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JED LONG 2016 CHURCHILL FELLOW

The AV Jennings Churchill Fellowship to study bamboo construction and treatment methods to develop Australia's bamboo industry.

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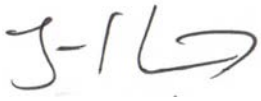
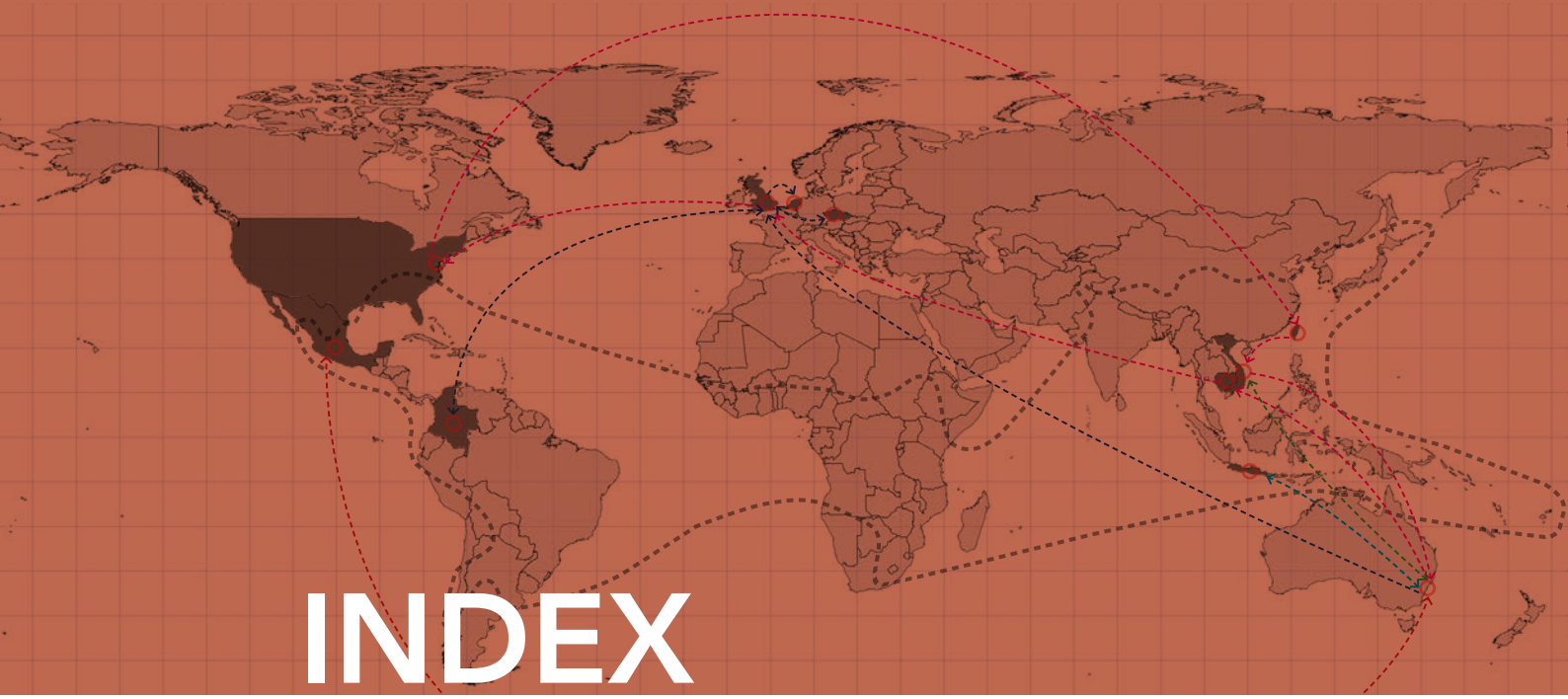


Jed Long
30th January 2018



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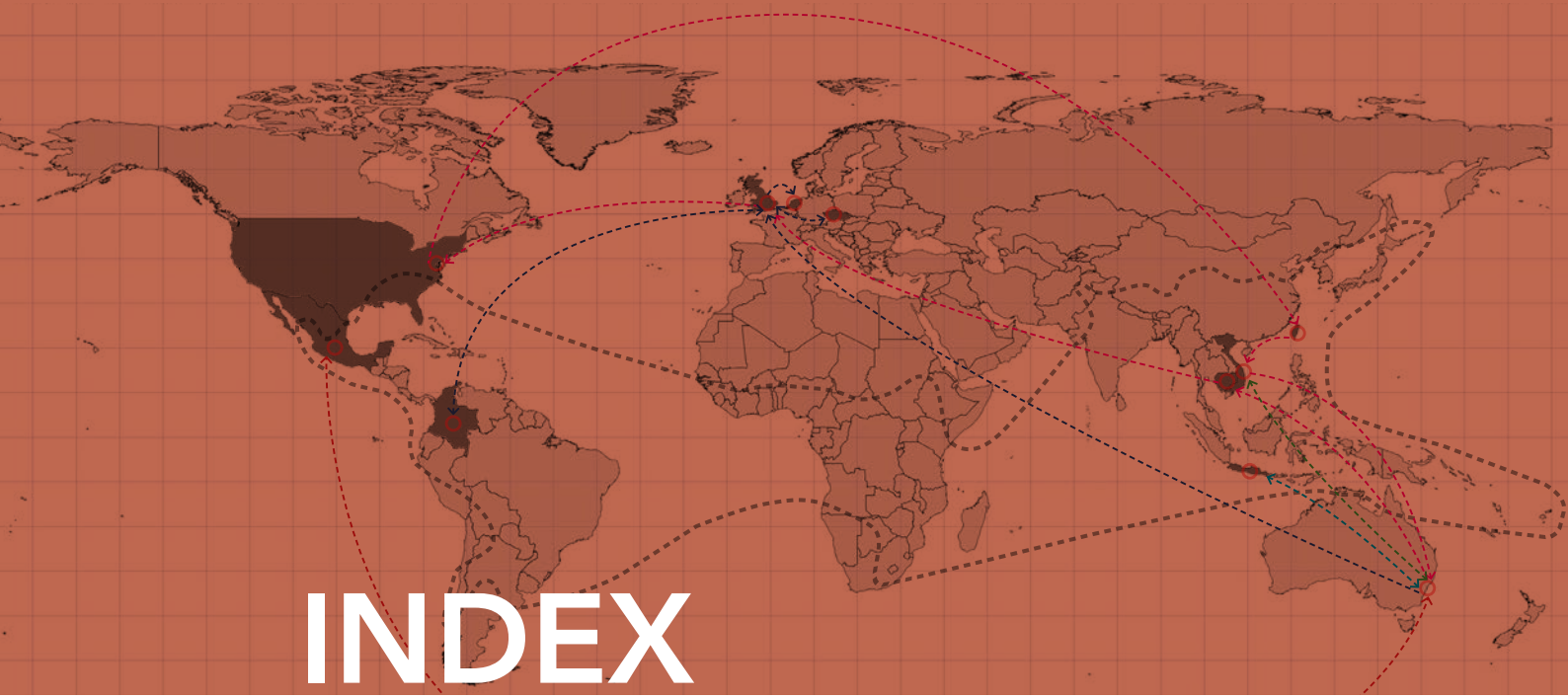

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INTRODUCTION

When we first founded Cave Urban, the only way we found we could learn about bamboo was to participate in workshops and learn through collaboration with other artists. These were not skills that could be read in a book and they often had to be sought out. One thing that immediately struck us was the passion that people had for this material, no one could really explain why, but we all knew that we carried the same enthusiasm that continues to burn inside our hearts.

The AV Jennings Churchill Fellowship was an incredible opportunity to continue developing my own education on bamboo in the built environment. It has provided the chance to formalise a process of inherent learning into outcomes that can be applied to our own context in Australia.

The following report is an investigation of the social, ecological and structural ramifications of working with bamboo. This knowledge does not exist in Australia and so the AV Jennings Churchill Fellowship was an opportunity to gain a global perspective on bamboo construction, value chains and leading research, to determine how it can be utilised within an Australian context.

Building upon my own experience with Cave Urban, I have sought to expand my knowledge by working directly with universities, NGO's, designers and the skilled artisans for whom knowledge is intrinsic rather than formalised.

The results of my research has revealed a much wider scope of study than initially planned. The initial proposal to 'research bamboo construction treatment methods to develop Australia's bamboo industry' led to the expansion into a broader field of enquiry that encompasses the entire value chain of bamboo cultivation and construction.

By travelling through Indonesia, Vietnam, Colombia, United Kingdom and Europe, I followed a transition from cultures with a long history of bamboo craft, to society's with no tradition but facilitating leading research into the application of bamboo to the built environment.

I would like to thank AV Jennings and the Winston Churchill Memorial Trust of Australia for providing me with this incredible opportunity to engage with numerous communities and organisations around the world. So much of what I have learnt and experienced was only possible through the direct interaction with all of those who generously shared their time and expertise with me. The connections that I have made over the last year will last a lifetime and the opportunities I have been given will continue to evolve long beyond the conclusion of my fellowship.

Finally I must also thank Georgia Saxelby for encouraging me to undertake this journey and Nici Long and Juan Pablo Pinto, for the support and encouragement that made this all possible.

Keywords: Bamboo, Architecture, Ecology, Sustainable Development, Engineering

Jed Long,
Project Director, Cave Urban
73 Bulkara Rd, Bellevue Hill, NSW 2023
M: +61402242882 E: jed@caveurban.com

EXECUTIVE SUMMARY

Bamboo has immense potential as a building material. Its impressive structural qualities are augmented by a rich social and ecological narrative. However Australia does not have the tradition of bamboo craft or knowledge base to utilise this material to its full potential. The AV Jennings Churchill Fellowship investigates the social, ecological and structural ramifications of working with bamboo. The following report outlines a global perspective on how bamboo is utilised in contemporary construction and the challenges faced in its application to a highly regulated construction industry. Charting the entire process of utilising bamboo including cultivation, harvest, treatment, construction and standardisation, the findings of this report identify the broader social and economic ecologies that influence how and why we may use this material in an Australian context.

This report is the product of working directly with universities, NGO's, designers and the skilled artisans for whom knowledge is intrinsic rather than formalised. It examines bamboo's application within both a developed and developing context noting the opportunities for working with this material as both a natural and an engineered product.

KEY CONTACTS:

Indonesia
-Arief Rabik | Indo Bamboo + Environmental Bamboo Foundation
-David Hodgkin | Humanitarian Bamboo Foundation

Vietnam
-Dr Helen Norrie | UTAS, Vietnam Bamboo Study Tour
-Huong Thuc Hao | 1+1>2

Colombia
-Dr Hector Archila | Amphibia BASE
-Carolina Salazar | UNAL Manizales

UK
-Dr Michael Ramage | Centre for Natural Material Innovation, Cambridge University
-Dr Bhavna Sharma | BRE Centre for Innovative Construction Materials, Bath University

Europe
-Arjan van der Vegte | MOSO

MAJOR LESSONS:

-The benefits of bamboo should be considered along all stages of the supply chain to gain a whole systems understanding that includes social and ecological benefits.
-The most successful bamboo buildings are those that are designed as a hybrid system that utilise timber, bahareque, steel or concrete.
-Engineered bamboo products will have a greater impact upon developed markets than round bamboo- design standards are necessary for facilitating this.
-Standardisation is key to establishing bamboo as a contemporary building material, but it risks removing it away from the artisanal craft that connects it to community.

DISSEMINATION

The findings of my research have direct relevance to my professional practice and my role as an educator across multiple universities in Australia. Through an increasing involvement with the University of Tasmania and the development of the field of 'agritecture', I will be presented with multiple avenues of dissemination, through academic papers and through the development of this design research project with Vietnamese Universities. Similarly I will develop the Woodford Festival site as a platform for hands on workshops, training and talks, continuing to facilitate leading practitioners to come share their knowledge.

PROGRAM

DATE	PLACE	ORGANISATION	CONTACT	COUNTRY
4/9	Swansea	Amphibia BASE	Dr Hector Archilla	UNITED KINGDOM
7/9	Vienna	ISO TC 165, WG12	Dr David Trujillo Dr Bhavna Sharma Arjan van de Vegte Dr Louis Filipe	AUSTRIA
11/9	Manizales	La Esperanza	Simon Velez	COLOMBIA
12/9		ZERI Pavillion Barrio Los Andres	Simon Velez	
14/9		Marcelo Villegas		
15/9		UNAL Manizales	Carolina Salazar Ricardo Leyva Dr Hector Archila	
18/9	Bogota	V SIB Guadua UNAL Bogota	Prof. Yan Xiao Ximena Londono Prof. Caori Takeuchi	
		Plaza del Torros Punta Jenny Garcia	Rogelio Salmona Simon Velez	
21/9	Medellin	UNAL Medellin	Prof. Eugenia Gonzalez Jose Eduardo	
		Orquideorama Libro Espania	Plan B Arquitectos	
27/9	Tabio	Fundacion Organizmo	Ana Maria Gutierrez	

PROGRAM

DATE	PLACE	ORGANISATION	CONTACT	COUNTRY
2/10	London	Architectural Association	Zachary Mollica John Naylor	UNITED KINGDOM
4/10	Cambridge	University of Cambridge	Dr Michael Ramage	
8/10	London	Katie Turnbull		
9/10	Hooke Park	AA Design and Make	Jeremy Ralph Martin Self	
10/10	Bath	University of Bath	Dr Bhavna Sharma Prof. Kent Harries Dr David Trujillo	
11/10	Dover	Pines Calyx	Kristian Bird	
12/10	London	The Hive	Wolfgang Buttress	
13/10	Amsterdam	MOSO International	Arjan van de Vegte	NETHERLANDS
14/10	Barcelona	Canya Viva	John Cory-Wright	SPAIN

PRE-FELLOWSHIP RESEARCH

Cave Urban was founded in 2010, by Nici Long, Juan Pablo Pinto and myself to research vernacular structures and their relevance to contemporary design. What began as means for research has developed into a practice that explores the intersection between art and architecture through the use of bamboo.

When we first became interested in bamboo, it was quickly evident that very little information could be learnt through reading books. Although Australia has a small but strong community of people growing bamboo, there was not the same community of designers and artisans working with the material. So we set out to learn through making, taking part in workshops overseas and inviting established artisans to collaborate with us on projects in Australia.

Over the last seven years, Cave Urban has developed a learning platform based on research, collaboration and the sharing of knowledge. Through artistic experimentation we have been able to explore the idea of ephemeral space, creating impermanent work that was free from the constraints we find ourselves adhering to as architects.

The AV Jennings Churchill Fellowship provided an opportunity to build upon our existing skillset and begin to examine how we could uncover new ways of working with bamboo that utilised best practice for treatment and design, enabling architectural longevity within an Australian context.

This investigation required engaging with cultures that have a long tradition of bamboo construction, to learn the construction techniques and methods of treatment that ensure the building does not degrade. But it also recognised that the contextual setting of Australia is very different to the equatorial developing countries that are home to the majority of bamboo craft.

