Generative design and bamboo

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Contents

4 Introduction
6 Site and brief
12 The tools
16 The team
20 Jörg Stamm text (Title TBC)
24 Project 1
30 Project 2
36 Project 3
44 Next steps

Spanish

4 Introduction
6 Site and brief
12 The tools
16 The team
20 Jörg Stamm text (Title TBC)
24 Project 1
30 Project 2
36 Project 3
44 Next steps
Introduction

The UN Sustainable Development Goal 11 (SDG11) requires that by 2030 all require adequate, safe and affordable housing and suggests that the building of sustainable and resilient buildings utilising local materials should be a catalyst for development. In 2014 the percentage of the Panama urban population living in slums was higher than India at 25.8%. Panama’s celebrated building boom, has also affected many which have seen housing made less affordable. Secure resilient housing is key to developing a countries economy and by 2030 if Panama is to achieve SDG 11, and address the need for all for adequate, safe and affordable housing, then architects are going to have to work practically and adventurously with locally available, natural sustainable materials such as bamboo.

Particularly at this critical moment for the environment, our global community, and our ever consuming construction sector, architects need to be active in reducing the cost of design and they have a duty to raise awareness of good practices and promote open source designs of sustainable, adequate buildings which ensure structural and aesthetic integrity [1, 2].

In order to reduce the cost of design, there have been moves by architects to develop a greater synthesis between their current computational design process and materials with natural variability such as bamboo.

Computational design tools allow the architect to visualise ideas and they can be modified and analysed interactively, though this modification can still be time consuming. Parametric software allows us to build on this process and specify relationships among parameters and instantly output versions or iterations of a design, based on associative rules set by the designer [3].

Generative Design and Bamboo was a workshop that looked at this relationship between the naturally variable, and the digital. This course was led by John Naylor, Cesar Cheng and Jorg Stamm, and took place at Geoversity, Panama City in October 2019.

Participants on the course were introduced to bamboo and a selection of 3D modelling software and these tools were then applied through a design process which addressed a brief developed between the local community of Brooklincito, Panama City, and the former Vice Mayor of the District of Panama, Raisa Banfield, to design a covered community space.

After an initial form finding exercise through physical model making with bamboo sticks, these concepts will then be modelled in the computer by participants, whilst learning Rhinoceros 3D. The design was then re-imagined as a series of relationships and interactions amongst various parameters. By learning the visual programming environment of Grasshopper, scripts were developed which would then respond to the variable inputs.

The wider aim of the course is to increase local design capacity and an architectural tool set. In applying these to underutilised locally available sustainable materials, will hopefully be a first step to build capacity in the construction sector of Panama, and apply this knowledge to the needs of those who need resilient, sustainable and adequate buildings.

Site and design brief

The design process focussed attention on one particular site, Brooklincito (Little Brooklyn) in Panama City. Participants designed a community hub for open land in the heart of Brooklincito adjacent to a creek and an open green space which is currently used by the local residents and threatened with destruction in the pursuit of ‘development’. The community hub was to create a sheltered space and include full-culm bamboo, however site observations and community input were used to define the activities of a design.

At the heart of the project is an acceptance that the current materials used in construction for the clear majority of buildings are not adequate for the climate or sustainable material palette of Panama. This project should be seen in wider terms as a means of being able to integrate lightweight materials such as bamboo into a typology which can have the widest possible impact. By specifying bamboo, this project is intended to create vision for bamboo’s role in an urban context and engender this material to the Panama construction sector.
Located in busy commercial and densely populated area, Brooklincito is one of the oldest informal settlements in Panama City.

In 2017 the residents were confronted with eviction notices from a government intent on demolishing their homes and cutting down old growth trees to make way for high rise development of subsidized apartment housing.

The residents organized, first to save their beautiful from the chainsaws and then to insist on being consulted and included in the planning process.

With support from then Vice Mayor Raisa Banfield, they envisioned an architectural plan that incorporated their public gathering and green spaces.

It was out of dialogue with Raisa and with other members of Geoversity Design that a proposal emerged to undertake an experiment in natural design with natural materials.

