DEVELOPMENT OF HIGH PERFORMANCE SEMI-TEMPORARY DISASTER RELIEF SHELTERS IN CHINA

by

Boyang Shi

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STATEMENT BY AUTHOR

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And Environmental Science

Date
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Abstract

This research is about disaster relief semi-temporary housing in China which based on disasters database, area selection and climate data in Yunnan Province, attempting to develop an effective and comfortable earthquake relief temporary shelter which can be processing both physical relief and psychological relief. The major components of this research are post-disaster analysis, project design, and computer simulation. By designing a new shelter model, we will try to identify different functions and reorganize them for the shelter in order to satisfy all special requests after disasters. After computer simulation, it will allow more energy efficient considerations and taking social responsibility to both the designing part and disaster relief process.
1. **Introduction**

Natural disasters are becoming one of the most intractable problem that tormenting people every day. When people don’t have the power to against natural disasters, taking a series of measures to alleviate the suffering is critical. Housing recovery as one of the most important process of disaster relief provides basic living condition for people, meanwhile, affords the opportunity of re-development for the community and society. Thrive, not just survive.

2. **Disaster Assessment**

Loss estimation and prevention measure are the basis of development, disaster relief and reconstruction programs. Assessment before disasters is used to dispatch rescue capability, post disasters assessment is used to measure the disaster loss and arrange reconstruction. With a detailed and accurate disaster assessment, the process of disaster relief and reconstruction will be more effective and timely.

2.1. **Disaster Impacts**

The physical impacts are casualties and property damage which is always the most measurable, obvious and always reported by the media. Social impacts include psychosocial, physical, economic and political impacts. Long-term social impacts tend to be maximal in China because most hazard agents have a relatively small scope of impact and tend to work on intensely urban area more frequently than rural area. Thus, local resources are not sufficient to prevent long-term effects from occurring.

Disaster impacts vary among households and business because of preexisting variation in the vulnerability of social units within social vulnerability which is people’s “capacity to anticipate, cope with, resist and recover from the impacts of a natural hazard”.

2.1.1. **Disaster Database**

These worldwide collection of disaster database from 1975-2011 including 4 items: disaster reported, people affected, people killed, estimate damage.
The highest point is in 2002, 530 Disasters Are Reported.

The highest point is in 2002, 680,000,000 People Are Affected
The highest point is in 1983, 470,000 People Are Killed.

The highest point is in 2003, more than 350 Billion US dollars are lost.
From these data we can see how serious the results are caused by disasters. It's not only leading to economic losses but also killing people.

### 2.1.2. Disasters in China

Average damage: 15.4 billion US dollars/year  
Average farming area affected: 40 million hectare/year  
Average people killed: 9369/year  
Average people affected: 352 million/year

**Earthquake**

An earthquake (also known as a quake, tremor or temblor) is the result of a sudden release of energy in the Earth's crust that creates seismic waves. Since 1949, more than 100 times of devastating earthquakes struck 22 provinces, caused 350,000 deaths, which is 75% of the number of deaths of all kinds of disasters. Earthquake disaster area more than 30 million square kilometers, up to 7 million houses collapsed.

![Figure 2-5: Distribution of Earthquake Area in China](image-url)
The first main earthquake hazard is the effect of ground shaking. The second main earthquake hazard is ground displacement (ground movement) along a fault. The third main hazard is flooding or Tsunamis. An earthquake can break dams or levees along a river. And the fourth main earthquake hazard is fire. It’s impossible to issue an advanced warning for a specific time at a specific location that would allow for an orderly evacuation, therefore, from 2003-2013: 25 disasters happened in China (higher than 5.0), 89700 people killed.

**Yunnan Province**

Region: Southwest China  
Capital: Kunming  
Area: 390,000 square kilometers  
Population: 45,966,239  
Climatic condition: plateau monsoon climate, rainforest
Yunnan Province is a part of the circum-pacific seismic belt and the Eurasian seismic zone. On the eastern side of Indian plate and Eurasian plate collision zone. The average elevation is 1,980 meters (6,500 ft.). The mountains are highest in the north where they reach more than 5,000 m (16,000 ft.); in the south they rise no higher than 3,000 m (9,800 ft.). The highest point in the north is 6,740 m. If you had to pick a single province in all China that would expose you to the greatest variations in topography and climate, it would have to be Yunnan Province. Yunnan has a generally mild climate with pleasant and fair weather because of the province's location on south-facing mountain slopes, receiving the influence of both the Pacific and Indian oceans, and although the growing period is long, the rugged terrain provides little arable land.

