**The Transitional Shelter:
A New Typology for Disaster Relief**

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ABSTRACT

This thesis investigates the architecture of transitional housing in regions recovering from natural disasters as a 'hybrid' architecture; a type of architecture that is neither permanent nor temporary; rather, it is permanent and temporary.

Using the 'Great Sichuan Earthquake' which took place on May 12, 2008 in the Sichuan Province as a study model, the construction of the proposed transitional homes will address the concept of 'hybridity' by working with both traditional methods and ideologies, as well as implementing new disaster relief strategies.

The economic and cultural characteristics of the Sichuan province and areas affected by the earthquake bring a unique complexity to the project. This complexity also embodies a wide range of traditional building expertise and knowledge of methods such as adobe, rammed earth and timber construction. The hybrid dwelling will examine the possibilities opened up by the confluence of these specific yet divergent building techniques and materials to provide a well-balanced and intimate transitional space for the family, or in other words a space for healing in the aftermath of the devastating earthquake.

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INTRODUCTION

*"Everybody wants the same thing, rich or poor...not
only a warm, dry room, but a shelter for the soul"¹*

Disaster relief shelters provided for the victims of the May 12, 2008 Sichuan Earthquake, were constructed nearly 3 months after the unprecedented earthquake left over 5,000,000 people across China without shelter. As a humanitarian response, the government of China with the assistance of both internal and international organizations initiated the construction of several transitional communities in the southwestern province of Sichuan. Though this was effort initially met with great public appreciation, it soon proved to be an action that not only did not help the physical and psychological recovery of the victims, it also created devastating short and long term damages to the victims as well as the community as a whole.

In order to further understand the complexity of this issue, field research was undertaken approximately 7 months after the disaster in the town of Dujiangyan, 50 km from the epicentre of the earthquake. Prior to this trip, I could only find a limited number of broadcasting sources that provided what seemed to be accurate coverage on the health and living conditions in the temporary communities. During my research trip, I visited one of these transitional communities in Dujiangyan where I acquired first-hand knowledge concerning the quality of life imposed by the transitional shelters. The

¹ Samuel Mockbee. Design Like You Give a Damn: Architectural Responses to Humanitarian Crisis. (New York: Metropolis Books, 2006) 50.

research revealed the many difficulties that these shelters introduced to the lives of the victims, and initiated a fundamental concern in my design process for an alternative solution to enhance the quality of life, health, healing and growth of the individuals and families living in transitional shelters.

The over-congested planning of the community, the lack of open communal spaces as well as over-crowded private spaces, posed negative psychological, safety and health related concerns. Similarly, the materials used in the construction of the shelters were in many cases inappropriate and unsafe. For instance, a large percentage of the dwellings employed wall panels that were made up of exposed asbestos-cement materials. Statistics show that today China is one of the leading consumers of asbestos based materials in the world with its highest use in the construction industry.² Shortage of clean drinking water, lack of washing facilities, insufficient natural light, poorly insulated walls and roofs which resulted in extremely hot and cold interior temperatures were some of the issues that ultimately resulted in an undesirable and unhealthy living experience for the victims of the disaster. These and many other underlying issues are evidence of the immediate need for a more humane proposal or in other words, a call for action.

This thesis investigates the architecture of the transitional housing through a methodology that is rooted in traditional Chinese ideologies and methods of construction and the utilization of available natural materials. This methodology is

² World Asbestos Report: Asbestos Experiences of Asian Countries: China, 2007. 15 04 2009
<http://www.worldasbestosreport.org/asbestosasia/China_experience.html>.

proposed in order to create an evolving shelter that can ultimately become a “home” for the victims. Since this evolution starts from a temporary shelter that is constantly subject to the act of making in order to move towards permanence, this proposed typology becomes a hybrid that is both permanent and temporary.

Similarly, in the Chinese traditional philosophy of the natural processes, the five fundamental elements of nature constantly evolve in a progressive manner to create and be created. This thesis will attempt to interpret and adapt the natural materials that exist within the cycle of Chinese Five Phases to a contemporary construction project in order to create a healthy, self sustained and adaptive environment for its inhabitants.

CHAPTER ONE: CASE STUDY

This chapter investigates various types of transitional shelters proposed for the victims of natural disasters in different regions across the world. The first three examples are variations of the model that was first developed by Shigeru Ban as a response to the 1994 earthquake in Japan. Section 1.4 identifies a different typology that was implemented in Peru in 2007. In the following chapters, the existing transitional shelters for the victims of the 2008 Sichuan Earthquake will be examined thoroughly as an investigation to underline the negative effects of this type of planning strategy.

1.1 Earthquake in Kobe, Japan 1994

These 4-square meter units employed a new type of assembly that relied heavily on the use of paper tubes to create the walls and the ridge beams of the roof. The walls were made out of tubes that were 108 mm in diameter and 4 mm thick. Self adhering waterproof sponge tape between the paper tubes insured a watertight fit. The temporary foundations of these units were constructed with donated beer crates filled with sandbags. The roof and the ceiling were made using PVC membranes with a gap in between the two layers to allow for air circulation in order to cool the interiors in the summer. In the winter, the gable ends could be closed to keep in the accumulated hot air and to work as an insulator in the roof. Each unit cost approximately ¥250,000 (\$2,500) and could be assembled in less than a day.³ These units could be easily assembled and dismantled, and most of the materials could be recycled after use.

³ Matilda McQuaid. Shigeru Ban. (New York: Phaidon Press Limited, 2003) 36.

However the nature of the material (paper) limited the life span of the units and more importantly limited the reusability of the materials for future constructions.

Figure 1. Left: Transitional community in Nagata, Kobe. Right: Worker constructing the roof by connecting the pre-dimensioned paper tube members to the main pre-fabricated connection hub (*McQuaid, 36-37*)

Figure 2. Left: Floor Plan. Right: Exploded axonometric view showing various layers and construction details (*McQuaid, 37*)

1.2 Earthquake in Kaynasli, Turkey 2000

Based on the shelter in Kobe, Japan, some improvements and adjustments were made to fit the lifestyle and climatic conditions in the north-western part of Turkey. For instance, one unit was 3 m by 6m, a different and slightly larger configuration, which was due to the standard size of plywood in Turkey and also to the country's larger average family size. Secondly, more insulation was added to the walls in order to resist the cold in the winter. Shredded wastepaper was inserted inside the tubes along the walls, and fibreglass in the ceiling. Cardboard and plastic sheets were also used for more insulation, depending on the resident's needs.

Figure 3. Left: Roof plan and Elevation. Right: Final assembly of the units in Turkey (*McQuaid, 39*)

1.3 Earthquake in Bhuj, India 2001

Unlike the units used in Japan and Turkey, rubble from destroyed buildings was used for the foundation of this model (rather than beer crates, which could not be found in this area). The compacted earth floors were coated with a traditional mud mixture. For the roof, split bamboo was applied to the rib vaults and whole bamboo to the ridge beams. A locally woven cane mat was placed over the bamboo ribs, followed by a clear plastic tarpaulin to protect against rain, and another cane mat on top. Ventilation was provided through the gables, where small holes in the mats allowed air to circulate. This ventilation also allowed cooking to be done inside, with the added benefit of repelling mosquitoes.

Figure 4. Left: Axonometric view. Right: Paper log houses adapted to traditional Indian customs (*McQuaid, 40-41*)

1.4 Earthquake in Pisco, Peru 2007

The transitional shelters that were proposed as a response to the 2007 earthquake in the coastal town of Pisco, Peru, relied on local materials and especially on the knowledge of the local work-force. The units were made up of wooden structural frames that sit directly on compacted earth. The posts were held in tension by using cross-bracing tensile members. The frame was then covered with a layer of plastic sheeting and woven bamboo for added waterproofing. The roof also incorporated a layer of waterproofing membrane in order to resist heavy rains. The following images show the process of construction which was lead by a group of trained builders and a large number of local volunteers.

Figure 5. A typical transitional unit assembled using local materials in Peru
(<http://www.chfinternational.org/node/21490>)

Figure 6. Above images show the construction process that starts by flattening and compacting the earth in order to create a firm base for the structure. Wooden frames are then assembled and covered by a layer of cane net and plastic tarp to waterproof the shelters (<http://www.chfinternational.org/node/21490>)

Each unit was 18 square meters in area. Each trained builder could install one unit in approximately 8 hours, and the life expectancy of this type of shelter was one year, with the total cost of \$200 USD per unit.

CHAPTER TWO: THE CHINESE HOUSE AND TRADITIONAL CONSTRUCTION METHODS

The traditional Chinese house that exists today is the result of a long evolution that took place over millennia, but today very few buildings of this great antiquity stand in China. This may be explained by examining Chinese ideology which was never based on permanence, meaning most buildings were built using impermanent materials such as wood and earth. Going back to the formation of early settlements in China, most historians and archaeologists present two fairly simple origins for the later developments of the Chinese dwelling, these being the cave and the nest.⁴ Figure 7 shows the hypothetical transition of the Chinese cave (*xue*) from a horizontal niche in the earth to a single room above ground. The post-and-beam construction, illustrated in the final part of Figure 7, is a preliminary foundation for the later development of the Chinese wood and timber framing.

Figure 7. Gradual development of Chinese dwelling from a horizontal den to post-and-beam wooden structure
(Knapp, *China's Traditional Rural Architecture*, 6)

2.1 The Chinese House

Chinese traditional dwellings, especially those in the rural areas, are more than mere structures to create protection for the household. They are places for the dynamic activities of the family in practical, ritual and psychological terms. In northern climates where buildings are exposed to severe weather, layering and assemblage of the layers

⁴ Ronald G. Knapp, *China's Traditional Rural Architecture*. (Honolulu: University of Hawaii Press, 1986) 6.

insure protection while dictating certain lifestyle differences due to form and layout of the living spaces. For instance *kangs* (brick beds) are located next to the kitchen with a shared brick wall separating the stove and the bed in the adjacent bedrooms to provide a heated sleeping surface. Most dwellings built in the southern part of China generally follow a deeper floor plan sometimes exceeding 5 meters in order to block the direct sun from reaching deep into the space during the hot summer days. This often results in a linear organization of the spaces with the central space dedicated to the main gathering space and the concentration of bedrooms towards the far end of the house for more privacy. South facing openings are often limited and walls are generally thicker to provide greater insulation against the summer heat. To enhance this effort, thick walls of pounded earth or composite materials are used to further insulate the walls of the common dwellings. Compact designs also reduce the exposed surface area of the dwelling which helps the building absorb less heat in the summer and keep most of the generated heat inside the house during the winter season.⁵ Based on observation, in the south-western province of Sichuan, exterior walls of many dwellings are often covered in a layer of white lime plaster or paint to prevent heat absorption. In more moderate climates, since most of the heat is generated by cooking, most kitchens are either placed outside or away from the core of the dwelling.

