Endogenous constructions under abnormal conditions

Taking two new rammed earth constructions in rural areas of Southwest China as examples

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ABSTRACT: In the context of industrialization and globalization, the unification of construction types in rural areas makes the area vulnerable to disasters and other abnormal social conditions.Referring to relevant theories and combining with practice, a new rammed earth construction mode under the framework of endogenous development has been selected. It can well combine the characteristics of rural areas, improve the resilience of the region and deal with many unexpected situations under abnormal conditions.

In this paper, two practical cases of new rammed earth construction in rural areas of southwest China after earthquake disaster and during COVID-19 pandemic were introduced, and the role of endogenous development strategies in improving regional resilience was analyzed and discussed, as well as its positive significance to regional stability and sustainable development. It is expected to provide reference experiences and options for the integration of architecture with other social disciplines for endogenous sustainable rural development, using actual construction projects as examples.

KEYWORDS:Endogenous development，Rural resilience，Rammed earth，Social suspension

1. INTRODUCTION

After the Industrial Revolution, industrial production was favored by the market due to its advantages of high efficiency and uniform quality, which gradually replaced traditional production and expanded from cities to rural areas.

In the construction of houses, modern construction techniques using reinforced concrete and brick are also rapidly gaining ground.

In rural China, The vast majority of folk construction techniques that have not been improved and upgraded cannot meet safety requirements according to the government's standards for poverty eradication and reconstruction. [1] These codes encourage the attempt of various technologies and materials, but there are no specific technical rules and guidance yet.[2] Therefore, almost new buildings are constructed using industrial materials such as brick concrete structure in rural areas, the proportion of minority building structures and materials decreased year by year(Fig. 1). [3,4]

Figure 1: Proportion of rural housing structure in China.

While large-scale industrialization has raised the material standards of people's lives, it has also squeezed out the space for the survival and development of traditional manufacturing industries, and even caused the disruption of the transmission of some production skills. The gradual of production patterns has led to an increased dependence of society on the overall system and a reduction in its resilience to withstand severe disasters. After realizing the risks brought by globalization, a systematic study was formed on "Risk Society" and "Reflexive Modernity". [5] At the same period, a Development response strategy of "Endogenous Development" was proposed. [6] Compared with cities, rural areas have natural resource advantages and is more suitable for endogenous development. [7]

In this paper, two practical cases of novel rammed earth construction in rural areas of southwest China after earthquake disaster and during COVID-19 pandemic were introduced.

2. LITERATURE REVIEW

2.1 Endogenous Development in Rural Areas

The concept of endogenous development was first put forward by UNESCO in 1988. [6] It is a new development paradigm suitable for rural areas which is promoted and participated by the interior of the development region, make full use of the strength and resources of the development region. [7] The comparison of old and new differences is shown in the table1.

Table 1: The comparison of old and new differences

Modernization paradigm	New rural paradigm
Inward investment	Endogenous development
Top-down planning	Bottom-up innovation
Sectoral modernization	Territorially based integrated development
Financial capital	Social capital
Exploitation and control of nature	Sustainable development
Transport infrastructure	Information infrastructure
Production	Consumption
Industrialization	Small-scale niche industries
Social modernization	Valorization of tradition
Convergence	Local embeddedness

The development strategy can make the regional development more dynamic and sustainable, and the production activities within the region have stronger resilience due to autonomy. [8]

2.2 Resilience of Society

Society resilience is about cultivating the capacity to sustain development in the face of expected and surprising change and diverse pathways of development and potential thresholds between them. Resilience can be assessed in two ways: 1. Proportion and ability to return to the original state after a disturbance ; 2. Ability to be resilient to change and control it to maintain stability [9]

Recently, "resilient city" has been proposed and received a lot of attention. It also has certain reference value in rural areas. It has the following properties:[9]

- **Robustness:** The ability of a city to resist disasters. Reduce the economic, social, human, material and other losses of cities caused by disasters;
- **Rapidity:** The ability to recover quickly after a disaster. The city can recover to a certain level of function in a short period of time after the disaster;
- **Redundancy:** The key functional facilities in the city should have certain spare modules. When a disaster occurs suddenly and the function of some facilities is damaged, the spare modules can be replenished in time, so that the entire system can still play a certain level of functions without being completely paralyzed;
- **Resourcefulness:** having basic disaster relief resource reserves and the ability to reasonably allocate resources. It can optimize decision-making and maximize resource benefits under limited resources;
- **Adaptability:** Cities can learn from past disasters and accidents, thereby improving their ability to adapt to disasters.

