LA UTILIZACIÓN DE LA BAJA TECNOLOGÍA EN LA ARQUITECTURA TRADICIONAL DE CHINA Y SU COMBINACIÓN CON EL MODO DEL DISEÑO ARQUITECTONICO MODERNO

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1. INTRODUCTION
The development of architecture and urban design in China and the problem we need to solve.

2. MATERIALS
Characteristics of each material. For what reason they are used to construct the city. How they are used. What can we do to improve them.

2.1. THE WOOD
2.2. STONE AND BRICK
2.3. EARTH
2.4. CONCLUSION

3. LOW TECHNICAL CONSTRUCTION SYSTEMS
The study of the low technology construction systems of ancient Chinese architecture could help us to understand the Chinese ancient architecture systems better. There are two major construction systems: the wood frame construction system and the earth construction system.

3.1. WOOD-FRAME CONSTRUCTION SYSTEMS
3.1.1 Characteristics of wood frame construction systems
3.1.2 Several kinds of wood frame construction systems

3.2. EARTH CONSTRUCTION SYSTEMS
3.2.1 Several kinds of earth construction materials
3.2.1.1 Rammed earth.
3.2.1.2 Adobe and earth block
3.2.1.3 Direct forming with wet loam
3.2.2 Several kinds of earth construction systems
3.2.2.1 The original loam building system
3.2.2.2 Clay-arch structure system
3.2.2.3 Wood and earth construction system.

3.3. CONCLUSION

4. LOW TECHNICAL ARCHITECTURAL PHYSICS
For architecture, the climate is an important environmental factor; it affects the use of material, the forms and the space of buildings. The research of low technical architectural physics can help us to learn how they solve those problems.

4.1. VENTILATION AND LIGHTING
4.1.1. Ventilation
4.2.2. Lighting
5. THE PRACTICE OF LOW TECHNICAL ARCHITECTURE

The use of low tech in architecture has been accompanied by human construction activities from the very beginning. Human beings summed up a lot of useful experience during long-term practice of construction. Now there are many architects are aware of the value of low technical architecture and try to combine it with new design.

5.1. THE PRACTICE OF LOW TECHNICAL ARCHITECTURE OF DIEBÉDO FRANCIS KÉRÉ

5.1.1. Diébédo Francis Kéré
5.1.2. The concept of design of Diébédo Francis Kéré
5.1.3. Several projects of Kéré

5.2. THE PRACTICE OF LOW TECHNICAL ARCHITECTURE OF EDWARD NG YAN YUNG AND MU JUN

5.2.1. The background
5.2.2. Design and Methodology
5.2.2.1. Local traditional construction techniques and materials
5.2.2.2. The combination of traditional low-tech architecture with modern design.
5.2.3. The construction of low-tech architecture.
5.2.4. Conclusion

5.3. CONCLUSION

6 CONCLUSION

NOTES

BIBLIOGRAPHICAL REFERENCES
1. INTRODUCTION

We all have heard the story of three little pigs. It says that there was an old sow with three little pigs, and as she does not have enough food to keep them, she sent them out to seek their fortune. The first went off and found a bundle of straw, so he built a straw house. The second little pig went to the mountains and cut back lots of wooden. Soon, the second covered his wooden house. Obviously this is stronger than the straw house. After seeing the house of his brothers, the third little pig decided to build a house with bricks, because this kind of house is strongest, and not afraid of wind and rain, but it takes a lot of effort to build. So the third little pig worked every day, brought back bricks and at last, he built a big brick house.

One day came a wolf, the first pig went back and hid in his straw house, but the big bad wolf huffed and puffed and blew the house down in minutes. The frightened little pig ran to the second pig's house which was made of wood, but the same thing happened again. At last, they ran to the third pig's house which was made of brick, the big bad wolf tried to huff and puff and blow the house down, but he could not. He kept trying for hours but the house was very strong and the little pigs were safe inside. The evolution of the house of the three pigs is just like the history of the development of architecture of human beings. (Fig.1)

Fig.1. The development of architecture of human beings. According to F. Javier Nella González’s Arquitectura Bioclimática en un entorno sostenible. 2004.
In ancient times, the economy and productivity of human society is relatively backward, and therefore the human beings are more likely to use local materials, such as clay, wood, stone, etc., to build houses. It does not require a very advanced technology to processing, so it can be learned and built quickly. For example, in ancient China, dating from five hundred thousand years ago, in the early Paleolithic age, hominids had used caves as natural living spaces. In the Neolithic Age, the tribe which is located in the middle reaches of the Yellow River use shallow caves of loess to be Neanderthal cave, and build the shelter with wood and clay outside, which gradually develop into the house on the ground. (Fig2.) To the 13th century BC, in the late Shang Dynasty, they have mastered the rammed earth technology, and the simple wooden structure has become a major way of Chinese architecture. From the beginning of the Yuan Dynasty, people learn to use brick and arch structure to build houses. As time progresses, the ancient architects create a variety of building types and unique construction techniques. Now in many parts of China there are still a lot of houses that are built with clay and bricks. The houses of different regions have their own characteristics. Due to the use of low-tech, for example, the use of natural ventilation, shading, drainage, etc., traditional houses of different regions can be adapted to the local environment.
But the industrial revolution occurred in the British in the 18th century changed the world, and also affected China, the rise of the technology of steel and concrete at that time has changed the face of architecture of the world. The architecture gradually developed from a low-tech era into high-tech era. The development of reinforced concrete buildings has changed the history of architecture of China, but it also brings a huge problem: all the cities lost their own architectural features; most of the cities are following the same pattern. This phenomenon can be traced back to the mid-20th century. Since the establishment of People's Republic of China in 1949, we have designed lots of residential buildings, and overall a large number followed the pattern of the Soviet Union and the "International style" of United States. The International Style is the name of a major architectural style that is said to have emerged in the 1920s and 1930s, the formative decades of modern architecture, as first defined by Americans Henry-Russell Hitchcock and Philip Johnson in 1932. "Utilizing new construction techniques and materials, buildings of the International style were starkly different than those of previous eras in not just appearance. Flat roofed, asymmetrical and with bands of windows set into a rectangular form, International style buildings were a dramatic departure from past eras." [1]

