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Rural Women's Participatory Construction in China

Based on New Rammed-Earth Construction Technology

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ABSTRACT: In China's relatively poor rural areas, new housing is mostly brick-and-mortar because of a massive outflow of labour and disruption in the inheritance of traditional construction techniques. But these houses are plagued by poor living conditions and high construction costs. This study proposes a method to improve the traditional ramming technology so that local women can participate in the construction, and compares it with local traditional cases. And this study also provides a new choice and reference for constructing a sustainable development mode in rural areas.
KEYWORDS: Rural Areas in China, Rammed Earth, Female Workers, Sustainable Construction

1. INTRODUCTION

With the deepening of China's urbanization process and the transformation of social productivity structure, in the rural areas of southwest China, a large number of male labor force go out to work, with mostly elderly, infants and women left behind. Therefore, a large part of the newly built farm houses are brick-concrete structures contracted by construction teams which are from out of town. The traditional rammed earth dwellings were eliminated due to the local labor force emigration. There isn't enough local labor force to improve its residential performance to meet modern needs, which led to an obvious gap in the inheritance of rammed earth construction technology.

This paper discusses the meaning and significance of women's participation in the construction of the new type of rammed earth residential buildings to the sustainable development of architecture and environment by means of a comparative study of actual construction projects and reinforced concrete brick houses under the same conditions in Sichuan province, rural areas of Southwest China.

2. LITERATURE REVIEW

2.1 Demographic structure in rural China

The process of urbanization has resulted in the outflow of high-quality rural labor force. China's rural population structure and employment structure have undergone great changes. A large number of social surveys show that the rural population is characterized by "aging" and "hollowing out", and "feminization" and "aging" stand out in agriculture.[1] In some places, natural villages have completely hollowed without permanent population while most villages only have women, children and the elderly as permanent population.

According to local government's report 'General situation of migrant workers in Sichuan Province' [2], the structural characteristics of rural emigrant workers are: men >women; young>old (table1 and table2), which can make an inference on the personnel structure of local left behind reversely basic on the data that the proportion of men and women in rural areas is roughly equal.

Table 1: Sex ratio of emigrant workers[2]

sex	Male(%)	Female(%)
ratio	59.7	40.3

Table 2: Age ratio of emigrant workers[2]

Age	18~29	30~39	40~49	50~65
ratio	31.5%	23.3%	29.8%	15.4%

2.2 Transformation of dwellings in rural China

Rammed earth technology has been used for thousands of years around the word especially in rural China. A large part of the folk dwellings in southwest of China rural area are traditional rammed earth dwellings.

But most newly built houses in rural China are built in brick-concrete or reinforced-concrete mode, and brick -concrete structure is more popular with the poor because of its lower cost. However, due to economic and technical constraints, most new houses lack sophisticated thermal insulation structure, which means the indoor environment quality is very poor. [3]

A small number of residents choose to install air conditioner after accumulating enough money to

improve their living comfort , which produced unnecessary energy consumption.

2.3 Building environmental assessment methods

The current assessment system for the sustainable development of the built environment includes the following three levels:

- Sustainable environment
- Sustainable society
- Sustainable economy

South African academics have established the first sustainable building assessment tool (SBAT) for a developing country[4].

China academics, Dr. WAN Li , reviewed the current situation and issues relating to the rural development and construction of China and the theory of sustainable rural development and has made evaluation recommendations that are more consistent with China's rural situation, emphasizing the endogenous development of rural areas and the overall improvement of social resources.[5]

2.4 Study purposes in current context

The massive outflow of labor force is a major current situation in rural areas of China, which results in the interruption of inheritance and renewal of traditional construction techniques. In the absence of local labor and technology, brick- concrete structure and reinforced concrete structure houses become the only and best choice to meet the requirements of housing replacement. The technology and materials for both types of buildings come from outside which make it possible to reach a cleaner and brighter living condition than traditional one. But at the same time, it also causes many problems that are inconsistent with the values advocated by sustainable development of building and environment.

