. The total cost of foundations with community labor was billed around PHP 115.000 (USD 2.500).

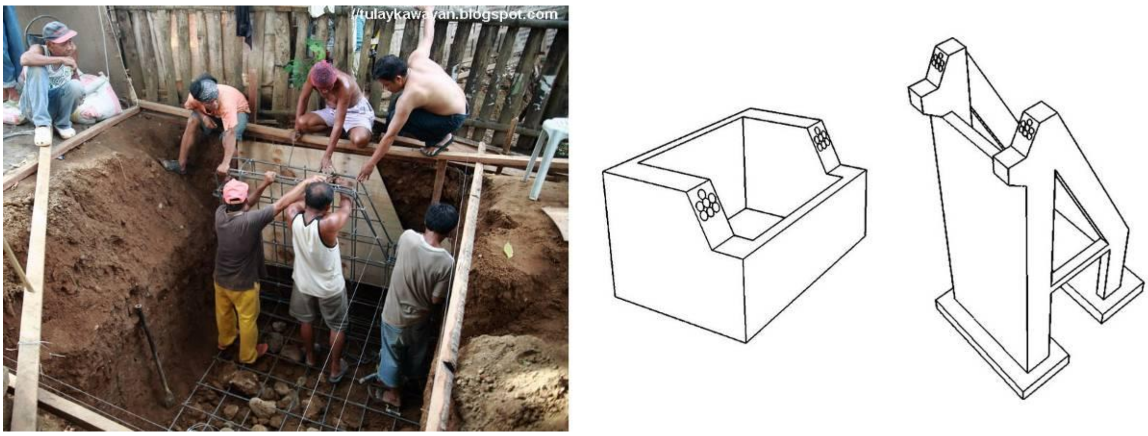

Figure 8 The foundation set

5 CONSTRUCTION AND NATURE'S TEST

5.1 Construction of Bamboo Components

With presence of two Indonesian bamboo carpenters, April 2011 was spent on construction of the entire bamboo structure. For convenience, the frame assembly location is set right next to the foundation. Not an ample area for work but just big enough to fit the frames and 5-10 workers. Six days is spent for each frame, the bridge's main carrier. The third week saw the installment of the pair of frames onto the foundation using a false bridge/scaffolding, bamboo rolls, three chain-blocks, hung to adjacent trees, and all of the men in the community. Indeed, the bridge is designed as "handmade" as there is no access for heavy equipment to the site. The fourth week is spent to install floor trusses, roof trusses, triangles, and diagonals. The whole bamboo structure is spray-washed and rubbed with sand until clean then coated with plastic varnish to protect the bamboo from sun. Intense sun exposure may accelerate drying of bamboo and spur hairline cracks in bamboo. A video documentation showing the construction process is available in *Youtube* (Kampung Kota: 2012).

Figure 9 Men push a completed frame to the foundation (left), sand-cement mortar injection on main joints (right)

5.2 Roofing and Mortar Injection

In May 2011 the work continues with roofing and flooring of the bridge. For the roof cover *nipa* leaves (*Nypa fruticans*) that is a vernacular material for people in area is used. A good bamboo design requires generous roof overhangs; a thorough protection from rain and ultraviolet light. In preparation for mortar injection on primary joints at the floor level, ø7/8 inches (ø21 mm) hole is drilled in designated bamboo internodes. Cement-sand mortar in ratio of 1:2 is prepared with regulated fluidity that is possible to flow through the holes with help of a plastic cone. It is aimed that the solid mortar would transfer loads between bamboo walls and the steel components; threaded bars, bolts, and pins.

5.3 Flooring

The basic idea of the bridge's floor structure is having a mould for 4 inches-thick concrete shell, which serves as the final finish. Over the floor trusses is ø8-10 cm bamboo stringers arranged to full width. Over the stringers is *amakan* or bamboo mats. A layer of tarpaulin is laid to retain moisture during concrete curing. Above that, steel bars of ø5 - ø7 mm is arranged in 15x15cm grid. Finally, 4 inches-thick of fresh concrete is poured to the floor. This was done in one day through community work and a mobile concrete mixer. The concreting starts from each of bridge's end and finishes at the center. Fresh concrete practically exposes the structure to a uniform load of not less than 9 tons, however there is no deformation recorded. The concrete floor contributes lateral stability to the bridge, provides maximum comfort for passengers, while also anchors the bridge to its foundations. Moreover, concrete surface is a good solution for durability of wear.

5.4 Completion and the Flood of July 27

As the concrete floor cured the bridge is technically completed and by the end of July 2011 a date is chosen for inauguration with plan to invite the city mayor. However, a huge flash-flood on 27 July at midnight swept the community and destroyed many houses. The new bridge was battered by debris that is brought by the flood and endured. In fact, it served as an evacuation platform and lifeline in the aftermath, providing access for emergency response and first aid. The inauguration was postponed until December 23 in the midst of house repair activities in the community.

5.5 Post Occupancy Issues

There is a damage on one floor truss created by debris from the flash flood, but does not compromise the structural integrity of the bridge. During the first three months of usage, the bridge is in close observation. The first three month period is critical as loads search for equilibrium, joints tighten, and the bamboo shrinks due to air-dry process. From observation there is no visible deformation on the bridge. Around one year after, in November 2012, a personal visit to the bridge confirms no problem on immunization of bamboo. Since beginning the bridge is guarded full time. Each pedestrian user is asked for PHP 1 (around 20 cents) contribution per day and PHP 5 for motorcycle/tricycle user per day. This generates income for repayment and maintenance fund; for expenses of regular roof repair and varnish coating. As this is written, the bamboo bridge is already serving Matina community for two years.

Figure 10 Debris brought by July 27 flash flood (left) engulfed the bridge (right), and the concrete floor which seamlessly connects the bridge to its foundation saves the bridge.

6 CONCLUSION

6.1 The Bamboo Renaissance

The beginning of 21st century saw the return of bamboo in architecture. The entire negative stigma is not completely erased, bamboo is on the way to it. In the case of Matina bridge project, bamboo is reintroduced and discussed in a more holistic way; not limited to construction but also including cultivation and its treatment. This aims for a profound new appreciation to the new *but* old material. The Matina communities rediscover bamboo's beauty and strength from the bridge which manifested their determination and hard work. However, another aspect that is certainly of community's concern is the accessibility and affordability of bamboo. There is no guarantee that accessibility and affordability is secured, as much of bamboo clumps grow on private farms. Besides, preservation requires sound management. A good collaboration among various local groups including the authorities remains as one of the key factors in up-scaling and mainstreaming bamboo to benefit communities.

6.2 Social Renewal

There are several learning curves passed through in parallel during the bridge development processes. Lessons learnt not only by the architects but also; by students and academes; by community volunteers on learning their new skills; by community women on project management and on community finance. New relationships were created and existing relationships strengthened. The inter-collaboration and support to each other counts for the success of the Matina bridge project. As an early conclusion, the bamboo bridge of Matina community in Davao City has shown that a reliable, affordable, and sustainable community infrastructure development is possible. The bamboo bridge is now an icon of the community's resilience; their ability to provide the best solution for their own development needs.

Figure 11 The Davao bamboo bridge (left); an affordable and reliable basic infrastructure serves to improve the life of many (right)

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