There are three lateral-spatial climatic zones in Yunnan Province: a temperate zone, a subtropical zone and a tropical zone.

The temperature and rainfall levels increase the farther south one proceeds in the province. The Jinsha River Basin, the world's deepest gorge (in the northwestern part of the province), exhibits a mostly dry, hot, subtropical climate at its base. The Yuan River Basin, located in the southern part of the province near the Laotian and Myanmar borders, is of the more humid subtropical climate type.
Distributed under tropical and subtropical conditions, bamboo species diversity is rich in Yunnan Province. It has the most bamboo species and abundant bamboo resources in Southwest China. Natural bamboo forests are extensively distributed and many types are very well-developed.

<table>
<thead>
<tr>
<th>Types of bamboo forests</th>
<th>Area (hectares)</th>
<th>Resources (tons)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural forests and plantations of large and medium-sized bamboo (diameter (&gt;2cm))</td>
<td>189 000</td>
<td>19 000 000</td>
<td>57.10</td>
</tr>
<tr>
<td>Natural forests of small-sized bamboo (diameter (&lt;2cm))</td>
<td>110 000</td>
<td>4 800 000</td>
<td>33.23</td>
</tr>
<tr>
<td>Total area with bamboo forests</td>
<td>299 000</td>
<td>23 800 000</td>
<td>90.30</td>
</tr>
<tr>
<td>Bamboo plantations</td>
<td>32 000</td>
<td>3 860 000</td>
<td>9.70</td>
</tr>
<tr>
<td>Total</td>
<td>330 000</td>
<td>51 250 000</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table 2-1: Forest Area and Bamboo Resources**

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution areas</th>
<th>Types of Culms</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dendrocalamus hamiltonii</td>
<td>Dehong, Baoshan, Lincang, Simao, Yuxiangbanna</td>
<td>Large-sized, &amp; sympodial-clusters</td>
<td>Including D. brandlei, D. asper, D. pachycaulhus, etc</td>
</tr>
<tr>
<td>Guanzhuinae fumilis</td>
<td>Zhongdian, Kunming (introduced)</td>
<td>Small-sized &amp; multiaxially-scattered</td>
<td></td>
</tr>
<tr>
<td>Pseudosasa yunnanensis</td>
<td>Kunming, Dali, Baoshan</td>
<td>Medium-sized, small-sized &amp; sympodially-scattered</td>
<td>Shooting in fall</td>
</tr>
<tr>
<td>Chimonocalamus fimbriatus</td>
<td>Dehong, Baoshan, Lincang, Honghe, Kunming (introduced)</td>
<td>Medium-sized, small-sized &amp; sympodially-clustered</td>
<td></td>
</tr>
<tr>
<td>Dendrocalamus semiarundineus</td>
<td>Dehong, Baoshan, Nuijiang, Lincang, Simao, Honghe, Yuxiangbanna</td>
<td>Large-sized, medium sized &amp; sympodially clustered (natural)</td>
<td>Including 8 species of this genus, shooting from spring to fall</td>
</tr>
<tr>
<td>D. fastuosus</td>
<td>Kunming, Honghe, Wenshan</td>
<td>Large-sized &amp; sympodially clustered</td>
<td>Shooting in summer</td>
</tr>
<tr>
<td>D. giganteus</td>
<td>Vastly cultivated from Western Yunnan to Southern Yunnan</td>
<td>Large-sized &amp; sympodially-clustered</td>
<td>Suitable for dried bamboo sheets, shoot slices and four shoot slices</td>
</tr>
<tr>
<td>Schizostachyum fungii</td>
<td>Honghe</td>
<td>Large-sized, medium sized &amp; naturally-clustered</td>
<td>Shooting from summer to fall</td>
</tr>
<tr>
<td>S. pingenense</td>
<td>Honghe</td>
<td>Small-sized &amp; naturally-clustered</td>
<td>Shooting in spring, summer and fall</td>
</tr>
<tr>
<td>Chimonocalamus yunnanensis</td>
<td>Zhongdian, Wenshan, Honghe, Dehong, Baoshan</td>
<td>Small-sized &amp; multiaxial type (natural)</td>
<td>Including 8 species of this genus, shooting in fall</td>
</tr>
</tbody>
</table>

