

## **SUSTAINABLE TECHNOLOGY RESEARCH AND DEMONSTRATION CENTER FOR EARTH STRUCTURES**

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**Abstract:** This is a discussion paper the authors present at the *International Workshop on Rammed Earth Materials and Sustainable Structures* and *Hakka Tulou Forum 2011: Structures of Sustainability*, October 28 - 31, 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 China Initiatives. The funding options to establish the proposed center has 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

### **1 RAMMED EARTH AND SUSTAINABILITY**

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), will take place from October 28 to 31, 2011. This workshop is being organized as the 2nd event of Hakka Tulou Forum Series. The first Hakka Tulou Forum: Lessons to Be Learned, Past, Present and Future took place on June 24, 2009 at Xiamen University, China where the International Hakka Tulou Alliance was also launched at the same time (Liang et al, 2009; IHTA, 2009). 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 (2011) 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 (Ostrowsky et al, 2007). The world heritage Hakka Tulou was recognized with the first "History Made for Tomorrow" award by US History Channel (AETN, 2010). The "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.

Rammed earth is a sustainable construction material with significant environmental benefits (Ueda, 2011), yet there are challenges to preserve and restore and modernize these Hakka villages, 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 will 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 these villages 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 AND IMPLEMENTATION**

The purpose of this discussion paper is to outline 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 complexes of Fujian province of China and the surrounding regions offer a unique opportunity to research and monitor existing structures to reveal ancient Hakka secrets on rammed earth construction for use in our modern world. 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.

Rammed earth construction is environmentally attractive however; sustainable buildings and communities must consider total energy efficiency, water and sewage systems and regional environmental management. A comprehensive approach is required to select appropriate existing technologies and develop and adapt technology specific to regional requirements.

Hakka people found ways to live in thermal comfort without the need of mechanical heating or cooling in both the summer and winter seasons due to their effective use of rammed earth construction. The proposed center will help make the engineering community aware of 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 the material 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 more widespread modern construction. Such construction methods would reduce our need for using concrete and thus reduce our greenhouse gas emissions for a more sustainable future of our planet earth.

## **3 CENTER CONCEPT**

The Center for Earth Structures concept is to establish a research and demonstration site at or near an existing Tuolu, 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 constructions. The proximity to Xiamen University, a leading school of architectural and engineering research can significantly augment the 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, of 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 being developed there is increased potential for new rammed earth construction in urban areas. The Wales Institute for Sustainable Education in Wales (WISE, 2011) and River Green Center in Durham, England (River Green, 2011) are excellent examples of modern earth structures which are well suited to commercial and urban applications. A 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 (CAT, 2011). CAT founded 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) ZeroCarbonBritain – a series of research reports addressing scenarios for reducing the UK's emissions to zero in 20 years; 2) Coed Gwern – 15 acres of sustainably 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.

Hence CAT provides a good base model for a research demonstration center especially with the dual role as visitor and interactive educational center. Access to a demonstration or pilot facility at an inhabited site is especially helpful for training and working with local decision makers.

#### *4.2 Environmental Sustainability Programs in China*

Examples of established international joint initiatives in China are also useful with reference to the proposed center. For example, the JUCCCE training program at the National Training Center for Mayors of China is a very interesting idea. This type of training program with a regional focus undertaken at a research and demonstration center could be particularly effective. Three environmental initiatives are briefly described below. Detailed information is available on their web sites.

The EcoPartnership Program (<http://www.ecopartnerships.gov/>): This is a high level organization which encourages US 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 US\_China Collaboration on Clean Energy (<http://www.juccce.com/>): JUCCCE develops training programs at the National Training Center for Mayors of China on how to build more sustainable urban centres 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 an energy smart city. The Green School program is one of their initiatives.

China US Centre for Sustainable Development (<http://www.chinauscenter.org/>): 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. Again detailed information can be found on the web sites. Auroville Earth Institute (India) (<http://www.earth-auroville.com/>): The Auroville Earth Institute is Asian representative and UNESCO Chair "Earthen Architecture, Constructive Cultures and Sustainable Development". The institute undertakes training and technology transfer in areas including Egypt, Nigeria and Tanzania. They plan to develop a curriculum for students of various education levels which would grant diplomas in earth based construction and design. The Auroville Earth Institute participated in the Post Earthquake Assessment of Vaulted structures in Bam Iran.

International Vernacular Architecture Unit- Oxford Institute for Sustainable Development (<http://www.brookes.ac.uk/schools/be/oisd/architecture/ivau/index.html>) : Research expertise of this international institute 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 the 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 (<http://www.ihbc.org.uk/>): Historic places attract people, activity and investment, giving new life to their communities and helping make places more competitive. IHBC plays a central role in regenerating towns, cities and rural areas in the UK. This organization maintains a data base 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, this center will require significant government support at the initial stage but it is important to consider corporate sponsorship from the beginning with the view that the center becomes partially self-supporting. As research progress and more emphasis is placed on transfer, implementation and promotion of technologies developed at the center private funding will necessarily play a greater role. We must consider 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 and six of China's largest solar companies are listed on the New York Stock Exchange (see Table 1). These companies benefit from international exposure and highlight social responsibility. 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	<a href="http://www.suntech-power.com/">http://www.suntech-power.com/</a>
Trina Solar, Changzhou, China	<a href="http://www.trinasolar.com/index.php">http://www.trinasolar.com/index.php</a>
Yingli Green Energy, Baoding, China	<a href="http://www.yinglisolar.com/">http://www.yinglisolar.com/</a>
JA Solar Holdings, Shanghai, China	<a href="http://www.jasolar.com/">http://www.jasolar.com/</a>
LDK Solar Co. Xinyu, Jiangxi, China	<a href="http://www.ldksolar.com/">http://www.ldksolar.com/</a>
China Sunenergy, Nanjing, Jiangsu, China	<a href="http://www.ldksolar.com/">http://www.ldksolar.com/</a>

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. The Four Seasons Hotel Istanbul 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) Data base 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 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 employment opportunities and meet government objectives especially sustainability goals and rural development. China in particular is moving in this direction.

At an eco- forum in Guiyang, on July 17 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 1,000 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. (Deng S., 2011)

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. Using 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 goals of each sector in 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 and 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 important in identifying a clear range of potential research activities and their relevance to the goals of the center. The objective at this stage is to clarify intent and ensure that this is evident to all potential parties.

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, gauge 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

The authors propose the development of a *Sustainable Technology Research and Demonstration Center for Earth Structures* either within or near the world heritage site of Fujian Tulou of China. The proposed center will be used as a work base not only to help save, preserve and revitalize Hakka rammed earth buildings for our common World Heritage, but also to implement Hakka sustainable technologies for design, construction and operation of green structures, and to advance and promote use of rammed earth as a viable building material option for a more sustainable future of planet Earth. It is hoped that the participants of the workshop, the friends of Hakka Tulou, the community of rammed earth research and construction, and any environmental conscious individuals will support and work together to make the proposed Center for Earth Structures become a reality.

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