The following pages of this report outline my experiences in Indonesia and Vietnam prior to undertaking the fellowship. Supported by funding from a Byera Hadley scholarship, I was able to gain perspective on how and why bamboo should be cultivated, the interrelation of the value chain and how traditional vernacular knowledge is being translated into contemporary design.

PROGRAM

The schedule below outlines travel undertaken in the lead up to the AV Jennings Churchill Fellowship that has influenced the findings of this report.

DATE	ORGANISATION	CONTACT	COUNTRY
9/16	Humanitarian Benchmark Consulting	Dave Hodgkins Fabian Prideaux	INDONESIA
11/16	MOMA, New York	Sean Anderson	USA
12/16	Woodford	Arief Rabik	AUSTRALIA
1/17	RAW Impact	Troy Roberts	CAMBODIA
1/17	Cambridge University University of Bath	Dr Michael Ramage Dr Bhavna Sharma Dr Hector Archila	UNITED KINGDOM
2/17	Vo Trong Nghia Architects 1+1>2 Phu An Conservation Village	Vo Trong Nghia Haong Thuc Hao Dr My Hanh	VIETNAM
3/17	DICMA Trade BRAVO Mexico TIBA	Martin Mortera Guillermo Mortera Peter van Lengen	MEXICO

INDONESIA

Bamboo rightfully deserves its nickname, "the miracle plant." It can be eaten, be used for creating housing, textiles, paper and even medicine, all while being incredibly beneficial to the environment. Bamboo related industries already provide income, food, and housing to over 2.2 billion people worldwide
-Arief Rabik

Bamboo is a material that has been utilised in construction for thousands of years. However it has only recently begun to be considered as a material suitable for contemporary construction. Architects and engineers promoting the use of bamboo in the built environment draw on either its structural properties or environmental credentials as justification for its application. Before we can begin to determine whether it is a material suitable for our own construction industry, we must understand a larger holistic overview of the material that examines ecological, economic and social value chains.

With some of the strongest traditions of bamboo craft, Indonesia serves as a starting point towards understanding the wider implications of utilising bamboo as a construction material. With the third highest population in the world and close geographic proximity to Australia, it is a country that will play a significant role in our future relationship with the Asia-Pacific region.

The intersection of traditional vernacular knowledge and contemporary design in bamboo can be traced back to Bali, where early pioneers such as the late Linda Garland, founder of the Environmental Bamboo Foundation (EBF) brought international awareness to the material. Linda had a profound legacy, helping to bring together disparate groups of researchers and designers, and began to form a global narrative of the ecological benefits of utilising bamboo in construction.

Treating bamboo using the boucherie system ▲
Jogjakarta, Indonesia
Image: Jed Long

Linda's son Arief Rabik, continues her legacy through the EBF and his company Indo Bamboo. Focussing upon the potential of bamboo as a tool for regenerating degraded landscape, Arief launched the '1000 Bamboo Villages' initiatives, presenting it at COP 21 in Paris 2015. Supporting the establishment of regenerative economies that cultivate, harvest and process bamboo, Arief argues for a decentralised system that looks to improve the economic ecology of communities across the Indonesian archipelago, whilst also manufacturing laminate bamboo products for global distribution.

The creation of the Green School by John Hardy helped to further establish Bali as one of the spiritual homes of bamboo design. Working with his daughter Elora, John founded the construction company Ibuku to enable the creation of landmark bamboo architecture. The development of a new bamboo aesthetic, drawing upon vernacular Indonesian design has pushed the limits of the materials structural properties and influenced a new generation of designers throughout the region. By connecting inherent artisanal knowledge with high end luxury design, Ibuku has commodified bamboo as a material symbolic of sustainable design.

In contrast to Ibuku, Humanitarian Benchmark Consulting (HBC) has chosen to focus on the role bamboo can play in post-disaster reconstruction. In direct response to the reconstruction outcomes of the 2006 Jogjakarta earthquake, HBC established the Humanitarian Bamboo Project in order to improve education within the shelter and development community in regards to best practice for bamboo construction.

The Churchill Fellowship has provided an opportunity to directly engage with these organisations and develop a deeper understanding of bamboo's entire value chain, from harvest, to treatment and construction. As one of the first countries I visited the outcomes of this engagement are already evident and will be discussed later in the report.

ENVIRONMENTAL BAMBOO FOUNDATION

Bamboo is the most community friendly timber on the planet. Why? Bamboo forestry is a labor intensive, human driven process. This means the poorest and most uneducated communities and people can learn and benefit within one year.
-Arief Rabik

Arief describes Indonesia as one of the three lungs of the world. Like the Amazon rainforest and the jungles of Central Africa, Indonesia is home to some of the world's richest biodiversity. High precipitation and warm temperatures make these ecosystems highly productive and capable of absorbing significantly higher levels of CO_2 than temperate forests. However like the Amazon and Central Africa, Indonesia is clearing these forests at an alarming rate due to a number of different social and economic pressures. Over 80 million hectares of land in Indonesia is considered degraded and 37% of Indonesia's total emissions are from deforestation.

The '1000 Bamboo Villages' program presents bamboo as one potential solution to help combat the destruction of one of the world's most valuable resources. By promoting bamboo as a tool for restoration, the program seeks to reduce pressure on timber stocks by introducing an alternative material, help restore degraded soil through bamboos ability to hold water and increase biomass, supply a resource that can be harvested annually, increase carbon sequestration and provide a material that can be utilised for construction and food. In order to prevent bamboo causing further degradation through misappropriation, as palm oil has, the program supports the notion of community based agro-forestry, focussing on existing degraded land to plant bamboo. This is a system of low external inputs and decentralisation, where communities provide semi-finished products to industry.

Starting with a single community, Arief establishes a system of stewardship, educating farmers on best practice cultivation and harvesting techniques. Through a coded labelling system, quality control is instigated to ensure participants are only harvesting bamboo of the correct age from clumps that belong to them.

Workers carrying a single pole of Asper ▲
Flores, Indonesia
Image: Arief Rabik

Indo Bamboo Factory ▲
Flores, Indonesia
Image: Arief Rabik

After harvesting the raw material, the bamboo is split into strips and treated through a process of carbonisation. By selling a semi-finished product to industry, farmers are value-adding, leading to a higher return for the product. Since bamboo culms are mostly hollow, splitting the material also allows for a higher transport efficiency, leading to a lower ecological footprint.

Each step of this process is labour intensive making it unsuitable for application in Australia, but highly applicable to Indonesia where low labour costs and subsistent practices provide opportunity for developing sustainable economic ecologies.

By encouraging farmers to cultivate bamboo Arief is able to ensure a material supply for his company Indo Bamboo. Working closely with MOSO, Indo Bamboo has been developing its manufacturing process to ensure a standard of quality that allows for distribution to high end European markets. Transforming bamboo from a raw material into an engineered product allows it to be utilised in highly regulated construction industry's like Australia, where its social and ecological narrative help promote it as a sustainable material.

Through examining the supply chain of bamboo from harvest through to construction we see that each step of the process provides opportunity for added value beyond a commercial outcome and that the consumption of certain goods in Australia can lead to a positive outcome elsewhere. It is Arief's aim that over the next 15 years '1000 Bamboo Villages' will lead to 2 million hectares of bamboo reforestation across Indonesia.

HUMANITARIAN BENCHMARK CONSULTING

Shelter is a process not a product
-Dave Hodgkin

Through landmark projects such as the Green School, Ibuku has brought mainstream attention to the potential of bamboo as a construction material. With a highly skilled labour force and affluent clients, they are able to create incredible structures that utilise bamboo unique structural properties.

However the application of bamboo as a tool for reconstruction or development, provides a very different set of requirements. With roughly 1 billion people worldwide living in housing that utilises bamboo as a buildign material, the vast majority of bamboo construction is informal, lacking architectural design and often built in a manner that ensures a short material lifespan. As such bamboo is often referred to as a 'poor man's material'. In countries with a tradition of bamboo craft, rising affluence and urbanisation is leading to the abandonment of bamboo construction in favour of aspirational and durable materials that are generating a raft of social and environmental problems.

In such situations, systemic solutions are more important than design in influencing change. Agency for self-determination can be provided through the dissemination of best practice guidelines to influence informal architecture. By focussing on appropriate low cost/technological solutions that build upon local wisdom, communities are able to utilise innovation and effort to counter low fiscal capacity.

Bamboo Shelter ▲
Jogjakarta, Indonesia
Image: International Federation of Red Cross and Red Crescent Societies

In 2006, Jogjakarta was struck by a 6.4 magnitude earthquake, resulting in the loss of more than 5,700 lives. The International Federation of the Red Cross, along with other NGO's saw the recovery program as an opportunity to utilise bamboo, given the long history of bamboo architecture in the region. Over a period of 9 months, more than 75,000 shelters were constructed at an average cost of $150 USD. Built by local communities, the program adapted traditional construction techniques of rope and dowel joints, to construct buildings with a higher resistance to earthquakes. It was an ideal example of utilising local wisdom for reconstruction, aided by sensitive technical support. By all measures the program was a success, except for one issue- the prescription of bamboo as the material of choice led to the deforestation of vast tracks of bamboo forest throughout the region. As a result local communities lost a valuable resource, decreasing resilience for future disasters.

The conflict of the humanitarian imperative against long term ecological and social consequences, is a recurring issue in post disaster reconstruction that is becoming increasingly prevalent. Dave Hodgkin's, founder of Humanitarian Benchmark Consulting (HBC) and a resident of Jogjakarta, saw this as a wakeup call for the international aid community and their understanding of bamboo. As a result he established the Humanitarian Bamboo Project as a means of educating the shelter cluster in best practice for bamboo. Through a series of grants and extensive workshopping with experts, the Humanitarian Bamboo Guidelines were published. Created as an open source document, the guidelines are often revised and updated to ensure accuracy of information. Although meant as a resource for post-disaster reconstruction, the guidelines provide a wealth of information about all stages of bamboo cultivation and construction that is applicable to anyone looking to utilise the material.

◀ Discussing bamboo cultivation with Dave Hodgkins during HBC Shelter Training Woodford, Australia Image: Fabian Prideaux

CONCLUSION

The key outcomes from visiting Indonesia was the establishment of relationships with Arief Rabik of the EBF and Dave Hodgkin of HBC. Ongoing collaboration with both of these organisations has led to the direct dissemination and application of knowledge in Australia, which will be discussed later in the report. Through association with HBC, I was invited to Cambridge University and introduced to many of the leading researchers investigating standardisation and engineered bamboo products.

VIETNAM

Can a single architect change the future of Vietnam's cities? One hopes that Vietnam's cities will be able to develop without losing sight of the best in the country's traditions or its love of tropical greenery, light, and natural breezes.
-Pham Thuy Loan

Vietnam has undergone a rapid transformation in the past 30 years. The introduction of the Doi Moi policy in 1986, transformed the country from a centrally planned economy to a market orientated one. The result being Vietnam has gone from one of the poorest countries in the world (1986 average income US $100) to a lower middle class economy (2016 average income US $2000 and US$4000 in urban areas). With a growing population of 94 million people, 40% of the population is under 25 years of age.

This has rapidly transformed Vietnam in just one generation from a rural based economy to a highly integrated part of the global community. The ramifications are numerous, particularly in regards to the environmental costs of this growth, with increasing urban populations and land degradation set to cause numerous challenges when paired with a high vulnerability to climate change and natural disasters.

As Vietnam clings to the increasingly fading remnants of its cultural heritage within an ever-changing and globalised urban way of life, bamboo has emerged as symbol of Vietnamese culture. It forms part of a juxtaposed narrative sold by developers keen to capitalise upon an idealised nostalgia of cultural heritage, whilst selling a product that provides a means to escape the reality of traditional rural society.

An overreliance on concrete for construction has led to Vietnam becoming one of the top ten manufactures of concrete worldwide. It is the result of decades of deforestation that has led to a scarcity of tropical hardwood timber and the ramification of a society where wealth and the image of success plays a vital role in social hierarchy. Two architects in particular utilise bamboo as a means of promoting a more sustainable built environment.

▲ Grading Bamboo for Laminated Flooring
Hanoi, Vietnam
Image: Jed Long

In a manner similar to Ibuku in Indonesia, Vo Trong Nghia Architects (VTN) has commodified bamboo as a luxury good, through the construction of numerous resorts and iconic buildings throughout Vietnam. The deep rooted tradition of bamboo in the Vietnamese vernacular is symbolised through these buildings, which have become cultural markers in a country disconnected from its traditional way of life.
In contrast, Hoang Thuc Hao of 1+1>2 has also been utilising bamboo, however in a manner vastly different from VTN. Through the design of his community based projects, Mr Hao has creating hybrid structures that utilise bamboo in conjunction with of other materials. These projects target a very different section of Vietnamese society and demonstrate a stronger resonance with the traditional ways of building with bamboo.

In parallel with this exploration through architectural projects, formalising local knowledge of bamboo is also allowing Vietnam to engage with the wider global bamboo community. World Bamboo Ambassador and founder of the Phu An Bamboo Museum and Conservation Centre, Dr Diep Thi My Hanh has been specialising in the taxonomy of Vietnamese bamboo species and the role bamboo can play in restoring degraded land.

Working in conjunction with the School of Technology, Environment and Design at the University of Tasmania, my research in Vietnam has consisted of two visits in 2017 in the lead up to my Churchill travels and one visit in January 2018. Engaging with local experts and universities, we have sought to forge a new cross-disciplinary field of 'agritecture', fusing architecture and agriculture. The new field of agritecture, explores the cultivation of bamboo to assist with biodiversity, water filtration and soil remediation, whilst also examining how it can be utilised in temporary and permanent construction in communities where the economic ecology is shifting.

BAMBOO IN VIETNAM

The idea that materials have a particular nature has an immediate appeal, but it requires only a moment's reflection to realize that it is far from straightforward.
-Richard Weston

Bamboo is not only a building material, but a cultural symbol in Vietnam embedded in the daily life of its citizens and vernacular architecture. The use of bamboo in the day to day life of modern Vietnam is still numerous. Walking down the streets of Hanoi or Ho Chi Minh, you will encounter countless examples ranging from chopstick to ladders and furniture. However the utilisation of bamboo in the built environment is rapidly disappearing as the French colonial legacy manifests itself in a propensity towards concrete and brick construction.

Traditionally bamboo was utilised in housing for all levels of society. The poorest farmer would live in a house of bamboo and earth, utilising techniques similar to those seen in the bahareque structures of Colombia. More wealthy citizens would utilise timber as the main structural support and sparingly apply bamboo as substructure or decoration. The application of bamboo in the later scenario, utilises bamboo in a manner that ensures a longer life span. Building an entire structure out of bamboo with only earth as protection is a valid form of construction. However if it is not executed correctly, it will lead to the degradation of the structure over a fairly short time period. It is no wonder that after generations of living in bamboo houses that require regular maintenance and reconstruction, that a material like concrete would hold great appeal. Reversing the perception of bamboo as a poor man's material, requires more than just commodifying the material to appeal to aspirational construction. It requires education as to best practice means of construction to ensure longevity and new innovation in the combination of bamboo with other materials to create an efficient form of construction.