Fig.4. Carl Mackley Apartments in Philadelphia.
The most common characteristics of International Style buildings include rectilinear forms, flat roof, lack of ornamentation or decorative details, and open, even fluid, interior spaces. In other words, the so-called international style means that it does not have any geographical features. In any country it looks like this: square boxes, flat roofs, unified windows and smooth vertical and horizontal lines of the facade. Mankind finally develop a universal architecture model, create a new situation of the so-called "modern architecture". (Fig.3. Fig.4)

The emergence of international architecture, which itself is undoubtedly a great pioneering in the history of architecture of mankind. Now a lot of houses that we can see in the city are its various derivatives. After World War II, it soon became global architecture design patterns, and until today, it continues to develop. One or several international-style buildings, is a symbol of modernization, but if there are lots of this kind buildings, the city is totally boring. I think we now need to do is constantly thinking of how to preserve special architectural culture, traditional arts and traditional low-tech, and then combine them with the development of technology, apply them to the design of modern urban and architecture. (Fig.5)
Another problem is that although China has developed several decades, this development is depletion of the environment; waste a lot of limited natural resources. For example, in 2011 to 2013, China consumed 660 million tons of concrete, and for every ton of cement, 700-900 kilograms of carbon dioxide exhaust. In 2014, the carbon dioxide emission of the production of cement is about 2 billion tons (accounting for more than one fifth of the emissions of China). Every year it produces 3.55 billion tons of construction waste in China. But at the same time, in many areas of China, especially towns and villages of China's western provinces, the people are not rich enough, the modern building material is too expensive for them, and locals also are lack of modern construction technology, therefore, how to build high quality houses with local materials and low-tech is a problem worthy of research.

China is a big country. China's landscape is vast and diverse, ranging from forest steppes and the Gobi deserts in the arid north to subtropical forests in the wetter south. The climatic and geographical differences in different regions resulted in a variety of characteristics of traditional Chinese architecture. The ancient people create a different style of architecture with local material. Due to the fertile loam layer fit in farming, people settled in the middle reaches of the Yellow River from the late Neolithic Age. This area was warmer and moister than it is now, it grows lots of forests, and therefore the wood and clay became the main material used in local construction. In order to resist the cold, the house of northern site towards the south in order to let the winter sunlight enters the room, and they use the ondol inside and thicker walls to keep warm. But in the south of china, the situation is totally different. The house of southern site towards the south or the southeast to accept the cool summer breeze, and they build stilt house to avoid the humid environment. Besides the wood and clay, they also use stone, bamboo and reed to build houses.

The traditional houses is the product of the agricultural society, it is built on limited natural resources and limited ability to transform the environment. After a long period of development, the traditional houses in the region is not only the most suitable way of living, but also a construction system led to very little damage to the environment. Its passive energy-saving measures and a more comfortable
way of living have been integrated with the climate, cultural and geographical environment of the region. Today the research of utilize of low-technology in Chinese traditional architecture will not be limited to mere description, but to understand how it be used and how to combine it with modern construction techniques to refresh the old building. Under the premise of respecting local culture, we should learn the essence of traditional architecture, while use modern building materials, construction technology and management methods of modern science to improve traditional construction techniques, make it more responsive to the needs of social development.

In this article, I will research this topic from these aspects: the material, architectural forms, building technology and space experience, hoping to figure out the characteristic of traditional Chinese architecture and the use of low technology in it, explore a suitable path of the development of Chinese Vernacular Architecture.
2. MATERIALS

2.1 THE WOOD

After several years of development, the wooden building has become synonymous with Chinese architecture, and widespread impact on neighboring countries. Different from the western architecture which is based on the stone, Chinese architecture form an independent building system. For the choice of materials, stones need to dig and mine, the wood need to plant and lumber. The first one mean to explore the earth and the other tend to keep in touch with nature. China is an agricultural country, during the ancient times lots of books are set out in detail about the various uses of wood and official planting program, so that common people can plan their own wood storage to build their houses. The foundation is important to them, the farmer can sit and wait and pick the best stones slowly, just because it takes at least five years for the trees to grow into the rafter, ten years to be a general girder o column, for some good sorts of wood, it takes more than 20 years. For modern people, it takes so long to wait. But fortunately, most of the time his father has planted it for his children, and passes down it from generation to generation, together with the valuable experience. (Fig.6).

From pick and transport the material to make brick and tile, the entire family members work hardly for their future. They use the accumulated experience to build, in china almost every farmer is amateur architect. Until today, along the upper reaches of the Yangtze River, the small village which is built in this method can still be seen. The family will construct on stage according to their abilities. First they erect trusses in spring, wait until the autumn harvest when they continue to cover the roof. Or they invite their neighbors to help, to work together to complete the house. (Fig.7). If the main material used for rural construction is not the wood but stones, it is probably that a few farmers cannot cope the technology and labor needed during the construction. Perhaps the Chinese traditional relationship of villager will be changed because of different building materials.
Fig. 6. The structure of traditional wooden building of China. According to Liang Si Cheng's *Treatise on Architectural Methods*, 1963.
Some people think that a large number of ancient Chinese buildings are use of wood is because of the lack of the stone. But it is not the truth. In the Yangtze River and other places it is not lack of the stone, but the building ruins of everywhere shows that the material of Chinese architecture is mainly the wood. The resource of material is important, but the technology is more needful. When we are still in the initial Iron Age, the process of wood clearly requires less technology. Therefore naturally the wood becomes the best construction material. Many characteristics of wood also make it suitable as a building material.

Technical reasons have been discussed in many articles, and here I want to emphasize one of them. Wood is a kind of material of ductility, which gives it a characteristic: earthquake-resistance. In ancient books of China there always are the saying "the wall falls down but the house does not collapse". In the period of that earthquake prediction system is imperfect; the advantage of wood can be manifested. After the enclosed structure collapse, the wood frame still strong enough to support the house.