Various site visits and Geoversity’s Course on Generative Design resulted in various proposals for bamboo structures as an organic part of its open and public areas.

The residents welcomed the creative ideas for a more environmentally satisfying development. They especially warmed to the designs that would enable informal trade and afford meeting spaces for the whole community and beyond.

The possibility of a bamboo workshop in Brooklincito, will be an unprecedented opportunity for this, until now, forgotten community.

Nathan Gray, Co-Founder, Geoversity Design
The tools

Two pieces of software well known to the architectural profession were used and they are emblematic of a set of tools which use a visual language environment.

Rhinoceros 3D is a three-dimensional computer graphics and computer-aided design software which uses Non-uniform rational basis splines (NURBS), to build geometry as opposed to a polygon mesh-based system.

The second is Grasshopper which is a visual programming environment which runs within the Rhinoceros 3D platform. The main interface for algorithm design in Grasshopper is the node-based editor. Algorithms are scripted by dragging components with inputs and outputs onto a canvas. A collection of components forms an algorithm, and the output of these commands is displayed in the Rhinoceros 3D window.

The process / Spanish
The team

John Osmond Naylor
AA Dip RIBA, Architect

John is a registered UK architect at Grimshaw in London, and PhD researcher at Newcastle University. He completed his AA Diploma at the Architectural Association in 2013, winning the Holloway Prize, the Fosters Prize for Sustainable Infrastructure, and was featured in Dezeen top 10 bamboo projects 2014. John has worked at MAD, Beijing, rare Architects in Paris, and the Singapore University of Technology and Design, on complex projects in the UK, Singapore, Malaysia, China and Haiti. He continues to lead the AA School’s bamboo visiting research programme which attempts to reduce the gap between digital design tools and materials with natural variability such as bamboo. These have taken place in Haiti, Myanmar and now Bandung, Indonesia. John’s ongoing research looks at how architects can advance full-culm bamboo as a material to provide adequate and sustainable urban housing to achieve the UN Sustainable Development Goal 11 by 2030.

César Cheng,
Architect, Suma

César Cheng, architect specialized in urban design, design technologies and digital manufacturing. He received his master’s degree from the Emergent Technologies and Design program, Architectural Association, UK. César has developed research in biomimetic design, alternative materials for construction, and advanced computational design. He has participated in international conferences and published research in academic journals in computer design. He has worked as a designer in international firms in Boston, New York, London, Berlin and Panama. Recently he worked with the team of Suma architects in the development of the POT for Panama City, leading the computer design and data analytics team.

Jörg Stamm,
Builder and Founding Partner, Geoversity Design

Jörg Stamm is widely considered to be one of the most accomplished and skilled master builders in bamboo in the world. Following a career as a furniture maker and structural carpenter in his home country of Germany, he spent the last 25 years working with several of the great designers in bamboo, including the Colombian architect Simon Velez, the founders of the Green School in Bali, Indonesia and the designer Linda Garland, the founder of the Environmental Bamboo Foundation. Inspired by the pioneering work in tensile structures of Frei Otto and grounded in old world post and beam construction, he specializes in fusing European contemporary design and traditional bamboo carpentry. Among Jörg’s most well-known accomplishments are the design and building of covered bridge spans, up to 30 meters long, in Colombia and Bali; the iconic Simon Velez-designed pavilion for Colombia in the 2000 World Expo in Hanover, Germany; and the Orchid Pavilion at the McKee Botanical Garden in Vero Beach, Florida, the first officially recognized bamboo pavilion in USA. Jörg has founded or helped start several bamboo-related companies and organized numerous introductory and advanced training programs in bamboo construction in numerous countries in Asia, Latin America and Africa, including The Green School of Bali, Indonesia.

Anand Devarajan,
Principal, Anand Devarajan Architects, Inc

Anand Devarajan holds a Masters of Architecture from Yale University, where he was Frank Gehry’s student while Gehry was the visiting Davenport Professor of Architecture in 1999. After joining Gehry Partners he has, since 2002, worked directly with Gehry, collaborating on the designs of a number of projects in the office. His international project experience includes a multitude of building types and scales ranging from museums and other cultural projects to commercial, residential and larger-scale, mixed-use developments. A co-founder of Geoversity Design, he continues as a Gehry Partners advisor while now heading up his own company of architects also based in Santa Monica, California.