Two architecture firms in Vietnam stand out for their work with bamboo. Vo Trong Nghia has received global attention for his cutting edge bamboo design that has synthesised traditional Japanese forms of construction with Vietnamese cultural markers. His buildings for the most part utilise only bamboo in their composition and are the result of a highly skilled construction team and large budgets.

Architectural studio 1+1>2 takes a very different approach, working with community on a smaller yet no less impressive scale, the building take their cues from traditional vernacular methods of working with bamboo. Traditionally Vietnamese buildings dealt with straight poles of bamboo on a two-dimensional plane. Hoang Thuc Hao of 1+1>2 continues this tradition with simply constructed yet highly sophisticated bamboo structures. Vo Trong Nghia on the other hand works with curved bamboo and structural systems that are operating on a three-dimensional axis.

Ede Long House
Hanoi, Vietnam
Image: Jed Long

VO TRONG NGHIA | SEN COMMUNITY VILLAGE

I want to bring nature back to the city, in Saigon, the population has reached nearly 10 million with only 5.35km2 of green space – only 0.25% of the entire city. Vietnam's unrestricted economic development has devastated the natural environment across the country. This is the problem architects need to solve.
-Vo Trong Nghia

The Sen Community centre demonstrates VTN's approach to bamboo construction. A large thatched roof spanning 30 metres is supported by 28 bamboo columns extending up to a central oculus. Constructed entirely from interlocking bamboos, 40mm in diameter and solid, the columns are impressive in their scale. Bamboo dowels and rope bindings hold the structure together, a traditional method of joinery.

From first inspection, it evokes an image of tradition. The thatched roof and circular form evoke a sense of tradition. However the system of construction, with its curved bamboo and highly sophisticated column/beam design is a new innovative form of constructed. It is a style of architecture that has quickly caught on across Vietnam and south-east Asia with other firms replicating VTN's aesthetic.

Visiting the Sen Community village reveals the scale of the structure. Situated above a small body of water, the space is a cool respite from the tropical heat of Vietnam. The high roof and open sides respond to the hot climate by promoting ventilation and allowing indirect light to enter the space. What is also evident is the juxtaposition of the building against the sprawling future development of concrete and brick townhouses. It exposes an attitude by developers towards invoking a kitsch nostalgia for tradition, playing upon the very real anxiety of Vietnam's rapid transformation towards an urban based society and the subsequent loss of culture.

Bamboo Formwork ▲
Ho Chi Minh City, Vietnam
Image: Jed Long

Sen Community Village
Ho Chi Minh City, Vietnam
▼ Image: Jed Long

Sen Community Village ▲
Ho Chi Minh City, Vietnam
Image: Jed Long

1+1>2 | CAM THANH COMMUNITY CENTRE

Hoang Thuc Hao takes a different approach to that of VTN. On first inspection, Cam Thanh Community Centre does not strike you as a bamboo building. Set amongst the rice fields and mangroves of Cam Thanh (a neighbouring village to the popular tourist destination Hoi An), the building is an activated part of the local community. Drawing inspiration from the world heritage courtyard houses of Hoi An, the community centre incorporates vernacular and contemporary principles of design. Double layer adobe brick walls wrap the building and timber columns hold up a bamboo and thatch roof that slopes down towards internal courtyards. Although not traditional in appearance, the hybrid construction system utilises materials in a manner consistent with the regions vernacular language. Where Sen Community village promotes a visual aesthetic that suggests a connection to tradition, Cam Thanh community centre demonstrates a compositional continuity, which allows a new contemporary aesthetic, deeply rooted in tradition, yet free from kitsch nostalgia.

Speaking to the local representative for Action Centre for City Development, the local NGO that runs the space, revealed the importance of programming to maintaining a buildings cultural relevance. Activities such as taekwondo classes, community meetings and the presence of a small library ensures that the building is utilised and not just an exercise in architectural goodwill. In the three years since its construction, the community have found some flaws in the buildings design- namely a roof that leaks and the degradation of openings exposed to weather due to the buildings lack of eaves. For some locals, the departure from a traditional aesthetic is a cause for concern and highlights the balance that must be achieved between the conceptual and aesthetic premise of the designer and the needs of the community.

50 years ago the village of Cam Thanh was constructed entirely from locally sourced bamboo, earth and coconut palm. The name for the local houses Nha Tre Dua, translates literally as House Bamboo Coconut and reveals how significant these materials are to the local vernacular. In a landscape that is now almost entirely dominated by houses made from concrete and tiled roofs, the Cam Thanh Community Centre stands out as an example of how traditional construction can translate into contemporary design.

Cam Thanh Community Centre
Hoi An, Vietnam
Image: Hoang Thuc Hao

1+1>2 | SUOI RE COMMUNITY HOUSE

Suoi Re Village Community House, also by 1+1>2, was one of Hoang Thuc Hao's first forays into social architecture and the use of bamboo. Like Cam Thanh, this building is not immediately identifiable as a bamboo building. Thick rammed earth walls sit atop a small hill, sheltered by a thatched roof. A lower level is embedded into the hill, creating natural ventilation through convective currents that pass up through the large opening between levels. The building is an example of protection through design, ensuring the structural longevity of bamboo by protecting it from exposure to the sun and rain. A series of 6 bamboo frames support the roof and derive from traditional two-dimensional framing systems. The truss-frames are at once both simple and complex. Held together by dowel and rope lashings, their design looked to maximise the skill of the local workers constructing the building. An arrangement of even and odd bamboo culms intersect in a manner reminiscent of the Japanese timber joinery that has inspired VTN's construction system. However by working with straight bamboo culm's, the building maintains an understated simplicity that differs greatly from the monumental works of VTN.

Suoi Re Community House
Hanoi, Vietnam
Image: Jed Long

Analysing the building, revealed some of the ways in which it has begun to degrade over the last 8 years. As a building made from natural materials, it is showing signs of decay, which can be overcome through maintenance. This is particularly evident at junction points where bamboo meets earth or bamboo connects to bamboo. Examining the bamboo revealed signs of borer infestation, demonstrating that traditional Vietnamese methods of bamboo preservation, by soaking bamboo underwater for a year to remove the sugars and starch from the material, are not entirely effective. The reliance upon bamboo dowels and rope connection is effective in some situations, but has also failed at other moments. Particularly where load transferals occur between bamboos, downwards force has caused shear to occur across the dowels. This has resulted in situations where particular bamboo culms are no longer carrying any load, increasing the workload of other structural members and causing subsequent failure. Whilst not catastrophic to the buildings structural integrity, it does demonstrate the need for regular maintenance to ensure that the failure of one member does not in turn jeopardise the structural integrity of another. How realistic it is to expect that a time and economically poor community will have the capacity for maintenance is a question that is worth asking. The complexity of community based architectural projects ensures a nuanced answer, which presents strong arguments both for and against.

Suoi Re Community House
Hanoi, Vietnam
Image: Jed Long

PHU AN CONSERVATION VILLAGE

Phu An Conservation Village was created in 1999 at the junction of the Saigon and Thi TInh rivers. Prior to the American War (Vietnam War), this community on the outskirts of Saigon was a landscape of rice fields and rubber plantations. Situated in the iron triangle, bombing by the US Air force had devastated the local landscape and community by 1975. Dr Diep Thi My Hanh, lived through this experience and returned later in life to restore part of this community through the propagation of bamboo. Dr My Hanh's work has centred upon utilising bamboo as a tool for remediation and the identification of native Vietnamese bamboo species, to provide the correct taxonomic classification.

The taxonomical study of Vietnamese bamboo is significant in order to cross-reference indigenous species of bamboo to international naming conventions to allow for the dissemination of information in regards to the structural and biological properties of various varieties. These properties can vary greatly even within species and is dependent upon the geographical location, age of the clump and nutrients available to bamboo during growth. Dr David Trujillo outlined many of the concerns that this generates in regards to the standardisation of bamboo, through his work establishing ISO 19624: Grading of Bamboo. Dr Trujillo concluded that the findings of the qualities of any particular species of bamboo is relevant only to the particular area the bamboo has been sourced from. This highlights the difficulty of standardisation and the reason as to why engineered bamboo product offer a solution to high variability.

By establishing the Phu An Conservation Village, Dr My Hanh has provided a means of disseminating information to farmers interested in cultivating bamboo. Her work with rural communities furthers this by introducing bamboo as a means of regenerating soils degraded through unsustainable farming methods. By dispersing bamboo throughout subsistence communities she is providing a resource that can provide both food and materials for construction, improving resilience and reducing informal forestry of hardwood forests.

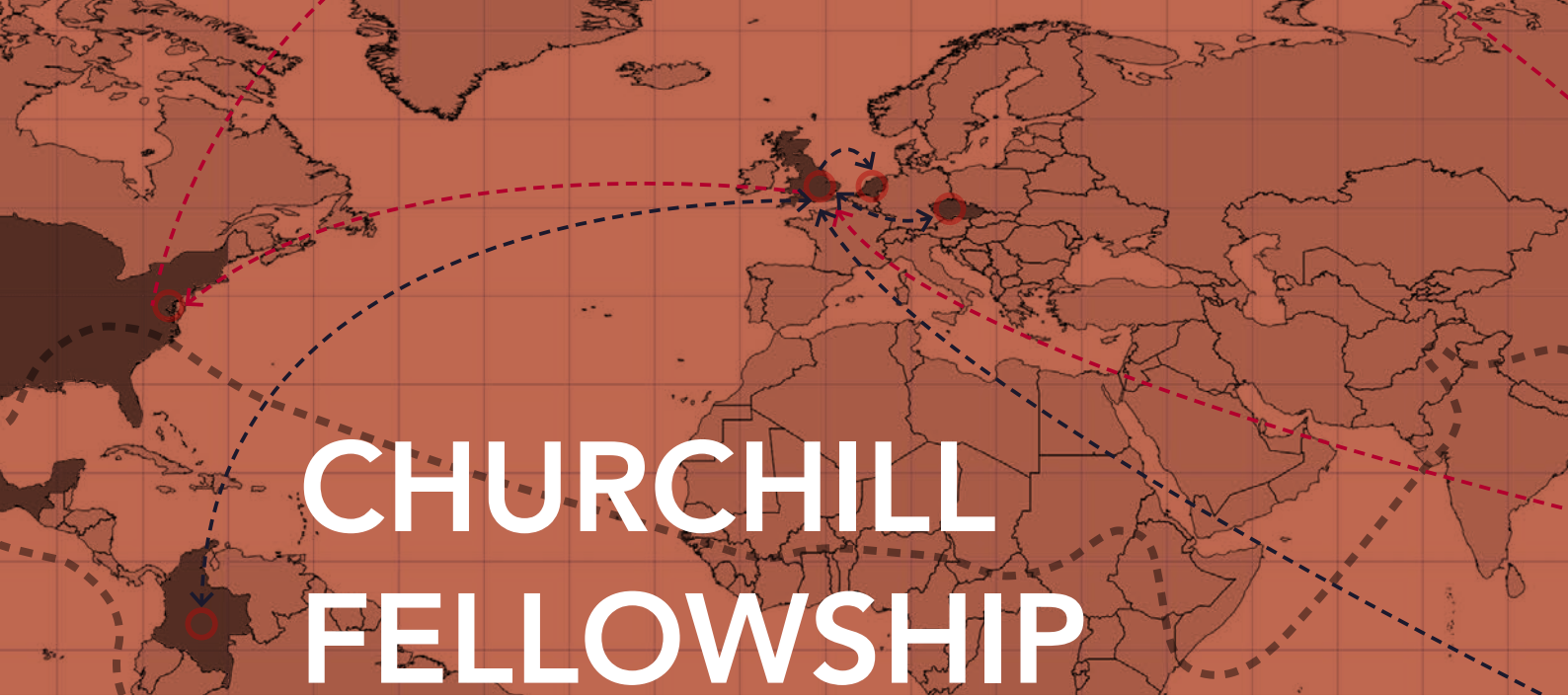
Phu An Design Workshop ▲
Ho Chi Minh City, Vietnam
Image: Jed Long

Meeting local community representatives ▲
Ro Koi, Vietnam
Image: Jed Long

CONCLUSION

The key outcome from visiting Vietnam has been the establishment of the Vietnam Bamboo Study Tour with the University of Tasmania, under the guidance of Dr Helen Norrie. Working with Dr Norrie to develop the idea of *agritecture*, has provided a means of ongoing collaboration with a number of universities and organisations within Vietnam. Through New Colombo Plan funding, Australian students are now able to join the program, exposing them to a vastly different culture and providing key learning outcomes that are directly translated back into an Australian context. It has also led to an ongoing summer research program that allows students to research bamboo and its application to the built environment.

▲
Transporting bamboo for planting
Ro Koi, Vietnam
Image: Jed Long



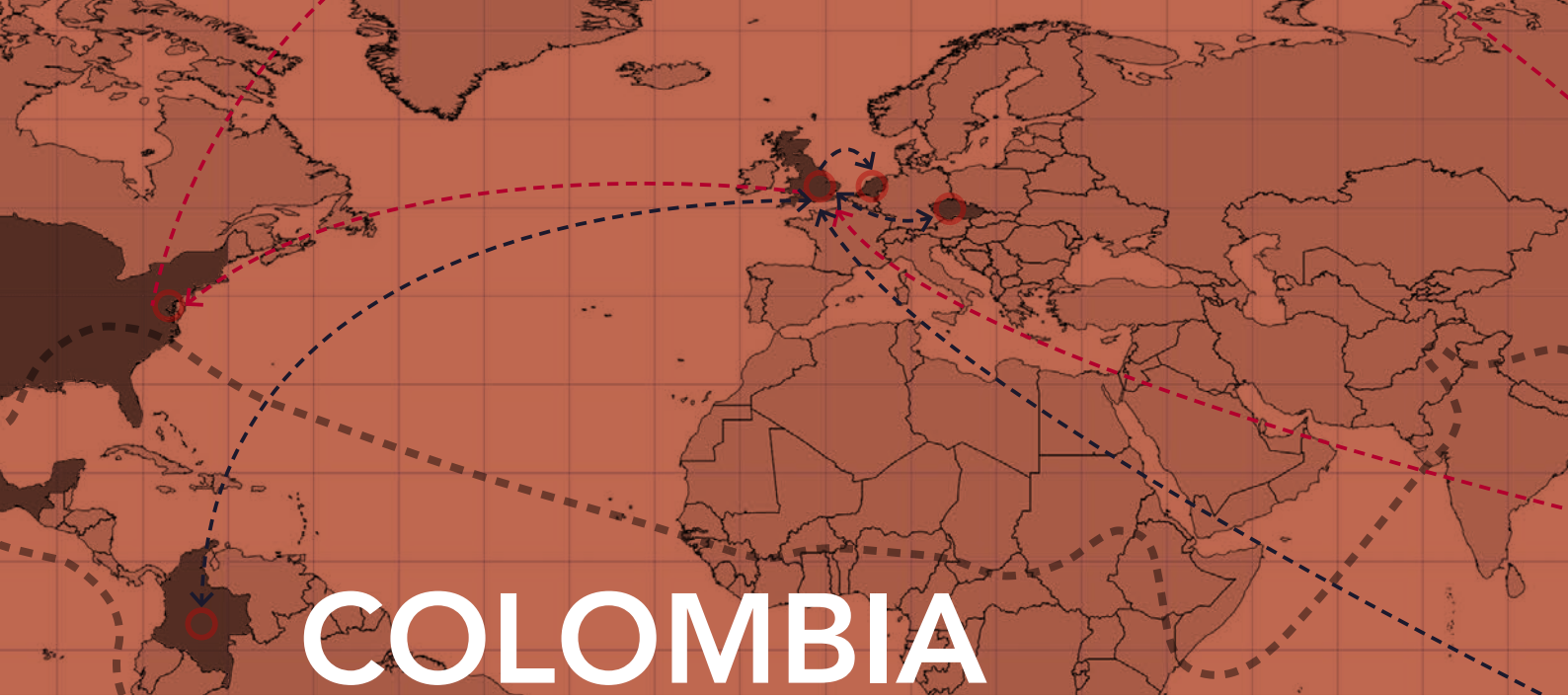
CHURCHILL FELLOWSHIP

The benefits of bamboo as a tool for development are clear. The social and ecological narrative that it establishes, creates a foundation for why and how we may source bamboo as a material for construction. The focus of my AV Jennings Churchill Fellowship was to firstly gain a greater understanding of treatment and construction systems in order to utilise this knowledge in Australia, but I also wanted to examine how bamboo may play a larger role within Australia's built environment.

