

*Discussion*

## **Sustainable Technology Research and Demonstration Center for Earth Structures**

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**Abstract:** This is a discussion paper that the authors presented at the International Workshop on Rammed Earth Materials and Sustainable Structures and Hakka Tulou Forum 2011: Structures of Sustainability, 28–31 October 2011, Xiamen University, China. A Sustainable Technology Research and Demonstration Center for Earth Structures is proposed to study, preserve, advance, promote, and implement rammed earth structures. The Center concept including the objectives, scope of activities and benefits of the proposed center are outlined. The Center for Alternative Technology in Wales, UK has been examined as a good base model along with a few successful environmental sustainability initiatives in China. The funding options to establish the proposed center have been discussed. The breadth of activities ultimately depends on funding capability. It is believed that the proposed center development will require significant government support at the initial stage but once corporate sponsorships are in place, the proposed center will potentially become self-supporting. The strategies, for the establishment of the proposed center are also addressed.

**Keywords:** rammed earth; earth structures; sustainable technology; green buildings; Hakka Tulou; center for earth structures; environmental sustainability

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### **1. Introduction**

The purpose of this discussion paper is to identify options for developing a framework for a research center focused on rammed earth construction methods, sustainability and the research,

development and promotion of vernacular Tulou and rammed earth construction methods. There are several papers focusing on research activities related to rammed earth construction [1]. This paper takes current research activities into account and looks at research organizations and funding options which could be considered in establishing an institute to advance research, promote rammed earth construction methods and identify potential areas for collaboration.

The International Workshop on Rammed Earth Materials and Sustainable Structures, in conjunction with the International Symposium on Innovation and Sustainability of Structures in Civil Engineering hosted by Xiamen University (XMU), took place from 28 to 31 October 2011. This workshop was the 2nd event of the Hakka Tulou Forum Series. The first Hakka Tulou Forum: Lessons to Be Learned, Past, Present and Future took place on 24 June 2009 at Xiamen University, China where the International Hakka Tulou Alliance was also launched [1–3]. The objective of the 2009 Forum was to demonstrate how the sustainability of Hakka village architecture built hundreds of years ago and still in-use today, would bridge the past, present and future, with lessons for our modern world.

Liang [2] notes in his introduction to the Workshop that Hakka rammed earth buildings in Fujian Province of China reflect the importance of historical precedents, universal evolution, emerging innovation and advancement in the science and engineering of rammed earth construction, from the 8th to 20th century. They are considered as “Eco-villages” of best practices for planet earth’s sustainability in their planning, design, construction, lifestyle, resource management, micro industries, renewable energy, recycling of human and animal waste, and a low ecological footprint [4]. The world heritage Hakka Tulou was recognized with the first “History Made for Tomorrow” award by US History Channel [5]. “History Made for Tomorrow” is a new community outreach initiative to show case historic places where lessons can be learned to build a sustainable 21st century.

Because of its high thermal mass, structural performance and inherent recyclability, rammed earth is considered as a sustainable construction material with significant environmental benefits [6]. The Building Research Establishment (BRE) Environmental Assessment Method (BREEAM) now recognizes rammed earth as a sustainable construction material (Element No. 1006220010–1006220013) with an A<sup>+</sup> rating [7]. Detailed information and research activities related to rammed earth construction and its inherent sustainability can be found at Paul Jaquin’s web site Historical Rammed Earth [8].

There are challenges to preserve, restore and modernize Hakka Tulou complexes, and to implement rammed earth technologies in modern constructions. The Workshop at XMU brings together experts from Australia, Canada, China, Japan, UK and USA to examine the research potential of rammed earth materials and sustainable structures. Topics include: (1) Rammed earth as a structural material and construction technique for sustainable structures; (2) Status and issues related to construction specifications and standards; (3) Challenges and strategies for incorporating (advancing) earth based structural materials in modern architecture; and (4) Challenges to preserve, maintain and/or modernize the Hakka complexes while maintaining their inherent environmental sustainability.

An important outcome of this workshop is to: (1) Establish a network of professionals to catalyze collaborative research, development and implementation including international partnerships and (2) Develop joint R&D programs emphasizing the commercial application of rammed earth construction with its inherent sustainability.

Much of the value of this workshop is the recognition of the potential viability of using rammed earth structures to meet the needs for sustainable affordable rural communities and to fuse historical techniques to advanced building science to meet today's building and environmental standards.

