

# Theme: Architecture, Engineering and Construction

## The Global Bamboo Collective

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### Abstract

Bamboo's recent emergence as a renewable resource of great potential is the continuation of a long and diverse tradition of vernacular construction globally. Ongoing developments in construction technology have expanded the capacity of bamboo beyond the traditional value chain that encompasses cultivation to construction. Additionally bamboo has also been recognized as a means to create new livelihoods and restore degraded landscape.

Different approaches to working with bamboo as a construction material are explored through a series of case studies that range from impermanent interventions to permanent construction. By examining the multitude of ways bamboo is employed in the buildings, attention is drawn to the social, cultural and environmental factors that determine how bamboo may be utilized to appropriately respond to particular contexts. This is achieved through a holistic understanding of the implications of utilizing low tech or high tech, short or long term solutions in design. The diversity of techniques can be understood as a complementary set of approaches that form part of a larger narrative that is the global bamboo collective.

### Introduction

Bamboo has been utilised as a building material for thousands of years. Despite this long vernacular tradition, bamboo has only recently gained widespread attention as a potential contemporary construction material. The environmental benefits and unique structural properties of bamboo suggest that it is a renewable resource with great potential. However there has been little discussion of how bamboo fits into a wider architectural discourse.

There is no single answer to the current challenges facing the global community. Overreliance upon non-renewable resources and increasing urbanization highlight the advantages and opportunities of exploring how bamboo can be utilized as a contemporary building material with strong environmental and social credentials. Both the benefits and challenges of working with bamboo can be understood in a number of different ways, depending on the context of the project.

This paper explores the multitude of ways different organisations are working with bamboo in response to the particular challenges of their own cultural context. The relevance of different design and construction systems, directly relates to the particular demands of site, culture and context. The case studies presented describe different ways of utilising bamboo in buildings, demonstrating a diversity of approaches that form part of a broader narrative of bamboo's relevance to the contemporary built environment.

### The Global Bamboo Collective

The ready availability and affordability of steel, glass, concrete and brick is leading to the disappearance of traditional building practices and the depletion of finite resources and the environment. This process is particularly prevalent in developing countries where rapid urbanisation is shifting agrarian based economies into industrialised and globalised economies within a single generation (The World Bank; Fenson, 2016). Urbanization, coupled with a growing global population, is driving an increasing consumption of non-renewable resources with a multitude of

environmental consequences. With the onset of the Anthropocene, the building industry stands out as one of the major contributors to human induced climate change.

Globalisation and urbanisation is not only causing degradation to the environment but is also responsible for an erosion of culture and context (Relph 2008). The result is homogenised and placeless cityscapes that stand in direct contrast to vernacular practice. As such, some architects see the notion of the contemporary vernacular as a means to design buildings suitable to place and responding directly to the cultural context in which they are working.

Bamboo has been identified as a material with great potential for application within the built environment. The social and ecological narrative of bamboo from cultivation to construction highlights a value chain with multiple benefits at all stages, some of which include;

- Fast growth rate
- Annual harvest
- High capacity for CO<sub>2</sub> mitigation when managed
- Restores degraded soil
- Shallow binding root system to stop erosion
- Multiple uses of the culm as a building material and also for food, paper, textiles, fuel, furniture etc
- Prevalent across the developing countries throughout the worlds equatorial region
- Sympodial bamboo is non-invasive
- Unique structural properties
- Long history of craft
- Lightweight

However there are also challenges involved in using bamboo in buildings, including;

- Round section
- Non-uniform shape
- Labour intensive
- Requires unique skill set to craft (Artisan knowledge)
- Treatment critical to longevity
- Non-homogenous structural properties
- Variation in species dependent upon site and climate
- Harvest requires specialised knowledge to select correct culms
- Monopodial bamboo is invasive
- Very little research available relative to other building products
- Challenging to standardise
- Public perception

Both the benefits and challenges are dependent upon context. The ability to address and overcome each potential challenge is relative to the way in which bamboo is being used. The context of working with bamboo in Australia is vastly different to Mexico, just as the context of building a resort in Vietnam is different to constructing post-disaster shelter in Indonesia. Thus there are a variety of best practice solution for working with bamboo that are specific to the cultural, social and environmental factors of the site.