Bamboo is limited in its application because of a number of factors. As a natural material it has no set dimension and will vary in structural capability. The hollow centre of the bamboo allows it to be incredibly light and its longitudinal fibres give it great tensile strength, however it also makes it unable to resist lateral pressures that cause failure. Because it is round, it also means that joining the material can be challenging and often requires a particular skillset that is not readily available in Australia.

In order to overcome these challenges, researches and designers have been working on methods of standardisation and ways to grade bamboo in order to achieve compliance to building code. Building on the research undertaken in Indonesia and Vietnam, my Churchill Fellowship took me to Colombia, the United Kingdom and a number of countries in Europe. The focus of the research was to investigate existing bamboo building codes, examples of highly engineered construction and connect with researchers and organisations developing new tools for standardisation and engineered bamboo products.

The following pages detail the key findings and contacts made through the duration of my fellowship.



COLOMBIA

Bamboo is the most marvelous plant in nature.
-Oscar Hidalgo Lopez

Colombia is home to one of the strongest traditions of bamboo architecture. Traditional vernacular construction coalesced with Spanish construction systems, creating bamboo architecture that could last up to 100 years and withstand seismic activity. Early pioneers such as Oscar Hidalgo-Lopez documented the construction methodology of traditional Colombian typologies and evolved these systems to suit contemporary design. Bamboo: Gift of the Gods, by Hidalgo-Lopez, continues to be one the most comprehensive texts on bamboo construction, influencing designers worldwide.

The Colombian architect Simon Velez, a disciple of Hidalgo-Lopez, continued his legacy through the development of mortar reinforced joints and the creation of some the most structurally ambitious bamboo projects worldwide. With the support of Gunther Pauli and ZERI, Velez brought bamboo onto the world stage during the 2000 Hannover Expo. The ZERI Pavilion was a landmark moment for bamboo architecture, proving that large scale bamboo construction could be achieved in a country with a highly regulated construction industry and no history of bamboo craft.
The vernacular tradition of construction that Velez draw on, is also kept alive through the work of Fundacion Organizmo and its founder Ana Maria Gutierrez. A bio-architectural institution, the focus of Organizmo is to preserve and develop the traditional skills of Colombia's Indigenous population.

In 1999, at the same time that as Velez was developing his pavilion for Hannover, a major earthquake hit Armenia. The resilience of bamboo construction during this disaster caused a widespread interest in testing bamboo's structural capabilities. The National University of Colombia (UNAL) led this research, which resulted in the world's first bamboo building code. This in turn contributed significantly to the establishment of ISO 22156:2004 and ISO 22157-1:2004 the international standard for whole pole construction and grading.

The Churchill Fellowship, provided an opportunity to travel to Colombia to investigate traditional methods of bamboo construction and the subsequent research to develop a bamboo building code. Timed to coincide with SIB Guadua V, the International Symposium on Bamboo, held at UNALs main campus in Bogota, it was also an opportunity to present the work of Cave Urban to the Latin American bamboo community.

Working in conjunction with Dr Hector Archila of the University of Bath and Carolina Salazar of UNAL, a three day workshop was held in the lead up SIB Guadua V, to test new methods of laminate bamboo construction. Situated in Manizales, it was also an opportunity to visit some of Colombia's most significant bamboo constructions.

Interior of the ZERI Pavillion
Manizales, Colombia
Image: Jed Long

BAMBOO IN COLOMBIA

The coffee zone of Colombia owed its development to guadua. Its houses, bridges, fences, aqueducts and coffee processing mills were built of guadua, part of an endless list of what guadua meant for the progress of this region.
-Marcelo Villegas

The traditional colonial architecture of Manizales and the surrounding state of Caldas utilised bamboo as the main structural component. Colombian historians often give credit to the early settlers of the region known as 'Antioquenos', for developing systems of bamboo construction. However this process was predated by the indigenous population of the region, who had developed methods of bamboo construction over a period of five thousand years. The resulting hybridisation between Spanish construction techniques and traditional vernacular typologies led to the development of a unique style of bamboo construction particular to Colombia and that region.

By 1932 the introduction of Portland cement into render mix and the use of a bamboo and timber structural hybrid led to almost every building in Manizales being constructed from bamboo. The use of differing styles of bahareque (Wattle and Daub) allowed the bamboo to be protected from the elements and for artisans to render buildings in imitation of colonial masonry architecture. There is evidence of buildings built in this style to have lasted up to 110 years, through regular maintenance.

The word guadua is synonymous with bamboo in Colombia, given it is the native species used in almost all bamboo construction. A sympodial scattered bamboo, Guadua Angustifoli Kunth can grow to a height of 20m with a diameter of 10-15cms. With strong thick internal walls it is an ideal bamboo for construction and was easily adapted to suited traditional timber framing techniques. The tradition of this construction typology continues today, enhanced by improved connection systems and high quality application of bahareque.

The steep topography and climate of Colombia's coffee region, led to an abundance bamboo. The poorest barrios of Manizales continue to utilise it as a lightweight construction system out of necessity and an ability to harvest it locally. Due to the high cost of plastering, venturing into these poor neighbourhoods provides an opportunity to examine informal settlements utilising bamboo construction.

▲ Typical Bahareque Construction
Manizales, Colombia
Image: Jed Long

BARRIO LOS ANDRES

Its low cost and ease of transport, its shape, its high resistance to tension, compression and flexion, its antiseismic properties- all of these make bamboo the ideal building material for low-cost housing.
-Eduardo Arango Restrepo

Barrio Los Andres is one of Manizales poorest communities and is one of the few areas where a tradition of bamboo architecture continues. Perched on a steep hillside, the community is a winding maze of houses, the majority of which are built from bamboo. Flattened bamboo (estrias) clad the external walls of houses and whole poles formed the dominant structure, at time used in conjunction with concrete or timber. For those with a little more money differing styles of bahareque cover the estrias, utilising either cement or mud as its base ingredient. Despite apparently haphazard way that the houses sit on the hillside, the barrio is incredibly clean and well organised, with backyard gardens filled with platanos and other fruiting plants. It stands in stark contrast to the cement and brick neighbourhoods of Medellin or Bogota. However decay is evident everywhere, with each house bearing signs of repair and reuse.

Situated in close proximity to the community are clumps of bamboo, demonstrating the ease of access the community has to the material. The lightweight properties of the bamboo are evident in the manner of construction, where each building clings to the hillside. Visual inspection of the bamboo revealed that the bamboo had little to no treatment against borer and fungal infestation. Decay was evident across most construction, with many signs of repair and reuse. The result was a feeling of temporality in the quality of the housing. The buildings relied instead on the guadua's inherent strength and ongoing maintenance to ensure longevity.

Simon Velez was born in Manizales to a family of architects and was exposed to communities like this. When Velez speaks of bamboo as a poor man's material you can see the evidence here. Elsewhere in Manizales the traditional bamboo construction has been replaced by concrete and brick. Even within the barrio, the more affluent houses have replaced bamboo with more expensive and durable materials. However it is clear what a crucial role bamboo plays within the community. Its versatility is demonstrated through its application as cladding, structural members, flooring, fences or gutters, on almost every building.

Barrio Los Andres
Manizales, Colombia
Image: Jed Long ▼

36

▲ Vernacular bamboo construction traditions continued. The estrias where often painted when a family could not afford to plaster them
Manizales, Colombia
Image: Jed Long

◀ Visiting Barrio Los Andres
Manizales, Colombia
Image: Jed Long

The front facade of buildings are given the highest priority. Often only that face would have bahareque applied. The edges and corners of the plaster would show the most decay.
Manizales, Colombia
Image: Jed Long

THE ARCHITECTURE OF SIMON VELEZ

Through their innovations, Vélez and Villegas have breathed new life into an ancient building material and have transformed it into one of the best performing materials in terms of strength, stability and suitability for constructing in earthquake prone regions. Their regular seminars and workshops have been instrumental in popularising bamboo as an ecological material that can be cultivated without damage to the environment and which can provide a low-cost construction method in many developing countries, removing a dependence on imported materials and technologies.
-Tatjana Schneider and Jeremy Till

Simon Velez was born in Manizales in 1949, into a family of architects. Best known for his work with bamboo, Velez refined the technique of mortar injected joints developed by Oscar Hildalgo-Lopez and utilised it to build some of the world's most significant examples of bamboo architecture.

The early work of Velez was heavily influenced by Le Corbusier and the Bauhaus. A commission to build a horse stables led him to begin to work with bamboo, indulging a growing interest in the indigenous architecture of Colombia and the use of traditional materials. Over the last 30 years with his partner Marcelo Villegas, Velez has developed new carpentry techniques and structural systems to allow bamboo to be utilised as a contemporary material, with impressive structural capabilities.

My proposal as an architect is to make architecture a bit more vegetarian, not so much concrete, but not totally vegetarian. You have to have a balanced diet between minerals and vegetables
-Simon Velez

The defining feature of much of Velez's work are the large bamboo roofs that utilise a similar construction to typology to what the Spanish builders traditionally used in the construction of church's, known as 'par and nudillo'. Velez is able to accentuate his use of bamboo by pairing it with materials such as timber or cement.

I am a roof architect. I design the roof and then what comes under it." (...) My architecture is tropical architecture. In a country where it rains a lot, you have to build roofs with large cantilevers, such as in Chinese or Indonesian architecture Learning about architecture in Indonesia was something radical in my life ... its huge bamboo ceilings built without any restriction or reserve. Affected by Le Corbusier's Modulor, always I thought a ceiling or a room should not exceed a certain height. But in Indonesia, poor people build roofs 10 or 15 meters high with their own hands! It is a cultural statement to create something important - a kind of exhibitionism without presuming.
-Simon Velez

Two particular projects hold special significance in regards to Velez's contribution to a larger bamboo narrative. The ZERI Pavilion designed for the 2000 Hannover Expo was the first bamboo building to receive a building permit in Germany and introduced bamboo to a global audience. Whilst the Jenny Garzon Bridge is 45 metre long, 3 metre wide and spanning one of the main roads entering Bogota, making it the bamboo bridge with the largest span in the world.

▲ ZERI Pavillion
Manizales, Colombia
Image: Jed Long

Simon Velez pour's a thin concrete layer atop his bamboo roofs to combat uplift from wind loads
Manizales, Colombia
Image: Jed Long ▼

SIMON VELEZ | THE ZERI PAVILION

The ZERI Pavilion is a rich symbol offering a message, which goes beyond the mere building itself. The ZERI Pavilion offers a number of symbols to the world.
-Gunter Pauli

The ZERI organisation commissioned Simon Velez to build their pavilion for the 2000 Hannover Expo. Never before had a bamboo building of that size been constructed in a country with as strict as regulations as Germany. In order to achieve certification from German engineers, a 1:1 scale prototype had to be first built in Manizales to undergo structural testing.

The goal of ZERI constructing this pavilion was:

"to change the image of bamboo since the majority of the estimated one billion people who use this readily available building material consider it to be a symbol of poverty. The intention of this project was to create a unique structure that would instill pride in and stimulate the use of this abundant, fast-growing construction material."

Velez's design made use of a hybrid construction that utilised timber as the main structural columns and guadua for the secondary and roof structure. The original design was constructed from simple sketches made by Velez, brought to life by his team of skilled craftsmen. The process of certification for German authorities required the generation of much more detailed construction drawings providing a much higher level of documentation than other projects by Velez.

The pavilion is a 10 sided polygon, 40 meters in diameter that utilises sloping columns to improve seismic stability. The large roof with its 7 meter overhang clearly demonstrates the primary principles of design with bamboo- a hat, raincoat and gumboots. In other words, a large roof to protect the structure from sun and rain, walls protect the main structural members and footings that raise the columns of the ground to avoid moisture transferal.

ZERI Pavilion
Manizales, Colombia
Image: Jed Long ▼

The bamboo in the ZERI Pavilion utilises two different systems of connection:
-Type A: Mortar reinforced threaded rod
-Type B: Lateral steel strap and mortar joint.