Raisa Banfield,
Ex-Vice Mayor of Panama City

Raisa Banfield is the former Vice Mayor of the District of Panama. She is an architect by profession and has devoted many years to environmental protection. She feels the social economic development of Panama
should be compatible with ecological sustainability. She was the Executive Director of CIAM (Center for Environmental Impact) from 2007 – 2010. She is the current President of Sustainable Panama (PASOS), an organization that she founded in 2010 to promote alternative solutions. She was co-founder of Alianza Pro-Ciudad (2010), Pro-Defense Committee of Camino de Cruces Park and other community organizations; and Coordinator and Producer of the television program Nuestro Planeta (2010) a program on deals diverse environmental topics. She founded the architecture and design firm RGB S.A. (1994–2007). She holds a degree in Architecture from the University of Panama (1993). Now, Raisa is part of Geoversity Design.
Geoversity Design is a growing circle of builders, designers, scientists and artists teaming up to model built environments and artistic expression that are in harmony with nature and that ultimately reconnect us with nature. We heed the natural lines of waves and mountains; we work into our designs the richly textured, crooked, curvy and rugged qualities of wood, bamboo, rock and nature’s many other building and artistic materials.

Nature has no straight lines. Over my 20 years of designing with bamboo—never perfectly straight nor uniform—I’ve sought to develop and teach skills for working with a material that is irregular and asymmetrical. Form follows function and by working with the curving lines of bamboo we can express and guide the flow or forces within the structures. The parametric and generative design tools that John Naylor, with César Chang’s assistance, are teaching us to use represent a breakthrough in our ability to work the inherent essence and logic of bamboo and begin to realize its full potential. Combine those tools with a passion for nature and, together, we’ll spark a renaissance in natural design.

Jörg Stamm, Co-Founder, Geoversity Design
Anand Devarajan
Principal, Anand Devarajan Architecture, Inc. and co-founder, Geoversity Design.

Drawing inspiration from the fine and performing arts, technology, and even cuisine, Anand has been a creative force behind some of the modern world’s most iconic structures. In his previous position as a Design Partner at Gehry Partners, Anand helped bring new and distinctive forms to The Philadelphia Museum of Art, Related’s Grand Avenue Development in downtown Los Angeles, The Guggenheim Museum in Abu Dhabi, and the Biomuseo located on the waterfront at the Pacific entrance to the inter-oceanic canal. He presented his Green Steel Pavilion concept to the Geoversity’s Generative Design course for a discussion about using bamboo in contemporary design and current processes such as the lamination of bamboo and other natural materials.

Overlooking Panama’s Miraflores Locks, the project sits between The City of Knowledge (a center for business, education, and technology) and the Camino de la Cruces National Park. The Pavilion is designed to evoke architecture of traditional sacred spaces and illustrate a powerful narrative celebrating the relationship between humanity and nature. Using both handmade components and digitally optimized processes through juxtaposing naturally harvested and industrially manufactured bamboo elements, it is intended to serve as a model for a 21st century approach of using renewable material in construction.
Project 1 - Brooklincito Market

Sigen Palis and Giuliana Patiño

In this project, it was determined that due to the tree coverage, the shaded area of the site was one of the unique factors which was able to create an atmosphere in which social interaction and commerce was able to happen.

It was decided after the site visit to Brooklincito, to add to this by providing a design which would provide a large shaded area to the central grassed area of the site, and also provide a shaded walkway to the main street which would also be an opportunity for commercial space and an area of social interaction. Therefore an easily constructable model was required which could perform both roles. The first being one which would span over a large area, and secondly one which could provide a linear shaded walkway. The ‘umbrella’ frame was chosen by the group (fig.2)

A script was developed which would generate the columns along a curve drawn by the user. The algorithm gave the user the ability to adjust the amount of columns to provide the required shade (fig.1).

