# Building with EARTH, China

## Organisation implementing the project

Building with EARTH is a partnership between a charitable foundation, academics, local government officials, international experts in earth architecture and local craftspeople. It is co-ordinated by Wu Zhi Qiao (Bridge to China) Charitable Foundation (WZQCF); delivered by Beijing University of Civil Engineering and Architecture (BUCEA) and Xi'an University of Architecture and Technology (XUAUT); and supported by the Ministry of Housing and Urban-Rural Development of China (MOHURD). In 2011 a demonstration research project was launched by the team with scientific support from CRATerre-ENSAG and UNESCO Earth Architecture Chair.

In collaboration with other academics and institutions, the Project leader, Professor Mu Jun, had previously completed two research projects - Maosi Ecological Primary School (UNESCO Award and RIBA Award in 2009) and Post-Earthquake Village Reconstruction and Demonstration in Ma'anqiao Village (UNESCO Award in 2011)[1]. These demonstrated that a more systemic and scientific study was needed to develop a more sustainable way of constructing homes.

## Project Description

Building with EARTH combines traditional rammed-earth construction methodologies with modern mechanical techniques to improve rural building design on the Loess Plateau and other regions of China. This approach is taught to local tradespeople and building officials through demonstration builds, volunteer construction programmes and training courses.

The project has four key aspects.

1. **High science, low technology:** Combining traditional rammed-earth building design with advanced machinery, suitable for the social, rural and economic conditions; whilst promoting cost-saving and self-sufficiency.
2. **Train the trainer with prototype building**: Tradespeople, masons and building officials are trained by the project team, and then cascade their knowledge throughout surrounding villages.
3. **Connecting people:** The project connects local government, private sector, philanthropists, academics, NGOs and local communities.
4. **Villagers as rammed-earth contractors:** Villagers who have been taught new skills are encouraged to become contractors themselves, providing work and growing the local market for earth-dwelling design.

The project began in 2011 on a main site in Macha Village, Dingjiagou Countryside (Huining County, Gansu Province) with the construction of a Village Centre and 32 prototype houses. Cross-regional demonstrations and building extensions have now happened in 19 more villages and in seven cities in 23 different regions in 17 provinces of China - including Gansu, Xinjiang, Qinghai, Inner Mongolia, Shaanxi, Hebei, Beijing, Tianjing, Henan, Hubei, Anhui, Zhejiang, Fujian, Guangdong, Jiangxi, Guizhou and Yunnan provinces.

[1] *Building with EARTH: a transformation of a traditional technique to climate-smart, affordable and safe construction that villagers could pass on and be proud of Interim Report 2011-2018.*

Around 655 villagers have been housed already, and in addition demonstration homes have been built in a further 19 villages (average population of 2,000).

## Aims and Objectives

Building with EARTH provides environmentally-friendlier, affordable and quake-resistant housing to rural villagers in China. It embeds academics within communities to share learning on traditional building methods. These are then adapted so that local craftspeople and masons can work throughout surrounding areas building new homes and benefitting financially.

It challenges current building methods - cement and brick designs - in China which are bad for the environment, expensive for rural villagers and less resilient to earthquakes. The project illustrates an affordable and sustainable way of rural construction using locally available resources that also offers an improvement to traditional building practices.

Upgrades focus on earth material science, modifying shuttering systems and ramming tools to compress earth to build walls, alongside adapting traditional structure and construction methods to improve earthquake resistance and increase heat efficiency.

Beneficiaries of the new homes are mostly from poor rural villages and those living in dilapidated houses which have an urgent need for rebuilding, including communities in the village of Macha and in neighbouring villages in Huining County, Gansu Province. They are invited to take part in the construction of demonstration buildings, with academics training local craftspeople.

The project aims to have housed 1,636 people by the end of 2020.[2] A further 292 buildings are being designed or are under early construction in Kashgar, Dongie, Wanjian and Tuguan. These are expected to be completed by late 2020.