The following case studies, identify different ways of utilising bamboo that are neither better nor worse, but are simply different form other ways in which the material may be utilised. Each organisation is engaging with bamboo and exploring its material properties relative to their own context. Through an environment of collaboration rather than competition, these stories can be seen as complimentary to each other.

# Architecture of Impermanence

Traditional methods of bamboo construction made use of various systems of preservation to ensure longevity. Despite this, bamboo has obtained a reputation as a low value material with a short lifespan. The rapid rate of growth of bamboo has traditionally compensated for this concern by providing an abundant supply of material to replace decaying elements.

The pursuit of material permanence is crucial to challenge preconceptions of bamboo as a temporal material. However by removing the constraints of permanence, bamboo can be utilised as a tool for education, experimentation and expression. Cave Urban and Wang Wen Chih take advantage of the properties of green bamboo to construct spatial experiences that are temporal and align with a cycle of growth, life and decay. It is a process that reframes the constraints of working with bamboo and encourages community participation as a means of education and empowerment. As such the process of construction is of equal importance as the built outcome.

## Cave Urban - Australia

Cave Urban was founded in 2010 to investigate vernacular architecture and its relevance to contemporary design. Vernacular architecture derives from the specific context of a site and the patterns of use over time. The construction methodology is often directly responding to climate, material availability and cultural context. It often is representative of an architecture of use, rather than aesthetics. Bamboo has been employed as a construction material by many different vernacular societies. The forms and methods of working with bamboo hold lessons that can be applied to contemporary practice. Because of this Cave Urban was encouraged to explore how it could be developed as a lightweight, temporary construction material.

Australia is a country with no tradition of bamboo craft. High labour costs and regulation, cultural preconceptions and only a small handful of people with knowledge about bamboo creates a challenging environment for working with the material.

When Cave Urban first began learning about bamboo, it was a challenge to gain access to information. This necessitated a number of research trips internationally, visiting buildings and participating in workshops, gaining knowledge through direct hands on experience. This information was documented through a research folio which is shared as open source information in the hope it may aid or inspire those who are also interested in bamboo as a building material.

Through collaborations with bamboo masters, this knowledge continues to grow and be shared to participants in Cave Urban projects, workshops or university courses. Key to this process is the notion of collaboration and the idea that the whole is greater than the sum of its parts (Figure 1). By openly sharing information, it allows others to build upon existing knowledge rather than having to reinvent the wheel every time. Since the bamboo industry is still in its infancy, this is critical to spreading enthusiasm about its potential as a building product.



Figure 1

Cave Urban's work with bamboo is a response to the context of working in Australia, which is covered by Juan Pablo Pinto (2018) in greater depth. For Cave Urban art projects have been utilised as a medium to navigate regulatory restrictions and has been utilised as a means of research and development. High labour costs in Australia have necessitated the involvement of groups of volunteers and students working with Cave Urban in a master/apprentice model that builds capacity and understanding of bamboo construction. The exchange of knowledge for labour serves to expose a larger body of people to the potential of utilising bamboo as a material and emphasises the built form as only part of the final outcome. The design of works responds in part to the process of construction, which takes into account the largely unskilled labour that will help to assist construction. As such there is often a limited number of construction techniques utilised, which can be taught and repeated en masse to great effect (Figure 2). By reducing a complex task down to a set of simple repeatable tasks, large scale works can be created in short time frames through the compilation of small singular elements into a larger more complex whole.



Figure 2

The informal process of research and development was influenced by collaboration with artists such as Wang Wen Chih and has developed Cave Urbans understanding of the potential of bamboo as a building material (Figure 3). Further partnerships with Humanitarian Benchmark Consulting and the Environmental Bamboo Foundation has led to new pathways being explored onsite at Woodfordia, Australia. The Woodford Folk Federation has facilitated the planting of a bamboo forest (Figure 4), new research into bamboo treatment (Figure 5) and the development of training models and typologies for post disaster reconstruction.





Figure 3



Figure 4 + 5

This research has been continued through a Byera Hadley research scholarship and a Churchill Fellowship, enabling Cave Urban to engage with the bamboo community globally. The focus of the research was to engage directly with universities, NGO's, designers and the skilled artisans for whom knowledge is intrinsic rather than formalised, in order to gain a holistic overview of bamboos role in the built environment.