Chinese traditional dwellings are characterized by simplicity and symmetry with spaces designed to accommodate future expansions. Most of these houses share a similar pattern that governs the layout and provides privacy for the inhabitants. Axiality

⁵ Ronald G. Knapp, China's Vernacular Architecture. (Honolulu: University of Hawaii Press, 1986) 29.

and symmetry can be seen in most of the courtyard houses specially those constructed based on traditional layouts. Courtyards (*tingyuan*) are common elements of the Chinese dwelling. Central open spaces often vary in size according to function and climatic conditions. As shown in Figure 8 courtyard houses found in Beijing have a symmetrical layout of trees, walkways and gateways to complement its balanced proportions.⁶ Symmetry also resembles power and is a sign of good luck.⁷

Figure 8. Courtyards are axiomatic components in Chinese palaces, temples and houses. In most siheyuan-style houses courtyards are usually larger than any of surrounding structures. (Knapp, *China's Vernacular Architecture*, 38)

In a traditional Chinese dwelling the arrangement of the rooms and spaces often guides the interaction of the residents with those who do not reside in the house, thus creating a gradual privacy. Most spaces are undifferentiated in terms of function and occupancy as a response to the dynamic living style and activities of everyday life. The construction and the form of a Chinese house is a product of an ongoing additive process, which relies upon tradition and experience. The use of building modules and simple floor plans facilitate future expansions around the main core which in most cases is the gathering space. Adding new rooms as the family's size increases is a common

⁶ Ronald G. Knapp, *China's Vernacular Architecture*. (Honolulu: University of Hawaii Press, 1986) 38.

⁷ Ibid, 34.

characteristic of the Chinese life style and a sign which shows the family's ambition for growth in size and wealth.⁸ Traditionally, Chinese dwellings have been built by the owner with the help of relatives and neighbours. The completion of most of these dwellings happened over several stages sometimes taking decades due to limited financial resources. In addition, since land ownership is mainly controlled by the government, buildings and materials became the focus for the Chinese family as a source of investment, therefore adding to the monetary value of the construction materials used in the buildings.

2.2 Methods of Construction

Even though most Chinese dwellings started as subterranean structures, today, they are mostly built as above-ground units with no accessible basements, and foundations are often not incorporated into the design. These dwellings normally sit on compacted earth that is either flat or slightly elevated. Tamped podiums (*jichu*) were first utilized during the Shang dynasty (roughly 1600-1100 B.C.) in order to reduce moisture penetration and also to provide a firm base for the structure.⁹

⁸ Ronald G. Knapp, China's Vernacular Architecture. (Honolulu: University of Hawaii Press, 1986) 3.

⁹ Ronald G. Knapp, China's Traditional Rural Architecture. (Honolulu: University of Hawaii Press, 1986) 52.

Figure 9 . Illustration showing various construction and planning techniques used in traditional Chinese construction (Drawing by Author. Adapted from images by Ronald G. Knapp)

2.2.1 Rammed Earth Construction

Traditional Chinese builders had to confront additional challenges that were not limited to climatic and geographical issues. By relying on local materials, builders utilized methods to construct bearing and non-bearing walls using earth and wood to solve structural issues dealing with gravity and other forces such as wind, rain and snow.

Traditionally, load bearing walls are found in buildings made of tamped earth, adobe or kiln brick. This tradition was based on scarcity of other building materials and the availability and economical feasibility of suitable local soil. Even today tamped earth construction is widely used in the people's republic of China, especially in the rural settings.¹⁰ The rammed earth method, in simple terms, is a method in which compacted earth is filled within a formwork structure which in most cases is made out of appropriate cut trees. In order to reduce moisture penetration from the ground, a low stone base is raised to create a solid base upon which the rammed earth wall will be constructed. Two inverted "V" shaped supports are constructed at either ends to provide a support for the side timber poles in order to create an enclosed formwork for the earth. Freshly dug earth is then piled into the formwork in stages and compacted by using hand-made rammers. Once an appropriate compaction level is achieved, side wooden poles are moved upward allowing for the next layer of earth to be piled and compacted. These steps are followed repeatedly until the wall reaches the desired height (Figure 10).

¹⁰ Ronald G. Knapp, China's Traditional Rural Architecture. (Honolulu: University of Hawaii Press, 1986) 54.

Figure 10. Rammed earth construction using temporary timber framing and handheld stone rammers (Left: Drawing by author. Right: Knapp, *China's Traditional Rural Architecture*, 54)

Many compacted walls rise as high as 4 meters. The soil is often mixed with a small amount of broken grain stalks, paper and lime. If the soil does not bind naturally, based on tradition, a mixture of oil and straw is mixed with the soil to provide sufficient bonding and structural strength.¹¹ At the top, where the roof is to be attached to the wall, a row of tiles is put in place to minimize the rotting of the roof timbers. When the ramming of the wall is complete, the side frames are detached and used to construct formworks for other walls.

Oracle bone inscriptions, dating back to the Shang Dynasty (1600–1046 BC), offer indications of different architectural forms that were used in China. Figure 11 illustrates variations of pitched gabled roofs without overhangs in addition to ridgepoles and raised platforms and overhanging eaves symbolizing houses in china. “The use of rammed earth foundations and walls as well as wood framing stand out to the degree

¹¹ Ronald G. Knapp, *Chinese Houses: The Architectural Heritage of a Nation*. (Tokyo: Tuttle Publishing, 2005) 38.

that the Chinese have come to use the joined characters *tumu* (earth and wood) to signify Architecture itself.”¹²

Figure 11. The top row indicates characters referring to dwellings. Note the lack of overhangs and podiums compared to characters associated with more prominent building, such as palaces, in the second row. (Knapp, *China's Traditional Rural Architecture*, 10)

2.2.2 Brick Construction

Adobe brick construction, also referred to as sun-dried brick construction, shares many similarities with rammed earth except it allows for greater flexibility. Adobe brick construction is practiced widely in the rural areas where most households cannot afford to buy fired bricks or provide the fuel necessary to bake the bricks. “The earliest use of adobe brick in China appears to have simply supplemented *hangtu* (tamped earth) construction in that bricks were used to build stairs, frame gateways, form interior partition walls and make heatable beds, known as *kang*, found throughout northern China.”¹³ While the procedure is simple, the size and the moisture content of the soil determines the quality and the curing time. Most bricks, whether sun or kiln dried, are made by digging fresh moistened clay soil from nearby sites and filling it into wooden moulds. They are generally compacted by hand and shaved using a bow-shaped wire cutter and then released from the mould and left to cure (Figure 12). For centuries, the

¹² Ronald G. Knapp, *China's Traditional Rural Architecture*. (Honolulu: University of Hawaii Press, 1986) 10.

¹³ Ibid, 40.

majority of dwellings in China were built using adobe brick for its inexpensive and flexible qualities and “only about 20 percent of all rural dwellings surveyed in China in early 1930s had kiln-dried brick walls.”¹⁴

Figure 12. Traditional sun-dried adobe brick production (left and centre). Image shows a layer of lime plaster being applied to the brick wall construction (right). (Left: Knapp, *China's Traditional Rural Architecture*, 57. Centre: *Ibid*, 58. Right: Agarwal, 145)

Utilization of kiln-dried Bricks in house building did not become common until the Han dynasty in the third century BCE.¹⁵ Kiln dried bricks are more durable and resistant to water and fire but they have always been more costly due to the firing procedure and the high cost of fuel necessary to bake them. In addition, once the clay bricks are fired at temperatures that reach as high as 1150 degrees Celsius, unlike adobe and rammed earth, the chemical quality of the clay changes making it impossible to be pulverized and reused.

Constructing a house using adobe bricks or fired bricks is a choice made by the owner or the builder based on the household's general wealth which is often accumulated over a long period of time. Gradual modification of the Chinese dwelling

¹⁴ Ronald G. Knapp, *Chinese Houses: The Architectural Heritage of a Nation*. (Tokyo: Tuttle Publishing, 2005) 41.

¹⁵ *Ibid*, 40.

resembles the evolution that is mainly tied to the family economics. Chinese peasants in the past were known to replace portions of the tamped earth wall with adobe bricks and later gradually replace the adobe bricks with fired brick to add strength and resistance to water.¹⁶ This method will be further examined as a design methodology in order to adapt and modify the temporary units based on the family's needs to create a permanent home.

2.2.3 Bamboo Construction:

Bamboo is a multi purpose grass that grows rapidly in most regions and is used as a versatile construction material in building Chinese houses. Bamboo is widely available and its structural qualities allow for diversity when used as a building material. It is light, extremely rigid, cheap and easy to cut. It can also be bent and woven to create structural platforms, vertical surfaces and partitions. Bamboo is also an excellent material when used as framing members, floor joists and roof components such as ridgepoles, rafters and purlins.

Based on gathered surveys, in the 1930's, nearly two-third of houses utilized walls made of woven bamboo and plant materials in south-western China.¹⁷ The condition in which bamboo is used is mainly determined by its shortcomings when compared with timber. Bamboo rots easily if it is placed in contact with damp soil. It is also more vulnerable to termites and is highly flammable. As a result, bamboo walls are often used in higher locations and not close to the ground. Chinese builders have developed various

¹⁶ Ibid, 41.

¹⁷ Ronald G. Knapp, Chinese Houses: The Architectural Heritage of a Nation. (Tokyo: Tuttle Publishing, 2005) 43.

techniques over centuries by relying on tradition and experience. Some of these techniques are illustrated in Figure 13 and Figure 14 showing how bamboo sticks are sliced and tied together to achieve a higher structural strength.

Figure 13. Bamboo is used to construct temporary scaffolding structures. Image on the right shows a structural platform made out of sliced woven bamboo strands.

Figure 14. Bamboo sticks are sliced and vertically clustered and tied together to achieve a higher structural strength

CHAPTER THREE: THE TRADITIONAL CHINESE SYSTEMS OF ORDER

3.1 The Cyclical Nature of Making and Remaking: Temporality and Permanence

In China, the earliest and most influential systems of order involved fitting a momentary event into the cyclical rhythms of natural processes. "The life cycle of every individual organism-its birth, growth, maturity, decay, and death- followed essentially the same progression as those more general cycles which went on eternally and in regular order: the cycle of day and night, which regulated the changes of light and darkness, and the cycle of the year, which regulated heat and cold."¹⁸ This system of order presents a permanence/temporality simultaneity that this thesis seeks to further define through the concept of hybridity. This process provides a seemingly permanent product which is subject to constant evolution. This theory corresponds to the traditional Chinese theory of the Five Natural Phases (Elements) and their continuous cycles of creation and destruction.

The theory of the Five Natural Elements dates back to the Zhou Dynasty (1122-256 B.C.E).¹⁹ In order to create a well balanced living environment, it was necessary to understand the relationship between the basic elements that surround us. In Chinese traditional philosophy, this explanation has been justified in terms of two opposing, yet complimentary, forces known as yin and yang. Yin and yang are two primordial forces that govern the universe and symbolize harmony. They are opposites. Yin is dark, yang is light, yin is passive, yang is active, yin is female and yang is male. However, unlike

¹⁸ N. Sivin. "Chinese Alchemy and the Manipulation of Time." Chicago Journals: The History of Science Society (1976): 513-526. 514

¹⁹ Dominique Hoizey. A History of Chinese Medicine. (Vancouver: UBC Press, 1993) 24.