In addition, the ancient Chinese people choose wood as the primary building material, which is also related to their thinking. Ancient people have different ideas about the theory of 'eternal'. Greek,
Indians and Egyptians understand 'eternal' as 'unchanged', therefore the best building that can embody the 'eternal' is made of stone (Romans discovered the effect of volcanic ash and created artificial stone - concrete). Therefore major religious buildings must be built of stone. Different from the ancient Egyptians and Europeans who consider that unchanged as eternal and build lots of stone buildings, Chinese people (and perhaps Japanese, Korean) consider the change as eternal. (Fig.8. Fig. 9.)

It has been written in the oldest book of China: “Book of Changes”. The seasons, spring, summer, autumn, and winter, peacefully give way to each other, year after year, this change is eternal. In the culture of China, people think that the wood and spring symbolizes life, the stone and winter symbolizes death. They use wood to build houses, use stone to build tombs. The wooden building gives a warm feeling to people, not like the cold stone building. This is also the reason that today Chinese people still like to do some wood-paneled decoration in the concrete building. (Fig.10.)

In ancient China, craftsman is always craftsmen, and scholar is always scholar. A craftsman will not write and read books, and a scholar will not do the work that a craftsman does. So the technology of construction can only be handed down from a craftsman to his apprentice. So thousands of years passed away, in China there is only one book is written about architecture, the YING ZAO FA SHI or Treatise on Architectural Methods of the Song Dynasty. This leads to a problem: If there was a war, and it lasted a long time, when the war ended, lots of craftsmen were dead, the technology did not
handed down, how can the common people build their houses? They can only research the house they already have. The old house is made of wood, so the new house is also made of wood.

Although the wooden building has been the mainstream of traditional Chinese architecture, from the Song Dynasty, the timber for the palace building has been scarce. Objective conditions and technical reasons make people give up using timber to build their house.

The wood has many disadvantages. For example, the wood building is vulnerable to fire; It has space problems. Although multistory wooden building have been widespread in the Han Dynasty, the wooden structure is still difficult to meet the high-rise buildings as well as larger and more complex space (extreme examples such as cinemas and stadiums and the like) needs; the construction of traditional wooden buildings. Since ancient times all of the construction methods of various components and details of the wooden building are set. The construction of wooden building on the one hand needs skilled workers, on the other hand it is also more time consuming.
Fig.11. The archaeological site of a stone city Shi Mao in China.
2.2 STONE AND BRICK

Although the ancient Chinese architecture is famous for the wooden building, what is cannot be ignored is the development of masonry of china. The history of masonry of china is very long. There was arcuate tomb of brick in Han Dynasty, and also the domelike tomb of brick appeared. During the Wei Jin Dynasty, people use brick to build some kinds of buildings, such as Buddhist pagoda and the city wall. (Fig.12. Fig.13) Brick and stone materials have many advantages, such as that they have the property of fire resistance and durability, and noise insulation; they also have the higher compressive strength than wood. It is very easy to make bricks; raw material can be taken everywhere. These features should make bricks and stones have a greater role in the ancient architecture of china, but the truth is just the opposite. In the West, bricks and stones can be used to build a magnificent temple and cathedral, but in China, they can only be used to build the crypt, tomb and the platform of houses. (Fig.14.) There are many reasons about this problem.

The first is that ancient Chinese people are lack of awareness for the characteristics of the stone and brick. The modern theory of the strength of masonry thinks that there are three conditions to make masonry to be load-bearing wall and have strength, rigidity and stability. First, the type and size of bricks and stones should be standardized and modularization, in order to ensure the convenience of work. Second, the method of stacking bricks and stones should be scientific to ensure that the brick walls are piled into a stable, solid masonry. And the last, the choice of mortar and its ratio should be suitable. It means that after the solidification and induration of mortar, it should be strength enough to bear the load of the wall. According to the research of China's ancient ruins and tomb unearthed, the first two conditions in the Han Dynasty has been basically solved: the type and size of bricks and stones have been basically finalized in the Eastern Han Dynasty, from the late Eastern Han Dynasty, the principles of masonry bonds of the wall of tomb have improved to that stretcher and header courses alternate regularly on elevation, the perpends of two successive courses are offset by 1/4 to 1/2 of the length of a masonry unit and never coincide. That makes the wall very stable. (Fig.15). The third condition is not resolved until the Qing Dynasty. But the third is the main reason for masonry
damaged. Since the Eastern Zhou Dynasty people began to use adobe, they use clay and mud as mortar until the mid-Qing Dynasty. Although later the technology is improved, they added lime, glutinous rice paste, even egg white, Chinese craftsmen did not realize that they need add the more reinforcing component to make the wall stronger. They turned a blind eye to one of the most common
Fig. 15. Several different ways of masonry bonds. According to Andrea Deplazes’s Constructing Architecture - Materials Processes Structures A Handbook. 2005.
material, sand, and they also did not consider the introduction of lime mortar technology which had been used by foreign counterparts, therefore the masonry was unable to replace the wooden frame as load-bearing walls. Another problem is that people cannot put mortar absolutely uniform in the brick surface, the mortar between the bricks is uneven and that form many fulcrum. When the load of bricks is more than his tensile strength, bricks will crack and the wall will lose of carrying capacity.

The second reason is that the ancient Chinese people are accustomed to using wooden, so they use bricks and stones just like the way they use the wood. The development of the technology of wood not only affects the structure of architecture, but also deepens the aesthetic tendencies of the style of wooden architecture. Therefore a variety of brick and stone buildings imitate wood structure. When they deal with the material of stone and brick, they still use the technology of tenon of wood, which virtually limit the further play of masonry. (Fig. 16.). They do not realize that the stone and brick are not tensile but compressive. But all the other way, Europeans find out this feature and find that the main reasons for the destruction caused by the pressure is uneven surface of brick and stone. So the Greeks and Egyptians use polished way, Romans use lime mortar mixed with sand until later developed a natural concrete, to solve the problem of load cannot be uniformly delivered. Chinese
people limit by their own wooden mindset, fail to observe the characteristics of the stone and brick, so it is difficult for them to develop masonry.