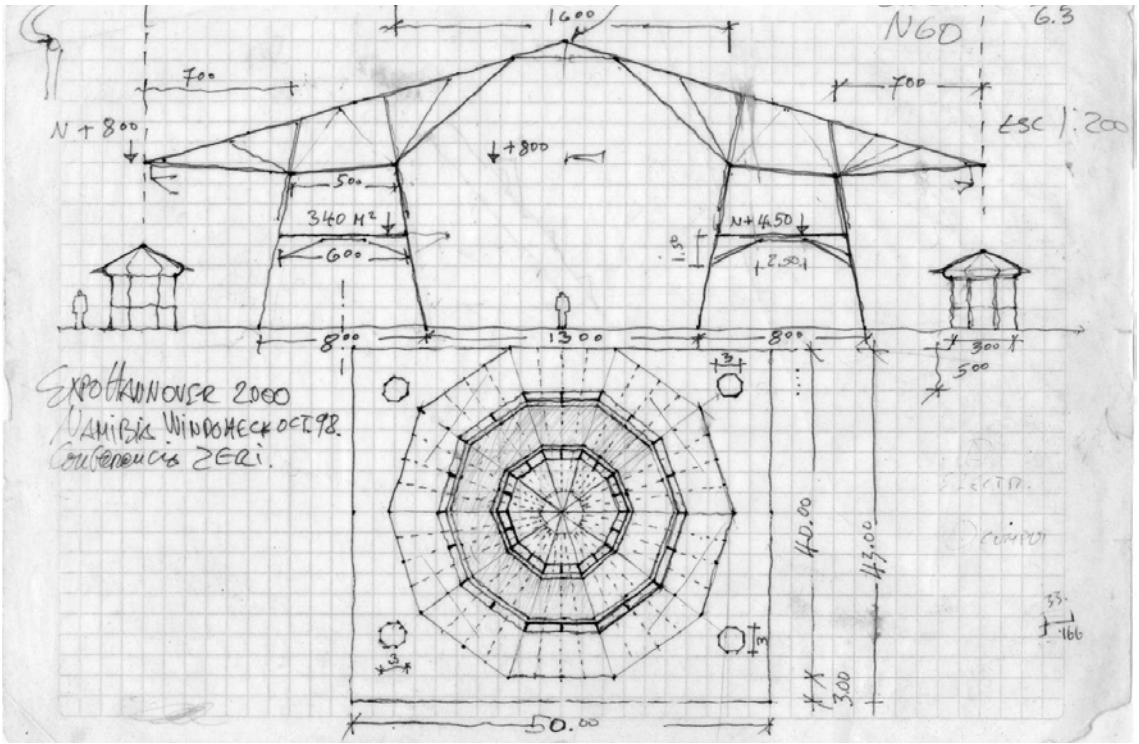
Both of these systems were tested at FMPA Stuttgart. The type A connection resulted in no initial slip and an ability to withstand a maximum load of 70kN. Type B had an initial slip of 1.5mm, but was able to withstand a load of 140kN.

Given that many of these systems had not previously tested, the 1:1 prototype was built in order to prove that the pavilion would meet German standards. During the construction of the prototype a number of different tests were performed, which were then replicated during construction in Germany.

The structural testing was developed from existing timber standards. Testing by FMPA Stuttgart found that bamboo strength values where better than the prescribed timber strength (NH 10). However flexuosity and shear where slightly worse. Experiments for the connections were undertaken in both Colombia and Stuttgart.

During the expo, the ZERI pavilion proved to be the most popular destination, attracting 6.4 million visitors during the 5 month Expo. However upon the conclusion of the expo, the pavilion was demolished to make space for a car park.

However the original 1:1 prototype still stands in Manizales.



Sketch, ZERI Pavillion ▲
Manizales, Colombia
Image: Simon Velez

Bamboo Connections, ZERI Pavillion
Manizales, Colombia
▼ Image: Jed Long

Constructing the ZERI Pavilion ▲
Hannover, Germany
Image: Carolina Salazar

SIMON VELEZ | JENNY GARZON BRIDGE

Bamboo is not a tree; it is a giant woody gramineae [true grasses] that also produces wood. It's an alternative forest product that allows us to avoid exploiting rainforest trees in search of wood. When we cut a bamboo, we are cutting a blade of grass that grows very fast. When we cut a tree you have to wait many years until the new tree is able to be harvested.

-Simon Velez

Spanning Calle 80, one of the main access points to Bogota, the Jenny Garzon Bridge is one of the largest bamboo bridges in the world. Visiting the bridge, demonstrated what an incredible feat of engineering it is. The bridge is incredibly robust and sits in a highly industrialised environment, a very different location to the majority of bamboo construction. Colloquially known as Puente Guadua, the bridge serves as a pedestrian and cycle path across the busy motorway.

Inspection of the structure revealed some signs of cracking bamboos, however for the most part the bridge appeared to be in very good condition. There was a clear connection to the tradition of timber construction that the Colombian bamboo movement has evolved from. A large bundled beam of bamboo arched across the space to which all of the bridges structure connected. It was a reinvention of existing structural systems, utilising bamboos tensile strength.

Jenny Garzon Bridge
Bogota, Colombia
Image: Jed Long ▼

ORGANIZMO

The flow of cultural homogenization is creeping rapidly across the built world. The speed of today's industrial growth is blanketing a tsunami of poetic loss.
-Travis Price

Organizmo Design Build Centre focuses on community empowerment through local knowledge and resources, and the development of educational models that emphasise participatory and cyclical methods of building

The founder of Organizmo, Ana Maria Gutierrez has been developing a pedagogical model for the reconstruction and conservation of the different ecological and social ecosystems in Colombia. The headquarters of the organization are in Tenjo, just outside of Bogota and plays host to a number of different initiatives that Gutierrez and her team have implemented over the last decade. By focussing upon education, Organizmo seeks to strengthen the intangible cultural heritage of communities within Colombia and the surrounding Amazonas. This process in turn opens up a dialogue on the role of traditional vernacular knowledge within a contemporary setting. The focus upon intuitive technology and the implementation of pedagogies for self-construction, builds upon the work of similar organisations such as TIBA that recognise the prevalence of informal architecture and the contemporary eradication of vernacular knowledge.

Organizmo's Centre for Bioconstruction in Tenjo housed a number of different architectural typologies that had been created through a series of different workshops hosted by local and international artisans and architects.

Of particular note was the Maloca, a traditional ceremonial building indigenous to the region that was constructed of bamboo and timber. The building utilises on ground pre-fabrication as a method of overcoming the absence of any machinery throughout the construction process. It also incorporates fire as a ritual ceremony that not only strengthens cultural heritage but also serves to preserve the building from insect infestation and mould.

Maloca
Tenjo, Colombia
Image: Jed Long

UNIVERSIDAD NACIONAL DE COLOMBIA - MANIZALES

As in the case for wood, bamboo can be engineered to form products with improved and/or standardised mechanical, physical and aesthetic properties The transformation of these lignocellulosic materials with variable shapes into engineered products with predictable properties and generally rectangular shapes facilitates their mainstream use in construction.
Trujillo and Archila

Bamboo has a high potential for use within the construction industry as a construction material with formidable environmental credentials. However, the use of bamboo in this capacity is currently limited because of its lack of standardization, structural non-predictability, temporality, and the high level of craftsmanship associated with bamboo construction. In order to address these constraints and facilitate the use of the bamboo in the new built environment, the workshop at UNAL Manizales, explored the latest processing technologies, digital modeling techniques and new construction techniques applied to bamboo.

The workshop introduced computational tools and advanced construction technologies for the parametric design and the construction of laminar space structures with bamboo. Participants had the opportunity to design, model and build these structures and evaluate its behavior under load. The results of the workshop were presented during the V SIBGUADUA in Bogotá.

The workshop was facilitated by Carolina Salazar, a professor in the Faculty of Engineering and Architecture at the Universidad Nacional de Colombia, Manizales. Dr Salazar was the Project Architect for the ZERI Pavilion.

Prof. Chepe Munoz explaining his research on bahareque ▲
Manizales, Colombia
Image: Carolina Salazar

▲ Prefabricating the gridshell on ground
Manizales, Colombia
Image: Jed Long

Left to right: Jed Long, Dr Hector Archila, Ricardo Leyva, Carolina Salazar
Manizales, Colombia
Image: Jed Long ▼

It also included Ricardo Leyva the founder of Mexican practice Ojtat Regenerative Architectural Workshop and Dr Hector Archila, the founder of Amphibia Group SAS (Colombia) and Amphibia BASE Ltd (UK). Dr Archila is also a researcher at the University of Bath specializing in the engineered transformation of bamboo and an Ambassador to the World Bamboo Organisation.

The desire to explore tensile structures in the workshop derived from the physical composition of bamboo. Unlike timber, bamboo has no radial cells. As such it is composed of unidirectional fibres the run along its length. At a cellular level, bamboo is composed of vascular bundles, fibre bundles and parenchyma cells. Because it is a grass there is only one growth stage. Bamboo reaches its full height in a very short period of time, after which it cells thicken which is why bamboo cannot be harvested for structural purposes until it is at least 3 years old. As a result bamboo is anisotropic and particularly weak perpendicular to its fibre.

Taking these factors into account the workshop identified how these properties can be best utilised through structural forms like grid shells. Combining the experience of Cave Urban with the research of Dr Hector Archila, provided an opportunity to explore ideas around how vernacular styles of construction can be formalised into a certifiable method of construction.

Dr Archila's thesis 'Thermo-hydro-mechanically modified cross-laminated guadua-bamboo panels' focused on the development of standardised products utilising replicable manufacturing technologies and engineering methods to measure and predict mechanical behavior. The process was based upon the development of a thermo-hydro-mechanically modification of guadua strips that densified the material and provided a uniform fibre content. The densified guadua strips enabled the bamboo to become a uniform engineered material that could then be utilised in the creation of a grid shell structure.

This research was significant as it presented a new direction for bamboo as a construction material. To date much of the research in regards to engineered bamboo focus's upon utilising existing knowledge around timber construction and adapting it for bamboo. Because knowledge of bamboo is so limited this is an efficient way of establishing a knowledge base for bamboo construction. However it limits the engagement with bamboo to explore new forms based upon bamboo's unique structural properties.

The workshop was set up so students would construct two separate structures. The first structure was a 5m diameter space created from untreated guadua splits woven together. It is a style of construction that has evolved from the work of Taiwanese artist Wang Wen Chih. It was a means to establish a control for the project and introduce a new style of construction to Colombia. The second structure would be the bamboo gridshell, designed utilising rhino and grasshopper. This structure would be constructed with a much more deliberate methodology and would be contrasted against the traditional style.

SIB GUADUA

The opportunity to present at SIB Guadua came about as a result of interactions with Dr Hector Archila in setting up research opportunities for my Churchill Fellowship.

The Research Network in Bamboo and Guadua (SIBGuadua) focus its study upon the growth and application of bamboo. The network brings together the leading researchers in Latin America, many of whom were responsible for pioneering research into the structural properties of bamboo. In particular, two of the most significant contributors to bamboo research, Ximena Londono, the president of the Colombian Bamboo Society and global expert on taxonomy and Professor Caori Takeuchi, one of the key drivers behind structural research of bamboo and the creation of the Colombian bamboo building code, were present.

Professor Yan Xiao, was one of the international invited keynotes. Dr Xiao, has pioneered the research and development of GluBam; a bamboo based glue laminate product. Inspired by the transport efficiency of the steel industry where flat sheet accounts for 50% of global trade, GluBam is processed into a flat product that can be easily transported before being process into columns and beams. By situating production close to where the product is grown and sourced, emissions and cost of transport are greatly reduced. With lower CO_2 emissions than timber, Dr Xiao wants to position the product as a timber substitute to enable it to fit straight into the existing market. Unlike other bamboo laminate products, GluBam has a density of less than 0.9 which allows everyday carpentry tools to work it. To overcome bamboo's unidirectional structural attributes, the product is cross laminated and glue-use is reduced as much as possible. Research to date on the product has investigated how it can utilise similar connection methods to timber and be able to resist fire. Some concerns remain around its exterior durability, however a water resistant GluBam has been developed.

Dr Hector Archila's presentation touched on a similar topic to what Dr Xiao was looking to overcome with his GluBam product. Investigating the difference between utilising bamboo in China versus exporting to Europe, Dr Archila referenced INBAR Technical Report 35 that demonstrated an 89% increase in embodied energy due to transport. The solution to this issue is to locate manufacturing as close to the point of harvest as possible. Transporting whole poles is highly inefficient and so bamboo should be processed into splits before transporting to a factory.

Dr Archila's argument ran counter to what Dr Xiao had discussed by stressing that bamboo is a grass not a tree. As such its structural qualities are in some ways very different to timber. The manufacturing of bamboo laminate products is yet to be optimised and can lead to up to 50% of the product being lost to waste and a glue content of up to 30% in the finished product.

Dr David Trujillo presented his work on the classification of bamboo. Acknowledging both the difference and similarities between bamboo and timber, Dr Trujillo has utilised existing timber standards as a starting point. The high variability of bamboo is evident not only between species but also within species depending upon location and a number of other factors. In order to address this variability, Dr Trujillo has drawn upon existing timber classification guidelines and established two concurrent processes of grading- visual and structural.

Visual grading requires a trained person with experience, who can identify the defects that need to be controlled. Mechanical classification of structural properties requires the correlation of properties measured destructively with properties measured in a non-destructive manner, i.e. Modulus of Elasticity. In order to correlate non-destructive properties, characteristic values to define a class must be established. The challenge is that every country is likely to have a different set of norms and so research is required across the variety of species in a variety of locations. To reduce variation, ISO 19624: Grading of Bamboo, to be published in 2018, sets out requirements for the manner in which these tests are to be undertaken.

To date the tests undertaken to drive this research has only been done with Guadua Angustifolia. Dr Trujillo stressed the need for similar tests to be undertaken with other primary structural bamboo species such as Moso or Asper. The value in establishing classification is to add value to bamboo as a reliable product. This enables higher levels of confidence and safety in its use, providing a platform for improved standards and engineering certification.

▲World Bamboo Ambassadors Ximena Londono, Jed Long, Dr Nirmala Chongtham and Dr Hector Archila at SIB Guadua V
Manizales, Colombia
Image: Jed Long

CONCLUSION

Visiting Colombia generated a number of key outcomes for my research. It was an opportunity to investigate a style of building that has evolved from traditional timber construction and could be directly applicable to Australia if we had workers with sufficient levels of skill. The Colombian building codes formed the framework of the existing ISO standards, which can be currently referenced in regards to construction in Australia. What continues to be prohibitive for our own bamboo industry is the absence of skilled craftsman and high labour costs.

Observing durable bamboo architecture demonstrated the longevity of the material provided it is utilised in the correct manner. Through the treatment of bamboo through a variety of different techniques, rendering it with bahareque and protecting the structure with a large roof, a road map is established for best practice for bamboo construction. However this is only one proven method of working with the material and other examples can be referenced when developing new methods of durable bamboo construction.

The opportunity to work closely with Dr Archila served as an introduction to the academic community of the UK and provided an introduction to the leading academics on bamboo standardisation. Similarly the many contacts made during SIB Guadua has served as a pathway into the Latin American community, which will continue to develop as a relationship over coming years. Due to my Churchill Research I have subsequently been invited as a keynote speaker for the 2018 World Bamboo Congress in Veracruz, Mexico.

▲ Tradition Maloca wall construction utilising bahareque, bamboo and stone.
Tenjo, Colombia
Image: Jed Long

UNITED KINGDOM

There is a strong narrative that connects the cultivation of bamboo to construction and social development in countries where bamboo is native. Round culm bamboo is often utilised as a building material and the construction methodology is the evolution of traditional vernacular techniques. However with increasing urbanisation, the methods of construction are not directly relatable to dense urban environments or to standardised systems of construction. In order for bamboo to be relevant to mainstream construction, these problems must be addressed.

Despite not having any indigenous species or culture of bamboo, the United Kingdom (UK) is currently generating some of the leading research on bamboo in construction. The growing interest in natural materials has led to the establishment of the Centre for Natural Material Innovation at Cambridge University and the BRE Centre for Innovative Construction Materials at Bath University.

The Architecture Association (AA) and Coventry University are also contributing to a dialogue that investigates how bamboo can be standardised and utilised through conventional construction systems.