Western ideas of conflicting extremes, yin and yang are complimentary while they depend on each other.²⁰ Yin-yang is one of the dominant concepts throughout the history of Chinese philosophy.

The Chinese yin-yang theory of balance and equilibrium also relates to the traditional understanding of the creation of natural elements. When Ch'i (the non-tangible energy that originates and exists within every material) moved, the clear and light rose to be heaven and the muddy and heavy fell and formed the earth.²¹ The cyclical nature of yin and yang and the opposing nature of changes in the universe can be interpreted in many ways. All phenomena can change into their opposites. Since one principle produces the other, we can therefore argue that all phenomena have seeds of their opposites within them.²²

This thesis refers to the theory of the Chinese five phases of order to demonstrate the cyclical evolution that exists within the traditional understanding of order and materials. Further, it proposes that this order be embedded and adapted in the architecture and conceptual strategy of the new transitional shelter in order to further strengthen the concept of hybridity in this proposed typology. In other words, the proposed transitional shelters will be subject to a continuous process of making and remaking. Similarly in the Chinese traditional philosophy, Fire, Earth, Metal, Water and Wood are known as the Five Elements or more correctly the five "stages of change" or

²⁰ Sarah Rossbach. FengShui: The Chinese Art of Placement. (New York: Penguin Group, 1983) 20.

²¹ Robin R Wang. The Internet Encyclopedia of Philosophy. 2006. 16 2 2009
<<http://www.iep.utm.edu/y/yinyang.htm>>.

²² Richard Hooker. Chinese Philosophy. 1996. 24 01 2009
<<http://www.wsu.edu/~dee/CHPHIL/YINYANG.HTM>>.

“Hsing”. The Hsing can flow in two different directions to create the generating and the destructive cycles. The creation or generating cycle flows from Wood to Fire. The Wood nourishes or gives life to the Fire. Once this action is completed, the Fire creates Earth or ash. In the Earth grows Metal. Metal carries Water and Water nourishes Wood²³. The other cycle of balance is known as the “mutual conquest order” or “overcoming” cycle in which the elements destroy each other in which Wood parts Earth, Earth absorbs Water, Water quenches Fire, Fire melts Metal and Metal splits Wood.

Figure 15. Generation and destruction cycles of the Five Elements.

(Image by Don Reynolds, Wikimedia Public Domain, March 2007)

Creation (Becoming) Cycle	Destruction Cycle
Wood nourishes Fire	Wood parts Earth
Fire creates Earth	Earth absorbs Water
Earth grow Metal	Water quenches Fire
Metals carries Water	Fire melts Metal
Water nourishes Wood	Metal splits Wood

Table 1. Creation and Destruction evolutions of the Five Elements

²³ Keyserling, Arnold. The Five Agents of Change in Chinese Philosophy. 1999. 05 11 2008
<<http://www.ichingwisdom.com/IChingWisdom/hsing.html>>.

Wood is the most “human” of the elements. It symbolizes Spring and the capacity to look forward, plan and make decisions, hence growth and expansion. Since it resembles growth and flexibility, the colour associated with Wood is green.²⁴

Fire is the element of heat, summer and enthusiasm. It represents the peak of growth and warmth in human relationship. It is associated with the colour red to represent dynamic, energetic and passionate energies.²⁵

Earth is the element of harvest, abundance, nourishment, fertility and the mother to child relationship. It is also associated with balance, change of seasons and it is represented with the colour yellow. It is regarded as reliable and stable. Earth’s motion is patient and reliable.²⁶

Metal is the force of gravity, the minerals within the earth, the patterns of heavenly bodies and powers of conductivity. Metal’s motion is determined, forceful, strong and self reliant. More importantly Metal has structure, but it can be turned into different forms when molten, which relates to the destructive force of Fire on Metal and once molten it becomes Water.²⁷

Water has the capacity to flow infinitely, silent and still, flexible, ever changing, with the capacity to nourish and cleanse. It is the fluid, the main component of the body, which nourishes and maintains the health of every cell. It is represented with the colour black/blue. Water is the ultimate yin; quiet, cold and represents the resting time

²⁴ Nations Online: Countries of the World. 13 01 2009. 14 02 2009
<http://www.nationsonline.org/oneworld/Chinese_Customs/five_elements.htm>.

²⁵ Ibid, Fire.

²⁶ Nations Online: Countries of the World. 13 01 2009. 14 02 2009
<http://www.nationsonline.org/oneworld/Chinese_Customs/five_elements.htm>.

²⁷ Ibid, Metal.

of winter. Water can create and destroy. It nourishes Wood (trees and plants) and has the power to destroy fire.²⁸

Water, being the most essential source of life, is the element that originated the formation and growth of many human settlements, towns and cities. Ancient tribes traveled among streams and bodies of water, listened to the sound of water for relaxation and used it in their surroundings for its symbolic gestures. People always associated water with life and prosperity. Many still believe that ponds, lakes, or rivers in front of a house bestow ch'i on residents. Lin Yun, a grand master in Feng Shui philosophy cautions that one must see if the waters are "alive"- clean and moving, activating pure and good ch'i or "dead"-dirty and stagnant, damaging health and diminishing ch'i. Size is also important, and if the pond is larger than the house, its ch'i may overwhelm the residents. Lin Yun explains, "The most important aspect of the land should be the house where the people live, not the water. They are the hosts and the pond should be the guest. The guest shouldn't be larger than the host."²⁹

The new transitional shelter proposes a re-imagination of materials and cycles that conform to this tradition and yet bridges tradition and contemporary sustainable ideas.

3.2 The Senses, Materials and Spaces

The definition of senses often goes beyond the simple boundaries within which we experience our physical surrounding by touching, smelling, seeing, hearing and tasting. We pick up feelings from people, places, dreams and atmospheric energies. Some people give us a sense of foreboding. Some places make us feel happy and comfortable.

²⁸ Ibid, Water.

²⁹ Sarah Rossbach. FengShui: The Chinese Art of Placement. (New York: Penguin Group, 1983) 64.

Qualities of space, matter and scale are measured equally and harmoniously by the eye, ear, nose, skin, tongue, skeleton and muscles.³⁰ The theory of senses has been reiterated frequently through various perspectives. Although some may focus on phenomena as a source of interaction with our surroundings, it is ultimately our senses that make the connection with the material and the spatial realm. By examining the traditional ideologies of senses and materials as well as recent developments in phenomenological theories, this thesis intends to converge the two distinct, yet complementary ideas into an architecture that is hybrid, whereby the 'reading' of balance will not require ancient knowledge of the Five Elements, but that balance, comfort and a healthy environment can be perceived through the senses.

Multi-sensory experience of space is essentially how human beings interact and learn from their surroundings. "A walk through a forest is invigorating and healing due to the constant interaction of all sense modalities. Architecture is essentially an extension of nature into the man-made realm, providing the ground for perception and the horizon of experiencing and understanding the world."³¹

As Juhani Pallasmaa argues, the most persistent memory of any space is often its smell. Every dwelling has its individual smell of home. A particular smell makes us re-enter a space completely forgotten by the retinal memory; the nostrils awaken a forgotten image and persuades us to enter a vivid daydream. The nose makes the eyes

³⁰ Ibid, 12.

³¹ Juhani Pallasmaa. The Eye of the Skin: Architecture and the Senses. (West Sussex: John Wiley & Sons Ltd., 2005) 41.

remember.³² “The retinal images of contemporary architecture certainly appear sterile and lifeless when compared with the emotional and associative power of the poet’s olfactory imagery”³³.

The sense of touch connects us with time and tradition. Through impressions of touch “we shake the hands of countless generations”.³⁴ The same way that touching a pebble polished by waves speaks of the slow process of its formation, as Pallasmaa describes it, one can feel the texture of each brick moulded, fired and laid to make walls to protect oneself, and ultimately take part in the process of creating one’s own home gradually and thoughtfully. This progressive approach makes us aware of the evolution of creation and generates a more thoughtful, natural and adaptive process. There is a strong identity between naked skin and the sensation of home. The experience of home is an experience of warmth. “The space of warmth around a fireplace is the space of ultimate intimacy and comfort.”³⁵ Fire with its power of creation fires the earth and creates bricks that are laid by the naked hand to create a space called home. In conclusion, “Architecture is the art of reconciliation between ourselves and the world, and this mediation takes place through the senses.”³⁶

3.3 The Phenomenology of Healing and Materials

The qualitative aspects of any space are directly affected by its materials, which in turn affect the mood and well-being of the inhabitants within that space. Some

³² Juhani Pallasmaa. The Eye of the Skin: Architecture and the Senses. (West Sussex: John Wiley & Sons Ltd., 2005) 54.

³³ Ibid, 55.

³⁴ Ibid, 54-56.

³⁵ Ibid, 58.

³⁶ Ibid, 72.

spaces are products of materials that defy aging whereas some are made to follow a natural life cycle and decay to become one with nature. "Like people, the harder [the materials] try, the more lifeless they look."³⁷ New manufactured materials such as glass and plastic tend to defy maturing and aging therefore they often feel "lifeless, boring and temporally disconnected" as Christopher Day describes them. On the other hand, masonry buildings suggest a past-to-present time continuum; stone, brick and earth have "old" associations. Timber is in-between. It is lighter, newer but rooted in nature.³⁸ Juhani Pallasmaa, in his essay "The Mind of the Environment" refers to Aalto who realized how important carefully designed details and elements with meaning and familiarity were for the well-being of patients, or for *man at his weakest*, after a stay at a hospital.³⁹ "Natural materials such as stone, brick and wood allow our vision to penetrate their surfaces and enable us to become convinced of the veracity of matter. Natural materials express their age and history, as well as the story of their origins and history of human use."⁴⁰

3.3.1 Natural Light

Based on observation, poor natural lighting inside the existing transitional units in Dujiangyan made the rooms feel rather dark and unfriendly. The North facing units,

³⁷ Christopher Day. Environment and Children: Passive Lessons from the Everyday Environment. (Oxford: Elsevier Ltd, 2007) 138.

³⁸ This categorization by Christopher Day should not be taken in a direct and literal sense as he notes: "There are, of course 100-year-old glass buildings, and ultra-modern clay ones". This material characterization relates back to the trend of the material use in construction based on socio-economical and cultural standards in different time periods.

³⁹ Birgit Cold. "Aesthetics, Well-being and Health." Cold, Birgit. Aesthetics, Well-being and Health. (Burlington: Ashgate Publishing Company, 2001. 11-23) 20.