The third reason is the Climate. The climate of the masonry developed areas is different from the southern China, where the summer is very moist. Dry climate in summer is an absolute prerequisite for the development of masonry. For example, in Spain there are many cave house made of stones, until today they still take advantage of it, and when you come in the house, you can forget the heat of Spain and feel cool. However, it will not work in southern china, in such hot and humid climatic condition. Therefore Indoor ventilation is considered to solve this problem. If you also use masonry in southern China in this geographical conditions, it will be very cold in winter and steam condenses into water and mildew in summer. Within the diagram are the monthly average temperature and humidity changes throughout the year in Nanjing, China and Athens. You can see the different climate between the southern china and the masonry developed areas.(Fig.17. Fig.18).

The forth reason is that in the Stone Age, East Asia is lack of the training phase of megaliths, so East Asia becomes a timber building world. The Missing of megaliths in the Stone Age indeed is a missing of a stage of civilization. This is just like that after the sudden intrusion of the Americas by European colonists, the Americas came from the original primitive society into the feudal era and the industrial ages skip the Bronze Age and Iron Age. East Asia is impacted by Western civilization, squeezing the
development of megaliths from the late Paleolithic to the Neolithic era. At this stage, because of the accumulation of knowledge of the feather of stones in millions of years, people can do anything with the stone, and eventually they decided to build houses with stones. But the arrival of the Bronze Age made the people in East Asia rapidly lose their interest in traditional stone technology, put all their energy into a new art – the bronze. This is the reason that in East Asia there is not megaliths like Stonehenge in England and pyramid in Egypt. The technology of the bronze is introduced before the technology of stone developed to the highest peak, this leads to a lack of megalithic buildings, and also leads to the lack of masonry for thousands years. From the point of view of art, when the East Asians just learned openwork carving, the Greeks learned another art: drama. They created the famous giant stone building for the drama: open-air theater.(Fig.19) But at East Asia, there was not this kind of art, so there was not this kind of building of stone.
Construction period

Another reason that in china masonry is not popular is the construction period. In the West, the construction period of cathedral is really long. Usually it lasts for hundreds of years. In ancient china, the longest dynasty is eight hundred years, and for the shortest, it only lasts a few years. If they use stone and brick to build their city, maybe when the dynasty is end, the city is still unfinished. The rulers of the city not only want their cities large enough and luxury, but also want the construction period is short, so the wood is clearly a good choice.
Fig. 20. The ruin of Great Wall of Han Dynasty.
2.3 EARTH

Earth construction techniques have been known for over 9000 years. In dry climatic zones of the world where wood is scarce, people developed this technology to build their houses with mud brick or rammed earth. According to records, “more than a third of the world's population lives in houses, which have been built completely or at least to some part in silt and rammed earth” [2], and in China, until now 20 million people live in underground houses or caves that were dug in the silty loam. Earth is the earliest building material that people used. From the earliest cave living, to live in the house on the ground, mankind has never left this most primitive material. We now have found many examples of earth building made by ancient people. The vaults in the Temple of Ramses II at Gourna of Egypt are built with mud bricks 3200 years ago. Parts of the citadel of Bam in Iran are built earth 2500 years ago. And for China, the evidence of the early use of rammed earth has been seen in Neolithic archaeological sites of the Yangshao and Longshan cultures along the Yellow River in China, dating back to 5000 BCE. “The 4000-year-old Great Wall of China was originally built solely of rammed earth, only a later covering of stones and bricks gave it the appearance of a stone wall.” [3] Earth is used as the building material in all ancient cultures. Up to 40 different earthen building techniques have been used. Just as different the local silt and loam compositions are.

In far north province of Cameroon, we can see a lot of thumb shaped Musgum mud huts; this kind of dwelling was built in a variety of shapes, such as tall domed or conical dwellings or huts, some with a reverse-V shape, and others with geometric designs. Their material is taken from the earth, and no tools are needed – hands, earth and water are enough. “The shape of Musgum is very close to the


Fig. 21. Drawing of a musgum dwelling.

Fig. 22. Cross section of a musgum dwelling.

Fig. 23. Curves and grooves are the language of natural forms. The musgum house follows the profile of shells—the arc of a chain.

Fig. 24. Maintenance of a musgum.

catenary arch, the ideal mathematical form to bear a maximum weight with minimal material. This profile also reduces the pressure effect of the impact of water drops on the walls." [4]

The convex inverted "V" shaped vein on the surface not only firms the durability of the wall, prevent the

wall from the damage caused by rain and dry climate, but also allows people climb up with it to the top of the building to maintain regularly. And it also is a decorative surface of the building. Such a “functional” decorative surface is not the product of the form; it is the mark of the construction.

In this example, material, the most basic composition of the building determines how to build and construct, and then determines the structure of the building on a larger scale. The nature of the material, the detail of the building, as well as the building structure determined by the mechanical properties, the three influence each other, work together, and finally decide the image of the building. (Fig.21. Fig.22. Fig.23. Fig.24)

Different materials have different properties, even for the same materials, if we use it in a different climatic environment and a different culture; it will show us a distinct appearance. The northwest of china is located in inland, far away from the sea, because of the barrier of mountains; ocean warm air is difficult to reach here. So the climate here is drought and low humidity. Most of the climate of Northwest of china belongs to the temperate monsoon climate, so summer and winter are very long, spring and autumn are very short. Summer is very hot and winter is very cold. The climate daily changes dramatically. Therefore, in this region, the main earth building is house cave. The earth that surrounds the indoor space serves as an effective insulator keeping the inside of the structure warm in cold seasons and cool in hot seasons. Consequently, very little heating is required in winter, and in summer, it is as cool as an air-conditioned room. (Fig.25. Fig.26)
But in southern China, FuJian TuLou is the highest point of the development of the rammed earth building. Due to more precipitation, in addition to the special waterproof treatment in the base, TuLou has a huge eave to prevent damage caused by rain. Unlike the scattered layout of buildings in small tribes of Africa, TuLou as a whole defense facility for the village, on one hand it needs to accommodate a large number of resident populations, and organize efficiently the complex social life, on the other hand it needs to resist enemies, maintain a relatively closed façade. Eventually, TuLou develop into a round building, it uses rammed earth outside and wood structure inside. (Fig.27. Fig.28)

Earth has several advantages when it is used as building material. Loam is a widely available, low-cost and sustainable resource, and utilizing it in construction has minimal environmental impact. This makes rammed-earth construction highly affordable and viable for low-income builders. The preparation, transport and handing of loam on site requires only 1% of the energy needed for the production, transport and handing of baked bricks or reinforced concrete. Unbaked loam can be recycled an indefinite number of times over an extremely long period. Old dry loam can be reused after soaking in water. The loam used are typically subsoils low in clay (between 5% and 15%), allowing the topsoil being retained for agricultural use.