Cave Urban partnered with the University of Tasmania in 2017 to establish the 'Agritecture' program. It is a means of exploring the intersection of architecture and agriculture, encompassing the entire value chain of bamboo cultivation and construction (Norrie et al. 2018). Initially focussing upon communities, organisations and university's in Vietnam, the program is widening its scope to include projects in Cambodia and Indonesia.

### Wang Wen Chih - Taiwan

Taiwanese artist Wang Wen Chih is best known for his largescale woven bamboo artworks. Having represented Taiwan at the 2001 Venice Biennale, Master Wang has exhibited globally and has collaborated with Cave Urban on eight occasions (Figure 6). His dynamic woven structures provide profound spatial experiences that utilise the materiality of bamboo. Through the creation of haptic spaces that sensually utilise sound, sight, touch smell and the memory of light to establish a dialogue between the body and nature.





Figure 6

Master Wang's works utilise community engagement and draws upon the traditional weaving techniques of his hometown Chiayi. Designed as temporary forms, Master Wang's structures explore our own temporal existence, resonating with the Japanese concept of *Mono no aware* or the "the awareness of the transient beauty of nature" (Brownell 2011). They are forms designed to be inhabited and remembered, rather than endure. It is an idea that integrates with the growth cycle of bamboo, which regrows another pole in the time it takes his work to decay.

The split and woven bamboo is not treated or is protected from the sun. Rather the work celebrates ephemerality and provides an appropriate solution for creating art for festivals and exhibitions that tend to adhere to short time frames, whilst utilising a sustainable resource that has little environmental impact. Working with recently harvested phyllostachys bamboo, Master Wang utilises the high flexibility of split green bamboo to weave a bamboo membrane that utilises a randomised weaving pattern that is very strong. As the bamboo is not covered with a membrane and left exposed, it allows light to pass through creating spaces that celebrate the interplay of light and shadow (Figure 7).





Figure 7

The Setouchi Triennale has commissioned Master Wang to create an installation for the past three exhibitions. Each exhibition, he returns to the same site situated in the rice fields of Shodoshima. The structural framework of the first work has remained in place over the last nine years providing a foundation from which each subsequent work has been created. Like Ise Jingu, Japan's most famous shrine that is rebuilt every twenty years on adjacent parcels of land (Figure 8), Master Wang's installation follow a cycle of growth, life, decay and rebirth (Figure 9). The three year life cycle of each work aligns with the three years growth cycle of the bamboo that he harvests locally to create the work. Whilst the more permanent foundations created from steel and concrete remain in place to be utilised time and time again, which is fitting given their large ecological footprint.



Figure 8 + 9



## Informal Bamboo Architecture

With roughly one billion people globally living in housing that utilises bamboo construction, the vast majority of bamboo construction is informal (Figure 10). Increasing urbanisation and the aspiration for a secure, durable home is resulting in temporary vernacular housing being replaced by non-renewable building materials and typologies that are often unsuitable for local climatic conditions.



Figure 10

The conflict between humanitarian imperative and long-term ecological and social consequences is a recurring issue that is becoming increasingly prevalent. Over consumption of resources and increasing emissions has led to a rise in extreme weather conditions that disproportionately effect the most vulnerable communities in less developed countries (Eckstein et al. 2018).

Whilst both the Humanitarian Bamboo Project and RAW Impact are focussing on vulnerable communities a distinction must be made as to the difference between the terms ‘humanitarian aid’ and ‘development aid’. Whilst development will look towards the long term improvement of a community, humanitarian aid responds to the immediate needs of a community.

Whilst seminal, largescale projects lift global awareness of bamboo, the construction techniques utilised are not suitable for application in low tech/unskilled architecture and as such do not address the issue of how to we make informal bamboo architecture more durable. Disaster reconstruction is not a testing ground (Prideaux 2016) and the fragility of the local economy will magnify any failure of novel building solutions or implementation if the local community is not familiar with building techniques. Thus utilising bamboo within this context requires a nuanced response to existing methods of construction and resource availability.



## Humanitarian Bamboo Project – Indonesia

The Humanitarian Bamboo Project was set up by the Indonesian based organisation Humanitarian Benchmark Consulting (HBC) in response to the 2006 Jogjakarta earthquake. During the reconstruction of Jogjakarta over a period of nine months, 70,000 transitional shelters, each 24m<sup>2</sup>, were constructed from bamboo at an average cost of US\$100-200 (Hodgkin et al. 2009) (Figure 11). The construction of these shelters represented one of the largest and most rapid post-disaster responses in recent history. However throughout the process it became evident that although bamboo had great potential as a strong, cost effective, readily available and rapidly constructed material, there was a lack of experience and clear guidelines for best practice within the humanitarian community (Hodgkin et al. 2009).