**Table 2-2: Ten Elites Bamboo Species**

There are many advantages of bamboo as a building materials:
1. Easy to cut, handle, repair, reposition and maintain.
2. Suitable for all types of structures and constructions.
3. Non-polluting and does not have crusts or parts that can be considered waste.
4. Light building material.
5. Can be utilized for permanent and for temporary constructions.
6. Does not require painting.
7. Bamboo can also serve other functions, such as: flooring, wall paneling, water pipes, drainage, and furniture.
8. It can be used in combination with other types of construction materials.

2.2. Disaster Recovery

2.2.1. Government Organization

In order to have a better participation, a cooperation with government is necessary. We can always find an appropriate position to get into and working on it.

Figure 2-10: Disaster Recovery
Federal Emergency Management Agency (FEMA) is an agency of the United States Department of Homeland Security. The agency’s primary purpose is to coordinate the response to disasters that have occurred in the United States and that overwhelms the resources of local and state authorities. The governor of the state in which the disaster occurs must declare a state of emergency and formally request from the president that FEMA and the federal government respond to the disaster.
2.2.2. Housing Recovery

**Figure 2-14: Disaster Housing Recovery**

**Emergency Shelters**

The basic characteristics of emergency shelters are light weight, transportable, can be assembled anywhere, easy installation, diverse usage. In other words, it is a temporary shed can block wind, rain and sunshine.

Figure -15 shows that simple partition shelters are a way to provide a sense of privacy to the families using a low cost, flexible and quick modular solution.

With cardboard tubing functioning as strut-beams, and plywood joints braced with ropes, each module measures 180cm square, and different sized rooms are established based on where the fabric walls are hung. [8]
The Water Shelter is primarily designed to cater to regions prone to flooding. The uniqueness of this structure centers is the way it assists the victims, during every phase of disaster relief. Not only does it provide housing, it also can be a temporary shelter even as it is being transported. Talking of which, it can be dropped to safer ground from aircraft. The structure also has a roof harvesting system which takes care of the drinking as well as sanitary needs. This makes the Water Shelter a very versatile design that manages to be practical enough for real time usage. [9]

**Semi-temporary Shelters**

Emergency Dialogues for Architecture to acknowledge the anniversary of the Sichuan earthquake, exhibition held at the National Art Museum of China.

Red+ Housing proposes an approach that tries to incorporate both the advantages of fast-response solutions, such as the deployment of military tents, with those of slower and more
considered responses such as neighborhood reconstruction efforts involving local traditions and user construction. \[10\]

The house is designed with the intent of creating a small self-sustained community. Our proposal seeks to minimize the area for a single house. The plan is divided into four 8’ x 8’ modules; each serving as a room. A bathroom/kitchen core divides the enclosed area into a sleeping quarter and a living/dining area. The structure of the house consists of 4”x 4” steel ‘H’ beams and columns; the skin is composed of Magnum Board panels. The structure is designed to withstand lateral forces both for wind and earthquake loads.

The house’s electrical needs are serviced by a 1 KW Solar Panel system. A cistern is provided to capture rain water which will be used for basic needs. The toilet is a self-composting unit. All Utilities are located in the central core in order to minimize plumbing and electrical conduit distances. \[11\]
3. Semi-Temporary Shelters/Housing

From emergency shelter to semi-temporary shelters, developments are more than creating bigger space, short term structure or even living environment. It includes environmental viable and operable operation, economical efficient expenditure and social unitive and nurturing community. Aim to provide a better quality of life.

Figure 3-1: From Emergency Shelters to Semi-Temporary Shelters

Figure 3-2: Semi-Temporary Shelters Developments
3.1. Criterion

In order to achieve the goal of quality life, performance criterions of semi-temporary disaster relief shelters can guide and optimize the design which includes critiques of existing semi-temporary shelters and optimizations.

3.1.1. Transportation

In most cases, main ways of transportation for goods and materials supply after earthquake are railway transportation and highway transportation in China. But the disadvantages of them are obvious:

Railway net cannot be spread all over the country, in this case, some small towns or villages cannot be well equipped in time. A county like Ludian, where located in a valley with complex topography, the closest railway station is 35kms away.