Loam is ideal for do-it-yourself construction. Provided the building process is supervised by an experienced individual, earth construction techniques can usually be executed by non-professionals.
Unskilled labor can do most of the necessary work.

Loam stores heat. One of the significant benefits of loam is its high thermal mass. Like brick or concrete construction, it can absorb heat during the day and release it at night. This moderates daily temperature variations and reduces the need for air conditioning and heating. Loam can balance indoor climate. “In climates with hot days and cold nights, where average temperatures lie within the comfort zone (usually 18°C to 27°C), thermal capacity is very important in creating comfortable indoor climates. In diagram 29, the effect of material and building shape on interior climate is shown by readings taken from two test buildings of equal volume constructed in Cairo, Egypt, in 1964. One was built of 50cm-thick earth walls and mud brick vaults, and the other of 10-cm-thick pre-cast concrete elements with a flat roof. While the diurnal variation of the outside temperature was 13°C, the temperature inside the earth house varied only by 4°C; in the concrete house, the variation was 16°C. Thus, the amplitude was four times greater in the concrete house than in the earth house. In the concrete house, temperatures at 4 pm were 5°C higher than outside, whereas inside the earth house, they were 5°C lower than outside temperatures at the same time (Fathy, 1986).” (Fig.29) [5]

Loam balances air humidity. Loam is able to absorb and desorb humidity faster and to a greater extent than any other building material, enabling it to balance indoor climate. Humidity is held between 40% and 60%, the ideal range for asthma sufferers and for the storage of such susceptible items as books.

The material mass and clay allows the building to "breathe" more than concrete structures do, avoiding condensation issues without significant heat loss. “Experiments conducted at the BRL show, for instance, that the first 1.5-cm-thick layer of a mud brick wall is able to absorb about 300 g of water per m² of wall surface in 48 hours if the humidity of the ambient air is suddenly raised from 50% to 80%. However, lime-sandstone and pinewood of the same thickness absorb only about 100 g/m², plaster 26 to 76 g/m², and baked brick only 6 to 30 g/m² in the same period” . (Fig. 30) [6]

But when we look back from the history of the development of vernacular architecture to the modern time, the earth building is undoubtedly absent in contemporary architecture. Architect doesn’t create a contemporary architectural language for this kind of architecture.

“Interest in rammed earth fell after World War II when the costs of modern building materials dropped. Rammed earth was considered substandard, and still meets opposition from many contractors, engineers, and tradesmen who are unfamiliar with earth construction techniques. The prevailing perception that such materials and construction do not fare well in earthquake-prone regions has prevented its use in much of the world. In Chile, for example, rammed earth structures normally cannot receive conventional insurance or even government approval in most cases.” [7]

I have to say that this thinking has some truth. Loam has some disadvantages when compared to common industrialized building materials.

Loam is not a standardized building material. Depending on the site where the loam is dug out, it will be composed of differing amounts and types of clay, silt, sand and aggregates. Therefore, there is no industrial standard can be used in earth building. Now in most areas of Africa and China, the construction of adobe buildings relies on past experience. This makes it difficult for earth building to promote. Loam is not water-resistant. Loam is not like stone or baked brick, it must be sheltered against rain. This limits the area of application of earth buildings. Earth building is not earthquake-resistance, loam mixtures shrink when drying.

If we can solve these problems, we can take advantage of it in future. Due to the different development status of each country and the different natural resource condition, lots country have achieved different research results about the utilization and performance optimization of Earth Construction. France is one of the first countries to carry out research about the modern earth material and construction techniques. Since the beginning of the 1970s, France uses the theory of modern material science, to study the optimization mechanism of earth construction. They have formed a theory that only need to

adjust the compositions of the original loam, without adding any artificial stabilizers, to satisfy the need of construction. It is suitable for most loam types and a variety uses (such as rammed earth walls, mud brick, mortar, adobe decorative materials, etc.). With rammed earth wall, for example, depending on the different composition of the original loam, people can add a certain proportion of sand and gravel to make the mixture similar with concrete. (i.e., the clay of the loam replace cement of concrete). Series of physical and chemical reactions happen because of the powerful tamping (greater than 5Mpa), after drying, rammed earth can reach the intensity of mud bricks.

Another important technique is Compressed Stabilized Earth Block (CSEB). Many countries in Africa as well as South America, India and South Asia have been using a lot this technique. “The loam, raw or stabilized, for a compressed earth block is slightly moistened, poured into a steel press (with or without stabilizers) and then compressed either with a manual or motorized press. The input of loam stabilization allowed people to build higher with thinner walls, which have a much better compressive strength and water resistance.” [8]

The improved earth blocks were made more than 70 kinds of shapes, and they can be used to make load-bearing walls, load-bearing columns, foundations, even beams and other structural parts of the building.

Fig. 32. Building a CEB project in Midland, Texas in August 2006
2.4 CONCLUSION

In fact, if you study the ancient architecture of the West, you will find that they also use a lot of wood, especially when they are readily get it and build the buildings which have nothing to do with eternal life and religion. You can even say that in this way there are similarities in the East and the West, in china, they also widely used stone to build tomb buildings and religious buildings, because stone really is the material not easy to molder. We can also compare the west castles with Chinese cities; they all play the role of defense in ancient times and all use rammed earth and masonry construction. In fact, I think that the construct logic of human beings of different regions is always the same. When the society is underdevelopment, people don’t have the technology to reform the surrounding, so they use the readily available materials to build. But when the society is developed, people tend to use the best and most durable materials.