Figure 11

In response, extensive consultation with experts in humanitarian shelter and bamboo construction has led to the formation of the Humanitarian Bamboo guidelines. The guidelines aim to be an open source resource that assist humanitarian workers to make better informed decisions as to when and how to utilise bamboo as part of a post disaster shelter response.

David Hodgkin, one of the founders of HBC talks of how ‘shelter is a process not a product’ (2016). Contrary to the continuing desire of architects to design innovative one size fits all response to humanitarian shelter, Hodgkin’s identifies systemic solutions as more important than design in influencing change. Given that majority of post disaster reconstruction is often undertaken by local inhabitants rather than Non-Governmental Organisations (NGO), agency for self-determination becomes a critical tool in the reconstruction process. This can be achieved through the dissemination of best practice guidelines to the local population that acknowledges the existing informal architecture and how it can be improved rather than replaced (Sharma 2017).

Provided that there is a locally available source, bamboo thus becomes a versatile material for constructing interim shelter that meets the immediate humanitarian imperative (Figure 12). By focussing on appropriate low cost/technological solutions that build upon local knowledge and skills, communities are able to utilise innovation and effort to counter low fiscal capacity. Given that transitory shelter serves as a placeholder for future construction, considerations such as treatment do not hold as high an importance, as it does in more permanent buildings.



Figure 12

### RAW Impact - Cambodia

Raising Awareness Worldwide (RAW) Impact is a NGO based in Phnom Penh, Cambodia. Founded by Australians Troy and Nicole Roberts, RAW Impact works directly with highly vulnerable Cambodian communities focussing on capacity building. The organisation's core principles to sustain, educate and protect, address diverse issues, establishing pathways for families to avoid debt slavery and child sex trafficking by providing education and a sustainable lively hood, as well as providing better housing and more secure land tenure.

Cambodia is an agrarian nation, with a largely rural population, whose people rely upon natural resources for food and income (MoE 2009). Over the last thirty five years, Cambodia's population has tripled from five million to fifteen million people as it recovers from the atrocities committed by the Khmer Rouge. The exploitation of diminishing resources is being amplified by the growing population, 36% of which is living below the poverty line (MoE 2009).

RAW Impact has identified bamboo as a resource capable of addressing some of the issues confronting Cambodia, providing multiple beneficial outcomes that includes housing, environmental remediation and employment. Working in collaboration with the University of New South Wales, Casey Brown Architects and Cave Urban, the Every Piece Matters program was established to design and construct housing prototypes (Figure 13). The process of building seven housing modules provided a means of educating local workers in bamboo construction, whilst also serving as a means of learning through making for all participants in the project. A continual process of critical reflection has allowed for the gradual evolution of designs towards an outcome that is suitable for bamboo construction and local ways of living.





Figure 13

Key to this process was the recognition that it was an iterative process that allowed for feedback from those involved and external consultants to guide the evolution of the designs. Troy Roberts (Rebel on a Rainbow 2014) describes innovation as a core value, stating “We’re not afraid to fail and learn from it, and we’re willing to try out-of-the-box solutions to some huge issues”. As a result over a period of two years there has been distinct improvements in construction knowledge along with social integration with the local community (Figure 14).



Figure 14

The most recent designs reflect a number of improvements that include:

- simplification of the buildings programs that recognises the majority of time is spent on the ground plane beneath the shade of the house and a single room is required for sleeping.
- utilising rope and dowel connections in place of threaded rod.
- concrete footings to raise the bamboo posts above flood water.
- larger eaves to protect the walls from rain and sun

The social context of the project- highlights the longevity of the housing modules, and investment is made in exploring this process. All bamboo is treated onsite to prevent degradation and building design is refined to minimise the effects of weathering.