Highway transportation is always limited by road condition especially after disaster. Once it’s destroyed, transportation will be paralytic. For instance, in Ludian County, the main traffic transportation is highway transportation, mainly are mountain area highways. After earthquake, a large area of highway facilities were destroyed including bridges, tunnels and retaining wall which marked by dehiscence, subgrade settlement and slope collapse.

There is time limit for both Highway and railway transportation that goods and materials cannot always delivered on time especially things need to be managed and expressed from other cities.

![Figure 3-3: Traditional Transportation](image)

Military helicopters can be deployed to transfer and deliver disaster relief supplies. Air delivery is expected to avoid ground barriers after the quake and offer higher rescue efficiency.
Meanwhile, in a certain weight, parachute transport can be considered once the surface state is not suitable for aircraft landing or need to invest large amounts of goods to designated locations.

![Figure 3-4: Proposed Transportation](image)

3.1.2. Assembly

Mobile dwellings as existing disaster relief semi-temporary shelters use light steel as skeleton and sandwich board as building material, which spatial organized by standard module series and using bolts to connect different components.

The construction method is similar as normal buildings. First, leveling around and partition with concrete, then set up pillars, connect the skeleton with transverse beams. Installing clapboards, cladding panels and door/window frames. Next, fitting purlins, floor slabs and flooring, meanwhile, stair need to be set up in order to add another floor. Finally, installing windows and doors, pulling the vertical support.

The all process of the construction required professions who have been trained and experienced as well as specialized equipment. So in the process of reconstruction, first of all, a lot of workers need to be transferred from other cities to the disaster area which cost a large amount of money and manpower, moreover, local idle labor has been wasted. Second, mobile dwelling is limited by topography and the surrounding environment. For a valley town like Ludian County, High
attitude on both east and west side, flat in the middle, temporary shelters need to be more flexible and adaptable in order to work in different geological conditions.

As semi-temporary shelters, there should be a simple construction method, thereby local idle labors can undertake the task which is not only saving money and manpower but also bringing local people back to their home and participate the reconstruction.

For example in Ludian County, a shelter with flexible and adaptable structure is necessary. After earthquake, the county town, in the middle of the county, was seriously destroyed where wreckage throughout everywhere. Thus, temporary shelters need to build in the east and west sides around the mountain ridge. The shelter need to adapt to the undulating terrain and maintain steady, moreover, each one should be a slight difference according to the topography.

- Local idle labors
- A simple construction method
- Flexible and adaptable structure
Basically it needs 5 days to erect a set of mobile dwelling by a professional team of 5 people. First 2 days for leveling around and partition with concrete, then another 2 days to assemble it, by the end, there is one more day to reinforce it. 5-day is an average number, it changes by different team and different geological conditions. For instance, a team of 15 people can finish all these works in 2 days including installation of windows and doors in a normal city but they will spend one week in a hillside town. Apparently, 5 days for a quality temporary dwelling is acceptable but as noted above, half of the time is leveling around and partition which means a steady foundation is extremely important for this light structure building. In Ludian County, with different geological conditions, the foundation of this mobile dwelling will use at least double time to equalize.

The construction time of a set of modern disaster relief semi-temporary shelter should be controlled around 1-2 days. The longer the time consumption, the more money and manpower will be wasted. Since the purpose of these shelters is disaster relief, saving time and money becomes particularly important.
3.1.3. Power

Power supply facilities for mobile dwellings must be additional configurations which normally are small diesel generators. But diesel generators have poor stability. First, Diesel generator produces a lot of high temperature exhaust and smoke while it’s working. Second, it makes a lot of noises and heavy vibration while it’s working which needs to be placed in a special room. Third, diesel evaporates easily, so it’s difficult to start it especially in winter.

Some new-type power supply facilities need to be used in semi-temporary shelters like solar panels which can generate power sustainably and also can cover shortages of traditional power generators.
3.1.4. Material

The main material of mobile dwelling is color steel sandwich panel: the outer layer is a color steel plate with high strength and the inner layer is a lightweight heat insulating material of polystyrene foam. Pressing color steel forming through the automated continuous molding machine then bonding with high strength adhesive. Corrugated sheet is used for roof.