In the last century, human beings make every effort to pursue economic development; they damage the natural to exchange for their wealth, while some environmental problems have become increasingly prominent and threat to people’s life, they begin to realize the importance of environment. Decades ago people built homes with modern industrial production methods, reinforced concrete box-style buildings spread around the whole world with modernist, replacing regional architecture and the lifestyle integrated with the natural environment. Stereotyped buildings lost characteristics of every culture, and also ignore the natural. In the 21st century, people finally began to pay attention to this issue. People began to be aware of the advantage of the wooden building, masonry and adobe building, and began to study the material property, forms, construction technology and space experience of those kinds of buildings.
3 LOW TECHNICAL CONSTRUCTION SYSTEMS

“Architectural form is the point of contact between mas and space.... Architectural forms, textures, materials, modulation of light and shade, color, all combine to inject a quality or spirit that articulates space. The quality of the architecture will be determined by the skill of the designer in using and relating these elements, both in the interior spaces and in the spaces around building.”

Edmund N. Bacon. The Design of Cities, 1974

The study of the low technology construction sistem of ancient Chinese architecture could help us to understand the Chinese ancient architecture systems better. Unlike the modernist architecture of reinforced concrete, Chinese ancient architecture is self-contained. For different materials, different architectural forms are used and formed their own architectural space.

China is famous for the wooden building; almost all residential buildings preserved today in most parts of the South of china are the wooden structure. Although they also use stone, it is mainly for the foundation of buildings, tombs, towers or bridges. Earth construction had been popular in the whole country, now in the northwest of china, it is still widely used. For the further research of the application of low-tech in Chinese dwelling building, I will introduce the form of the wood frame building and earth construction in this chapter.
3.1 WOOD-FRAME CONSTRUCTION SYSTEMS

China's major building material is wood, others materials, such as stone, brick, clay and tile, are used in some parts of the building. A typical Chinese style building can obviously divide into three sections: the foundation, beam column system and the roof. Most buildings are typically erected on raised platforms as their foundations. Vertical structural beams may rest on raised stone pedestals which occasionally rest on piles. The beam column system between the foundation and roof is made of wood. It use of large structural timbers for primary support of the roof of a building. The roof is usually made of tile, but sometimes it also uses reed and bamboo. Flat roofs are uncommon while gabled roofs are almost omnipresent in traditional Chinese architecture. These three parts can be said to be essential elements of the form of our building. (Fig.33. Fig.34)

Eastern and Western people focus on different part of the building. We all initially lived in shabby wikiup. With this as a starting point, at a later time, the Westerners tend to reinforce the wall, while
Chinese people tend to lift the roof. For the West, the wall of wikiup eventually evolved into majestic stone wall, plays maintenance and support functions. The larger the volume of the house, the thicker the wall, finally it turns into a brilliant facade. The roof is still there of course, but a lot of time it implicitly hides behind the wall. This kind of construction of wall with stones is a typical shell structure. Before the emergence of reinforced concrete, the stone is the best material to build a high building. (Fig.35)

For Chinese, They developed a lightweight supporting technology, wood framing system, carefully lift the entire roof. In addition, we can also see the maintenance function of the wall of wood-frame building slowly subside, the interior and exterior spaces of the building communicate with each other. (Fig.34) Enclose or disperse the building space, these two tendencies constitute two distinct systems in the history of architecture of human beings.

3.1.1 Characteristics of wood frame construction systems
We often use this phenomenon "the wall falls down but the house does not collapse" to describe China's wooden building. In fact, the wall doesn't support the roof; it is the frame consisting of columns and beams. For authentic wooden building, the walls are lightweight to remove or reinstall easily. So when the wall falls down, the house will certainly not collapse.

The framing system is very simple. Wooden timber, usually large trimmed logs, are used as load-bearing columns and lateral beams for framing buildings and supporting the roofs. These beams are connected to each other directly or, in larger and higher class structures, tied indirectly together through the use of brackets. (Fig.36) "Timber frames are typically constructed with joinery and doweling alone, seldom with the use of glue or nails. These types of semi-rigid structural joints allow the timber structure to resist bending and torsion while under high compression. Structural stability is
further ensured through the use of heavy beams and roofs, which weighs the structure down. The lack of glue or nails in joinery, the use of non-rigid support such as dougong, and the use of wood as structural members allow the buildings to slide, flex, and hinge while absorbing shock, vibration, and ground shift from earthquakes without significant damage to its structure." [9]

The biggest difference between the framing system of China and other kinds of support systems is: firstly, the column is used to support the weight so that the wall can only play the role of partition. Secondly, the material of the column is wood, not like in Greece, it was replaced by stone. (Fig37. Fig38.) Such differences make traditional Chinese architecture have the following characteristics in the

appearance. First, the height of the building is limited by the height of wooden timber. Second, even a very stately building, it also present a lightweight appearance. Third, the position of the window and door is unrestricted, the grid can be installed between the column and the column to let the light shining. In fact, before the invention of glass, the interior already has enough light. Due to climate, the area of wall is more than window in northern China, but the south is just the opposite.

These are the characteristics of the framing system; in addition, there are many unique and interesting parts such as the roof and the bucket arch in Chinese ancient buildings. The roof is the most essential part of the building, therefore since ancient times, Chinese people are in constant develop the form of the roof. "Roofs are either built on roof cross-beams or rest directly on vertical structural beams. In higher class construction, roof supporting beams are supported through complex dougong bracketing
Because of the special curved form of the roof, the foreigners have noticed it a long time ago. There are many discussions about it. Some people think that Chinese roof is come from the tent of the nomadic era, and other says it likes bird's wings. Scholars speculate the reason why the Chinese roof is curve; they proposed several explanations, such as this is based on functional consideration, the ancient waterproof material is not perfect, so increasing the slope of the roof can make rainwater discharge speedy. This is the natural phenomena that the building material bends by gravity. This is to make eave large. The wider the eave is, the closer it is to the ground. To prevent rainwater splashing, they fold up the roof at an angle, formed a curved roof. (Fig.41)

Architecture produces in the actual needs, limits to the natural environment, the structural system, as well as the form, are decided by its materials and the surrounding. Perhaps we can look at the roof from this perspective.