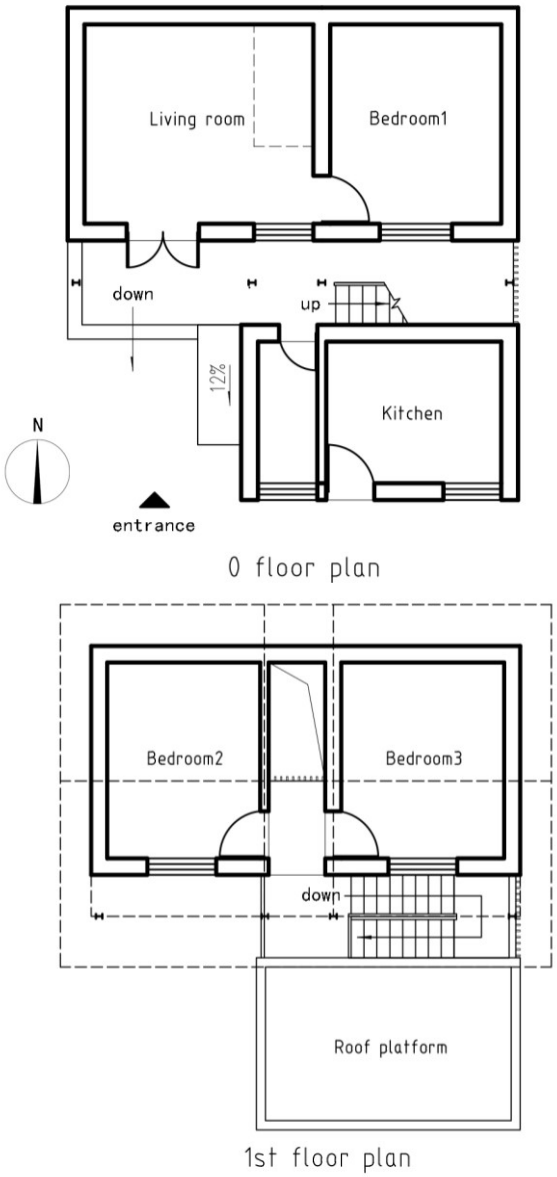
Through the introduction of university research, the traditional construction technology has been improved to be able to build a safe and comfortable house, and easy to operate, so that females which are available in rural area can participate in the housing construction, filling the vacancy of the local labor force. In addition, the use of local materials and local labor reduces energy consumption and environmental damage, and has positive significance for the endogenous development of the region. In this study, we try the above methods and compare them with the cases of self built houses of villagers.

3. CASE STUDY OF FEMALE PARTICIPATORY PROJECT

The project was located in a remote mountainous area in southwest China, with 1.2 km away from the nearest folk market, motorcycle was the only accessible transportation except walking in rainy season. The majority of male labor force around the area went out as the migrant workers, with women and children left behind.

The case study was based on the new rammed earth construction technology whose strategy is "high science and low technology". The construction auxiliary equipment was optimized to make it possible for rural women to participate in construction.

Picture 1 : Plans of the study case



In addition, A brick house of the same village, which was a poverty - alleviating housing built at the same time by the government in a unified way, was selected as a comparison. The basic information of the two buildings was compared in the following details:

Table 1: Contrast of two cases

	Study case	Comparative case
Building Type	Rammed-earth building	Brick-concrete building
Wall	Rammed earth	Red brick
Roof	Steel frame and Light tile	Concrete
Construction method	Villagers' participation and Guidance of Universities	Extraneous construction team

3.1 information of construction workers

The project's workers, all from the surrounding countryside, were made up of five men and five women, and male workers had regular construction experience, which means they had the skills of erecting formwork、removing formwork and building houses with concrete and bricks, before they arrived at that construction site .

The five female workers were all married and stayed in the local area due to family and children, with low education level.

Table 3: The information of female workers

NO.	Age	Education	Experience	Family information
1	37	Junior middle school	Yes	Married/has 2 kids /husband is a migrant worker
2	46	Primary school	Yes	Married/has 2 kids /husband is a migrant worker
3	42	Junior	No	Married/has 2 kids
4	37	Junior	No	Married/has 2 kids
5	29	Junior	No	Married/has 2 kids

3.2 New rammed earth technology and skills' training

The new rammed earth construction technology is improved on the traditional rammed earth technology. Appropriate size of concrete foundation with a correct cement mortar to enhance the integrity of the foundation of the house. The soil of the site was examined in the lab and adjusted properly with sand, straw, and small amount of cement (4%) to avoid cracks and make the wall solid. Concrete ring beams are added to the wall to improve structural integrity and to avoid vertical cracking. The quality of the rammed tools and formwork is increased. Aluminium alloy formwork and electric rammer has been used to make the wall substantially compact and smooth.