First, Mobile dwelling is design by using steel, sheet metal and other raw materials as units for on-site installation which has poor sealing, noise, fire, moisture, heat and other insulations. It can be only known how effective after installation, it’s not conducive for people to compare options. Second mobile dwelling is mosaic structure, poor resistance, when the foundation is not solid or encounter typhoons, earthquakes, etc., it’s easy to collapse, fall apart, not safe enough. Third, mobile dwelling need to be broken up and then install again, goods had to be cleaned up properly, and material loss, high cost, also time-consuming and labor-intensive. After four or five times after it basically will be scrapped.

As a disaster relief shelter, in addition to be as comfortable as ordinary residential, recyclable, safe, light weight, easy to disassemble are also very important.
Regarding insulation board, need to have the following characteristics:

1. Fireproof. Non-combustible fireproof material, no fire, no melting drop objects, no gas no smoke appears.
2. Light weight, non-absorbent.
3. Safety and environmental protection. Does not irritate the skin, and cause no harm to humans.
4. Better thermal insulation properties.
5. Good dimensional stability. It won’t appear any shrinkage or deformation no matter what the environment is.
6. Repeatedly recycled.
7. Long life.

After comparing of different polymer materials, as table 3 shows, polypropylene is one of the best material as wall panels with high performance and relatively low price.

<table>
<thead>
<tr>
<th>TENSILE STRENGTH (psi)</th>
<th>STIFFNESS (psi)</th>
<th>TOUGHNESS (ft-lbs/in)</th>
<th>DENSITY (g/cm³)</th>
<th>THERMAL CONDUCTIVITY (W. m⁻¹ K⁻¹)</th>
<th>RECYCLABILITY</th>
<th>MATERIAL AS WALL PANEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid PVC</td>
<td>7,500</td>
<td>481,000</td>
<td>1.0</td>
<td>1.3–1.45</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>Acrylic</td>
<td>10,000</td>
<td>480,000</td>
<td>0.4</td>
<td>1.18</td>
<td>POOR</td>
<td>POOR</td>
</tr>
<tr>
<td>PETG</td>
<td>7,700</td>
<td>310,000</td>
<td>1.7</td>
<td>1.38</td>
<td>GOOD</td>
<td>POOR</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>9,500</td>
<td>345,000</td>
<td>12.0–16.0</td>
<td>1.20–1.22</td>
<td>POOR</td>
<td>GOOD</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>3,500</td>
<td>310,000</td>
<td>2.0</td>
<td>1.05</td>
<td>POOR</td>
<td>BETTER</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>5,400</td>
<td>225,000</td>
<td>12.5</td>
<td>0.905</td>
<td>BETTER</td>
<td>BETTER</td>
</tr>
<tr>
<td>PTFE</td>
<td>1,500–3,000</td>
<td>72,000</td>
<td>3.5</td>
<td>2.20</td>
<td>BETTER</td>
<td>GOOD</td>
</tr>
<tr>
<td>UHMWPE</td>
<td>3,100</td>
<td>110,000</td>
<td>18.0</td>
<td>0.945</td>
<td>GOOD</td>
<td>POOR</td>
</tr>
</tbody>
</table>

Table 3.1: Properties of Polymer Materials

3.1.5. Building Performance

Mobile dwellings as temporary buildings use the color coated steel sheet for surface material and polystyrene, glass wool as core material. As thermal insulation material they have serious flaws. The average annual temperature of Ludian County is around fourteen degrees Celsius, the minimum temperature in winter can reach zero degree Celsius. Instead of heat preservation,
these materials are more for insulation. Also, after a period of use of polystyrene, especially foam boards with low density, there would be a serious contraction which degrades the insulation performance.

Even in the southern region, high temperature in summer, the Insulation effect of color coated steel sheet with polystyrene and glass wool is still unsatisfactory. After a period of exposure to the sun, surface of mobile dwelling becomes boiling hot as well as interior.

Environmental monitoring and control (automated or user-controlled systems, active systems such as heating and cooling and passive systems such as shading).

Providing or allowing personal equipment such as desk fans can improve the thermal comfort. Meanwhile, using passive system, natural ventilation, heat insulation and indoors moisture solutions as design methods can dramatically increase the living quality of indoor spaces.

The current mobile dwellings in China are using diesel generators as power supply facilities which is designed to run on fuel oil. A 5kw diesel generator need to consume 1.61L diesel per hour which is about 12.2 Yuan (2 US dollar) when it’s working.
A 5kw diesel generator can serve only one family since its maximum power output is 5.5kw, therefore a mobile dwelling community needs either a large generating unit or several small generators which will consume a large amount of diesel.