“The timber skeleton consists of posts and cross beams rising toward the ridge in diminishing lengths. The purlins-horizontal members that support the rafters- are positioned along the stepped shoulders of the skeleton. The rafters are short, stretching down only from purlin to purlin. By manipulating the heights and widths of the skeleton, a builder can produce a roof of whatever size and curvature are required.” [11]

The timber of this structure is short, so the selection of the timber is very easy and can be built rapidly. Triangular roof structure can be mounted on solid load-bearing walls safely, but for the columns of wood frame, the lateral loading of the roof will cause very serious problems. At the same time it will consume too much material, also limit the width of the roof. The most reasonable approach is to disperse gravity progressively, pass it to the ground through more columns to make the roof wider, while the support structure stabler.

Another feature of Chinese wooden building is Dou Gong. It is translated to the “Bracket System”. The use of the Bracket System first appeared in buildings of the late centuries BC and evolved into a structural network that joined pillars and columns to the frame of the roof. It is the most used component of the entire building, the number of its use has always been used to calculate the amount of construction works. In the Song Dynasty, the Bracket System became the basic module of the building. There are many benefits to build houses with module, for example, it’s easy to calculate the number of building materials, maintain and replace the component in future. (Fig.39. Fig.40)

3.1.2 Several kinds of wood frame construction systems

There are different approaches to build for different wood species, climate and geography. China has 56 nations; each nation has different habits and different cultures, therefore, the development of building types are different. I want to introduce several major wooden architectural construction systems.

1. The Chuan Dou-style architecture.

The Chuan-Dou style (column and tie construction) building is one of the most common historic building types in southwest of china. It consists of a timber frame with continuing posts and mortised beams. The voids of the timber frame are filled up with wattle and daub, brick or plank walls. The diameter of the column and column interval is small. This kind of building has characteristically high ductility and low stiffness. (Fig.43. Fig.44.)

2. The Tai Liang-style architecture

It is also translated as post-and-lintel construction. It is system with a lintel, header, or architrave as the horizontal member over a building void supported at its ends by two vertical columns, pillars, or posts. It is a method to reduce interior column, developed from the Chuan Dou-style architecture. Although the number of columns is small, it requires better quality of columns because of the need of carrying more loads. This structure is popular in the north; it is widely used in the palaces, temples, monasteries
and other large buildings. Sometimes the Tai Liang-style and the Chuan Dou-style are used simultaneously. (Fig.45. Fig.46.)

3. The Jing Gan-style architecture.

The Jing Gan-style (log cabin construction) building is a structure without post and beam. Logs are flattened on the top and bottom and then stacked (usually with butt-and-pass corners). This style requires large amounts of timber, and the position of the window is limited. It is only used in some mountainous regions in the northeast and southwest of China. (Fig.47)
The advantages of those construction systems are quite obvious. When we resume pursuing green building and ecological building, we can carefully study these architectural forms to find out the reason why they can be in harmony with nature. Combining them with modern architectural design methods, we can develop a new vernacular architecture.
Fig. 47. The Jing Gan-style architecture.
The earth is just like wood, it plays an important role in the traditional construction of China. With a history of thousands of years, the earth construction widely distribute around the whole country. In 2011, the Ministry of Housing and Urban-Rural Development carried out the largest sample survey of the status of rural house after the establishment of People’s Republic of China. Different from the point of view that the earth construction is only distributed in the western region where clay resources are rich, the survey shows that in all the provinces the earth is used in rural houses. Especially in the 12 provinces of central and western, the proportion of the earth construction of rural houses is more than 20%, in some areas of Gansu, Yunnan and Tibet, the proportion is even over 60%.(Fig.48)
There are several earth construction techniques: rammed earth, adobe and earth block, cave house and direct forming with wet loam. These types of technologies are all used in the earth construction of China.

3.2.1 Several kinds of earth construction materials

3.2.1.1. Rammed earth.

Fig. 49. Formwork for rammed earth. According to Gernot Minke’s *Building with Earth: Design and Technology of a Sustainable Architecture*. 2009. PP. 52.
On all five continents, rammed earth has been well-known for centuries as a traditional wall construction technique. Temples, mosques, and churches were built of rammed earth throughout the ancient Middle East. In China, the technique was used not just for houses, but even for the Great Wall. In ancient times, the war between various cities and countries are very frequent, a large number of military facilities and walls are built with rammed earth. In the northwest, there are many ancient cities of rammed earth, such as the ancient city of Gaochang and Jiaohe. And also some passes of the Great Wall in northwest. In addition to the wall, rammed earth is also used in the construction of high-platform building. The high platform is used to be the foundation of temple, palace and city. For example, the city of Fuping of Shaanxi is built on a large high platform to improve the safety.

With rammed earth techniques, moist earth is poured into a formwork in layers of to 15cm thick, and then compacted by ramming. The material is compressed iteratively, in batches, gradually building the wall up to the top of the frame. The formwork usually consists of two parallel walls separated and interconnected by spacers. Once a wall is complete, it is strong enough for the frames to be immediately removed. In modern variations of the method, rammed-earth walls are constructed on top of conventional footings or a reinforced concrete slab base. (Fig.49. Fig.50. Fig.51)
3.2.1.2. Adobe and earth block

Fig.52. Making adobes in Ecuador

“Building with earth block is widespread in all hot-dry, subtropical and moderate climates. Earth block buildings dating from 8000 to 6000BC have been found in Turkestan.” [12]

Even today in many regions of Central Africa, people still use adobe and earth block to build houses and public buildings. It is a great technical progress from build with wet loam to build with earth block. It is an innovation of building materials. The emergence of the earth block lays the foundation for the emergence of brick in future.(Fig.52)

Adobes are made either by filling moulds with a pasty loam mixture or by throwing moist lumps of earth into them. And pressed earth block is a building material made primarily from damp soil compressed at high pressure to form blocks. Types of earth block include compressed earth block ( CEB ), compressed stabilized earth block ( CSEB ), and stabilized earth block ( SEB ). We can use adobe and earth block to build a variety of buildings, such as the walls of houses, firewall, stoves, chimneys and many important fortifications.

3.2.1.3 Direct forming with wet loam

Unlike other building materials, wet loam has the capacity to be formed into any shape. Therefore, in many areas, people make the wet loam into various shapes, and build it with the construction method of adobe, it is more flexible, but not stabler than the earth block.