Through the invitation of the Humanitarian Bamboo Project and the support of my Byera Hadley scholarship, I had been invited to participate in a scoping review at Cambridge University in January 2017. This opportunity opened a dialogue with Dr Michael Ramage of the Centre for Natural Material Innovation and provided a starting point for my Churchill research into the material properties of laminate bamboo structures and the wider social and environmental relationships of manufacturing bamboo.

During my stay in January, I used the time to reach out to a fellow World Bamboo Ambassador, Dr Hector Archila of Amphibia BASE. Dr Archila was able to introduce me to the BRE Centre for Innovative Construction Materials at Bath University and our time together led to the development of the workshop with UNAL in Colombia. Returning to the UK during my fellowship provided an opportunity to continue to develop relationships with these organisations and to uncover the possibilities for the application of bamboo within a highly regulated environment.

CAMBRIDGE UNIVERSITY
CENTRE FOR NATURAL MATERIAL INNOVATION

...the culm is naturally a structural form. The efficiency of the section is the product of millions of years of evolution.
-Trujillo and Ramage

Dr Michael Ramage founded the Centre for Natural Material Innovation (CNMI) at Cambridge University as a means of bringing together scientists, engineers and architects to develop alternatives to traditional manufactured materials. Identifying that the built environment is one of the most resource intensive fields of human endeavour, CNMI seeks new sustainable applications for plant-based natural materials.

Working on a scale that ranges from molecular to high rise construction, Dr Ramage and his research associates have adopted a position that natural materials are an essential component of a sustainable future built environment. However to ensure long term durability and structural optimisation, modification is required to uncover new opportunities for material application.

The CNMI identifies the key themes to their research:
-Assembly of plant based materials
-Impregnation of intact materials for better properties
-Understanding and designing improved functional materials

Their research into bamboo address these themes by examining the effect of treatment systems upon whole culm bamboo and how engineered bamboo products can increase performance and provide standardisation.

Working in conjunction with HBC, the CNMI obtained funding to explore the potential of bamboo to help mitigate the impacts of climate change in Pakistan. The final meeting of the scoping review was held in January 2017 and provided an opportunity to discuss how bamboo can play a role in increasing resilience to natural disasters and provide capacity building for communities in developing countries.

The outcomes of the meeting were applicable not only to Pakistan and generated some wider research questions as to how bamboo can be used as a tool for regeneration and development, given that the majority of countries growing bamboo are also those most vulnerable to climate change.

The research of Dr Ramage and Dr Bhavna Sharma has built upon these ideas to conclude that engineered bamboo products are critical to providing a pathway for the utilisation of bamboo in a dense urban setting. The processing of raw material into laminated composites allows for standardisation in construction and less inherent variability when compared to the natural material. Through their research they have been able to demonstrate that engineered bamboo products have properties that are comparable or surpass that of timber and timber-based products. Whilst there are still a number of limitations to the use of these products in structural design, further research is being undertaken to resolve these issues.

UNIVERSITY OF BATH
CENTRE FOR INNOVATIVE CONSTRUCTION MATERIALS

The inherent variability of bamboo geometric and material properties continues to be a disadvantage for engineering design. The variability, however, can be overcome with standardized testing and reporting methods that provide the necessary information to create engineering design standards.
Dr Bhavna Sharma

Dr Bhavna Sharma, joined the BRE Centre for Innovative Construction Materials (BRE CICM) after previously working with Dr Ramage at the University of Cambridge. Dr Sharma's work has centred upon utilising an interdisciplinary approach to the investigation of and development of bamboo as a structural material. Together with Dr Kent Harries, the Leverhulme Visiting Professor at BRE CCIM and co-director of the Nonconventional Engineering Materials initiative at the University of Pittsburgh, Dr Sharma has co-edited the highly influential text; Non-conventional and Vernacular Construction Materials.

Meeting with Dr Harries provided an opportunity to understand the development of research towards engineered bamboo products that has arisen in the UK. Of interest to both Dr Harries and Dr Sharma was the application of structural bamboo in an urban context. Developing countries with an existing history of bamboo craft were identified as having a strong case towards the development of bamboo industries to support urban development. A strong raison d'etre for the utilisation of bamboo in the built environment was established by referencing the increasing environmental degradation of certain countries that is amplified through climate change, population growth, urban development and unsustainable farming and resource extraction practices.

In order to make a strong case for pursuing the development of bamboo economies and building practice, they both argued that the entire product cycle must be examined to ensure value is gained at all stages. Drawing upon research from INBAR (The International Network for Bamboo and Rattan) they discussed the ramifications of over 1 billion people globally living in bamboo housing, the majority of which is informal without the input of architects. With 73% of people in Bangladesh (one of the country's most vulnerable to climate change) living in bamboo houses, the opportunities and benefits for improving current building practice are extensive. However the push towards western ideals of modernism has also led to the erosion of traditional building knowledge and the transition towards architecture of concrete and brick, materials highly unsuitable to the climatic and cultural conditions of these locations.

Dr Harries and Dr David Trujillo (Coventry University) have helped set the agenda on this topic through the establishment of three symposiums hosted by the University of Pittsburgh entitled Bamboo in the Urban Environment. The declaration from the initial symposium sets out a vision for bamboo as a construction material for the 21st century. Stating that "bamboo can contribute significantly to achieving many of the social, economic and environmental objectives of the new UN Sustainable Development Goals" and that

"when used sustainably in its untransformed culm-form, bamboo has a smaller environmental impact than any other conventional structural material, including timber".

However they identify that "standardisation is essential for empowering construction professionals to adopt bamboo as a mainstream building material".

As a recommendation the symposium called for participation in the ISO bamboo standard development for the newly created ISO Technical Committee (TC) 296 – Bamboo and Rattan, as well as in ISO TC 165 – Timber Structures, Working Group 12 – structural use of bamboo.

The findings from this symposium set out clear and necessary steps towards the standardisation and utilisation of bamboo as a modern building material. However, the outlined visions also underscores the predominance of engineers driving this push towards standardisation and highlights the need for other disciplines to provide a whole systems understanding of the relevance of bamboo to the construction industry and the impact towards development of community.

Dr Sharma voiced a similar concern stressing that the exploratory/artisanal/ making process is of just as much value as the standardisation / efficiency / best practice mindset that tends to be prioritised. Dr Sharma stressed the idea of design as a medium that transcends the boundaries of any one discipline and allows for a larger holistic perspective that creates potential for disruption of existing systems and the creation of more resilient supply chains. The outcome being that we remove existing bias towards western research institutions and implement the utilisation of broad non-derogatory terms that combats the branding of the un-modern as less than.

Engaging with a non-biased agenda when assessing the efficiency of bamboo construction is a necessary step towards a larger holistic understanding of bamboos role in the built environment. Over emphasis upon the empirical methodologies of colonial institutions neglects the embodied knowledge of vernacular culture. As such research and the move towards standardisation is just as important as improving the pedagogical models that allow for information to be spread through informal channels to improve the standard of informal construction. These alternative forms teaching and researching can be seen in the practice of organisations such as Organizmo, Humanitarian Benchmark Consulting or Cave Urban and are just as necessary as the work generated through institutions such as BRE CICM.

THE ARCHITECTURE ASSOCIATION
VISITING SCHOOL

In comparison with importing new housing technologies to developing countries in both long-term development and postdisaster scenarios, simply improving traditional housing can often be a more appropriate solution in many respects
-Sebastian Kaminski

The Architectural Association (AA) Visiting School is a short course program that provides opportunity to apply the AA pedagogical approach to a growing diversity of projects around the world. John Naylor, founded the Haitian Visiting School in 2013 as a means to engender bamboo to the Haitian construction industry. Building upon design generated by Haitian architecture students, the program has run four successful design and build workshops that aim to highlight the structural and aesthetic qualities of bamboo.

Working in conjunction with Sebastian Kaminski of ARUP Engineering, the program responded to the need for buildings to be earthquake resilient and tied into research that Sebastian has undertaken in El Salvador, and other Latin American countries. The typologies utilised through this methodology had evolved from the traditional bahareque housing of Colombia which has proven resilient to seismic activity.

Meeting with John provided an opportunity to discuss, the methods of disseminating knowledge through educational programs and the challenges of working in a post disaster environment. John highlighted the need for on the ground partners and maintaining goodwill across the community. Drawing on his experience in Haiti over a period of years, John reflected that much of devastation that is wrought on the island through floods, storms and earthquakes is the result of a broken ecology, poor construction and widespread deforestation. The consequence of which is the rejection of traditional building practice in favour of concrete and heavy weight construction.

Establishing an educational framework that integrates architecture with land stewardship, vernacular typologies and hands on experience, provides an opportunity for students to engage with local community and establish a dialogue on the value of light weight construction and reforestation. Utilising bamboo not only as a means of construction but also a form of regeneration, John's work examines how the cultivation of bamboo can stabilise hillsides, create wind barriers and reforest land. Through the creation of new opportunities for employment that also repairs the islands ecology, the program is working towards creating sustainable, resilient housing and redefining the value of an architect.

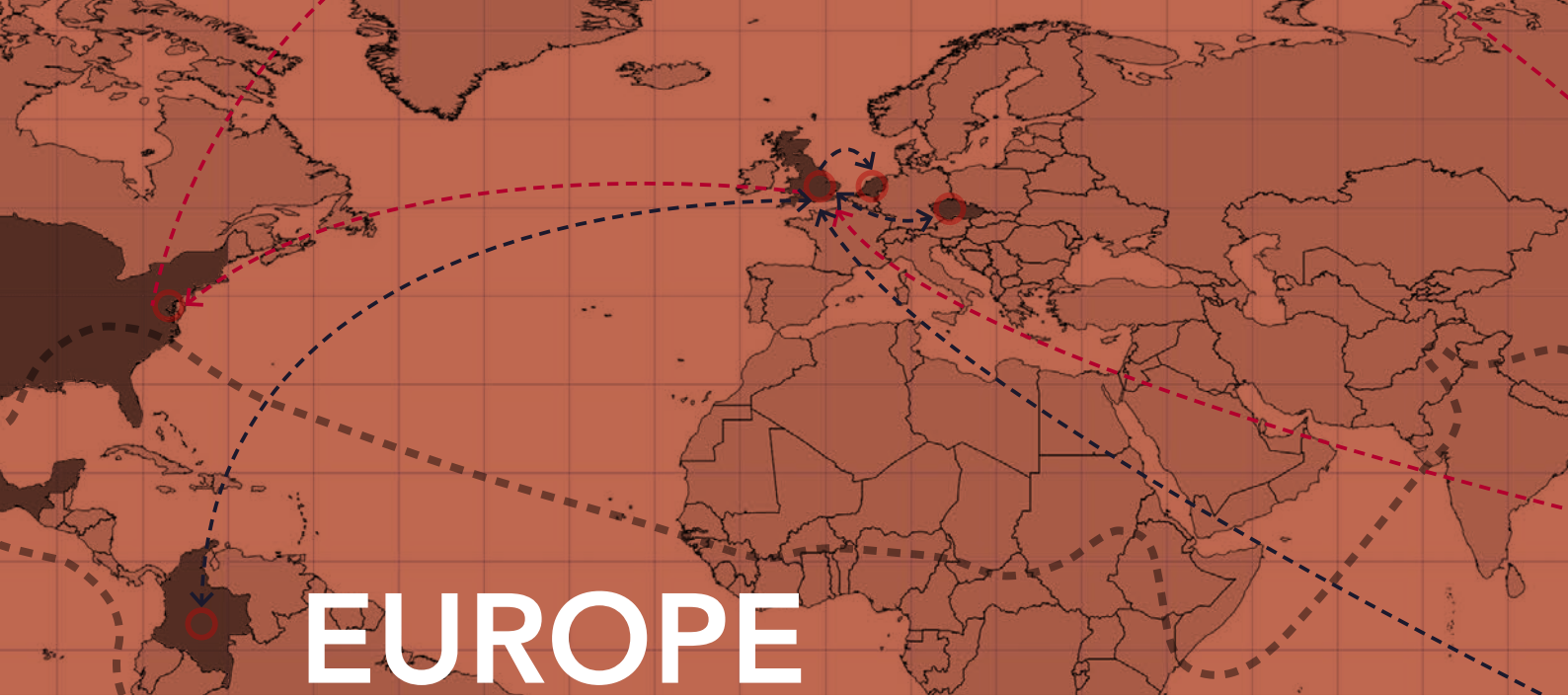
CONCLUSION

The key outcomes from my time spent in the UK was being able to establish an ongoing relationship with leading researchers at the University of Cambridge and Bath. The emphasis of current research upon the standardisation of bamboo through mechanical transformation, demonstrated an underlying tendency towards delivering outcomes that address the application of bamboo in an industrialised setting.

Whilst the most direct pathway to utilising bamboo in a highly regulated built environment lies in engineered bamboo products. It must also be balanced with research that investigates how the existing population of people living in bamboo housing can adapt or improve their current situation. With 1 billion people living in buildings that utilise bamboo, there is the potential for this housing stock to be replaced by materials with high embodied energy such as concrete, causing further environmental degradation. Despite none of these people living in the UK, the research being undertaken and disseminated has the potential to help alleviate this issue.

▲ End Bolt
Hooke Park, England
Image: Jed Long

Workshop ▲
Hooke Park, England
Image: Jed Long



EUROPE

Europe provided an opportunity for examining how bamboo could be utilised in a society with no history of bamboo craft and a highly regulated construction industry. A number of different organisation in multiple countries provide alternative examples of how and why bamboo can play a role in the built environment.

In 2013, I attended a workshop in Portugal with bio-construction group Canya Viva. The Churchill provided an opportunity to reconnect with Jon Cory-Wright (founder of Canya Viva) in Barcelona, to discuss the longevity of their buildings and the future direction of their company. In a manner similar to Cave Urban, Canya Viva have been utilising workshops and harvesting their own material to create houses that utilise bahareque to ensure longevity.

Sven Mouton has adopted a different approach to design a home from bamboo in the town of Ghent. Drawing upon Colombian jointing techniques, Sven has utilised bamboo as part of a hybrid construction system. Without a building code for bamboo in Belgium, construction of the house was only possible through reference to ISO 22156:2004. As a case-study for how bamboo can be utilised in Australia, it highlights the importance of the International Standard for bamboo.

ISO Technical Committee (TC) 165 is responsible for overseeing ISO 22156:2004. During my fellowship, the annual meeting for TC 165 took place in Vienna, providing an opportunity to witness first-hand the process of establishing and maintaining international standardisation for both whole culm and engineered bamboo.

Attending TC 165 was also an opportunity to meet Dr David Trujillo (Coventry University and current head of Working Group (WG) 12), Dr Bhavna Sharma, Dr Louis Felipe Lopez (A key contributor to the Colombian Building Code and ISO codes) along with Arjan van der Vegte (Research and Development Manager, MOSO).