## **2. Moving toward Technology Transfer Implementation**

As noted, this paper outlines the benefits and issues related to establishing a research and demonstration center focused on the transfer and implementation of sustainable solutions to preserve, maintain, advance, and promote rammed earth structures.

There are rammed earth structures throughout the world. However, the concentration of massive structures which have been continually inhabited for centuries is rare. The Hakka rammed earth Tulou complexes of Fujian province in China and the surrounding regions offer a unique opportunity to research and monitor existing structures and examine ancient Hakka rammed earth building techniques for use in modern construction. There is also a need to develop prototypes for environmentally efficient solutions to upgrade and modernize many of these complexes to current living and environmental standards.

There is a vast area of Tulou construction in Fujian, Jiangxi and Guangdong provinces in southern China with more than 20,000 Tulou in Yongding County of Fujian province alone. 46 Tulou in Fujian were inscribed and protected as a UNESCO world heritage site in 2008. However, many of the Tulou have been poorly maintained or are uninhabited. The last Tulou was built over 40 years ago while new buildings in this region are predominantly brick and concrete structures. Therefore these traditional construction methods are being lost. By recognizing the sustainable features of rammed earth and promoting rammed earth construction methods and research to modernize these structures many of the Tulou could be preserved and retrofitted. While some villages would require more restricted preservation and restoration for historical reasons others may be candidates for the fusion of traditional and new technology and could incorporate cutting edge design.

Focusing on earth based construction is an important environmental decision but to create viable sustainable buildings and communities equal emphasis must be placed on total energy efficiency, water and sewage systems and regional environmental management. For this a comprehensive approach is required to select appropriate existing technologies and develop and adapt technology specific to maximizing building and community sustainability.

The proposed center would encourage the engineering community to further examine the advantages of rammed earth construction, bring to their attention what rammed earth is capable of, and promote new research opportunities that can further advance our knowledge on earth materials for modern construction.

By combining what we know of rammed earth from the Hakka people with science and technology of today, the efficiencies of rammed earth can be further expanded and used in modern construction. Such construction methods would reduce the need for concrete and thus help reduce greenhouse gas emissions.

### **3. Center Concept**

The Center for Earth Structures concept is to establish a research and demonstration site at or near an existing Tulou complex, and build the facilities to monitor and demonstrate sustainable technology at the site. The site would be open to researchers and visitors and have a significant demonstration and educational component. Activities would include monitoring existing structures and prototype installations, identifying sustainable solutions for local development, demonstrating Hakka sustainable technologies on site, and determining the adaptability of existing technology to contemporary rammed earth construction. The proximity to Xiamen University, a leading school of architectural and engineering research can significantly augment activities at the center.

Creating a center of excellence for sustainable rammed earth building techniques, in the heart of China's World Heritage Site of Historic Hakka Architecture will increase awareness of the center. At the same time the activities of the research/demonstration center can address important regional issues. Benefits include: (1) Capitalize on the environmental sustainability of these historic structures, and increase their energy efficiency and comfort with advanced technology; (2) Preserve and restore Hakka villages; (3) Retrofit villages to current living standards; (4) Promote the creation of new buildings combining traditional building techniques with new technology and cutting edge designs; (5) Develop a training, education and visitor center which demonstrates environmental stewardship and promotes practical environmentally sustainable solutions; (6) Provide information to support regional development policy and influence decision-makers; (7) Provide a living laboratory for advanced environmental research; (8) Take advantage of government plans for model eco cities, and rural development; (9) Promote heritage-led regeneration and access to the historic environment; (10) Provide training in rural areas to create employment opportunities in sustainable development.

The breadth of research activities to be conducted at the proposed center depends on funding capability. Activities may include: (1) Ongoing temperature, humidity, and energy usage monitoring of inhabited complexes; (2) Maintenance, monitoring and restoration of existing historical buildings; (3) Research in building science and engineering related to earth structures, sustainable communities, for both retrofit and new projects; (4) Research related to codes and standards; (5) Sustainable retrofit design and implementation; (6) Adaptation of rammed earth construction to modern building designs; (7) Technical training to maximize local opportunities to maintain and preserve Hakka complexes.