New energy includes biofuel energy, wind power, distributed energy, solar energy can be used in new type of semi-temporary shelters. With proper heat insulation, using of natural light and storm water management, it can achieve the goal of efficient energy use.

3.1.6. Master Planning

According to Chinese earthquake transitional resettlement housing construction technology guide, based on the construction site conditions, set safe evacuation routes for at least two directions, width of fire exits is wider than four meters. Ordinary road setting by two levels:

1. Width of main road cannot be less than 4 meters, provides lighting facilities and connecting with the external road network.

2. Width of passageway cannot be less than 2.5 meters.

However, in reality, passageway is often used to dry clothes and debris piled which is difficult to ensure unimpeded.

The basic requirements of pedestrian are safe, functional and interesting.
According to Chinese earthquake transitional resettlement housing construction technology guide, resettlement housing should be constructed in a sunny open area, with determinant layout. Splice length should be four to ten sets with varied sites, the distance between each line should be four to five meters and natural lighting area should be greater than or equal three square meters.

In the existing master plan, most shelters do use a determinant layout, however, due to site limitation, the distance between each line cannot be fully controlled within four to five meters, not to mention the natural light area. A case study of Wenchuan Earthquake, in the construction process of temporary housing, the splice length is much greater than four to ten sets and the distance between each line is less than 4 meters even with two stories buildings. Solar access cannot be guaranteed.

A proper design by using winter sunlight to warm up the space and using shading system to block summer sunlight can improve the quality of solar access and thermal comfort.
3.1.7. Social/Culture

By developing disaster relief semi-temporary shelters, social and cultural issues are being ignored in most countries. For example, there are 56 nations in China with different culture and living styles, but wherever disasters occurred, with one design of transitional housing, which are being settled everywhere without any changes.

In order to satisfy different needs by different culture and living styles, a concept of community becomes a really important element and the basic unit of a community is neighborhood. By
adjusting the connection between private living space and public space depends on different sites, a new type of neighborhood can be created. The process of combining these neighbors is actually the way of creating a new local community which can satisfy varied habit by different nations or culture.

3.1.8. Conclusion
3.2. Proposed Design

3.2.1. Background

At 16:30:10 on the 3rd August, Ludian County, Zhaotong City, Yunnan Province 6.5 earthquake occurred, focal depth of 12 kilometers from the epicenter leading Ludian County, southwest town 23 kilometers. Leading town in Ludian epicenter earthquake zone, average population density of 265 persons per km. This was the highest magnitude earthquake occurred in Yunnan. As of 7 Aug, 615 people had been killed, 3,143 had been injured and 114 people were still missing. 230,000 had been relocated. Rescue teams were still combing the rubble in search of survivors. 80,900 houses were destroyed, 120,100 were seriously and 466,100 slightly damaged.
In Yengan village, 90 per cent of houses have been reported damaged. Concerns of continuing landslides and risk of flooding in certain areas due to wet season are mounting. Fears over mass disease outbreaks are high due to lack of access to safe water and proper sanitation methods. The number of fatalities and injuries are expected to rise as remote villages become accessible.

The Chinese government sent a 30-man team to the epicenter region immediately after the earthquake struck, as well as 2,000 tents, 3,000 folding beds, 3,000 quilts, and 3,000 coats to provide shelter for the displaced and homeless. The majority of the injured have been transported to safe areas.

3.2.2. Site
There are 12 towns in Ludian County, a total area of 1487km².
Dry season is from November to April; low temperature, scarce rainfall, plenty of sunshine. Wet season is from May to October.
Ludian County is a small narrow valley town with 26 nations of 41800 people.

Figure 3-24: Ludian County

As figure 42 shows, 50.4% of local economical incomes are form secondary industry, but more than 90% of the local community are agriculture population which leads to the third pie chart that more than 70% are poor population.

Figure 3-25: Economical Income of Ludian County
After research of the consisting of local families, there are only 5% of families have one child, 51% of families have two children and 44% of families have more than 2 children. Apparently, “one child policy” is not working for this society.