The construction process has been refined to allow for capacity building of the community. Training young Khmai workers who may not have any building experience requires a system of construction that is repeatable and ensures a level of quality control (Figure 15). A series of jigs have been fabricated which allows for all work to take place on ground and repeated to achieve a higher level of efficiency. Previously work had taken place in-situ and had posed a number of challenges that prefabrication on ground solves. Low-tech innovation such as this is highly suitable to the circumstance and presents a simplified methodology that is an appropriate response and an opportunity for changing perceptions about bamboo as a building material.



Figure 15

The individual buildings are carefully arranged to form a village, allowing an increased permanence for the community. However the contextual fluidity of the project suggests that housing may only need to last ten to fifteen years before the context in which families are living will have changed and a different housing solution is required. Working with bamboo allows the material resources to fit the contextual requirements of architectural fluidity.

RAW Impact is working on improving housing for the lowest socio economic bracket and developing typologies that suit the particular cultural context in which they are working. By creating simple low tech solutions to bamboo architecture, RAW Impact is going a long way towards demonstrating how bamboo can remain relevant for those seeking a more secure life.



# Contemporary Bamboo Architecture

## 1+1>2 - Vietnam

Vietnam has a long tradition of utilising bamboo as a building material. Vernacular hybrid systems of construction utilised bamboo in combination with hardwood timber and thatch. In the colder northern regions of the country, split bamboo is utilised as a substrate over which mud is applied in a manner similar to wattle and daub or *bahareque* (Norrie et al 2018). Increasingly concrete and masonry has replaced these traditional methods of construction, with bamboo being relegated to the status of ‘poor man’s material’.

Hoang Thuc Hao, of Vietnamese architectural practice 1+1>2, continues the tradition of utilising bamboo as part of a hybrid system of construction. Working with a broad material pallet, Hao designs community buildings that simultaneously evoke feelings of tradition, whilst sequencing space and program using modernist principles of design. Each of 1+1>2 buildings respond directly to the context in which they are created. Traditional methods of joining bamboo with dowel and rope are utilised and there is a low tech simplicity to how the buildings are constructed. Yet complexity is established through the highly thought out series of spaces and the way in which multiple materials are utilised to optimise their material qualities (Norrie et al 2018) (Figure 16).



Figure 16

The skill in Hoang Thuc Hao’s work is that on first inspection, his buildings do not distinctly read as bamboo architecture. Rather they are representative of the notion of contemporary vernacular, where traditional building methodologies are re-contextualised in alignment with modernist aspirations. By separating a material ideology from design, he is able to create work that can be appreciated for its spatial and programmatic qualities alongside the strong social and environmental agenda that is present in his work (Figure 17).



Figure 17

### Vo Trong Nghia - Vietnam

The rapid change Vietnam is undertaking from an agrarian economy to a highly connected part of the global community is causing distinct change to its urban landscape. Vernacular building methodologies have been replaced by a taste for new buildings methods, processes and materials (Norrie et al 2018). The loss of cultural character, particularly in urban environments has begun to be recognised and emphasis has been placed on the notion of 'homeland' (a connection to cultural heritage). Bamboo has subsequently emerged as a symbol of Vietnamese culture and often forms part of a nostalgia for a traditional way of life. Subsequently it has begun to be recognised as a high end material in contemporary architecture that utilised sophisticated methods of construction. However this has not served to protect traditional low tech methods of working with bamboo from being replaced by masonry construction.

Vo Trong Nghia (VTN) has developed an international reputation for his iconic bamboo buildings, starting with the first project for the Wind and Water Café in Ho Chi Minh in 2006 (Figure 18). VTN's distinct methods of construction combine the particular structural and material qualities of Vietnamese bamboo with a Japanese architectural education. Traditionally bamboo in Vietnam was constructed on two-dimensional planes, often as a series of frames. The architecture of VTN innovates through the application of a three-dimensional structural systems that utilises bundled and curved elements of bamboo. Utilising small diameter but solid bamboo VTN constructs truss's and arches that form spaces on a monumental scale as can be seen in his design for Naman Retreat or Sen Village Community House (Figure 19).



Figure 18 + 19



The iconic forms of VTN's structure are highly expressive and evoke a nostalgia for the vernacular, but utilise high-tech construction techniques (Norrie et al 2018). Through extensive international recognition, VTN has come to represent bamboo architecture in Vietnam. Many derivative organisations have been inspired by the unique method of construction seen in VTN's work, subsequently raising the profile of bamboo as a building material in Vietnam.