A second script was developed to apply the material of bamboo to the in order to produce relevant output (Fig.3). The script produces the following:

- To take the lines of the frame and convert them into poles of a diameter set by the user.
- To generate a sphere at each node which is representative of the type of connection which will be used.
- To offset the length of each member by the distance required for the metal connection and metal rods connecting to the bamboo poles.

Fig.4 shows the required additional support and proposed foundation system.
Fig. 3. The Grasshopper algorithm was able to take the line model in Rhinoceros, and decrease the length of members and place a ball joint at each node giving the user control over the size of the joint.

Fig. 4. The module which forms the walkway from the road with tension cables for support and the proposed foundation system.
Fig. 5. The module which forms the walkway from the road.
Project 2 - Brooklincito
Community Space

Arturo Zavala Haag

In this project the demolished community hall was chosen as a structure to give focus to. Following initial form finding exercises the column was decided as a structure which could be easily constructed and provide a great deal of strength. Following the design of this column as a physical model (right), an algorithm was developed to take the principles of this system into Grasshopper to give the designer the ability to amend the design digitally.

This algorithm was developed to adjust the profile of the column (Fig.1), by changing the base or top radius, and also increase the number of members which made up the column. All these variables have structural implications.

A roof was then proposed which would span between the column and the former community hall, and would be supported by a structure attached at the top of the former community hall. The algorithm was developed to generate a structure which would connect between the ridge beam of the roof and the top of the former community hall at locations set by the user. If the user moved the locations to attach to the former community hall, then the algorithm would update instantly (Fig.3) and the density of this structure could also be amended by the user in the algorithm (Fig.2). The secondary structure of the roof could be again amended to generate a denser roof structure in the algorithm (Fig.4).
Fig. 2. The algorithm would allow the user to change the support connection locations on the ridge beam.

Fig. 3. The algorithm was developed to allow the user to adjust the footing location and instantly the roof supports would be updated.

Fig. 4. The density of the secondary roof structure.
Fig. 5. A render of the proposed design.
Project 3 - Birds of Brooklincito

Xavier Pino

In this project, the former community hall was again selected as the focus of the project. Given the ease of construction the form, the hyperbolic paraboloids were proposed to cover this structure.

Three hyperbolic paraboloids were modelled in Rhino and then this geometry was assigned into Grasshopper. The script was then developed which would be able to model the required grid and structure and give the designer the ability to set restrictions to the structure such as the dimensions of standardised material lengths or the diameter of the available bamboo.

The output from this would then allow the designer to assess the lengths, dimensions and quantities and ensure that as the form was augmented in 3D, the material requirements could be assessed in terms of cost, availability and overall buildability.

Fig.1: render of the proposal on site covering the former community hall.

Fig.2: The algorithm was able to place a 3D representation of the bolt at each intersection of the bamboo poles. This would then provide a quantity of bolts required instantly as the form was updated by the user.
In section 1 of fig.3, the base surface is drawn within Rhino, and then assigned to Grasshopper as the input geometry of the algorithm. Curves are then extracted from the edges of this surface. The four edges produce four curves. In section 2 (fig.7), two curves which form the opposite edges of the surface are selected and used as the outer curves of an array of curves which form the first direction (u) of the grid. The same process is repeated with an offset surface to the diameter of the bamboo to be used and a grid in the perpendicular direction is developed in the same way (v direction). This grid is developed to never have a distance greater than that of the available material lengths or the required maximum distance as determined by a local building code. In this design 750mm was proposed. Section 3 is where the surfaces are generated which would represent the roofing material modelled to the required width between poles.

In section 4 (shown in fig.6), the overlap of each member in the roof grid is used by the algorithm as a location to add a bolt.

In section 6, the outputs of the algorithm allow the designer and construction teams to check the required material quantities to assess quantity, cost and buildability in real time as the hyperbolic paraboloid 3D form is updated by the user.
Fig. 6. The script would identify and input bolts where members in the roof structure crossed.

Fig. 7. The maximum distance between roof poles was set by the user to ensure that the roof grid would never be larger than available material supplies.
Fig. 9. A render showing the proposal.
Next steps

Nathan would you like to add a piece of text here?