⁴⁰ Juhani Pallasmaa. The Eye of the Skin: Architecture and the Senses. (West Sussex: John Wiley & Sons Ltd., 2005) 31.

especially, lacked sufficient natural light which is needed not only to illuminate the physical environment but also for its health and psychological benefits. “Recently Biologists have discovered new information concerning immunological effects of visible and UV radiation on the human immune system.”⁴¹ In architecture the importance of lighting has been repeatedly emphasized. The early examples of studies on the topic of natural sunlight in architecture can be found in Vitruvius’ Ten Books on Architecture from the first century BC where he underlines the importance of picking a healthy site-one which is oriented to permit natural light. Vitruvius was the first Western architect to write about the qualitative and quantitative aspects of daylight, proposing explicit rules to assess whether an interior space is well lit. Today, poor day lighting is known to be the cause for a common disease known as Seasonal Affective Disorder (SAD) which includes depression and mood disorder which is simply caused by the lack of sunlight.⁴² In addition to issues concerning human health, psychological studies have shown the increase in productivity related to the existence of adequate daylight in the work environment,⁴³ which is a concerning factor for children and students occupying the transitional shelters over numerous years.

3.3.2 Air Quality

Air quality as well as poor heating and cooling in the existing transitional units were some of the other issues that caused dissatisfaction among the members of the community. Lack of natural ventilation especially in the summer due to the heat island

⁴¹ Gregg D. Ander. Daylighting: Performance and Design. (New Jersey: John Wiley and Sons, 2003) 26.

⁴² Derek Phillips. Daylighting: Natural Light in Architecture. (Oxford: Architectural Press, 2004) 18.

⁴³ Ibid, 20.

effect created by the vast absorptive paved surfaces and un-insulated metal roofs, made the interior temperature rise unbearably. The quality of air, when dealing with small spaces, can be easily enhanced by employing simple and effective methods that rely more on traditional, inexpensive and natural methods than on industrial machineries. Natural ventilation is inexpensive, locally responsive and easily adjustable. Using a breathable wall construction will also allow the fresh outdoor air to replace stale indoor air even when windows are closed therefore improving the indoor air quality. Clean outdoor air is negative-ion rich. These air molecules, being an electron short, fasten onto small particles such as bacteria. Now heavy, they sink to the earth where the soil bacteria digest them, explaining why 'fresh air', although healthy, feels cold. Different heating and cooling methods affect air quality differently. Each method has mood, health and energy implications.⁴⁴ Re-circulated air recycles the existing bacteria making it an unsafe method to use in situations like disaster relief housing. Based on personal observation, illnesses such as the Flu were common amongst victims living in the transitional homes. Even the healthy, were often prescribed medications for mental healing therapies that eventually weakened their immune system, making them more vulnerable to catching contagious diseases. "In most mechanically ventilated buildings, bio-pathogens account for half of all building-related sicknesses. Forcing air through ducts also destroys bug-removing negative-ions and increases airborne particulates which make the indoor air unsafe for the inhabitants."⁴⁵ These and similar construction

⁴⁴ Christopher Day. Environment and Children: Passive Lessons from the Everyday Environment. (Oxford: Elsevier Ltd, 2007) 69.

⁴⁵ Ibid, 68.

methods will be exploited as part of the design strategy that this thesis seeks to investigate in order to create a 'healthier' environment for the inhabitants.

3.3.3 The Healthy Habitat

How we feel often has to do with how we interact with what surrounds us and this interaction happens through our senses. "Humans have the capacity to see, smell, touch, hear and taste specific constituents of their habitat. How people use their sensory capacities is not just determined biologically but also culturally. The built environment is an integral part of our livelihood and it can have multiple implications on human health and well-being."⁴⁶ The term *health* can relate to physiological, psychological and social conditions of human individuals, groups and communities. According to the World Health Organization "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."⁴⁷ A healing environment often offers rich stimuli and considers man at his weakest. It helps in orientation, movement and use of space, as well as creating a feeling of security, comfort, meaning and familiarity. Therefore, knowledge of people's preferences and needs are the basis for creating and designing healthy environments.⁴⁸

The World Health Organization has developed guidelines regarding Sick Building Syndrome (SBS) that differentiates buildings based on the health level of their inhabitants. Although these guidelines are primarily used as an assessment tool for

⁴⁶ Roderick Lawrence. "Housing, Health and Aesthetics: Reconnecting the senses." Cold, Birgit. Aesthetics, Well-being and Health. (Burlington: Ashgate Publishing Limited, 2001. 143-156) 148.

⁴⁷ Ibid, 146.

⁴⁸ Birgit Cold. "Aesthetics, Well-being and Health." Cold, Birgit. Aesthetics, Well-being and Health. (Burlington: Ashgate Publishing Company, 2001. 11-23) 26.

more complex environments, they were developed to address the very basic needs of building inhabitants and to acknowledge how our senses and health respond to our living environment. Therefore, the SBS guidelines can be used as a tool to help improve the health standards in both transitional shelters as well as the community as a whole. Based on the World Health Organization's report, common symptoms such as headaches, cough, dizziness, nausea, eye, nose, throat and skin irritations are signs of SBS.⁴⁹ There are many interrelated strategies that can be employed to achieve a healthy habitat, such as maximizing daylight penetration while controlling solar heat gain, providing operable windows and configuring the building to allow for natural ventilation and using the thermal mass of the structure to absorb and re-radiate heat as required.⁵⁰ The concept of creating a transitional space that is well balanced and harmonious based on both traditional systems of order and perceptual elements is the foundation for the design of a healthy transitional community.

The existing transitional shelters in Dujiangyan not only fail to provide the very basic needs of the families such as heating, cooling and healthy spaces, they also disregard the importance of creating an environment for the families in order to create a sense of belonging which would ultimately play a part in improving their psychological well-being and health.

⁴⁹ Thad Godish. Sick Buildings: Definition, Diagnosis and Mitigation. (Boca raton: CRC Press, 1995) 2.

⁵⁰ Peter Busby. Busby: Learning Sustainable Design. (Quebec: Janam Publications Inc, 2007) 10.

CHAPTER FOUR: CHINA IN MIDWAY OF INDUSTRIALIZATION

4.1 Field Research: A Study of Manufactured and Natural Materials in China

Approaching and mastering a project that is deeply rooted in cultural and traditional grounds requires a certain critical observation that can only be achieved through direct engagement with the place and its potential end-users. Part of this thesis relies upon certain qualitative approaches that were undertaken to further understand and examine the context in which the design decisions will be implemented.

In November 2008, I traveled through various regions in China as an attempt to further understand the extent of the damage caused by the 2008 Sichuan Earthquake. This trip was also crucial in beginning to understand the cultural structure and the life-style of the people living in China, especially those living in the transitional shelters in Sichuan. As part of the investigation, I was involved in a series of informal consultations with both the providers (the city officials and municipal and emergency relief agencies) as well as the end-users (displaced families) of the existing transitional shelters. During my stay in Shanghai I focused my research on the availability of various construction materials that could be transported and utilized in the construction of transitional houses. Based on observation, and information provided by the locals and tradespersons, abundance of steel and alloy products in China, both for exports and internal use is considered an advantageous asset in the construction industry. As shown in Figure 16 various steel products such as pipes, rods, channels and standard sheet metals are all manufactured in China.

Figure 16. Steel market in Shanghai, China

Corrugated steel as a construction material has a long history in the architecture of many cultures. Corrugated metallic sheets were invented in 1829 by Henry Robinson Palmer in England. Structural integrity of this product allows for enormous flexibility and durability. Its versatility, light-weight, portability and non-flammable characteristics make it a highly practical building material in disaster relief reconstruction where speed of construction is one of the most crucial factors. One of the main advantages of corrugated steel, which this thesis underlines, is that it can be utilized by both skilled and unskilled users for various purposes. While an unskilled labourer can use recycled sheets to improvise a shed in an afternoon, the same material can also be used with higher precision in the design of highly engineered homes.⁵¹ As illustrated in Figure 17 (top left), corrugated sheets are stored in large volumes ready to be delivered to devastated regions for disaster relief purposes. In addition, from the environmental

⁵¹ Adam Mornement. Corrugated Iron. (London: W.W.Norton and Company Inc, 2007) 7.

point of view, steel is a bio-degradable⁵² and recyclable construction material with a reasonably long life span, and its lifecycle can be further extended by applying different treatments to its surface. It is however true that in some parts of the developing world the availability of sheet metal has contributed to the erosion of traditional building practices.⁵³

Figure 17. Top left: abundance of corrugated metal sheets in Dujiangyan. Top right: protective wall of corrugated steel surrounding the construction site. Bottom: combination of corrugated steel and woven bamboo sheeting to construct a temporary wall around the site.

My proposal utilizes this valuable and abundant resource in the initial construction of the transitional homes in order to initiate a quick and simple construction that could fulfill the basic needs of the victims at the first stage and

⁵² Bio-degradation is a process through which a material, when exposed to the natural elements, returns to its initial state. In this case, metals return to Earth through oxidization (corrosion).

⁵³ Ibid 138

function as a primary formwork to allow for implementation of traditional building methods in the later phases of development. As illustrated in Figure 17 (bottom), in many cases non-structural bamboo sheets are used to replace the corrugated steel or aluminium sheets where structural members are not needed.

Bamboo has a long history in the construction industry in China. In 268 BCE, the Dujiangyan Irrigation system was built using woven bamboo baskets filled with rocks to divert the Min River water.⁵⁴ As illustrated in Figure 17 (bottom), today woven bamboo is used extensively as a construction and furnishing material in China. As discussed in chapter 2.2.3, Bamboo is often used as a temporary building material, however by understanding its strengths and shortcomings we can incorporate this highly renewable material in many other building applications.

Other wood products such as laminated recycled wood (Figure 18, left), as well as prefabricated structural products have also retained popularity in the Chinese construction industry. Due to a high level of demand and limited resources, wood is slowly being replaced by other alternative materials, while recycled wood can be easily salvaged and used in the construction of the new details in the architecture of the transitional housing. Figure 19 is one of the many instances found in Dujiangyan which shows the abundance of salvageable wood products that have been discarded from the damaged buildings after the earthquake.

⁵⁴ Bruce G . Doar. China Heritage Newsletter: Taming the Floodwaters. march 2005. 17 12 2008
<http://www.chinaheritagenewsletter.org/features.php?searchterm=001_water.inc&issue=001>.

Figure 18. Left: Sheets of veneered wood planks used in construction. Right: A typical wood supplier shop in Chengdu.

Figure 19. Wooden doors and trimmings salvaged from buildings after the earthquake, Dujiangyan

Figure 20. Strands of bamboo to construct structural and non-structural wall and platforms

Similar to wood, brick is another material that can be salvaged and re-used in most post-disaster reconstructions. However the labour involved in extracting and

cleaning each individual block and the cost of transportation makes it a long and labour intensive process.