2.3 Present Situation of Rural China

By 2020, China will have achieved the total elimination of poverty among the rural poor under the current standards, eliminating absolute poverty and overall regional poverty [10]. Rural revitalization is the focus of China's work in the next stage after comprehensive poverty alleviation.

"Poverty alleviation" is only a solution to the most basic problem of survival guarantee [10], while the regional development characteristics caused by the special geographical environment in rural areas of southwest China still exist: [11]

- The physical and geographical conditions are poor, the settlements are scattered and the population density is low, and the transportation conditions are generally poor .
- The operation level of the rural social and economic system is low, young and middle-aged labor force mostly go out to earn money to make a living, resulting in serious hollowing out of villages.
- Relatively poor subjects are characterised by a low level of education, a weak capacity for self-actualisation, and a lack of self-identity and self-confidence.

Because of this, many of today's policies do not adequately consider the remote rural areas of the southwest and are not widely adaptable. A single model of modernised rural development is no longer appropriate for the poorer rural areas of the South West.

2.4 Rural new rammed earth construction

The new rammed earth construction technology is improved on the basis of the traditional rammed earth technology by using modern mechanical technology. By enhancing the density of the wall, it can meet the safety requirements. It combines the original characteristics of being able to take materials from the local area and being recyclable, energy saving and environmental protection in line with the requirements of sustainable development; at the same time the earth wall has good thermal stability and good thermal insulation performance. With the '3Ls' (local materials, local technology, and local labour) as its guiding strategy, the '1U1V' project has undertaken a number of new rammed earth construction demonstration projects in relatively poor rural areas of southwest China. [12]

3. CASE STUDY A: POST-EARTHQUAKE RECONSTRUCTION OF GUANGMING VILLAGE

3.1 Earthquake damage

In 2014, a 6.5 magnitude earthquake struck Ludian County, Yunnan Province, at a depth of 12 kilometres. The people's government of Ludian County reported that almost all rural houses in the whole region have been seriously damaged. Among them, 80% of the houses collapsed due to the earthquake were traditional rammed earth houses of adobe construction [13], which not only caused damage to property but also took the lives and health of some of the inhabitants. This has led to a loss of confidence in, and even fear and resistance to, traditional rammed earth buildings, and almost always a preference for modern building types when rebuilding. However, due to economic and technical constraints, the brick and mortar structure, with reinforced concrete cast-in-place frames as the load-bearing structure and red bricks or hollow bricks as the main wall filling material, has become the only choice for most people.

The post-quake reconstruction project is located in Guangming Village, Longtoushan Township, close to the epicentre of the earthquake. As a result of the earthquake, local social and productive operations were hit hard, and the dramatic increase in demand for the reconstruction of farm buildings caused a serious supply shortage of industrial construction materials and labour in the area. Under such a background, the cost of conventional house-building strategies rose sharply, far beyond the means of villagers, and demand outstripped supply. The ability

of villages and villagers to heal after major disasters is thus weakened and recovery time is lengthened.[14]

3.2 Demonstration Project of Guangming Village

The team entered the village of Guangming 2 months after the earthquake and selected two homes to serve as demonstrations of the new rammed earth construction model. Detailed project information can be found in the table.2 [14]

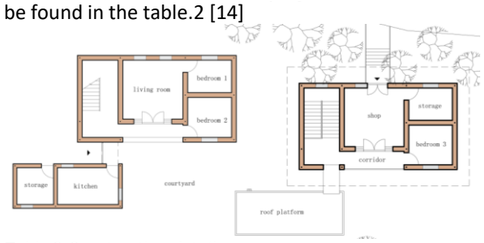


Table 2:Construction details

	Rammed earth demonstration 1	Rammed earth demonstration 2	Other building
Year	2015	2016	2015-2016
Structure type	Rammed earth wall bearing + steel and concrete floor slab ring beam structure		brick-concrete construction
Roof	Sloping roof with thermal insulation construction layer		Cement flat roof
construction organization	Self-built by villagers		Construction team contract system