Bamboo as one of the best construction materials are being used widely by local architectures and shelters which is stable, cheap and easy customization. “The process of construction can include training, skill sharing and creating economic benefits for local suppliers and markets. Relief and reconstruction offer an opportunity to stimulate and support local businesses.”[17] By using local materials like bamboo as a part of shelters during construction can be an investment for local community and serving for other disaster relief efforts.
The design process of this project can be three steps.
First, design a specific housing unit.
Second, having different housing combinations with different functions depends on varied needs of users.
Third, applied these combinations to the site, Ludian County.

3.2.3. Dimension

Each unit of the existing shelter is 10 feet by 13 feet which provides for a family of three. With a combination of three units, floor area of each member is 44 square feet.
In the proposed design, the basic unit of each shelter is 10 feet by 20 feet which provides for a family of four. With a fore and after combination, every three units are 900 square feet, then floor area of each member is 75 square feet including outdoor spaces which can be used as courtyard. Thus, the efficiency of usable area is higher than the existing shelter.
3.2.4. Plan

Since this is a disaster relief project, simply applying shelters on the site as long straight rows cannot meet the requirements of functional and safe pedestrian as well as appropriate solar access. Using a flexible method that combine modules differently in order to have different sizes of units can satisfy the purpose of a better master plan. For example, a combination of 3 modules can be used as a community center, or a combination of 2 can provide for a family of 8, meanwhile, with different directions of combination can create a different size of outdoor gathering space.
3.2.5. Structure

The basic structure of the proposing design is connecting pipes with joints which can be PVC, bamboo, carbon fiber or steel. This ordinary method is familiar by almost everyone, which is also being wide used of simple structures such as bridge and interior shelter.

According to the feature of pipe joints, modules can be easily connected in different angles and directions which flexible and economical.

3.2.6. Module

As figure 52 shows, floor area of each module is 10 feet by 20 feet with a 4 feet by 4 feet window and a 5 feet by 4 feet window on two sides. Also, a 3 feet long overhang on the front side and 4 feet tall lift on the back side of roof.
With 5 different types of joints, a structure of bamboo pipes can be connected. As a popular local material, bamboo is stable, though and with low stiffness. According to these characteristics, there are 3 advantages:

First, it’s easy to train local labors that how to assemble the structure since they are familiar with it.

Second, when shelters meet different geological conditions, it’s easy to customize them.

Third, by investing local materials, it can actually benefit the community and support local business.

After assembling structure, attaching polypropylene wall panels on it including 28 pieces of 5 feet by 10 feet panels, and simply installing windows and doors, a module can be finished.
3.2.7. Combinations

With the basic fore and back combination of 4 modules, a 10 feet by 10 feet courtyard can be created for each unit which can be a family gathering space, a simple homework space or a social space.
3.2.8. Layout

Since the shape of each module is rectangle, the circulation of each unit is simply go through the door to the other side of the unit. But because of the feature of structure especially pipe joints that every two modules can be simply connected with a shared wall, and an opening in the middle can interconnect two modules as one unit provide for a bigger family. Therefore, users can go into the unit from the door on one side then go through the door in the middle to reach the other side of the unit. With this circulation, it guarantees private space for users but also hold two spaces together tightly.

In order to keep the neighbors safe, keeping their eyes on the street and courtyard is crucial. With two windows on two sides of the unit, users can watch the street and the courtyard easily so that they can know what’s happening around them for the sake of security.
In the interior layout, there are multi-groups of storage units against walls. By covering the all wall, these units are not just functioning as storages but also an improvement of building performance.
3.2.9. Environmental Performance

Figure 3-42: Exploded View
With a development of environmental performance, it can greatly improve the thermal comfort, efficient energy use and social environment.

In the proposing design, it includes 7 issues of development of environmental performance:

First, a semi-open courtyard. A courtyard can absorb air and have its own circulation, meanwhile, air moves from the courtyard all the way through the unit, providing a proper natural ventilation.

Second, Air movement/ ventilation for multi units. With an opening in the middle of every 2 modules, air can move across one unit and pass through the opening to the other unit. This ventilation can reduce the indoors temperature and create a comfortable natural ventilation in order to improve the quality of thermal comfort.

Third, roof ventilation. In the raining season, indoors air is hot and humid which discomforts residents. But with a venti-roof, when this poor air goes up to the ceiling and roof, with two openings on two sides of the roof, air movement can bring the hot and humid air out and keep the indoors space cool and dry.