Figure 21. Salvaged kiln-dried bricks ready to be used in new construction, Dujiangyan

After spending 3 days in Shanghai, I moved to the city of Chengdu, situated in the south-western province of Sichuan where I spent the next 22 days conducting field research relating to this thesis. Chengdu, An urban city with a population of over 12 million citizens, is the closest major city to the epicentre of the Sichuan Earthquake (Wenchuan County). The undesirable air pollution, heavy traffic, enormously spread out urban and suburban fabric and the highly congested city core were the first alarming issues that caught my attention. Despite all the warnings from the locals concerning dangerous road conditions and the spread of disease in the region, I was still in search of

possible ways to visit the area. On November 27, two days after my arrival in Chengdu, while I was still in the midst of organizing a trip to Wenchuan, a severe aftershock with a magnitude of approximately 5 Richter shook the region and caused further damage to the connecting routes which made the trip to Wenchuan extremely unsafe due to consequent landslides and possible aftershocks. Therefore I extended my stay in Chengdu while trying to find an alternative solution and possibly a different research strategy. In Chengdu, I continued my material investigations as well as arranging meetings with various people who could contribute to the development of my research.

I visited the Sichuan Urban Planning Department in Chengdu where I talked to one of the officials responsible for the general post disaster reconstructions in Chengdu as well as the construction of the temporary disaster relief units. Even though language was a major communication barrier, with the help of a translator we managed to carry on a coherent and informative conversation. We discussed issues regarding the scope and phasing of the reconstruction and possibilities to enhance the project in similar future incidents. Prior to this meeting, I was informed about the availability of public transit service to the town of Dujiangyan and its similar post-disaster conditions in comparison with Wenchuan, therefore most of the discussions revolved around the reconstruction process in Dujiangyan. It was apparent that economic limitation was the main challenge in implementing and providing services and shelter for the displaced families. I raised a question in regards to using imported prefabricated units and as expected, it did not seem to be a feasible solution due to economic limitations. However, due to the large quantity of shelters needed for the displaced, the idea of

utilizing a modular design to increase efficiency in distribution and assembly seemed rather appropriate. Our discussion was mostly focused on two points; economic feasibility, and ease of assembly during the construction phase. Anytime the issue of human comfort and health was raised, it was entirely ignored. Finally, as he stated, the ultimate outcome from the design and implementation of such units is to build “cheaper and faster”. This thesis will attempt to address all three of these issues equally; feasibility, assembly and health.

Similar to most disaster relief efforts, utilization of local work force and materials was the most effective solution encouraged by the Chinese government and the officials. The import of workforce and building materials in disaster relief efforts is often unnecessary as there are usually a vast number of volunteers who are willing to participate in the reconstruction efforts. Based on the United Nation’s guideline, *Shelter after Disaster*, the factors limiting the participation of external assisting groups include time, scale of disaster and self reliance. People in developing countries are more self-reliant in the basic skills of shelter construction than those living in industrialized counties. This is particularly true in rural areas where people have always built their own homes, although they may need technical and material assistance.⁵⁵ China is a country that possesses a large local work-force, therefore in similar emergency cases the issue of construction time is not of great concern, given appropriate guidance, material and assembling techniques. The assembly of the transitional units are often delayed until

⁵⁵ Ludovic Van Essche. Shelter after Disaster: Guildlines for Assistance. (New York: United Nations Disaster Relief Co-ordinator, 1982) 5.

the preparatory steps have been taken during the emergency phase which often takes up to three months post-disaster. During the initial phase, efforts are mostly focused on the provision of emergency tents, preparation for reconstruction and assuring adequate health and safety measures in the region. The next phase, which is the transitional phase, can take from three to five years until the permanent reconstruction begins (Figure 22). Between the provision of transitional shelters and permanent reconstruction lies a range of intermediate options. Therefore the architecture of transitional shelter should be understood as a “process” rather than a “product”. It is the goal of this thesis to investigate ways through which the structure and materials used to construct the initial shelter can be transformed into a more permanent architecture. The envisioned life-span of the existing transitional shelters in Dujiangyan is approximately three years but the future use and possible adaptation of the shelters and materials remain unclear.

Figure 22 Diagram illustrating the common phases of disaster relief operations and the concept of hybridity

I also visited the Sichuan University where I discussed my thesis with Professor Li Bixiong, from the Department of Architecture who was investigating the Sichuan Earthquake from a more technical perspective. We discussed issues regarding structural

capabilities of the existing transitional units as well as the living conditions inside the temporary communities.

One day prior to my departure to Dujiangyan, I visited the Tianfu Expo Center in Chengdu where the focus of the exhibition was on post disaster reconstruction proposals in Sichuan, especially Dujiangyan and other surrounding areas that were heavily affected by the earthquake. At the centre of the main exhibition hall, a large size re-planning model of Dujiangyan displayed proposed infrastructure and future expansions. With numerous architectural and planning proposals on display, the exhibition was helpful in understanding the scale of the reconstruction efforts. In the same hall another captivating wooden model gave emphasis to the reconstruction of the old town of Dujiangyan (the current city centre) located on the northern edge of the city. As illustrated in Figure 23, courtyard houses define a predominant language for the reconstruction of the ancient town centre. As highlighted in Chapter Two, this thesis will further investigate the social and cultural aspects of this design approach that dates back to the Shang dynasty and utilize it in order to create a safe, healthy and social living environment.

Figure 23 Reconstruction model of Dujiangyan's city centre displayed at Tianfu Expo Centre, Chengdu

4.2 Dujiangyan and Transitional Communities

On December 1st, 2008, I visited the town of Dujiangyan, approximately 50 km from the epicentre of the 2008 Sichuan Earthquake in Sichuan province. During this trip I was accompanied by Jing Lin, a recent graduate from the Sichuan University, who assisted me in general translation and communication with the officials and the members of the transitional community. Once we arrived in Dujiangyan, we walked from the bus terminal towards the third ring road where clusters of transitional communities had been constructed. Walking through narrow streets, the city was characterized by juxtaposing qualities. On the one hand, the atmosphere seemed rather ordinary with people engaging in their everyday lives nearly 7 months after the incident, and on the other hand, the devastated streetscape with abandoned crumpling buildings and standing debris created an overwhelming degree of chaos. An abandoned 12 storey

police department with broken windows, temporary relief clinics and hospitals still in operation along the sidewalks and merchants squatting and forming new street markets, were some of the fascinating characteristics that initially caught my attention. We arrived at the site where approximately 7000 displaced people were sheltered. Enclosed within four concrete walls which separated the camp from the city, a highly secured gateway was the only passageway for those who resided in this community. At the main gate there were two armed police officers controlling the traffic. I had prepared some documents, notes and letters to explain the intent of my visit. Although the initial interaction was polite, they refused to allow us to enter the site. The officer at the security gate had to report the matter to a higher level official who then contacted the main office in Beijing to seek authorization. A seemingly complicated procedure that took nearly forty-five minutes was suddenly approved after they found out that I did not belong to any national broadcasting or news agencies. Finally we managed to enter the complex where the view was cluttered with blue and white prefabricated structures. Concrete-paved streets with gutters running along them were the predominant forms of landscaping. The grid-based planning of the community made it seem rather harsh and unnatural. Most occupants had already started to modify their units to adapt to their everyday activities. Different types of trees were planted in either self-built or manufactured plastic planters (Figure 24). They relied on the most basic found materials to create enclosures in order to provide space to grow plants and vegetables either for the family or in some cases to create an additional source of income by selling fruits, vegetables and other home made products to both the community and the outside

markets. As one of the homeowners explained, in many cases, families planted small trees and shrubs in front of their units in order to transform the community into a greener and livelier environment. (Figure 25, right)

Figure 24. Self-built planters in one of Dujiangyan's transitional communities

Figure 25. Left: homeowners selling agricultural goods, fruit trees and plants

In this transitional community all units were arranged in a linear fashion opening up to a street on the front and 2 meters of separation on the rear side. Even though the main purpose of this separation was to increase daylight penetration into the units, it was proven to be dysfunctional especially in the winter months when the sunlight hits the surface at a lower angle. In addition, these spaces were mostly transformed into storage spaces and used to store bikes, furniture and other household items due to the lack of enclosed storage space inside the units. As a result, as illustrated in Figure 26,

most residents created overhead enclosures using available materials in order to protect the stored items from the natural elements. This transformation further blocked the natural daylight which resulted in poorly lit interior spaces especially in the north facing units. Furthermore, these isolated spaces posed safety concerns as they were easily accessible and hard to monitor.

Figure 26. Spaces In-between units were mostly used to store oversized items

Services such as kitchens, toilets and washing facilities were designed based on a centralized scheme. Kitchens, approximately 14 square meters in area, were designed side by side in a row situated in between five to seven residential streets. Each kitchen was shared by 5 families providing them with the most basic necessities including an electric boiler, gas burning ovens and cutting and preparation surfaces. Poor proximity with the residences, shortage of space and facilities were the main reasons for most residents, especially elderly, to either transform a small portion of their units into food

preparation spaces or simply cook outside their shelters on the front street using portable heat sources.

Figure 27. Left: A typical communal kitchen in the temporary communities in Dujiangyan. Right: Inhabitants utilizing the space in front of the units for their everyday activities.

Similarly, toilet facilities were located far from the residential clusters making it difficult for the residents to access them, especially at night. This was an issue that many residents also brought to my attention. In addition, the existing toilets were poorly maintained and rarely cleaned which posed great hygienic concerns that could ultimately endanger the health of the inhabitants. Due to poor waste and sewage control, absence of de-pressurizing vents, as well as poor ventilation and lack of airflow, unpleasant odours filled these spaces and the areas surrounding the communal toilets. Showers, also clustered centrally in each zone, did not provide sufficient hot water for the residents. In addition, since they were placed distant from the shelters, it was difficult for the elders to access them during the cold days of winter. Another apparent issue was the lack of laundry facilities and drying surfaces that were never incorporated into the design of the units. As illustrated below, in many cases residents simply relied

on pre-existing surfaces and objects such as bikes, karts, window sills and protrusions to hang their laundry to air-dry.

Figure 28. Inhabitants using unconventional methods for drying washed item

This community which was given the title, “The Happy Town” was subdivided into 3 zones; A, B and C. Zones A and B featured a smaller type of shelter with a floor area of approximately 14 square meters. Each unit was occupied by 3 people. In most cases, the members came from different families. Zone C which had the capacity of over 2000 residents utilized a different type of structure that was larger in size. This type covered a floor area of approximately 20 square meters which fit up to two families per unit. Both units were assembled using simple steel and aluminium post (light gauge channels) and beam system (Figure 29) held in tension by cross bracing tensile cables to increase their structural integrity against possible aftershocks. Type C units incorporated a wall paneling system made up of 2-inch polystyrene panels covered with polyurethane sheets on both sides. On the other hand the type A and B units used a similar type of wall except the insulation was sandwiched between two asbestos panels protecting the insulation.