Table 3: Comparative analysis of constructions

	Rammed earth demonstration	Other building
Costs	Labour: 60% Building materials: 40%	Labour: 50% Building materials: 50%
Labour	Skilled labour (Formwork): 33.33% Unskilled labour (Mixing, transporting materials, ramming walls): 66.67%	Skilled Worker (Formwork, Walling): 66.67% Unskilled labour (mixing and transporting materials): 33.33%
Resource required	Adequate (Earth): 15.6% Average (Unskilled labour): 39.6% Shortage (Skilled labour, commercial building materials): 44.8%	Adequate: 0% Average (unskilled labour): 16.5% Shortage (skilled labour, commercial building materials): 83.5%
Capital Flow	Local: 65.2% External: 34.8%	Local: 16.5% External: 83.5%

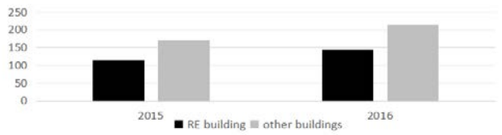


Figure 4: cost comparison between demonstration and other constructions （$）

The demonstration case shows better stability through comparative analysis with conventional construction.

1/ construction costs for both types of buildings increased in 2016 compared to the previous year,and the growth of the new paradigm is smaller.

2/ As the main building material used in rammed earth construction (soil) can be sourced locally ,the cost of rammed earth construction is 29-42.9$ per square metre less than conventional construction of the same period.

3/ The rammed earth construction technique is simple, requiring less skilled labour than conventional construction, and is less exclusive and more inclusive.

Figure 2: First floor plan and second floor plan of demonstration 1

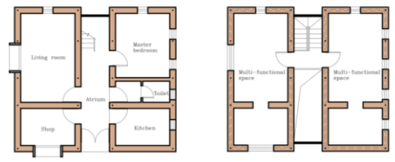


Figure3: First floor plan and second floor plan of demonstration 2

4/ Of the resources required to build a house, rammed earth construction requires only 44.8% of the scarce, irreplaceable resources, compared to 83.5% for conventional construction. Therefore, the price increase for conventional construction (42.6$) is greater than that for rammed earth construction (29$) and is more volatile due to market influences.

5/ A greater proportion of the money from the rammed earth building process stays in the region and continues to participate in the region's economic cycle.

4. CASE STUDY B: CONSTRUCTION OF MALONG VILLAGE DURING THE COVID-19 EPIDEMIC

4.1 COVID-19 And Rural China

The COVID-19 that broke out in late 2019 swept the world. Mainland China has largely contained this major local public health event 2 months after the outbreak and has shifted to a post-pandemic period with the dynamic zero COVID-19 strategy.[15]In the post pandemic period (as of the completion of the article), any production activities need to make way for the COVID-19 control, so the whole society has increased a lot of uncertainty than before.

The village has always been the most basic unit of governance. Its social structure is based on blood, kinship and local ties, creating a society of "acquaintances" with a simple demographic composition[16] which facilitates the detection and control of epidemics. In times of recurring epidemics, by cutting off access roads, a "large quarantine, small circulation" defence circle can be formed and social production activities within the region can be guaranteed to function normally. At present, many sociological studies and analyses have pointed out that a greater proportion of self-sufficiency in rural areas has largely reduced the impact of the epidemic and control measures, but most of them remain in the regional supply self circulation of daily consumables.[18]

Theoretically, the changes around construction brought about by the COVID-19 pandemic in rural areas can be tackled with the new paradigm:

Table 4: Changes around construction brought about by the COVID-19 pandemic and the new paradigm

The impact of the epidemic and containment measures	Conventional construction	Rammed earth construction
Reduced movement of people and lower circulation of materials	External materials and technicians	Local materials, local labour as the mainstay
The situation is fluid and unpredictable	There are construction beats and time costs	Flexible construction schedule to accommodate other production
External work stoppage and reduction in	Buy materials and services	Self-sufficiency, internal circulation