## Context

Construction with earthen materials is one of the oldest traditional building technologies in the world and has been widely used across China for several thousand years. Earthen materials played a crucial role in various traditional architectures - even more so than timber - as they are available almost everywhere.

Combining traditional earthen building design with modern pneumatic hammers and advanced shuttering is extensively used across developing countries, particularly in projects aiming to maintain cultural inheritance and deliver ‘green architecture’. Due to China’s size, low levels of education in rural areas, and difficulties implementing international building principles, this project has developed a specific Chinese construction system, adapted for the methods and conditions of rural China.

According to the latest statistics (MOHURD: 2010), at least 100 million people in China are still living in traditional earth dwellings, across five main rural regions - Loess Plateau, Tibet, Xinjiang, the southeast and the southwest of China. Over 60% of these are built with rammed-earth technology. Despite China’s recent rapid economic development these traditional ‘earth architectures’ are still common because of rural China’s low-level economy.

[2] This is calculated using an average rural household number in China of 3.36 Source: https://www.statista.com/statistics/278697/average-size-of-households-in-china

Since 2008, there have been several catastrophic earthquakes which have destroyed many old earthen dwellings. Most local governments and villagers simply rebuilt or repaired using concrete and brick design. As there were no standard building codes, over time 'earth dwelling' has been labelled as a 'poor' and 'dangerous' option despite their bioclimatic features which respond well to local climate, culture and geographic conditions. As building culture has shifted away from rammed-earth; knowledge and expertise in local communities is lost in favour of concrete and fired brick building - which is less resistant to earthquakes and is not as environmentally sustainable.

Tens of millions of villagers live in traditional earth dwellings across China, and the government's policies to move people out of poverty have involved moving them out of earth dwellings completely.

Like many typical Chinese villages, Macha Village has suffered significant decline in population as residents move to the larger urban areas and cities for work and a better standard of living. Macha's population is 2,100, with more than 500 families (at the administrative village level) distributed in nine community groups. In 2018 the annual net income of each villager was around $509 USD, while the average for China's rural population was $2,126 USD. This has increased from 2011 (when the project was launched), when the figures were $280 USD and $1,015 USD respectively.

**Key Features**

Rammed-earth construction is a traditional model of building that involves compressing gravel, sand, silt and a small amount of clay into place between flat panels called 'formwork'. This is usually completed manually by a group of craftspeople with long poles, which is labour intensive and time consuming. In the 1990s, project partner CRATerre-ENSAG found that the mechanical and waterproofing performance of rammed-earth could be greatly enhanced using pneumatic hammers and a mixture of clay/sand/gravel with 8-12% of moisture content.

This project adopts the traditional model but uses handheld machine-ramming tools, as well as strengthened modern bamboo shuttering systems - using local bamboo plywood, shape steel, and tension screws. The building method can be delivered by three people, whereas, traditionally, six were needed. Villagers have been able to build homes at two-thirds the cost of conventional concrete and fired-bricks.

To share this new model, in 2014 WZQCF and MOHURD co-published an advanced rammed-earth DIY construction manual and have provided training for over 400 local villagers (formed in five co-operatives), which allowed them to build advanced rammed-earth buildings as contractors - building a further 200 houses and five rural public facilities across 23 regions in 17 provinces of China.

This project provides support to:

- **governments** - climate-smart, locally appropriate, disaster-resilient and comfortable housing options for remote villagers;
- **villagers** - appropriate skills and tools to build their own homes and improve living conditions through self-help. It preserves cultural building tradition within the community, promotes self-confidence and reduces potential mortgage burdens through use of free local natural materials and no need to borrow money as they hire local contractors; and

- **skilled craftspeople** - with new skills they become paid contractors and increase their income. They can also stay in their local areas rather than having to travel to larger urban areas for work.

The project has substantial academic input from international earth-dwelling experts, alongside students and academics from Beijing University of Architecture and Design and Xi'an University of Architecture and Technology (XUAUT). For each demonstration house, masters students spend at least six months living in rural communities to learn and adapt traditional building methods alongside local craftspeople.