Figure 29. Tensile cables used to provide additional lateral strength

Figure 30. Profile of a typical asbestos-cement prefabricated wall panel and steel framing member

Asbestos-based materials not only pose long-term fatal health hazards, they can also cause skin irritation and allergic reactions. These reactions were already apparent among some of the residents living in these shelters. Most residents used available materials such as newspapers and plastic sheets to cover the interior surfaces of the walls to reduce direct contact with asbestos surfaces (Figure 31, left). Even though today the use of asbestos based construction materials is banned in most countries; China still remains the world's leading asbestos user, with an annual consumption of 537,000 tons

with the majority being used in the production of asbestos-cement building materials, including insulation products.⁵⁶

Families relied on salvaged materials to furnish their shelters. The interior spaces were dark, unhealthy and congested with used, recycled or self-built furniture leaving no additional space for the activities of the households especially children. As mentioned earlier, in many cases people allocated a large portion of the interior space for the storage of their merchandise and personal items. (Figure 31, right)

Figure 31. Homeowners covered walls with newspaper to avoid contact with asbestos wall units. Right: Interior of a typical unit congested with personal belongings and merchandise.

Images below show the construction of the existing temporary housing units in Sichuan. In these images we can clearly see the congested and tight planning of the community. In Figure 32, the poured in place concrete platforms demarcate the edge of the row-units designed with minimal separation with the adjacent units. Figure 33 (right) shows the asbestos-cement foam wall units prior to assembly.

⁵⁶ World Asbestos Report: Asbestos Experiences of Asian Countries: China, 2007. 15 04 2009
<http://www.worldasbestosreport.org/asbestosasia/China_experience.html>.

Figure 32. Site preparation and formation of concrete base (Zhao Mu, <http://zhaomu.blog.sohu.com/89698174.html>)

Figure 33. Concrete base and stacked prefabricated wall units and columns ready to be assembled (Zhao Mu, <http://zhaomu.blog.sohu.com/89698174.html>)

Figure 34. Unit assembly near completion (Zhao Mu, <http://zhaomu.blog.sohu.com/89698174.html>)

CHAPTER FIVE: DESIGN PROPOSAL

5.1 What is a Hybrid?

A hybrid, by definition, is a thing “derived from heterogeneous or incongruous sources; having a mixed character”.⁵⁷ Based on the nature of hybridity, which argues that a hybrid carries the qualities of both of its origins, a hybrid therefore “is neither this nor that, rather, it is this and that.”⁵⁸ Architecture is in itself a result of hybrid factures. It is the amalgamation of high and low technologies, sophisticated and naïve structures, complicated and simple mechanical systems, and refined and elemental construction events.⁵⁹ By understanding the nature of post-disaster relief operations, starting from the initial stage that involves the distribution of “temporary” tents to the later phases of “permanent” reconstruction (Figure 22); transitional shelters bridge the gap between permanence and temporality.

More specifically, as established in this thesis, the transitional shelters will initiate permanent construction by transforming from a temporary unit into a “permanent” house whose essence is based on temporality by being subject to constant evolution. Therefore we can claim that the transitional homes are neither temporary nor permanent; rather they are temporary and permanent. As discussed in section 3.1, in China, the earliest and the most influential scientific explanations were made in terms

⁵⁷ “Hybridity.” *Oxford English Dictionary*. 2nd ed. 1989

⁵⁸ Stephen Fai. “Cultural Heritage Conservation in a Hybrid Manner.” (n.d.).

⁵⁹ Marco Frascari. “The Virtue of Architecture”. Author’s Private Collection.

of time by fitting a momentary event into the cyclical rhythms of natural processes⁶⁰. This ideology also subsumes the notion of time to underline the coexistence of “temporality” and “permanence” in the evolving architecture of the transitional shelters.

This thesis explores the existence of a hybrid structure by amalgamating these traditional ideologies with new disaster relief methodologies in order to create a shelter that is created through the act of making by relying on the traditional building expertise and ideologies while taking advantage of new industrialized techniques of production and assembly.

5.2 The Adaptive Shelter

This design proposal is an attempt to challenge the preconceived notions that are often used in the design and construction of transitional disaster relief shelters. These structures are often designed solely based on economic affordability without giving any consideration to the human well-being and comfort. The design strategy of this thesis uses short and long term needs of the inhabitants as catalysts in order to facilitate an evolving process of construction from temporary to permanent and ultimately create a community that can develop and sustain itself.

The goal is to design a model micro-community that can proliferate into a larger and more permanent one on the same site. Today, especially in the urban areas, contemporary practices usually force individuals to leave their disaster relief community once their “new home” has been constructed. This further undermines the social bonds

⁶⁰ N Sivin. "Chinese Alchemy and the Manipulation of Time." Chicago Journals: The History of Science Society (1976): 513-526, 514

established in the community. This strategy uses specific cultural and philosophical assets that were inherited by the Chinese people throughout the centuries in order to create an environment that generates a sense of belonging, or in other words, an absolute “home”.

Figure 35. Victims often modify their emergency shelters in order to create a more permanent house to create a sense of belonging and safety. (*United Nations, Tents, 21*)

This transitional shelter is intended to be interpreted as a “process” rather than a “product” which further emphasizes the notion of evolution towards permanence; and its hybrid nature allows it to connect itself to the traditional Chinese techniques and ideologies while functioning in a modern environment.

My design will use the notion of hybridity, which combines new construction methodologies with traditional ideologies and materials as a response to the dual characteristic that China holds today as one of the fastest developing countries as well as a country enriched by its ancient history. As illustrated in Figure 36, the concept of hybridity will allow the transitional shelter to evolve from a design that follows the existing guidelines and criteria set by the governing disaster relief bodies both in terms of affordability and flexibility to become a more permanent architecture that is thoughtfully hand crafted and adapted by the inhabitants themselves.

Figure 36. Above illustrations (bottom to top) show the evolution of the transitional shelter from a prefabricated unit into a larger dwelling with a central courtyard, all constructed using natural materials

As much as defining accurate site boundaries may be irrelevant to this project, there is still a need for certain guidelines to be established and followed for the site selection process. The first criteria are the availability of a site that can be cleaned up and flattened easily and quickly before the assembly of the transitional units can begin. Earthquakes create land deformations that are often unpredictable which makes the predetermination of the site rather impossible. However, there are numerous factors that can help us predetermine an appropriate site for this proposed typology. The main criteria are to find a site that is in close proximity to major connecting routes for future supply of materials. Excess and flexibility in terms of land area is to be considered as the number of victims may vary and grow based on the scale of disaster. In the case of the Sichuan Earthquake over 5 million people were left without shelter across China. Dealing with such high numbers requires a thoughtful siting strategy that can become part of the future expansion of the city. The other issue that is important to consider is the possible flooding danger on sites that are close to bodies of water due to obstruction of rivers caused by landslides. Even though this danger may be of little concern given the time it takes for the initial rescue phase to be completed before the transitional homes are built (3 months post disaster), possible after-shocks can create minor flooding posing great danger to nearby structures.

Figure 37 shows the town of Dujiangyan with its ancient town centre at the northern edge (circle in red), which has evolved over centuries in a concentric fashion towards the south to form the existing fabric that currently expands as far as the third ring road (Figure 37, left, shown in yellow). The third ring is essentially the line where the

urban fabric starts to transform into rural context. Proposed (by local town planners) post disaster expansions can also be seen beyond the outer boundaries of the green belt (Figure 37, right, bottom right corner). The dotted lines in the figures below show the boundaries within which this project can potentially be implemented.

Figure 37. Site plan, Dujiangyan

The United Nations' general guidelines (based on numerous similar incidents) indicates that the preparation and assembly of transitional shelters usually starts after the first phase of disaster relief which usually takes up to 3 months post-disaster. This typology is intended to respond to the basic needs of the victims in the initial stages of reconstruction. Following a careful investigation of various local materials and their availabilities and performances under similar conditions, the design of the proposed transitional shelter will incorporate a temporary steel frame construction. Expected to take approximately 1 day to assemble, each shelter is 4 meters by 4 meters in floor area and provides space for a family of 3-5 members. The current occupancy limit of the existing transitional shelters in China is fixed at 3 people per unit which rigidly follows the One Child policy that currently exist in China. This policy, however successful as a tool to control population growth, in most cases has caused psychological discomfort

for many extended members of the family who were assigned to live in separate units for an extended amount of time along with [what some referred to as] 'strangers'. The objective is to improve the emotional comfort of the victims by allowing families to have the option of living within one unit, if necessary, and also to maximize social interaction among families to create a more dynamic environment.

Figure 38. Grid-based construction of the initial prefabricated unit using light-weight steel members

As shown above, the layout of each unit is based on a 3 by 3 grid of steel load-bearing columns that support the walls. Each side, 4 meters in length, is subdivided into 3 sections that match the width of a standard sheet (1.2 m) while allowing 4 steel columns, 10cm each, to support the roof structure. The wall system consists of one or in some cases two layers of corrugated steel filled with earth, wood and straw insulation embedded between the layers. The roof is also made up of corrugated steel panels supported by the main beams that rest on the exterior columns and slopes down towards the south with extended overhangs to reduce heat gain during summer while allowing sufficient daylight penetration inside the units in the winter. Similarly, the roof system also incorporates a dual-layer corrugated steel with incorporated air gaps and

insulation to reduce thermal bridging. The unit floors are initially built with slab-on-grade compacted earth and lime. Using this typology, at the start, facilitates a quicker and cheaper construction which is a crucial factor for the maximum provision of temporary units based on a fixed budget. By reducing the initial cost of construction, more shelters can be distributed in a shorter amount of time. In addition, due to simple assembly techniques, more local work force (with minimal knowledge of construction) can be utilized to further optimize the speed of construction. By employing this methodology, the initial temporary structures can become the framework to support an additional layer of structure that would then become the main load bearing walls as the project evolves. For instance, the temporary corrugated steel walls will act as formwork for the construction of the new rammed earth or brick wall, and once the earth wall is erected the temporary structure can be removed to facilitate future expansions. The replaced materials are also intended to be used in the fabrication of new elements such as water management systems and other servicing facilities.

5.3 The Transitional Community and the Natural Environment

In order to create a natural environment that could contribute to the health and mental well-being of its inhabitants and also an architecture that is capable of creating a sense of belonging to nature, the material palette used for the modification of the initial structures corresponds to the five natural elements. Wood, Fire, Earth, Metal and Water have long existed as the balancing factors in various Chinese practices and philosophies. These are the five basic elements that exist in nature that are constantly being

transformed from one into another. This evolution determines our physical, psychological and emotional balance by connecting us to nature.

Human beings often turn to nature to seek psychological comfort and distress. The existence of nature and natural materials play an important role in our psychological and physical well being. In this proposal, each unit is assembled in a way to allow for green spaces around the unit which essentially function as arable plots of land for the residents of the community. These agricultural zones also function as shared transitional spaces from the front yard of one unit to the backyard of the next. This arrangement not only maximizes the green space accessible by both units, it also provides a space for social interaction by creating gathering places within the shared green zones.