4.2 Demonstration Project of Malong

4.2.1 Project and Farmer Information

The Malong Rammed Earth Demonstration Project is located in an ancient village protected by national policies in Miyi County, Panzhihua City, Sichuan Province. Its regional characteristics are universal in the rural areas of Southwest China:

- **The transportation is inconvenient.** The construction site is located in a mountainous area with narrow roads. The straight-line distance from the county seat is 23.5km, the distance is 66km, and the drive is 1h45min.
- **Abundant in natural resources and lack of industrial products.** Due to the limitation of transportation distance, the local industrial products are less in quantity and higher in price. In particular, most industrial building materials need to be purchased in the county seat. Taking steel as an example, the final use cost is 110%~120% of the purchase price of the county seat.
- **Single means of livelihood and labor outflow.** The local traditional industry is mainly fruit and vegetable cultivation. The government is developing and encouraging tourism to gradually attract foreign-exchange laborers to return to their hometowns for employment.

The construction of the project is an economical house for three families (the three heads of households are siblings). The household information is shown in the table below:

Table 5: The household information

Families (Age)	Situation
Father (58) + Son (32)	The fathers of the two families basically lost their labor force and were widowed divorced due to illness and divorced; The sons used to go out to work, but are currently unemployed and unmarried.
Father (55) + Son (32)	
Husband (45) Wife (35) + Daughter (12) + Son (5)	The whole family works and goes to school, hoping to return home to earn a living.

The current demographic structure of this extended family is relatively common and representative in rural China:

- **The family demographic structure is unstable.** In rural areas, there has long been a lot of manual labor and the phenomenon of "preference to women" is serious. Women have little living space and low social status in rural areas. Rural women will move to cities on their own when conditions permit. Therefore, the older generation cannot retain women, and the younger generation cannot attract women. The younger generation has to choose between going out to earn a living and taking care of the family.
- **Long-term shortage of labor force, period surplus.** Due to the shutdown of industries and the uncertainty of the future of the epidemic, some of the labors who would otherwise have gone to work were left behind in the local countryside, creating a surplus of labour. This is the case with the 2 young men of the family who are now out of work.

4.2.2 Residential Design

The design of the house follows the order of importance of safety, economy, comfort and aesthetics. The residence is a 2-story building with two entrances, shared by three households. (The kitchen is unified and built separately)

In terms of appearance, the sloping roof design of this household complies with thetraditional village protection code and meets the waterproofing of raw soil buildings. In order to prevent the old-fashioned earth walls from being weathered and eroded, and to unify the architectural style, all buildings in Malong need to spray a layer of real stone paint (about 21.4 $/㎡) on the outer walls. The new paradigm's own strength, durability, and aesthetics have all met the requirements, so no further treatment is required.

Picture 1:Malong project

Figure 5: First floor plan of Malong project

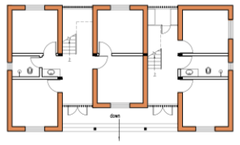
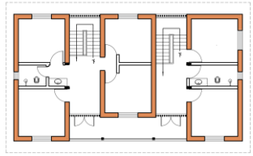


Figure 6: Second floor plan of Malong project



4.2.3 Construction

The project adopts the construction model of "university-guided technology + farmer-organized construction + employment of local odd workers". It is mainly sent by our university research team to send two master craftsmen who are proficient in this technology to train and guide on-site. According to the progress and requirements of the foundation construction of the household head, we can flexibly hire the required labor force locally to participate in the construction.

- The project will start in November 2021 and be completed in February the following year. The area and the entire construction process were not directly impacted by the pandemic, but were also affected to varying degrees in many aspects:
- The labor force is tense at stages, and the personnel are not fixed. The pandemic has caused the import of fruits and vegetables to be blocked. The fruit and vegetable industry in Miyi County has experienced a surge in prices (in the case of tomatoes, the price is 4 to 7 times that of the same period last year), which indirectly leads to a large flow of labor to fruit and vegetable planting and harvesting positions. Labor prices on construction sites are rising and personnel are unstable.
- Inflation led to rising prices of labor and building materials. The local construction labor wages in the past three years obtained after the interview and survey show that the labor wages have increased year by year, and the wages of foreign workers are higher than those of the same type of work in the same period.