Efforts to preserve existing complexes in the Fujian region and upgrade these to modern sustainable structures can demonstrate the viability of sustainable rammed earth construction in remote and/or developing regions in Asia, South America and Africa in a practical living environment. As new standards and building codes on rammed earth construction are developed there is increased potential for new rammed earth construction in urban areas. The Wales Institute for Sustainable Education in Wales [9] and River Green Center in Durham, England [10] are excellent examples of modern earth structures which are well suited to commercial and urban applications. This type of demonstration site is an effective tool to promote sustainable earth architecture.

## 4. The Model

### 4.1. The Center for Alternative Technology

The authors have recently visited The Centre for Alternative Technology (CAT) in Wales, UK. Given the priorities of this workshop and intent of moving toward joint research, technology transfer and implementation of rammed earth techniques, it is worth looking at CAT. Their comprehensive approach to sustainability and hands on demonstration of practical sustainable technological solutions is an instructive model.

Detailed information on The Centre for Alternative Technology can be found on their web site [11]. CAT established in 1973 as a small environmental technology demonstration site continually expanded over the years. Today it houses the Wales Institute for Sustainable Education (WISE) with a new rammed earth lecture theater, teaching and conference facilities and research laboratories. From its inception CAT focused on development, demonstration and practical application of sustainable technology—an experimental “Eco-village” prototype. Today the site includes a graduate school with a range of postgraduate degrees in environmental architecture and renewable energy.

CAT is an education and visitor center demonstrating practical solutions for sustainability covering all aspects of green living: environmental building, eco-sanitation, woodland management, renewable energy, energy efficiency and organic growing. The visitor center with 7 acres of hands on interactive displays and interpretive tours is open daily and has 65,000 visitors per year.

The site, with 90 permanent staff and 60 volunteers (summer high season), is a unique and practical demonstration center, a living laboratory with a broad range of real life examples of installed sustainable solutions and a test-bed for new ideas and technologies.

Along with their fee based consulting and training services they offer a free information service answering enquiries on all aspects of sustainable living. Day to day operation is funded primarily by income generation through courses, an eco-store, visitor center restaurant, *etc.* External grants and funding were required to build the WISE facilities and for large capital expenditures.

CAT participates in national and international projects including: (1) Zero Carbon Britain—a series of research reports addressing scenarios for reducing the UK’s emissions to zero in 20 years; (2) Coed Gwern—15 acres of sustainable managed woodland, which is home to a range of courses, as well as being monitored and managed for biodiversity; and (3) Dyfi Biosphere—the only UNESCO Biosphere in Wales.

CAT provides a good base model for a research demonstration center particularly because of its dual role as visitor and interactive educational center. Access to a demonstration or pilot facility at an inhabited site in Fujian near an existing Tulou complex would be extremely beneficial for training and working with local contractors, residents and decision makers to preserve and promote local Tulou construction methods and promote sustainable solutions for local development.

### 4.2. Environmental Sustainability Programs in China

Examples of established international joint initiatives in China are also useful with reference to the types of activities which could be undertaken by the proposed center. For example, the JUCCE training program at the National Training Center for Mayors of China is a very interesting initiative.

A similar type of regionally focused program undertaken at a research and demonstration center in Fujian could be particularly effective. Three environmental initiatives are briefly described below. Detailed information is available on their web sites.

The EcoPartnership Program [12]: This is a high level organization which encourages U.S. and Chinese governmental and non-governmental stakeholders to share best practices, foster innovation, advance energy security, promote economic growth, and work towards environmental sustainability.

Joint U.S.-China Collaboration on Clean Energy (JUCCCE) [13]: JUCCCE develops training programs at the National Training Center for Mayors of China on how to build more sustainable urban centers, educating city mayors and China's State Owned Enterprises. Their objective is to empower China's decision makers and provides top local decision makers with case studies, experts and resources for developing energy smart cities. The Green School program is also one of their initiatives.

China U.S. Centre for Sustainable Development [14]. This organization is an international public private partnership (PPP) with a joint board of councilors representing business, government, science and non-governmental organizations. They demonstrate the commercial, social and environmental advantages of sustaining enterprises and are committed to all sectors of society: business, governments, universities, non-governmental organizations and people in their communities.

#### 4.3. Other International Earth Institutes

We should also consider international organizations whose activities relate in part or in whole with the activities of the proposed center to identify areas for potential collaboration. Three international organizations are highlighted here. Again detailed information can be found on the web sites.