Figure 39. Diagram showing the arrangement of initial units and the communal green spaces

In the Chinese philosophy, each element or phase corresponds to a geographical direction. The Earth, at the centre, is the anchor for the other four elements to wrap around and define the other directions. Earth is signified as reliable and stable and it is the ultimate habitat for the people. Wood represents the direction east while Fire is the ultimate south and Metal and Water represent west and north respectively. (Table 2)

Phase	Direction
Wood	East
Fire	South
Earth	Centre
Metal	West
Water	North

Table 2. The five natural elements and their corresponding directions used in the planning process

This transitional community will also rely on the natural elements in order to sustain itself. Water will be used as a nourishing agent. The rain water is directed to the agricultural lands as a means of irrigation. Strategic arrangement of the residential units, services and support mechanisms are based on both analytical studies of the environment and the site, as well as the Chinese Five Phases in order to create a well-balanced and harmonious environment that complements Chinese culture and customs.

Figure 40. Diagram showing the directional placement of the five elements

The evolution starts when the inhabitants start the construction of the “fire” element which is the catalyst for the regeneration of the units. Fire creates Earth; this simple philosophy is adapted in this thesis by the firing of bricks. Fire, or essentially heat, chemically alters the properties of earth by increasing the bonding strength of the *particles and gives earth more structure. The earth is fired in the ovens that are powered by the natural cycle of transforming stalks (from crops), weed, leaves and agricultural waste (Wood) into fuel by using a biomass fuel generator located between units. When the biomass is burned, most of the generated heat and the fertilizing constituents are not utilized. The biomass burnt every year is equivalent to burning 2 million tons of pure nitrogen which can be used as a fertilizing agent*⁶¹. The estimate, made in the early 1980’s in China states that “if half of all human and animal excrement, as well as crop stalks were used to produce methane gas the output in methane gas would be 68,300 cubic meters a year. In addition to supplementing rural energy production, this can be used to generate power and electricity.”⁶² The methane production relies on basic assembly of an underground fermentation chamber, a gas storage chamber, feeding pipe and residue removing chamber. The construction of the chamber can be done by the local workforce using local materials, however nowadays they are mostly constructed using concrete that works both as structural and waterproofing member to create the tank.

⁶¹ Zhang Ji-G. "Rural Methane Use in China." The Changing Rural Habitat. (Beijing: Concept Media Pte Ltd, 1982. 123-130) 123.

⁶² Ibid, 123

Figure 41. Longitudinal view showing (left to right) the proposed agricultural land, residential unit (background), oven with water retention tank (foreground), showers, toilets and biomass fuel generator (far right)

The arable plots of land, which may seem insufficient for taking on large scale agricultural projects, function as a way to raise public awareness about the cycle of growth and production. They also reduce reliance on external sources for food and therefore increase self-sufficiency within the community, in addition to planting high demand products such as fruits and vegetable as a source of income. Once these agricultural products are consumed, the accumulated waste is then transformed into fuel using the biomass fuel generators. The produced fuel can then be used for everyday cooking as well as preparation of construction materials and firing adobe bricks and wood members in the ovens that are constructed in front of the units.

Construction methods proposed here all rely on the knowledge of local construction techniques. The main focus of this transformation relies upon the process that encourages the inhabitant to take part in the general construction of their homes and bring a sense of belonging which might be absent in the initial temporary shelters, or in other words, transform their shelters into homes. The use of traditional materials such as earth has been proven to provide high efficiency and flexibility in construction. As Anil Agarwal describes, traditional building materials are not only cheap and readily available, “a house built with traditional materials can be easily extended as the occupant’s income increases; and such houses can be built in far greater variety as each householder builds according to his choice, thereby creating a far better social, cultural

and psychological environment than that provided by most low-cost mass housing schemes".⁶³

The area surrounding the initial shelters, allows for horizontal expansion of the units as well as potential addition of top floor mezzanines to provide additional bedrooms and storage spaces.

In China, based on tradition, bathrooms and toilet facilities are often found outside the dwelling units. The same arrangement is applied to this design with the exception that as the house grows in size the toilets and washing facilities can be accessed directly from the interior spaces. Toilets and shower facilities, only 3 meters away from the unit, are integrated into the re-cycling system where the toilets are designed based on the traditional composting techniques. These cabins are designed with the capability to slide from side to side to allow for aeration of the waste captured in below ground chambers. The nutrient-rich waste can then be used as natural fertilizer directly from the storage pits.

⁶³ Anil Agarwal, "Research: Mud as a Traditional Building Material." The Changing Rural Habitat. (Beijing: Concept Media Pte Ltd, 1982. 137-146) 138

Figure 42. Diagram showing a composting toilet mechanism (<http://www.oikos.com/library/compostingtoilet>)

The Water element is perhaps the element that can bring tranquillity and psychological comfort to the living environment. Water, from the environmental stand point, is often wasted as a result of poor water management strategies. This design implements strategic methods to capture the rain water and use it for irrigation of the agricultural lands. In addition, a healthy filtration system supplies sufficient clean water that can be used for cooking, cleaning and drinking purposes. The corrugated steel roofs are designed to collect the rain water. Additional steel members that are now available as a result of adding the earth and brick walls to function as structural load bearing walls are used to expand and construct a basin to capture and lead the runoffs to a central basin above the main fireplace. The collected water is then heated and redirected to the showers and toilets on the north side of the units and used directly around the fireplace for cooking. Subsequently the water is then directed back to the irrigation system and

eventually back to the earth for agricultural purposes, or theoretically, the Water will nourish the Wood in order to feed the Fire in the ovens and create Earth.

In adobe or earth constructions, additives should be used in the mix to increase durability and the bonding strength of the adobe. Different materials are used as additives for improving the modern construction of earth walls. Joints and major corners should be reinforced using materials that can perform well under tensile forces.⁶⁴ As a response to the shortcomings of this specific type of construction, this thesis introduces a series of wall assembly techniques by combining the traditional methods of earth wall construction (rammed earth and adobe brick) and new methods by reusing the provided materials that can be replaced and salvaged from the initial temporary shelters.

In the planning and design process when dealing with post-earthquake rural reconstruction, there are general guidelines that should be followed; especially when Earth⁶⁵ is used as one of the predominant materials. 1) Construction sites should be selected carefully considering that unstable slopes, loose sand or clay soil are not suitable for rural habitations. 2) In terms of design, plans for houses should be as symmetrical as possible in order to enhance the ease and speed of construction. 3) Joints between all members should be perfect and if possible flexible. 4) When materials are not strong in tension or excessive compression, stronger materials such as timber or steel tie beams should be provided in vulnerable conditions. 5) The general quality of

⁶⁴ Mufit Yorulmaz. "Earthquakes and Rural Construction." The Changing Rural Habitat: Volume 1 Case Studies. (Beijing: Concept Media Pte Ltd, 1982. 131-134) 133.

⁶⁵ Earth: all products and techniques that originate from earth such as rammed earth, adobe, kiln-dried brick and other similar constructions that have low structural integrity against seismic forces unless reinforced.

workmanship should be improved which can be achieved by the educative involvement of experts or supervisors.⁶⁶

Point (1) refers to site selection measures that are crucial not only to increase safety but also to ensure that the dwellings do not negatively interfere with the future expansions. A simple symmetrical design (point 2), not only makes the construction process faster and easier, it is also one of the fundamental planning techniques in the Chinese traditional architecture. In China it is *Jian* or essentially the space between four columns that determine the unit of space. *Jian*, meaning “the space in between” is a measurement of area that represents a room. This tradition is used in this thesis as a modular method of construction where the spacing of columns initially correspond to a standard unit of measurement which is 1.2 meters in width and 2.4 meters in length (Figure 43).

⁶⁶ Mufit Yorulmaz. "Earthquakes and Rural Construction." The Changing Rural Habitat: Volume 1 Case Studies. (Beijing: Concept Media Pte Ltd, 1982. 131-134) 132.

Figure 43. Proposed grid layout for the construction of the initial units

This thesis also seeks to introduce construction techniques which are based upon the same idea of reusability and transformation in which stronger materials are used to provide additional structural integrity to the new construction to prevent minor damages. Figure 44 demonstrates a technique that reuses the existing steel columns and steel mesh surfaces used in the initial construction to reinforce and add sufficient tensile strength to the rammed earth walls. The same members can also be used to tie the brick wall to the main structure. The reinforcing mesh panels are extracted from the ventilation panels that are initially integrated at the top portion of the walls and the ceiling to create natural air circulation within the units. Once removed, a system of woven straw and bamboo screen can replace the screens below the roof.

Figure 44. Integrated recycled reinforcing steel mesh and column system to provide optimal strength in the construction of tamped earth and brick walls

Temporary shelters are often constructed without underground foundations. These shelters often sit directly on compacted earth or in this proposal a layer of lime is introduced to make the surface breathable. This system will also allow for the addition of a future foundation system in order to support the new structural walls. This system is made up of salvageable steel barrels filled with rubble and re-bars with a mix of cement to increase bonding and compressive strength. Once the empty barrels are embedded into the ground, the filler and the mix can be added to embed and fix the new wooden or steel post in place (Figure 45).

Figure 45. Proposed foundation system using recycled oil barrels filled with debris, salvaged re-bars, earth and cement to hold the main structural columns in place.

This flexible structure can also expand vertically. Once the structural walls of earth and brick are extended to the desired height, new beams can be introduced to the structure to hold the second floor mezzanine. The corrugated steel roof is then put in place to complete the addition.

The initial planning of this micro-community relies on similar principles that governed the planning of the traditional courtyard houses in China. Implementing this strategy will provide more privacy and security to the community and will create a stronger sense of intimacy as the community starts to evolve.

Images below show the transition of the proposed typology from a prefabricated unit that is economically feasibility, easy to assemble, transport, disassemble and transform into a more permanent house that is well grounded into the natural landscape, and more importantly one that is built by the inhabitant to suit the needs of the family.

Figure 46. 12 steel columns are erected 1.2 meters apart on top of compacted earth

Figure 47. Tie beams are connected around the periphery of the grid

Figure 48. Steel beams are installed to support the roof. Overlapping corrugated steel wall panels with openings are assembled between the columns

Figure 49. Corrugated steel roof and adjustable shading flaps (which will be used as sliding formwork for the construction of rammed earth walls) are assembled. Sliding mesh panels are installed at the bottom of the exterior walls to allow for insertion of earth, rubble and wood between the two layers of corrugated wall units for additional insulation

Figure 50. Barrels are filled with rubble, earth and cement to embed and support the steel columns. These barrels sit directly in front of the existing wall. A shallow stone foundation is constructed to form a water and decay resistant podium for the new rammed earth wall. The existing corrugated walls and detachable shading flaps are used as formwork for the construction of new earth wall

Figure 51. Similar process is repeated to construct the other walls. Once the first tamped earth load bearing wall is constructed, corrugated panels can be removed to create formwork for the next wall. Reinforcing tie beams at bottom, mid-height and top of windows create additional tensile strength.

Figure 52. After all exterior walls are constructed, a layer of woven bamboo matting is placed at the top of the earth walls to reduce contact between the wall and the wooden roof joists to minimize decay.