Trained craftspeople offer their building skills to local villagers, and craftspeople in other regions, increasing the market for traditional earth dwelling design. The knowledge, practices and traditions of local people has been the foundation of the advanced techniques that have been developed. The perspectives, concerns and worries which were shared by local people during the research stage helped to understand local context. Working with local craftspeople helped the team to localise the technique and tools which had been learnt overseas – their practical experience and skills taught them how to improve efficiency with the limitations of the local context.

The local community, including women, have supported volunteer and construction activities, and are involved in managing and running the Macha Village Centre, and organising different community events.

## Funding

The total cost of this project up to February 2019 was $1,476,354 USD. The Wu Zhi Qiao Charitable Foundation raised over $599,067 USD through corporate donations, family foundations and charitable trusts. The following also provided funding:

- **Swire Properties Limited:** research, experiments, technical advancement, prototype building, publication and promotion;
- **Lee Hysan Foundation:** sustainable development and operation of WZQCF;
- **Chan Cheung Mun Chung Charitable Foundation:** operation of mainland centre, tools and staff cost for demonstration across 23 regions, construction of village house prototype and village centre in Macha;
- **Hong Kong Jockey Club Charities Trust:** volunteer programmes and earth-related construction training;
- **MOHURD** provided $223,248 USD of funding to support demonstration in 23 different regions of China;
- **local governments** in the Loess Valley region provided a grant of $356,748 USD for the construction of 200 prototype houses;
- **Beijing University of Civil Engineering and Architecture and Xi'an University of Architecture and Technology** provided funding of $297,290 USD for experimental research; and
- the general public supported the construction of the Village Centre through a Charity Walk called Wu Zhi Xing 2014.

The average cost of an earth house is $95 USD per m2 when purchasing all materials (excluding earth) and labour. In Macha Village the homes are approximately 60-80m2 with the total construction cost around $5,670-7,560 USD.

Beneficiaries generally pay for part of the construction (around 20% = $1,134-1,512 USD), or provide equivalent manpower from neighbours and relatives and recycled materials (such as stone and timber) from their old houses. This mobilises beneficiaries to work closely with the project team and craftspeople during design and construction, so as to reach a higher cost-efficiency and find effective solutions to meet their living needs - rather than waiting to be given a house. The beneficiary contribution is equivalent to two/three unskilled labourers for one month - most provide one or two labourers, (usually male family members or neighbours) - and recycled materials, instead of paying the 20% in cash. In cases where this is too difficult for families, the percentage contribution is reduced to 10% or lower, depending on what level of assistance they are able to provide in the construction. Other funds come from government housing subsidies (40%) and the WZQCF (40%).

**Innovation**

Building with EARTH supports communities to maintain their cultural connection with traditional building design, challenge growing negative stereotypes of earth dwellings, and provide greater resistance to seismic shocks. It is significantly more environmentally friendly than current Chinese building design, which is focused on concrete and fired-bricks.

The adoption of modern mechanical techniques means the model can be delivered far more efficiently and cost-effectively than traditional designs, and significantly cuts down labour time. Training local craftspeople helps spread the model to neighbouring villages.

**Environmental Impact**

Traditional rammed-earth construction dwellings are environmentally friendlier as they make use of abundant raw soil (not from farmland) in most of China's regions that traditionally uses rammed-earth construction.

The Building with EARTH project provides climate-smart, low-carbon, healthy and sustainable housing.

1. **Thermal comfort:** Rammed-earth walls, straw-based roofing insulation, double-glazing timber windows, and roof space isolated by ceilings as a thermal buffer, provide efficient thermal mass and insulation. During winter in Macha Village, indoor temperatures are on average 5$^{o}$C higher than houses built with fired bricks and concrete, meaning residents use less carbon-based fuels to heat their homes. During summer, rammed-earth buildings are on average 7$^{o}$C cooler.
2. **Low carbon emissions**: Over 80% of the building materials (earth, sand, gravel, straw, and timber) can be collected locally without much transportation. Simple tools, shuttering systems and electric hammers are used to improve cost-efficiency. Rammed-earth dwellings cost two-thirds of conventional houses, while energy and carbon emissions caused through construction are between 20% and 25% lower than conventional houses.
3. **Zero/low construction waste**: As most construction materials are natural or recycled materials, 80% less construction waste is produced.