In this situation, the application of "high science and low technology" with the participation of universities and the advantages of using local materials and local labor are becoming more and more prominent.

4.2.3 Comparative Analysis

The actual data generated during the construction of the project are recorded truthfully:

Table 6: Quantity and cost of construction

Details		Quantity	Price
Building materials	Processing materials	6.14t	10145 $
	Natural materials	355.7t	5821 $
Labor	Skilled worker	138	6357 $
	Unskilled worker	345	7885 $
Tool and equipment damage ($)		628 $	
Total cost ($)		30838 $	

Combining the interviews with the construction workers and the material market at that time, we calculated the cost of the same design scheme, the same structure type (wall load-bearing), and different types of walls (section of wall, beam, floor) for analysis and research:

Table 7: Comparison of three type of walls

Wall type	Hollow brick wall 200mm	Red brick wall 240mm	Rammed earth wall 350mm
Cost $ (Material:Labor)	11994 (1:1.69)	13525 (1:1.14)	11131 (1:2.68)
Material (natural:processed)	91.75 t (1:0.3)	197.39t (1:2.1)	345.63t (1:0.18)
Labor people (Skilled:Unskilled)	220 (1:1.8)	235 (1:1.9)	254 (1:4.5)
Seismic safety	Poor	Medium	Good
Thermal resistance	0.25 K/W	0.3 K/W	0.5 K/W

(If exterior wall spraying is considered, the cost of brick houses will be increased by 5000 $)

From the above table7, it can be get：

1/ This new paradigm obtains a safer and more comfortable living building at a lower cost than conventional ones.

2/ larger percentage of money is being paid to people rather than being used to purchase foreign materials, which enhances the economic vitality of the region.

3/ The use of a larger proportion of native natural materials, which saves costs and reduces the energy consumption of the construction process.

4/ A larger proportion of labor wages are paid to non-technical employees, allowing more local ordinary people to participate.

5. CONCLUSION

The five indicators of resilience are used to analyze the construction mode:

- **Robustness:** Scientific structure improves the structural strength of buildings and pre reduces the damage to people's lives and property caused by natural disasters.
- **Rapidity:** Local personnel and materials can respond quickly by themselves after trauma.
- **Redundancy:** Low technical requirements and easy operation reduce the threshold of construction, so that many idle manpower and material resources can be converted into buildings.
- **Resourcefulness:** The local materials, technologies and labor are abundant and replaceable resources in abnormal times.
- **Adaptability:** The relatively abundant labor, materials and technologies make the construction highly adaptable and flexible, and reduce the opportunity cost.

The Guangming Village project demonstrates the advantages of return rate after major trauma; the Malong Village project demonstrates the advantages of elasticity and stability in the abnormal period of society. The two paradigms under the background of different social conditions are concrete examples of construction that meet the requirements of the Endogenous development model (Figure 7). Both projects address and respond to the characteristics and difficulties caused by the special period of rural areas in southwest China, and improve the resilience of the area in terms of construction.

Indeed, the slight participation of research institution played an indispensable and important role in the early stage of these projects, but after a short period of learning and adaptation, the village can operate this model independently.

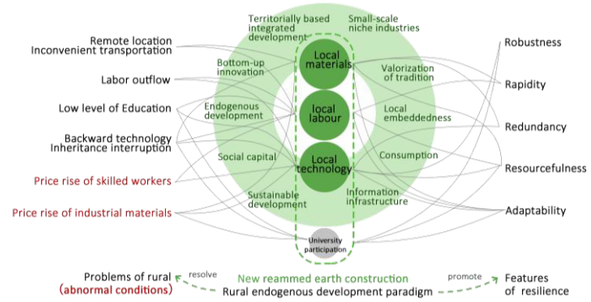


Figure 7: Action mechanism between endogenous development & resilience & rural problems

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