VTN's work has become key icons in the global 'iconomy', the imaged based economy of marketing and architourism (Smith 2005; Norrie et al. 2018). Demand for VTN's work is driven by restaurants and resorts seeking to market themselves utilising bamboo and VTN's distinct architectural style. Similarly works such as Sen Village Community House (Figure 20) and the Diamond Island Community Centre have been commissioned by developers to serve as icons of a narrative that evokes a traditional way of life. The utilisation of bamboo as marketing presents a contradiction that risks bamboo being seen as a fad if it becomes too closely associated with iconography.



Figure 20

### Simon Velez - Colombia

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 (Figure 21). The ZERI Pavilion was a landmark moment for bamboo architecture, proving that largescale bamboo construction could be achieved in a country with a highly regulated construction industry and no history of bamboo craft (Long 2018).



Figure 21

Velez proposes a style of architecture that seeks to amend the imbalance between renewable and non-renewable resources. Although considered one of the great champions of bamboo design, his work utilises concrete, timber and masonry in a hybrid system of construction. Velez's proposal to make architecture 'a bit more vegetarian' (Frey 2013) utilises timber and concrete to accentuate the structural capabilities of bamboo. This is typically done through the construction of a distinctive roof element that is in part influenced by his experiences in south-east Asia. It is a direct response to the tropical climate in which the majority of his work resides and serves to protect the bamboo structure from exposure to wind and rain.

The work of Velez has inspired a generation of designers across Latin America and his influence can be seen in the current bamboo revival taking place in South East Asia. The fluidity of bamboo building technologies to be shared and transposed to different cultural contexts is displayed through the creation of Cross Waters Eco lodge designed by Paul Pholeros in collaboration with Velez (Figure 22). The project utilised organic and recycled materials found in the immediate vicinity of the project. Clay roof tiles sourced from demolished buildings in the nearby village are paired with rammed earth walls and bamboo construction (Wang 2007). Although constructed utilising Colombian construction methodologies, the buildings feel distinctly Chinese in character and relate strongly to the surrounding landscape.



Figure 22



## Standardizing Bamboo

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, these methods of construction are not directly relatable to dense urban environments or to standardised systems of construction required for highly regulated building industries. In order for bamboo to be relevant to mainstream construction, these problems must be addressed.

Research by a number of institutions and individuals conclude that engineered bamboo products are critical to providing a pathway for the utilisation of bamboo in a dense urban setting or as building material for highly regulated societies. The processing of raw material into laminated composites allows for standardisation in construction and less inherent variability when compared to the natural material. Research has demonstrated that engineered bamboo products have properties that are comparable or surpass that of timber and timber-based products (Sharma et al. 2015). 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.

## Technical Research

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 and practical application has led to the understanding that whilst a significant first step, ISO 22156:2004 requires significant revision to maintain relevance. 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.

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. A proposed standard for engineered bamboo products has begun to be developed and will be developed over the coming years.

Whilst standardizing bamboo construction system will open up new areas of growth and application to a wider construction industry it does not need to sit in opposition to vernacular methods of bamboo construction. A resilient bamboo industry would utilise both methods dependent upon the context in which one is working. The notion of un-modern as less than only continues to promote a western/academic bias that discounts the wisdom of artisan and vernacular knowledge. Whereas a non-biased agenda that derives from a contextual understanding is critical in obtaining a larger

holistic understanding of bamboo's role in the built environment. Thus research and the drive towards standardisation is of equal but not greater importance than improving pedagogical models that allow for information to be spread through informal channels for the implementation of best practice in informal architecture (Figure 23).



Figure 23

## Engineered Bamboo

There is a strong narrative that connects the cultivation of bamboo to construction and social development in countries where bamboo is native. The capacity of bamboo to restore landscape, provide industry for subsistence communities and as a renewable building material has been well established in this context. Vernacular traditions in this region often integrate bamboo as part of the cultural legacy given the multitude of applications that it is capable of.

Outside of this region the argument for utilising unprocessed bamboo diminishes. Scarcity of resource, absence of a bamboo culture and highly regulated building industry are some of the challenges that may need to be overcome.

Engineered bamboo provides an opportunity to open these markets to a different form of bamboo construction. Since the 1990's this industry has grown to a global trade valued at US\$60 billion annually (van der Lugt 2017).