As the Loess Plateau region is an earthquake zone, building methods were evaluated and modified to include the following features to improve earthquake resistance.

1. Capping the span, storeys, and floor height of the rammed-earth house to reach a reasonable shape co-efficient for seismic resistance.
2. Involvement of timber-made (or prefabricated concrete) structural columns in wall corners and ring beams on both the top and bottom of earth walls.
3. Improving structural measures for joints between walls, roofs and walls, and foundations to further enhance structural integrity.

**Financial Sustainability**

Future delivery is reliant on continued funding from charitable foundations, development organisations, volunteer programmes, central government and universities.

By demonstrating the benefits of new earth buildings and turning local craftspeople into advanced rammed-earth constructors, this increases demand - creating more sustainable sources of income for local people.

Over the next five years, the project will undertake further research into traditional earth construction, through funding from BUCEA and Central Government. Two new base sites will be built in Southern and Eastern rural China, using funding from central government and WZQCF. Training for local craftspeople, professionals, government officials and the general public will continue, also funded by WZQCF.

So far, the beneficiary contribution of around 20% has worked well, but the project believes they need to optimise this policy to ensure affordability into the future.

**Social Impact**

Over 400 craftspeople have been trained in Macha Village and 22 other regions in China. As demand for advanced building design increases, local craftspeople have greater economic stability in an area with traditionally high levels of poverty. The benefits go directly to local communities, rather than contractors and other larger building companies from outer urban areas, addressing one of the major poverty/income gaps in contemporary China.

The project has promoted resilience of communities in the Loess Valley, including women, older people and children who spend most of the time at home and have traditionally suffered in poor buildings. Through new building design, they are better protected from excess cold and heat which contribute to poor cardiovascular and respiratory health. Craftspeople are able to find work locally - rather than having to travel to urban areas - and spend more time with their families.

Macha Village now has a communal building with a clinic, nursery, library, stage, shop and a multi-functional hall – supporting community cohesion through shared facilities.

**Barriers**

The project faces a number of challenges.

- Local villagers were sceptical about this building design due to the perception and prevailing stereotypes that it has poor light, is unsafe and a symbol of poverty. This, coupled with their lack of confidence in their own traditions and the rapid pace of urbanisation, results in a desire for ‘urban lifestyles’. Even those who have adopted the advanced technique try to decorate the walls with paint and tiles to conceal that it is an earth building, which can create technical problems.

- Some local governments may not opt for eco-alternatives as some counties have high poverty relief targets to meet by 2020. Therefore, they choose mass construction projects - funded by central government - that produce quick and easy outputs, rather than co-ordinating villagers to learn construction. For this reason, there are six villages where prototype houses have been built but this has not led to the construction of further rammed-earth properties.
- Housing subsidies from some local governments are only available if they fulfil certain conventional building codes and regulations. These limitations on funding have also contributed to some villages having no further homes built after the demonstration build.

Some challenges have been overcome by:

- initially embedding researchers within communities to learn traditional building practices and understand what local villagers wanted from both public buildings and village homes. Following this, training on the new method was delivered;
- forming rammed-earth co-operatives, empowering people with skills and equipment, creating local markets with like-minded officials in Gansu, and involving them in national international awards;
- sharing successes through media and senior ministry/provincial level reporting to recognise local efforts and solicit upper-level endorsement. Central government are now considering how to empower local people in village revitalisation campaigns after completion of the specific poverty relief campaign; and
- helping to draft relevant codes for rammed-earth building and provide further training to government officials at different levels.

**Lessons learned**

In order to increase the scale of the project and achieve greater outcomes, they recognise a need for:

- a large-scale training programme for more craftspeople, to cope with immediate demand to improve rural living conditions;
- joint effort from local and national NGOs and experts to research the best construction skills for different localities across China (not just Loess Valley); and
- comprehensive local and national policies on building regulations, codes and technical guidelines for safety and quality control.