Through the above improvement measures, the 1:1 full-scale model passed the shaking table test of earthquake simulation, and the results showed that When the peak acceleration of shaking table is 0.4g, the structure is in good condition, the stiffness is basically unchanged, and the structure is in elastic state[6]. This means that it can completely meet the requirements of 8-degree seismic fortification area in China's seismic design code[7].

Construction process of the projects was divided into: broken soil, mixing ingredients, formwork, compaction, foundation ring beam.

Training is accompanied by construction, the work of breaking and moving earth is very simple, and the female workers can handle it completely. The work of mixing ingredients can also be mastered by female workers through simple announcement, and they can accumulate experience in many times of repetition. Considering physical strength, the formwork is made up of male workers.

Picture 2 : Women in construction training

3.3 Upgrade of construction equipment

In the early preparation stage, the equipment has been improved to make them more convenient to control for women.

Table 4: Equipment upgrading

Equipment	Old type	New type	Advantage
Tamper	Vertical rammer (75kg)	Pneumatic tamper (9kg)	More light
Air pump	No	Yes	Supply to the tampers
Electric generator	No	Yes	Supply to the Air pump
Mixer	Vertical	Flat	smaller、easier to control

formwork	Made by Aluminium alloy	Made by wood	More light
Crane	No	Yes	Easier to transport
Mini-tiller	No	Yes	Easier to dig

4. COMPARATIVE ANALYSIS OF BUILDING AND ENVIRONMENTAL SUSTAINABILITY

4 .1 Environmental sustainability

With regard to environmental sustainability, the following points should be considered:

- Ecosystem conservation
- Resources protection
- Control the use of resources that damage the environment
- Garbage and pollution
- Water resource
- Energy

The energy consumption and pollution of the rammed earth are lower than that of the brick-concrete structure under construction, operation and demolition.

4.1.1 The state of construction

Taking the construction site as the centre, the area of ten kilometres is reclaimed slope land, with only soil and scattered boulders. For rammed earth buildings (study case), these boulders can be used to build foundations, earth can be used as the most important wall material, and masonry buildings (the case study) have to be removed from the market except for stones.

In both cases, the foundation and the girders are reinforced concrete, so the biggest difference in materials comes from the walls.

When the wall is the object of study, by recording and calculating, the data（Table 5） shows that 57% of the materials by weight can be obtained from the construction site in the study case while all materials of the comparative case need to be taken from market. It means that 57% of money of materials was saved, meanwhile the energy and money which is consumed during transit is also saved . Rammed earth building materials do not need complex processing and long-distance transportation, which makes the embedded energy lower.

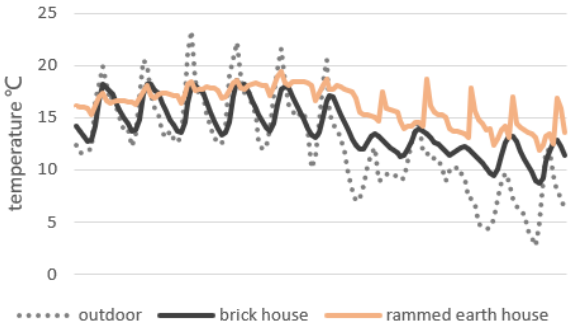
Table 5: source of main materials of walls and respective weight proportion in the wall

Source	Study case	Comparative case
From site	Earth (57%)	
From market	Sand (20.4%) Gravel(18%) Cement(4%) Steel(0.6%)	Sand (19.4%) Gravel (0.8%) Cement (3.84%) Brick (72.9%) Steel (2.06%)

4.1.2 The state of running

Several temperature recorders (HOBO U12-011) are hung in the middle of different rooms of two houses and 800 cm from the ceiling. In the months after the completion of construction, the temperature changes of each room were recorded continuously, 12 times a day. The temperature outside the building is also recorded. (Table 6).

Table 6: Air temperature measurement results in winter（11/26/2019-12/06/2019）



Due to the good thermal inertia of rammed earth wall, the fluctuation of indoor temperature can be maintained in a small range(<4.6℃) and much higher than the minimum ambient temperature.

In order to obtain better natural lighting and ventilation, the window opening of the study case was optimized according to Code for design of buildings[8]. (Table 7).