Figure 53. Once all exterior walls are replaced with tamped earth walls, corrugated wall panels can be disassembled to form the new roof for the dwelling. A layer of lime plaster is then applied to reduce heat gain and make the walls more resistant to water and natural decay.

Figure 54. Side elevation of a newly constructed rammed earth dwelling

Figure 55. After wall units are installed, sliding bars are screwed to the main posts. Steel Mesh panels are then placed at the bottom of the overlapping wall panels to hold the wall infill (insulation) from falling out. By sliding the panels the insulating content can be removed.

Figure 56. Earth is filled between the existing wall and the detachable shading flaps to function as temporary formwork. A layer of mesh fastened to the main steel columns is embedded within the wall at 30 cm intervals to create additional tensile strength.

Figure 57. A steel post is holding the adjacent walls in tension, therefore creating a stronger corner structure that can resist general movements and possible aftershocks and prevent the earth walls from collapsing. A layer of lime plaster is introduced to the walls on both sides. A thin layer of mesh can be fastened to the protruding edge of the embedded mesh reinforcements prior to plastering in order to increase bonding and durability.

Figure 58. Top view showing the contrast between materials and methods used in the construction of the initial unit (right) and the new addition (left)

CONCLUSION

It is evident that today, China is one of the world's leading producers and exporters of manufactured construction materials and products. Abundance of such materials has reshaped China's architectural methodologies, and has resulted in the disappearance of many traditional architectural ideologies and methods. This phenomenon has created many challenges especially in architecture as more and more people are finding the urge for modernization. Reliance on natural methodologies and materials has also declined rapidly. This mentality is portrayed in today's architecture of disaster relief that this thesis has attempted to re-define. This shift towards modernization has simply disregarded the benefits and effects of the natural environment on the wellness of human beings.

The ultimate goal of this thesis is to re-establish this relationship with nature through an architecture that relies on the natural elements in order to create and re-create itself gradually and naturally. Even though a set of systematic guidelines have been established to create this model, the evolution of the transitional dwelling relies primarily on the involvement of the inhabitants based on their needs and resources. This involvement is the factor that generates a sense of belonging and happiness which this proposal is intended to establish. Victims taking part in the reconstruction of their homes, children helping parents in preparation of building materials, neighbours assisting each other in everyday activities, are all catalysts for creation of a setting that can bring a stronger social bond and a sense of livelihood to the family and the community.

“My name is Xia He, and I’m twelve years old. We moved into this shelter that was built for us after our home collapsed almost a year ago. I lost my father in the earthquake. Now I live with my mom, my uncle and my grandmother. After my father’s death, it took my mom a few months to regain her health before she could walk and become active again. During this time, our neighbour Li Na, who lived in the shelter next to us, helped us by making us food and taking care of my younger sister. My uncle works at the local bus terminal. He makes very little money. Everyday after school, my uncle and I spend a few hours gathering old bricks and wood from the ruins of our old house. Now we have over 200 pieces of brick that we can use to build other things. Soon we are going to build an oven beside our house so my mom and my neighbours can get together during the day and cook. When my neighbours come to visit my mom, everything changes. She gets more energetic and happier. I think if they spend more time everyday together, my mom can soon feel better and forget about the past. My grandma is 65 years old. She usually wakes up early in the morning and takes me to school. She spends a lot of time taking care of the plants and the garden. Right now, she is weaving a bamboo mat for our house. She lays down the mat on the ground, under the shadow of the apple tree, and spends hours weaving the strands of bamboo together. It’s hard work, but she says that it helps her relax. In our garden, in front of our house, we have planted trees and flowers. We have six apple trees, two orange trees and plenty of potato plants that we grow mainly for our own use. We also have a lot of vegetables that we dry and sell in the winter. Our other neighbours have a lot more fruit trees. We always help them pick the fruits and carry them to the market. I also help them make bricks. They have a big oven that they use to bake the bricks. Sometimes when I help them, they give us bricks, and even let us use their oven to make more bricks for ourselves until we can finally build our own oven. They also taught me how to build a wall with earth. Most of our neighbours have added small rooms beside their shelters to store

things or even to live in. My uncle wants to add two more rooms to our house. One of them is going to be my bedroom. This way I can study and focus on school, or even invite my school friends to our house so we can study together for our exams.

Life without my father is very different. It is sad but I am thankful that I have my mother and my relatives around me. I am also surrounded by a lot of kind neighbours who share a lot of time with us. This way we can help each other do things, build things, share our happiness together, share our stories when we are sad, and more importantly, be a big happy family.”⁶⁷

As described in the memoirs of Xia He, this lifestyle allows the victims to fulfil their ambitions for growth and assists them in getting involved in healthy social activities in order to ease the emotional pain and grief caused by the loss.

This evolving shelter is a hybrid that is neither permanent nor temporary; rather, it is the product of both temporality and permanence. It also relies on traditional ideologies while incorporating new disaster relief methodologies. And finally, it borrows the qualities of the Chinese five elements to anchor itself in the natural environment in order to create an adaptive, well- balanced and healthy living environment for the body and the soul.

⁶⁷ Excerpt from an imaginary memoir through the eyes of a young adult living in the proposed transitional community

Figure 59. Physical Model: Illustrating a modified earth dwelling with a north-facing adobe brick addition (far right), as well as arable plots of land and communal green spaces (foreground)

Figure 60. Final Rendering: Right: Chinese traditional construction methods. Centre: East elevation of proposed shelter and facilities. Right: Details proposing various construction and modification methods.
Graphite on paper. Actual dimension: 116 in x 22 in

Figure 63. Details illustrating various traditional construction methods practiced in China

Figure 64. Cross-section through a self-made brick oven and water tank above with the residential unit illustrated in the background

Figure 65. Cross-section through a typical shower with water storage (left) and composting toilet (right)

Figure 66. Cross-section through a biomass fuel generator

Figure 67. Details illustrating various techniques used in construction and modification of dwellings

Figure 68. Details illustrating various techniques used in construction and modification of dwellings

Figure 69. Details illustrating various techniques used in construction and modification of dwellings

BIBLIOGRAPHY

Agarwal, Anil. "Research: Mud as a Traditional Building Material." The Changing Rural Habitat: Volume 1 Case Studies. Beijing: Concept Media Pte Ltd, 1982. 137-146.

Ander, Gregg D. Daylighting: Performance and Design. New Jersey: John Wiley and Sons, 2003.

Architecture for Humanity. Design Like You Give a Damn: Architectural Responses to Humanitarian Crisis. New York: Metropolis Books, 2006.

Ashmore, Joseph. Tents: A guide to Use Logistics of Family Tents in Humanitarian Relief. Geneva: United Nations Publication, n.d.

Busby, Peter and Jim Taggart. Busby: Learning Sustainable Design. Quebec: Janam Publications Inc, 2007.

China Heritage Newsletter: Taming the Floodwaters. march 2005. 17 12 2008
<http://www.chinaheritagenewsletter.org/features.php?searchterm=001_water.inc&issue=001>.

Cold, Birgit. "Aesthetics, Well-being and Health." Cold, Birgit. Aesthetics, Well-being and Health. Burlington: Ashgate Publishing Company, 2001. 11-23.

Day, Christopher. Environment and Children: Passive Lessons from the Everyday Environment. Oxford: Elsevier Ltd, 2007.

Fai, Stephen. "Cultural Heritage Conservation in a Hybrid Manner." (n.d.).

Frascari, Marco. "The Virtue of Architecture." Author's Private Collection.

Girard, Greg and Ian Lambot. City of Darkness: Life in Kowloon Walled City. Hong Kong: Everbest Printing Company, 2001.

Godish, Thad. Sick Buildings: Definition, Diagnosis and Mitigation. Boca raton: CRC Press, 1995.

Golany, Gideon S. Chinese Earth-Sheltered Dwellings: Indigenous Lessons for Modern Design. Honolulu: University of Hawaii Press, 1992.

Gutierrez, Jorge. "Notes on the Seismic Adequacy of Vernacular Buildings." 13th World Conference on Earthquake Engineering. Vancouver, 2004.

Hoizey, Dominique and Marie Joseph. A History of Chinese Medicine. Vancouver: UBC Press, 1993.

Ji-G, Zhang. "Rural Methane Use in China." The Changing Rural Habitat: Volume 1 Case Studies. Beijing: Concept Media Pte Ltd, 1982. 123-130.

Kent, Randolph C. Anatomy of Disaster Relief. London: Pinter Publishers, 1987.

Knapp, Ronald G. China's Traditional Rural Architecture. Honolulu: University of Hawaii Press, 1986.

— . China's Vernacular Architecture. Honolulu: University of Hawaii Press, 1986.

— . Chinese Houses: The Architectural Heritage of a Nation. Tokyo: Tuttle Publishing, 2005.

Lawrence, Roderick. "Housing, Health and Aesthetics: Reconnecting the senses." Cold, Birgit. Aesthetics, Well-being and Health. Burlington: Ashgate Publishing Limited, 2001. 143-156.

McQuaid, Matilda. Shigeru Ban. New York: Phaidon Press Limited, 2003.

Mornement, Adam and Simon Holloway. Corrugated Iron. London: W.W.Norton and Company Inc, 2007.

Nations Online: Countries of the World. 13 01 2009. 14 02 2009
<http://www.nationsonline.org/oneworld/Chinese_Customs/five_elements.htm>.

Pallasmaa, Juhani. The Eye of the Skin: Architecture and the Senses. West Sussex: John Wiley & Sons Ltd., 2005.

Phillips, Derek. Daylighting: Natural Light in Architecture. Oxford: Architectural Press, 2004.

Recanati, Catherine. "Hybrid Reasoning and the Future of Iconic representations." LIPN-CNRS UMR 7030, Universite Paris 13 NA.

Rosbach, Sarah. FengShui: The Chinese Art of Placement. New York: Penguin Group, 1983.

— . Interior Design with Feng Shui. New York: Penguin Group, 1987.

Shiqiao, Li. "The Journal of the Society of Architectural Historians, Vol. 62, No. 4." Reconstituting Chinese Building Tradition: The Yingzao Fashi in the Early Twentieth Century (2003): 470-489.

Sinclair, Cameron. Design Like You Give a Damn: Architectural Responses to Humanitarian Crises. New york: Distributed Art Publishers Inc, 2006.

Sivin, N. "Chinese Alchemy and the Manipulation of Time." Chicago Journals: The History of Science Society (1976): 513-526.

United Nations. Tents: A guide to the use and logistics of family tents in humanitarian relief. Geneva: United Nations Publications, 2004.

Van Essche, Ludovic. Shelter after Disaster: Guildlines for Assistance. New York: United Nations Disaster Relief Co-ordinator, 1982.

World Asbestos Report: Asbestos Experiences of Asian Countries: China. 2007. 15 04 2009
<http://www.worldasbestosreport.org/asbestosasia/China_experience.html>.

Yorulmaz, Mufit. "Earthquakes and Rural Construction." The Changing Rural Habitat: Volume 1 Case Studies. Beijing: Concept Media Pte Ltd, 1982. 131-134.