Through Arjan, I was able to visit MOSO and gain a commercial perspective on the value of the bamboo industry and how it can be further developed for both developed and developing markets. The work of Dr Pablo van der Lugt, the MOSO's Head of Sustainability, also provided insight into the LCA analysis of bamboo and how it compared to other building materials.

ISO TECHNICAL COMMITTEE 165 | VIENNA

The intent of the ISO (2004a) standard is to establish a modern limit states design approach while recognizing traditional design and practices. Precisely because of this dichotomy, however, the standard is simultaneously inadequate on both counts in the context of application in developing regions.
-Harries and Sharma

The recent emergence of bamboo as a contemporary building material correlates to research undertaken to establish national building codes for bamboo. The 1999 earthquake in Armenia, Columbia has been directly attributed to the subsequent production of the Colombian Code for Bamboo Construction. As the first building code for bamboo construction, the Colombian guidelines have subsequently been adapted as the foundation for national codes in Ecuador, Peru, China and India.

ISO Technical Committee 165, Working Group 12 was established to develop an international standard for bamboo structural design. Sitting within ISO/TC 165 Timber Structures, working group 12 drew upon existing national codes and timber guidelines to develop ISO 22156:2004, first published in 2004.

Subsequent research has led to the understanding that whilst a significant first step, ISO 22156:2004 requires significant revision. Since only a handful of countries globally have developed a nation code for bamboo construction, the ISO standard has become the benchmark for certification worldwide. As such continuing input from WG 12 is required to ensure its ongoing relevance.

With more than 2000 species of bamboo worldwide, the structural properties of this material vary significantly, posing significant restriction to full culm construction. A major obstacle for mainstream construction is the lack of standardisation in connection and jointing techniques due to bamboo's round and variable section. The application of bamboo as a material for highly regulated building industry has thus centred on the potential of engineered bamboo composites for its environmental credential and standardisation of shape.

Since ISO 22156:2004 is applicable only to full culm bamboo, the need for a similar code for engineered structural bamboo is evident, in order to ensure quality control for products entering the market. During the proceedings of 2017 ISO/TC 165 meeting in Vienna, Arjan van der Vegte (Research and Development Manager, MOSO) and Dr Bhavna Sharma put forward a proposal for the creation of a new ISO standard for engineered bamboo products. The proposed standard would be derived from existing engineered timber standards and cover standardisation, characterisation and manufacturing. Future research would thus be able to ascertain whether existing timber standards are relevant or require modification to suit bamboo's unique structural properties.

The research required to generate this standard is currently being undertaken at a number of institutions around the world. Mateo Gonzales, a PHD candidate from the University of Queensland is part of this process through his investigation of the fire resistance of engineered bamboo. Meeting with Mateo and following on from discussions with Dr Trujillo, Dr Sharma and Arjan demonstrated how much research is still required to develop a comprehensive understanding of the behaviour of laminate bamboo products.

What does become clear is that even when considering engineered bamboo products, a strong connection still links it back to its point of origin and the social and ecological narrative that accompanies it. Attempts to standardise and rationalise bamboo, must then continue to involve partners outside of university settings, particularly those working directly with the production of bamboo products in order to provide a real world perspective on the implications of manufactured bamboo products.

TC165 Group Photo
Vienna, Austria
Image: Paul Jaehrlich ▼

MOSO | AMSTERDAM

If we only let the facts speak, we have insufficient logic to gather the attention for bamboo it so much deserves.
-Gunter Pauli

The MOSO Group was founded in 1997 in the Netherlands. As an early adopter of bamboo distribution and with headquarters in China, Africa, the Middle East and North America, MOSO is a global leader for engineered bamboo products. MOSO maintains a strong research and development focus, working closely with Universities to drive development of new bamboo products.

Arjan van der Vegte and Dr Pablo van der Lugt have been leading MOSO's research into the structural and environmental properties of bamboo. Arjan has been working closely with Chinese suppliers to instigate best practice throughout the manufacturing process and is particularly concerned with quality control and the negative impact on consumer confidence caused by inferior product. Arjan sees the introduction of an ISO standard for engineered bamboo as a vital step to ensure producers are held responsible for the quality of their product and that the environmental benefits are real.

Dr van der Lugt has meticulously detailed the carbon footprint and Life Cycle Analysis (LCA) of MOSO products, establishing that almost all industrial bamboo products are CO_2 negative when utilising best practice. By providing complete transparency on the embodied energy of their products, MOSO seeks to establish market differentiation from lower cost products that often having issues regarding durability and the higher embodied energy.

Sample of a cold press utilised in the manufacturing of bamboo laminate beams. Amsterdam, Netherlands
Image: Jed Long

In his analysis, Dr van der Lugt identifies the energy consumed during the processing of industrial bamboo products as having the largest effect on carbon footprint (50-60%)

The next largest contributing factor is transport. Local transport can be optimised by locating the manufacturing process close to the point of harvest and by splitting poles prior to transport to ensure maximum volume in each delivery. For products destined for overseas markets, international sea transport can contribute up to 15-25% of the carbon footprint. This can be optimised by sourcing bamboo products from closer countries, for example in a European market China could potentially be replaced by a growing Ethiopian market.

Whilst not a large factor in carbon footprint, the resin used in bamboo products can make up a large percentage of the eco-costs of the product. MOSO is working towards replacing chemical resins with bio-glues, however there is currently no bio-glues capable of providing a high enough level of durability.

Since such a high percentage of the carbon footprint results from the manufacturing process, it can be said that the most environmentally friendly building material is the whole stem. However a low transport efficiency results in a substantial increase in carbon footprint from 0.20 kg CO_2 e/kg stem to 1,369 kg CO_2 e/kg stem when comparing locally utilised bamboo to bamboo that is shipped to Europe from China.

Arjan van der Vegte showing me the MOSO product range ▲
Amsterdam, Netherlands
Image: Jed Long

Dr van der Lugt makes the case that the major benefit of bamboo is the fact that it is a giant grass species making it less susceptible to clear cutting/deforestation and very suitable for reforestation for a number of reasons that include:

-The mother plant is the many stems that connect its vast underground root system, that produce many stalks each year.

-Bamboo is harvested like a crop. A steady annual harvest is able to provide a regular income to farmers and further stimulates bamboo growth. This is a significant point of difference to wood production where long term growth cycles make forests vulnerable to illegal logging or clear cutting for short term gain. As bamboo can be harvested regularly, clear cutting would signal a loss of capital for the farmer and thus occurs rarely.

-The extensive roots system of bamboo allows it to be cultivated on land where farming is not feasible, for example degraded land or eroded slopes. Its fast growth cycle provides a significantly shorter establishment time that wood plantations and help re-establish functioning eco-systems by improving soil quality and restoring the water table.

- Since 1998 when China instigated a nationwide logging ban of certain forests, bamboo has increasingly been seen as a substitute for wood timber and has entered many markets traditionally dominated by wood. Improving the durability of these industrial bamboo products will in turn increase the volume of carbon stock.

The utilisation of industrial bamboo products is a different narrative to the creation of whole culm bamboo structures. In the opinion of Arjan van der Vegte, it is the only way to engage on a large scale with bamboo construction in countries that do not have a tradition of bamboo craft. By standardising dimensions and connection methods bamboo can be utilised without material specific skill, allowing it to become a mainstream building product.

However an overemphasis upon engineered solutions risks ignoring the inherent artisanal knowledge that is present in informal vernacular construction and accounts for the majority of bamboo construction worldwide. Thus a balance must be struck and each avenue of research is just as valid as the other. Both narratives of round pole construction and engineered bamboo derive from the same starting point- that bamboo is a sustainable resource that provides social and environmental benefits in addition to a material resource. By taking a whole systems view we are able to identify benefits at every stage of production, which stands in direct contrast to non-renewable resources such as steel or concrete, or even tropical hardwood.

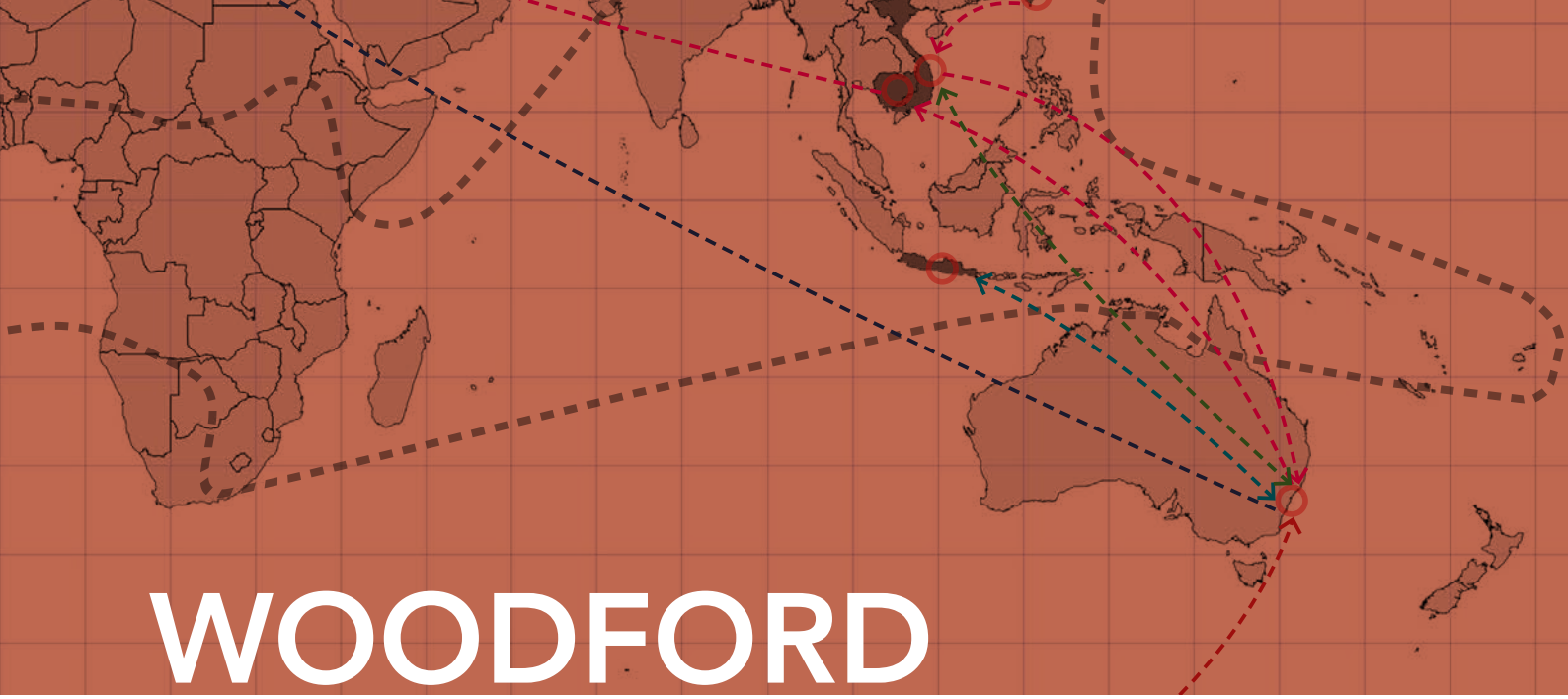
CONCLUSION

The key outcomes from my time in Europe was the introduction to the community of researches leading the development of bamboo standardisation. Through conversation and attending meetings to discuss the future development of standards I was able to gain access to information otherwise unobtainable. It proved to be hugely informative in shaping an understanding of the current global context of bamboo construction. Whilst time in Colombia and South East Asia has exposed me to how bamboo is applied in a built context, time with MOSO and Working Group 12 uncovered a twin narrative that begins from the same starting point but develops a method for how bamboo can easily be utilised in a regulated built environment.

The outcome is a system where bamboo is grown, utilised in construction and manufactured at its point of origin, but is also distributed to a global market as a manufactured material, creating new income streams. It demonstrates that we cannot simply look at Australia in isolation but rather we examine how Australia can fit into this wider context.

Drawing on my prior experience working with bamboo and the research undertaken during the fellowship, I also believe that it is not unreasonable to suggest that full culm bamboo construction is possible in Australia. However to achieve this we must think outside the box to deliver new methodologies for working with bamboo.

The Cave Urban Research Folio at MOSO ▲
Amsterdam, Netherlands
Image: Jed Long



WOODFORD

The Woodford Folk Festival provides an opportunity for research and experimentation that is globally unique. The strong support of festival leadership has created a platform for collaboration with various international experts and a space for direct dissemination to the Australian public through large scale installations, workshops and talks.

The collaboration between Taiwanese artist Wang Wen Chih and Cave Urban in 2013 proved to be a catalyst for encouraging Woodfords engagement with fostering a culture of bamboo cultivation and design. It is a process that has organically evolved over the past five years. The AV Jennings Churchill Fellowship has served as an opportunity to formalise this process into one with direct quantifiable outcomes.

Partnering with the Woodford Folk Festival and Cave Urban, Arief Rabik has been working to help grow the bamboo community in Australia. Utilising the Woodford site as a testing ground for further research that can directly translate back to Indonesia, Arief has been prototyping a new treatment system for bamboo.

The focus of the project is to create a closed loop system for growing, treating and constructing with bamboo. The project begun with the propagation of a two hectare bamboo forest, which is watered from the disinfected waste water of the entire site. Situated on a hillside, the project will study the change in soil conditions and the effect of utilising nutrient rich black water on the bamboo.

Planting begun in 2015 and was finished in 2017. Over the next 5 years the forest will establish itself and provide a sustainable annual yield of bamboo to be utilised across the Woodfordia site. To ensure the longevity of the bamboo that is harvested it will in turn have to be treated.

The development of the 'Bamboo Smoker' is the result of cross cultural collaboration between Australia and Indonesia. The aim of the project is to develop a system for permanent treatment of bamboo in a short time period, utilising machinery that is low tech, low cost and easily sourced. Currently the majority of bamboo is treated by soaking it in a Borax solution. This is a cheap and reliable process, however Borax is water soluble and as such will leach out of the material over time leaving it vulnerable to borer infestation. By smoking the bamboo, the project aims to transform the chemical composition of the culm, removing the sugars and starch through a process of carbonisation that leaves the culm permanently protected. It is an evolution of traditional bamboo treatment methods seen throughout south-east Asia and more sophisticated methods utilised in Japan.

By developing the project at Woodfordia there are direct educational and practical outcome for the Australian bamboo community, whilst also providing a means for direct translation back to Indonesian communities. The process looks to extract value from all stages of production, in order to explore the idea of a restoration economy. It is a closed loop system and its development provides benefit to both Australian and Indonesian communities, whilst also laying the foundation for future collaboration.