Table 7: The ratio of window to ground of two houses

Space type	Study case	Comparative case	Code
Living room	0.24	0	0.16~0.25
Bedroom1	0.125	0.135	0.125~0.16
Bedroom2	0.13	0.145	0.125~0.16
Bedroom3	0.184	0.145	0.125~0.16
Kitchen	0.24	0.115	>0.143

With the application of passive energy saving design methods, study case was relatively low in energy consumption for building, simple in maintenance and thus was more energy-saving in the long term.

4.1.3 The state of demolition

Whether the construction waste can return to the ecological cycle after demolition is one of the important criteria to judge the sustainability of a building.

For rammed earth buildings, rammed earth walls are made of a mixture of earth, sand and other natural materials, with 4% cement added as stabilizer. After the

wall is demolished, the building fragments pulled from the wall can be returned to the soil by adding some cement anticoagulants (such as zeolite/silica) for replanting replants..

For reinforced concrete brick houses, red brick is made of clay and shale powder fired at a high temperature of 900℃, and irreversible chemical reaction takes place in the whole process. It is a non-renewable resource. In addition, the amount of cement added to the conventional concrete is 16.7%, and cement hydration occurs during the setting process, which is also an irreversible chemical reaction. The debris of the whole building cannot be returned to the ecological cycle again.

4 .2 Social sustainability

On social sustainability, those following key points should be considered:

- Accessibility
- Education
- Inclusiveness
- Health and Safety Assurance
- Public participation Energy

In the study case, local women participated in the construction process, which means the idle labor resources were fully used. Besides, supervision and training from research institutions ensures the safety of construction, which fully mobilizes the participation of the society. It also displayed a good inclusiveness and public participation in the construction process. And we observed that the female trained workers performed good soil mixing and construction skills. Some of them process good learning ability and communication skill. This means that the construction technology is accessible to people, they can easily use it or obtain. Therefore, it is not only a production process, but also a good education process. Villagers can acquire new building skills during construction, and make a living by it in the future.

In the comparative case, brick masonry required a certain skill, and it belonged to the advanced technical work. Constructing by the team is nothing but the repeated output of mature skills, without educational significance. What is more, the contract responsibility mode with construction teams from outside of the town makes local villagers cannot participate in . The whole process is not educational at all.

4 .3 Economic sustainability

On economic sustainability, those following key points should be considered:

- Employment and autonomous employment
- Efficiency and effectiveness
- Local knowledge and technology
- Scientific monitoring
- A transparent, fair and supportive environment
- Diversified economies

In this term, the advantages of the research case are:

- Jobs were provided for local women.
- Combined with traditional rammed earth technology.
- It is a small-scale, local and diversified economy that is highly compatible with local conditions.

In the comparative case, conversely the construction workers, materials and technology are all come from out of that hamlet result in the outflow of wealth.

Under the condition of same building area, the total cost of rammed earth building is higher than that of comparative case. But 57% of the spending of study case was left there while 100% of spending was gone to other places. (Table 7) This means that more wealth is left in the local area and can continue to promote local development, rather than being absorbed by foreign capital.

Table 7: Expenditure items and its flow direction

Flow direction	Expenditure of study case （CNY）	Expenditure of comparative case （CNY）
The hamlet	Labor：74,200	————
Out of the hamlet	Materials：44,890 Transportation：11,950	Whole commercial contract:120,000
Gross	131,040	120,000

The study case has better overall quality (Picture 3) and more comfortable internal space (Picture4), although the total cost is slightly higher than the control case.

Compared with the old rammed earth building, it has an absolutely obvious improvement.

Picture 3: Exteriors of brick-concrete house (left), traditional rammed earth house (middle) and new type house (right)

Picture 4: Interiors of brick-concrete house (left), traditional rammed earth house (middle) and new type house (right)

5. CONCLUSION

Practice and analysis show that the new rammed earth buildings and the construction forms participated by women embody the advantages of environmental protection and low energy consumption, with good living environment and safety, and more wealth left on the local people to continue to promote the development of the region.

The improvement of technology not only improves the living comfort, but also provides opportunities for local rural women to learn and participate in construction activities. Women can participate in construction, which not only solves the problem of young labor force shortage, but also provides rural women with job opportunities and skills. This is a construction method that is very suitable for China rural areas. In the process, we also noticed that the acquisition of skills not only brings rural women work and income, but also significantly enhance their self-confidence.

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