A variety of engineered bamboo building products now exist, the majority of which tend to be timber substitute products. The transformation of raw bamboo into an engineered product overcomes challenges in regards to construction knowledge, certification and aesthetic quality (Figure 24). However it often places it in direct competition with similar timber products that may have equal if not greater environmental credentials.





Figure 24

In comparison to tropical hardwood products that are often uncertified, bamboo has a clear advantage when considering its environmental credentials. However when comparing it to softwood products that are from sustainably managed forests, (often located closer to the target market) the distinction becomes less clear.

It is not necessary to see these as competing materials, rather it is important to recognise the larger ecological picture. Alternative products with equal or greater environmental credentials, requires us to ask the question of how or why should bamboo be in a particular market.

The largest component of bamboo's ecological footprint is the energy consumed during processing, followed by transport of the material (van der Lugt 2017). Differing products will consume vastly different amounts of energy during processing, resulting in the contextual application of each product bearing a large influence on its ecological suitability.

The round and hollow section of bamboo makes it inefficient to transport. Thus in order to limit the second largest contributing factor to ecological footprint, manufacturing should take place close to the point of harvest.

The Environmental Bamboo Foundation offers an example of a restoration economy model through the implementation of its '1000 Bamboo Villages' program. Decentralised bamboo plantations are utilised to restore degraded land and managed by individual members within a village cooperative (Rabik 2018). The poles are semi processed into splits before being transported to a centralised manufacturing point. By splitting the bamboo, growers are value-adding to the bamboo as well as maximising the volume of bamboo that can be transported at one time. By decentralising the supply chain, added benefit is provided to local communities and smaller micro-economies are able to be established across the archipelago of Indonesia.

Manufacturing engineered bamboo close to the point of harvest, ensures that largest addition to product value is taking place within the economy where bamboo is grown (most likely a developing country). Through a best practice scenario this leads growing local capacity and provides an ecologically beneficial industry in place of a subsistent reliance on a degrading natural environment.

Utilising engineered bamboo locally could reduce the reliance upon uncertified hardwood timber or act as a substitute for non-renewable building materials.

Exporting the material to developed markets provides an opportunity for a higher price point given that the product being manufactured is of significant quality. Moso International has been working closely with their China based factories to improve the quality of output. By setting a benchmark of best practice allows for differentiation from other bamboo competitors. The introduction of an international standard for engineered bamboo may help to ensure a level of quality control across the industry that stops products being undermined by cheaper, less sustainable products of unreliable quality.

Engineered bamboo products can be celebrated as a material that has both social and environmental benefits. The direct connection back to communities in developing countries and the restoration of degraded landscape could become a point of differentiation from competing softwood products.

Engineered bamboo presents the opportunity for expanding bamboo's potential in the built environment. It forms part of the overarching narrative of bamboo but does not need to be seen as competing with raw bamboo. The application of engineered bamboo to the built environment meets a different set of social, cultural and environmental contexts that make it unique in its own right.

## Agritecture

The University of Tasmania has been collaborating with Cave Urban in the development of the notion of 'Agritecture', a means to understand the relationship between bamboo as a building material and as part of an ecological and economic supply chain (Norrie et al 2018). Drawing together the different ways in which organisations are utilising bamboo to solve challenges faced by the built environment, the project demonstrates a clear connection between architectural and agricultural considerations.

There is a net positive environmental and social benefit for growing bamboo and creating industry around processing the material to various degrees. This process establishes a narrative in clear juxtaposition to the consumption of non-renewable resources that serve to increase global emissions and cause environmental and social degradation. Through a holistic understanding of bamboo's entire value chain from cultivation to consumption, alternative futures can be imagined, particularly in regards to rural and subsistence communities (Norrie et al. 2018).

Through art, research and practice each of the case studies above utilise different methodologies to integrate ecological and social narratives into the built environment. The suitability of utilizing bamboo in each scenario is determined by the context of the project. The opportunities and constraints of each project demonstrate that there is no single solution as to how bamboo may be deployed as a building material. Rather an appropriate architectural response is achieved through responding to the client, site and the social and cultural context.

These differing responses can be seen as complimentary to each other regardless of whether one is creating temporary or permanent interventions, or making use of low tech or high tech construction systems. By sharing knowledge and remaining sensitive to the contextual consideration of a project, bamboo can help form part of the collective solution to challenges currently being faced by the built environment and global community.



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