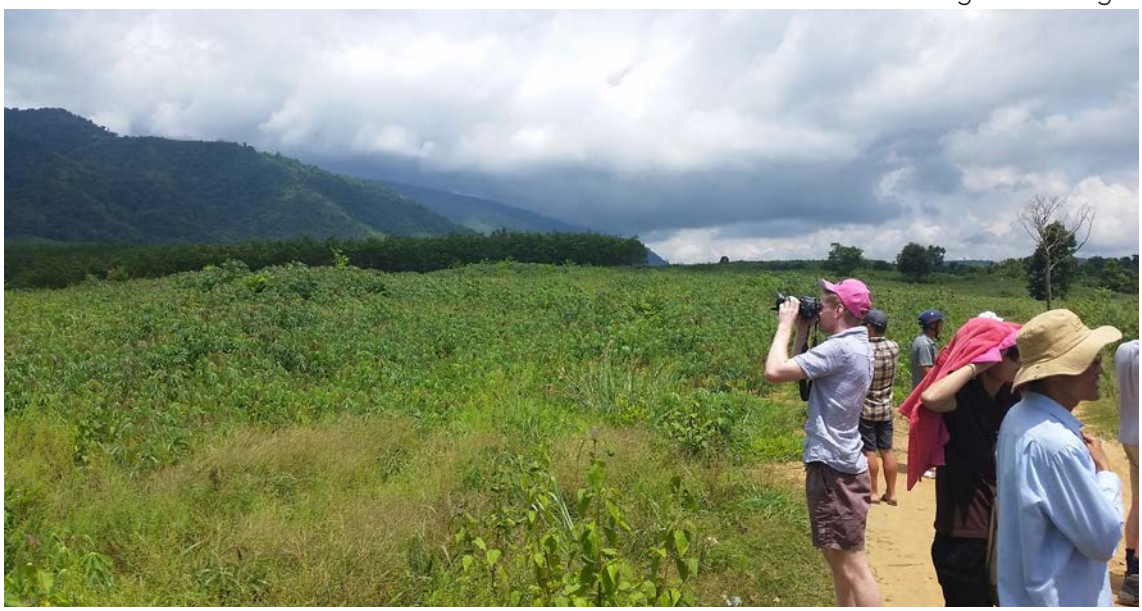
Humanitarian Benchmark Consulting has also begun to engage with Woodford. Running trainings on post-disaster reconstruction, the HBC has been disseminating the findings of the Humanitarian Bamboo Guidelines to a wider audience and testing ideas for direct application back to a real world application. In April 2017, HBC and Cave Urban came together to run a 5 day training workshop that taught participants the foundation of best practice for bamboo cultivation and construction.

Arief Rabik introducing Bamboo Smoker v1
Woodford, Australia
Image: Jed Long ▼

The purpose of these activities is to establish a bamboo community at Woodfordia to help educate and drive further investigations into utilising it as a construction material. Inviting Dr Ramage from Cambridge University to speak at the 2017 Planting festival helped also to elevate the rigour of what we are undertaking by inviting universities to collaborate on projects across the site.

▲ Humanitarian Bamboo Project, Post-disaster shelter workshop
Woodford, Australia
Image: Fabian Prideaux

Students visiting the proposed site in June 2017
Ro Koi, Vietnam
Image: Jed Long ▼

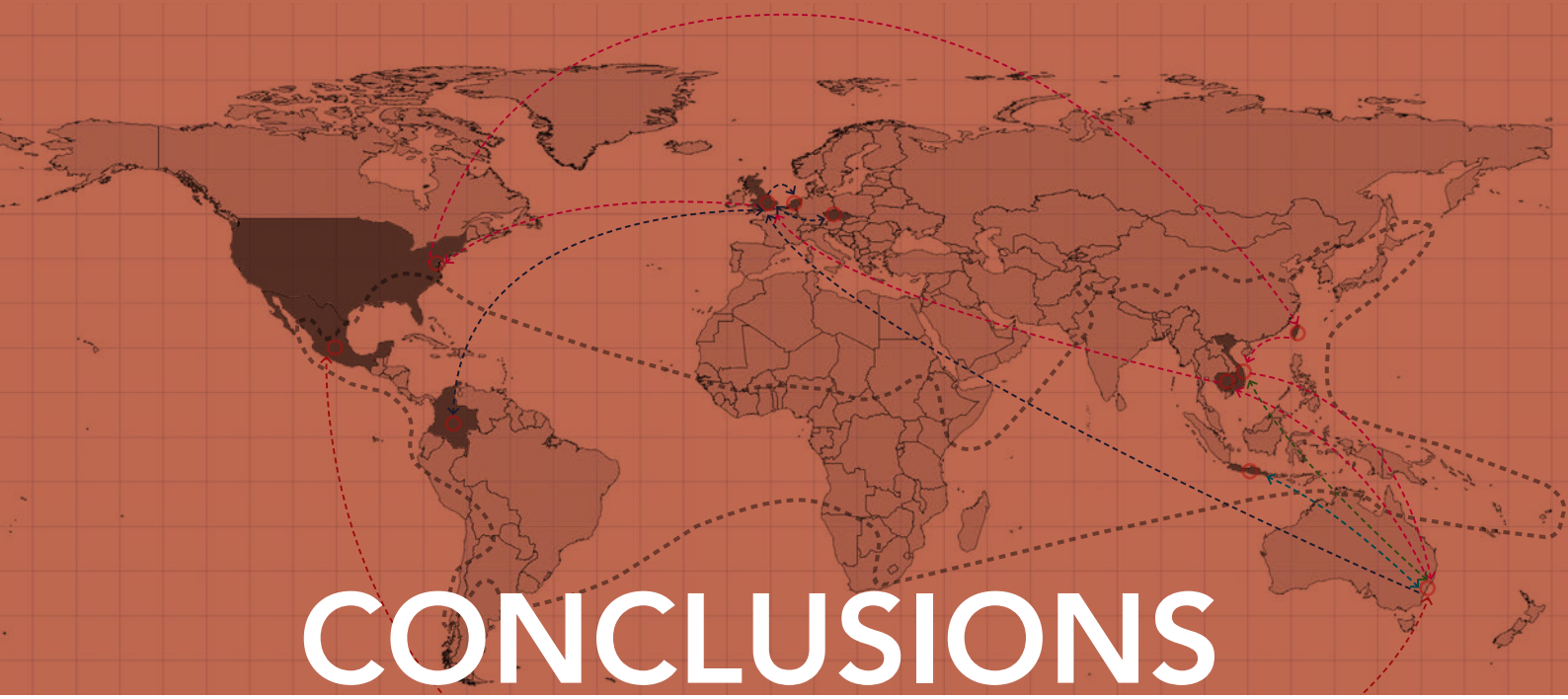


The University of Tasmania's Vietnam Bamboo study program has provided another means to continue to establish ongoing relationships with universities. The June 2017 studio introduced students to the community of Ro Koi in Vietnam's central highlands. Students were asked to Woodford 2017/18, a 1:1 prototype of this building was constructed over a period of three weeks. Working with a team of fifty unskilled enthusiastic volunteers, the process of construction drew upon a pedagogical system of master/apprentice. Skilled Cave Urban workers could educate volunteers through the construction process, providing an educational/labour exchange and simulating the process of capacity building through construction that would occur in Vietnam.

The results of the project were then brought back to Vietnam and further developed in the January 2018 studio, through a workshop with the National University for Civil Engineering and Hanoi Architecture University. Students were asked to continue to develop the design for the community in Ro Koi, by resolving construction details and exploring the potential of pre-fabrication.

1:10 and 1:3 Prototype for Ro Koi ▲
Hanoi, Vietnam
Image: Jed Long

▲ The Hammock Hut, 1:1 Prototype for Ro Koi
Woodford, Australia
Image: Jed Long



CONCLUSIONS

The AV Jennings Churchill Fellowship provided an opportunity to establish and develop relationships that would allow me to continue to undertake research and disseminate information beyond the conclusion of my fellowship. The relationship with Woodford and UTAS have provided two platforms for ongoing engagement in Australia, in addition to what I will implement through Cave Urban.

By engaging with organisations in both a developed and developing context I have witnessed firsthand the challenges of working with bamboo. But I have also gained great insight into the potential of bamboo, particularly when examining its benefits along the entire value chain. The translation of traditional vernacular knowledge into a contemporary architectural setting provides many lessons as to how we may work with the material in Australia. In particular it underscored the importance of utilising bamboo in a hybrid structural system.

The development with Dr Norrie of agritecture as a means of linking cultivation, harvesting, manufacturing and constructing with bamboo into a single social narrative, has provided a means to connect Australia with our neighbouring bamboo cultures. It establishes principles that can be translated into an Australian setting and expands architectures scope beyond the built environment.

The connection to institutions in the UK, Europe and Colombia, provided a link to how bamboo is being utilised outside of the Asia Pacific Region. The opportunity to meet these contacts would not have been possible without the opportunity provided by the AV Jennings Churchill Fellowship and has established relationships that will be vital as we encourage a research community in Australia to develop.

The following pages outline the key findings that have been taken from my fellowship. I have categorised them into Environmental, Construction, Social, Engineered and Research as a means of identifying the key areas of research to which this report has applied.

KEY POINTS

Environmental

-Environmental benefits are augmented by a social narrative- we must look beyond material properties to measure the social benefits of the entire growth/production cycle.

-Round Pole bamboo needs to be utilised near its source- transportation results added embodied energy.

-Bamboo is a great tool for regeneration, however if it is a highly valued material it has the same potential danger of palm oil, where rainforest could be cut down to plant monocultures.

-To achieve carbon efficiency bamboo requires some processing prior to transport over long distances.

-Full culm bamboo has the lowest carbon footprint provided it is utilised close to the point of harvest.

-Bamboo is capable of regenerating degraded soil, making it an excellent pioneer plant.

-One hectare of bamboo can absorb fifty tonnes of CO_2 per annum.

-Bamboo can grow on steep slopes and can be utilised to stabilise hillsides.

-Bamboo will not solve any of the world's issue's but it can help contribute to building resilience against the impacts of climate change.

Construction

-The most successful bamboo buildings are those that are designed as a hybrid system that utilises timber, bahareque, steel or concrete.

-Differing styles of bamboo construction throughout Asia and Colombia. Each country tends to replicate existing typologies derived from leading designers or precedents without reference to other locals and often without full understanding of how to work with the material.

-Australia does not currently have the capacity to develop its own bamboo standards.

-Online publications celebrate bamboo design that does not demonstrate best practice and as such leads to the dissemination of incorrect design strategies.

-Bamboo does not currently have the ability to be utilised in an urban context.

-Traditional construction methods require maintenance to extend life

-There are three broad categories of bamboo construction Vernacular, Low Skill, High Skill- the utilisation of each particular typology is dependent upon location and client.

Engineered

-Engineered bamboo products will have a greater impact upon developed markets than round bamboo

-Design standards for engineered bamboo are necessary to developing bamboo's potential. They are currently in the process of being written, drawing inspiration from existing timber design codes.

-Standardisation is key to establishing bamboo as a contemporary building material, but it risks removing it away from the artisanal craft that connects it to community.

-Engineered bamboo highest carbon component is manufacturing

-Engineered bamboo products have properties similar to timber and can be used to reduce pressure on tropical hardwood markets. Oversupply of European and North American softwoods means that it is not as necessary to support what is already a sustainable industry.

Social

-Informal settlements house a huge proportion of the world's population living in bamboo structures and have been created without input from architects and engineers. How can we address upgrading this style of housing so that people do not substitute bamboo for aspirational materials and in turn increase carbon footprint.

-Architecture should evolve from place and existing construction typologies in order to have the greatest impact.

-Capacity building for informal architecture needs to educate inhabitants on protection through design. Education is key to delivering large scale impact.

-The social benefits of bamboo require rigorous documentation to determine whether they are real or merely hyperbole.

-The benefits of bamboo should be considered along all stages of the supply chain to gain a whole systems understanding.

Research

-Any grading of bamboo is relative to the particular species in a particular place. However the framework for classification and testing are broad enough to cover all bamboo

-Technical knowledge around standardisation, engineering and manufacturing is being developed by a small cohort of academics deriving mainly from an engineering background and could be supplement by input from other disciplines.

-Research from Colombia has established the knowledge base for all building codes, it is developed on a particular vernacular history of guadua construction and so does not currently incorporate knowledge about other bamboo species

-Australia proximity to South East Asia positions us in a much better location to lead research and strengthen connection to our surrounding region.

-Collaboration between academia and industry is vital in order to push a balanced agenda. There is not nearly enough information sharing occurring particularly between developed and developing countries across different regions.

DISSEMINATION

The findings of my research have direct relevance to my professional practice and my role as an educator across multiple universities in Australia. Through an increasing involvement with the University of Tasmania and the development of the field of 'agritecture', I will be presented with multiple avenues of dissemination, through academic papers and through the development of this design research project with Vietnamese Universities. Similarly I will develop the Woodford Festival site as a platform for hands on workshops, training and talks, continuing to facilitate leading practitioners to come share their knowledge.

To date these are the following ways in which I have begun to disseminate information:
-UNSW Masters of Architecture, Design Studio
-UTAS Bachelor of Architecture, Vietnam Study Tour
-UTAS Summer Research Fellowships
-2017 Australian Student Architecture Conference
-ABC News December 26/12/17
-Woodford Folk Festival
-The Planting Festival
-Sydney Design Festival
-Keynote, SIB Guadua
-Humanitarian Bamboo Shelter Training Program
-UTS Masters of Architecture, Design Studio
-Green Magazine (https://greenmagazine.com.au/sustainable-bamboo-structures-built-queensland-music-festival/)
-Invited Keynote, World Bamboo Congress 2018

Hosting round table discussion about the future of the bamboo program at Woodford. ▲
Woodford, Australia
Image: Jed Long

RECOMMENDATIONS

-Australia's geographic proximity makes it an ideal location for engaging with Asia Pacific countries for developing research into bamboo construction.

-Understanding bamboo and its role in the built environment requires a multi-disciplinary field of expertise that can provide new potential research outcomes.

-Australia does not have the capacity to currently establish its own building code and so should instead contribute to developing international ISO codes by supporting TC165 WG12.

-Engineered bamboo products will have a larger application in developed markets that unprocessed bamboo. To ensure consumer satisfaction, high quality control is required to ensure cheap inferior products are not devaluing engineered bamboo. This can be regulated through the development of an international standard as certification.

-Investment in building resilience to natural disasters in low income, high population countries in close proximity to Australia will be crucial to the ongoing stability of this region. Government support should be provided to organisation investigating how existing bamboo construction systems can be improved.

-Woodford has created a unique space for cultivating research outside of a University setting. This process requires further development to formalise non-traditional research outcomes by partnering with artisans, designers, organisations and universities.

-To develop workshops at Woodford that can have a course code applied to it by a university, in order to provide a means for further student engagement.

-To prevent research groups working in isolation, the interchange of knowledge between institutions must be fostered and colonial bias eliminated from the way we engage across cultures. This process can be advanced through the support of global organisations such as the World Bamboo Organisation.

-Designers utilise best practice when designing with bamboo to ensure longevity of construction. Open source documents such as the Humanitarian Bamboo Guidelines are fantastic resources to achieve this and require further support to ensure ongoing relevance.

-When selecting materials for construction, consider its entire value chain, including the social and ecological impacts.

-Bamboo is best utilised as a hybrid construction system working in conjunction with other complimentary materials.