Using demonstration constructions to train and educate local villagers is a slow and inefficient process. However, training Macha craftspeople to form their own rural co-operatives, involving up to 40 members, is more efficient and sustainable. After completing the demonstration homes, local co-operatives can either build new homes in different locations or build extensions on the demonstrations.

**Evaluation**

This project regularly self-evaluates their activities in the following areas.

1. **Government reporting and engagement in expert technical committees:** As a close partner of MOHURD, the project co-ordinates committee meetings and prepares reports (national and local) on key results. These include government-supported research; prototype builds; and training for officials and craftspeople. The project receives ongoing feedback from villagers, craftspeople, architects and officials.

2. **Livelihood, community and volunteer engagements:** Annual activity reports document key scientific advancements, training for university students and craftspeople, which are reported in academic journals and at international conferences.
3. **University:** Reports summarise the impact of funding on outcomes, including improving villagers' livelihoods, enhancing volunteers' experiences and promoting university-experiential learning. Quantitative records and qualitative measures, including feedback and reflections from villagers, were documented and published.
4. **Linking project evaluation to foundation's governance:** Secretariat from WZQCF have maintained close connections with local communities and visit project sites to evaluate users' feedback, enhance performance and develop improvement measures. Key findings were also reported and reviewed by WZQCF councillors as internal governance.

**Recognition**

Since 2011, the programme has received awards from international, central governmental and academic organisations.

- 2012 - Outstanding Work Prize in the 1st China Design Exhibition (Ministry of Culture)
- 2014 - The Prize of Excellent Young Scientist of Shaanxi (Shaanxi Province Civil Construction Society)
- 2014 - Science & Technology Award for Chinese Youth of Shaanxi (Shaanxi Province Government)
- 2016 - Top Ten Personalities in Contribution to Rural Development (China Central Television)
- 2016 - First Prize of Excellent Rural Building Design (Ministry of Housing and Urban-rural Development of China)
- 2017 - Innovation Award, UNESCO Asia Pacific Heritage Awards (UNESCO)
- 2018 - World Architecture Award of China Architecture Design Experiment Award (Journal of World Architecture, Architectural Society of China)
- 2018 - Highly Commended Award of the World Architecture Festival

The Macha Village-based project has also attracted significant national media attention:

- "Earth house has not been a symbol of poverty", reported by China Central Television, 2018
- "What kind of earth houses we need in rural China?" (30mins), China Central Television, 2017
- "The first upgraded rammed-earth demonstration in China", reported by China Central Television, 2014

The project is linked with the earth building sector worldwide, they have held exhibitions and international students, academics, architects, contractors and over 30 provincial and county governments have visited Macha Village.

**Transfer**

This model has been transferred to 23 regions in 17 provinces of China. In recent years, most projects were initiated and funded by MOHURD, local government and even village heads. Developers/the private sector have now adopted rammed-earth technology in landscaping projects, museum buildings, elderly activity centres, community centres and exhibitions in large cities across China, including Beijing, Tianjin, Fujian, Guangdong and Anhui.

Invited by MOHURD and provincial governments, the project has trained 5,520 grassroots officials, craftspeople and professionals about rammed-earth construction. This led to the development of 20 other rural rammed-earth construction projects in local government areas across nine provinces.

Over the next five years there are plans to:

- undertake systemic research to explore and advance the application of traditional earth construction in contemporary architecture towards building sustainable cities and communities;
- develop and publish national technical standards and regulations on the earth architecture method;
- expand the model and develop two more construction bases in Southern and Eastern rural China; and
- promote regional demonstration and technical training, while also offering training for craftspeople, professionals, officers and the public.

In late 2019, the Chinese Government is expected to publish a national standard for rammed-earth design and construction. This is a significant reverse to policies to move people out of earth dwellings - official notices issued by MOHURD to all provinces with the tradition of earth building (to encourage demonstration and transfer of what has been achieved through this project) have contributed to changing the mindset and perceptions of government officials.