The Auroville Earth Institute in India [15] is Asian representative and UNESCO Chair "Earthen Architecture, Constructive Cultures and Sustainable Development". The institute undertakes training and technology transfer in a number of countries including Egypt, Nigeria and Tanzania. They plan to develop a curriculum for students of various education levels and grant diplomas in earth based construction and design. The Auroville Earth Institute participated in the Post Earthquake Assessment of Vaulted structures in Bam Iran.

Research expertise at the International Vernacular Architecture Unit—Oxford Institute for Sustainable Development [16] includes: (1) Interdisciplinary, cross-cultural and comparative study of vernacular architecture traditions; (2) Transmission of indigenous, traditional and vernacular skills, expertise and knowledge; (3) Conservation, regeneration and sustainability of vernacular building heritage worldwide; (4) Historic towns, tourism and heritage management; (5) Thermal comfort in vernacular architecture; and (6) Design in a vernacular context.

Institute for Historic Building Conservation (IHBC) [17]. IHBC stated on their website that historic places attract people, activity and investment, giving new life to their communities and helps make places more competitive. IHBC plays a central role in regenerating towns, cities and rural areas in the UK. This organization maintains a database of authorized conservation specialists.

## 5. Funding Options

Access to funding and funding alternatives is highly correlated to the activities of an organization. The proposed center is a hybrid, including practical solutions to regional issues and the transfer and

implementation of environmentally sustainable technologies. Additionally, there is an emphasis on promotion and dissemination of technical information to the public and private sectors. Public private partnerships (PPP) are well established in North America and Europe. This type of funding is particularly attractive for a center focused on applying and demonstrating technology.

Realistically, at the initial stage this center will require significant government support but it is important to consider corporate sponsorship from the beginning with the view that the center becomes partially self-supporting. As research activities progress and emphasis is increasingly placed on the transfer, implementation and promotion of technologies developed at the center, it becomes more feasible to attract private funding. At this later stage PPP's should necessarily play a greater role. However, from the beginning we must understand the reasons corporations fund projects and their incentives for participating in public private partnerships.

Corporate sponsorship should focus on companies with obvious links to the activities and objectives of the center. One example would be the solar industry. Chinese companies are leaders in solar power. Six of China's largest solar companies are listed on the New York Stock Exchange (see Table 1). These companies highlight social responsibility and benefit from international exposure. More information on their activities and priorities are available on their web sites.

**Table 1.** China's Solar Companies for Potential Corporate Sponsorship.

Name of company	Website
SUNTECH, Wuxi, China	[18]
Trina Solar, Changzhou, China	[19]
Yingli Green Energy, Baoding, China	[20]
JA Solar Holdings, Shanghai, China	[21]
LDK Solar Co. Xinyu, Jiangxi, China	[22]
China Sunenergy, Nanjing, Jiangsu, China	[23]

The web sites of these world class companies confirm their international status and commitment to environmental stewardship. Last year Yingli Green Energy joined the list of 2010 FIFA World Cup sponsors by providing solar panels and recently Trina Solar announced official sponsorship of the Lotus Renault GP Formula 1.

The tourist industry is another source of sponsorship. Increasingly large hotel chains are restoring and reforming historic sites. The Hyatt Regency incorporated an historic site in their convention complex in Calgary, Canada. The Four Seasons Hotels recently opened the Hangzhou at West Lake [24]. The Four Seasons Hotel Istanbul [25] at Sultanahmet in the historic center of Istanbul is created from a century-old neoclassic Turkish prison steps from the Blue Mosque and Topkapi Palace.

The center's location either within, or near the World Heritage site is the type of positive exposure attractive to both regional and large international corporations. Large international enterprises consider corporate sponsorship for both commercial opportunities and social responsibility. Smaller regional companies are more likely to participate as corporate members, commercial opportunities are critical for them. Other considerations include: (1) Links between companies and research activities; (2) Awareness of products and services local and regional suppliers could supply; (3) A strong

networking environment to exchange research and promote implementation opportunities; and (4) Database for member companies.

The CAT model discussed previously relies significantly on volunteers but in the rural communities of Fujian providing training and employment opportunities for local inhabitants would have greater impact. A training component is equally beneficial if and when the center participates in regional or international development projects. Governments, in general, are more willing to fund programs which promote training and employment opportunities. Rural development and sustainability are also important government objectives. China in particular is moving in this direction.