Fourth, Overhang. Every module has a 3 feet long overhang as a simple shading system which can block sunlight in summer and doesn’t affect the winter sunlight for heating the space.

Fifth, Shared wall. With the combination of modules, every unit is actually sharing a part of their walls with other units which reduce the exposure areas and keep the high performance of heat insulation.

Sixth, Storm water management. This design uses a part of the structure as water pipes. Bamboo pipes provide superior water, dirt and ultra violet resistance. When it’s raining, water follows the slope roof coming down to the gutter which connects to one bamboo pipe using as a part of the structure, pipes are connected to the underground leading to a water tank.

Seventh, solar panels. With a south facing 15 degrees included angle roof, solar panels can be functioning efficiently when it’s generating solar power.
Figure 3-43: Environmental Performance

Figure 3-44: Roof Ventilation
3.2.10. Computer Simulation

In term of wind tunnel simulation in Vasari, figure 63 proves that proposing nature ventilation and air movement are working well includes interior air movement and roof ventilation.

![Figure 3-45: Wind Tunnel Simulation in Vasari](image)

3.2.11. Social/Culture

In the process of disaster relief, people’s psychological conditions varied. After initial fright and alarm, people start to calm down and enter a period of loss. In this case social activities become an important part of psychological relief which can bring people together comfort and take care of each other as well as mutual supervision.

After research on social habit of this specific site, mail activities of each family including playing chess, housework, family dinner and simply chatting. With the basic combination of modules, all these activities can be taken place in the yard by every family.
In addition, when some community activities occur, such as community dinner, farm works or material distributing, wider spaces can be created by multiple module combinations as figure 65 shows.

Here are 2 examples of master plan which varied by different sizes and geological condition. First one is in Longshan Town, within this small town, there is an open area in the southwest corner which can satisfy all of the shelter needs. With simply arrangement, people can move in and live close to their original residence in order to reconstruct their homes.
Cuiping Village, it’s a really small village surrounded by mountains, it’s difficult to find an open area inside and arrange shelters. Therefore, an open area nearby can be the best choice, as figure 67 shows, a round shape area near the village is big enough to set up a temporary community of semi-temporary shelters. People live away from their home with a walking distance so that some infrastructures also need to be built in the new community.
Figure 3-50: Rendering of Community

Figure 3-51: Rendering of Neighbors
4. Livable Urban/Rural Community

From a short-term standpoint, both “physical relief” and “psychological relief” should be doing at the same time in the process of disaster relief. After Japanese earthquake in 2011, within 1 month, there were more than 3000 people suicide. According to the analysis of post disaster psychological rehabilitation, the most dangerous period is from 2 weeks to 1 month after disaster occur when people enter the lost and hopeless period. “As one of the most productive ways to temper psychological trauma is to engage people in positive collective activities.” [19]

The best way to resolve this crux is bring people back to community and creating a new community by themselves which is not just government’s responsibility but also every participant’s obligation. “Good community consultation and planning can be a powerful engine for change”. [20] With an easy construction method and a great potential of flexible customization, people can literally create and built their own homes and community which is not just saving time, money and manpower but also engage people in positive activities.

From a long-term standpoint, since semi-temporary shelters can last up to 18 months, “the process of construction can include training, skill sharing and creating economic benefits for local suppliers and markets. Not just results from design and quality construction, but also relies heavily on maintenance will be managed by local community.” [21] We’ve heard a lot stories that people abandoned their houses because it’s too expensive and complicated to maintain them. Using local materials and maintenance method with strong operability, habitants can easily fix or replace parts of their shelters in the period of residence. In principle, sustainable reconstruction requires that each stage of development-technical, social, financial and institutional privilege sound ecological practices.

Design of disaster relief semi-temporary shelters is not only “architectural design”, moreover, it’s using the wisdom of designer to guide and help victims building their own livable community. The design process should focus on user’s physical and psychological feeling and using responsibility to shape the design.
5. Conclusion/ Future works

After proposed design of disaster relief semi-temporary shelters, the process was not just creating spaces and buildings, but trying to build better relationships, and this project is not just a system which can provide a better living condition, but also a network for living together.

As a designer, except using inspiration to have design concept, using software to generate drawings, using technology to improve building performance, responsibility, which also need to become a kind of ability throughout the all design process.

This thesis is just a starting point for becoming a responsible designer.
6. References