At an eco-forum in Guiyang, on 17 July 2011, Li Ganjie China's Vice Environment Minister stated that 14 Chinese provinces are striving to build themselves into "eco-provinces", where local governments seek to promote sustainable development with respect to environmental protection. So far, more than 1000 cities and counties have worked out blueprints and timetables to achieve eco-civilization which features harmonious relations between people and nature, as well as environment-friendly consumption and lifestyles. Over the next few years, China will set up indices and build an evaluation system to further speed up the process of an eco-civilization [26].

Government support as noted earlier is crucial. Private sector involvement depends on the commercial opportunities and goodwill associated with participation in the center. Financing of a private public partnership depends on the structure and activities of the center. However, a useful guideline of how financial resources could be broken down is shown Table 2.

**Table 2.** Financial guideline for the proposed center.

Center income 20% from activities such as:
<ul style="list-style-type: none"> <li>• training programs</li> <li>• visitor admission fees</li> <li>• seminars</li> </ul>
Membership fees 10% (corporate, academic, government agencies)
Private Sector sponsorship 25% (award programs, project sponsorship)
Government sponsorship 45%

The CAT model is worth consideration in developing a research demonstration facility in Fujian to promote the preservation of these spectacular rammed earth structures and to develop sustainable solutions to modernize the facilities and infrastructure of rural villages of the region, and to apply this experience nationally and internationally. Establishing a center that is "hands on", interactive and educational will promote the development of rammed earth structures and ensure sustainable choices are understood and promoted. Participation, joint research and information exchanges with relevant organizations will enhance the capabilities and success of this program.

## 6. Strategy

The first step is to establish a committee of government, academic, and corporate representatives to identify potential partners. Representatives from each sector must work together to determine and understand the objectives for establishing a research/demonstration center. At the initial stage it is critical that government objectives and guidelines are clearly understood and that government

organizations understand the intent of the initiative, how it fits into government policy and how it benefits the region. All levels of government should be consulted. The academic role at this stage is crucial in identifying a clear range of potential research activities and their relevance to the goals of the center. The purpose at this stage is to clarify intent and ensure that it is evident to all potential parties what the goals and role of the centre will be.

Private sector involvement is best initiated at the second stage, after activities and goals of the center are defined and government organizations are on side. At this point, a market survey is extremely useful in identifying corporate interest and potential sponsors. A survey is multifunctional; it should introduce companies to the concept, gage their level of interest, help in identifying private sector priorities and finally provide ample opportunity for input. A well designed survey is an invaluable marketing tool to design an effective membership campaign. Interviews with local business associations are also crucial at this stage. Organizations and sectors to be considered include: (1) Environmental technology companies in areas such as, solar, water management, energy efficiency, *etc.* (2) Structural, civil and consulting engineers; (3) Architecture and design companies; (4) Urban and community design; (5) Landscape architects; (6) Tourist organizations; and (7) Local tradesmen.

These preliminary stages determine the level of interest in the research/demonstration center, provide concrete goals and objectives for each sector and hopefully identify organizations and companies willing to actively pursue and participate in the project. Without consensus and one or more champions it would be difficult to proceed with this type of project. However these two steps are essential in determining the direction a project should take and the type of structure that would ultimately be acceptable.

Finally, if there is sufficient interest in establishing a Sustainable Technology Research and Demonstration Center for the Preservation and Development of Earth Structures a major issue will be selecting an appropriate site. One attractive solution is to hold a competition for villages to bid on the project. This type of selection process offers a high degree of community participation and helps inform communities in the region of the intention and potential for working with the center once it is established.

## 7. Conclusions

Given the large number of Tulou complexes in the three provinces Fujian, Jiangxi and Guangdong in southern China, this area would be appropriate for a research and development center based on rammed earth construction and sustainability. Establishing a Sustainable Technology Research and Demonstration Center for Earth Structures either within or near the world heritage site of Fujian Tulou of China would not only help preserve traditional construction methods but also introduce and promote new sustainable building practices in this region. The proposed center would be a base to help preserve and revitalize Hakka rammed earth buildings for our common World Heritage. The centre could also promote Hakka sustainable technologies for design, construction and operation of green structures, and advance and promote the use of rammed earth as a viable sustainable building material. It is hoped that the participants of the workshop, those interested in the preservation of Hakka Tulou and the community of rammed earth research and construction professionals, can identify areas

for collaborative research and the promotion of rammed earth construction. A Center for Earth Structures would benefit the region and would be applicable to researchers advancing rammed earth construction internationally.

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