There is a special building type of loam, the cave house. The existing cave houses are closely related to the troglodytism. The technology of digging cave houses is totally different from the construction of rammed earth and earth block. It does not change the natural structure of the soil. Therefore, it requires the property of soil is tough enough to bear the load. (Fig.53)

3.2.2 Several kinds of earth construction systems

Earth construction system means that the construction materials are soil, adobe, mud brick or rammed earth, or the construction form which soil acts as the main load-bearing structure or building envelope. It includes cave houses, other adobe houses and public buildings constructed with adobe material.
(such as walls, castles, granaries, dams, etc.). There are several earth construction systems: The original loam building system, clay-arch structure system and wood and earth construction system.

### 3.2.2.1 The original loam building system

In the original soil building system, all parts of the building structure (foundation, wall, floor, etc.) are made of original soil. Generally they are free-standing buildings cut from soil and hollowed out. We call it architecture by subtraction. The main representative of this type of earth construction in China is the cave dwellings of the Loess Plateau. From the use of the natural caves of cave period to the use of artificial excavation at the present time, cave dwellings have been closely linked with people's lives in Northwest. The topography of Loess area is very complex, according to characteristics of loess, it needs to be very carefully to choose the location before the construction. It's the key to build success.

**Individual cave-dwelling**

The individual cave-dwelling is the basic unit of the courtyard and village of cave houses. It is very important for the cave dwelling design and the research of building technology of soil. It is also a great help to understand the lifestyle and custom of this area. (Fig.54)

The transverse section type of individual cave-dwell is a curved arch based on the mechanical requirements. In general, the span of small cave is 2.4m to 3.3m, medium is 3.6m to 3.9m, large is 4.2m to 4.8m. The depth of small cave is 6.9m to 9m, medium is 7.9m to 9.9m, large is 12m to 16.5m. The height of the dome is 1 time to 1.3 times of the span of the cave. In addition, just like the modern residential building, there are different combinations of individual cave-dwell. (Fig.55. Fig.56)
Fig. 54. The basic plan character of individual cave dwelling

Fig. 55. Façade and section of an individual cave-dwelling
A group of cave-dwelling

Cave-dwellings against hill

It appears in the edge of the hillside. This kind of cave-dwelling must be built along the contour line, therefore, the layout of the cave-dwell is curved or zigzag. It reduces the amount of earthwork, and can be harmony with the environment. (Fig.57)
Subterranean cave-dwelling

Subterranean cave-dwell is located on the area of Loess Plateau without hillside. “It is one of the most radical solutions in the field of shelter is represented by the underground towns and villages in the Chinese loess belt. Loess is silt, transported and deposited by the wind. Because of its great softness and high porosity (45%), it can be easily carved.” Local people dug a square pit, forming an underground courtyard. It takes a second glance to notice that what looks like flat roofs is earth, bare except for a few trees. There is water well in the courtyard to solver the drainage problem.

The plan types of subterranean cave-dwell is varied, it includes type of square, rectangular, oval, round and triangular. (Fig.58)

“The photographs show settlements of the most rigorous, not to say abstract, design near Tongguan. The dark squares in the flat landscape are pits an eighth of an acre in area, or about the size of a tennis court. Their vertical sides are 25 to 30 feet high. L-shaped staircases lead to the apartments below whose rooms are about 30 feet deep and 15 feet wide, and measure about 15 feet to the top of the vaulted ceiling. They are lighted and aired by openings that give onto the courtyard. One may see smoke curling up from the fields, even though there is no house in sight. The dwellings are clean and free of vermin, warm in winter and cool in summer. Not only habitations but factories, schools hotels and government offices are built entirely underground.” [13] (Fig.59. Fig.60)

Fig.59. Fig.60. A view of an underground village near Loyang in northern China.
The entrance of the subterranean cave-dwell is set based on the terrain. There are many types of the entrance. For example, it can be classified as three types in plan, linear type, zigzag type and rotary type; it can be classified as two types from the sectional relationship between the courtyard and the entrance, ramp type and hole type; it also can be classified as three types from the positional relationship between the courtyard and the entrance, outside type, inside type, and middle type. In order to make full use of the space, in some areas they use cellar as the entrance and the space to store things. In some subterranean cave-dwell of Shannxi, the entrance can be used as kitchen in summer. The floor/roof of subterranean cave-dwell has a double function: shelter and crop field. Neither additional air-conditioning nor heating is required, due to natural thermal lag kept in the soil mass. Furthermore, grain from the fields may be dried above ground, and afterwards stored downstairs in the cave dwelling, simply by letting it directly fall into the storage room, through a hole on the floor/roof.

There is also one kind of cave dwelling, it calls separate cave-dwell is a kind of vaulted houses. In some area of Loess Plateau, the height of loess wall is not enough to build a whole cave-dwell. So people retain the bottom of loess as the load bearing wall, construct vaulted roof with adobe and rammed earth in the upper part.
### 3.2.2.2 Clay-arch structure system

The entire structure and building envelope material is loam. Some of them use original loam with processed loam, others only use original loam. The so-called processed loam refers to that the process only change the physical properties, not the nature of loam, such as rammed earth, adobe and mud brick. This type of architecture has been preserved a lot. Some of ruins of ancient city Gaochang and Jiaohe belong to this type of loam building. “This structure demonstrates several advantages in hot and dry climates, especially in areas with a wide range of diurnal temperatures. Given their inherent thermal mass and their greater heights at the center of a space, where light, warm air gathers and can be easily discharged through openings, vaulted spaces provide better natural climatic control than standard cubic ones.” [14]

The clay-arch house uses a centralized layout; the main rooms are concentrated together in the courtyards. The orientation of house is not affected by sunlight, according to each family's economic situation, habits and usage, the layout is very flexible and reasonable. The plan types of clay-arch houses can be summarized as the following two:

**Block form**

This layout is more common in urban and rural areas. According to the terrain, three or more clay-arch houses are planned in line or L-shaped, become the main room of the block.(Fig.62)

**Apartment style**

This layout corresponds to build a long and wide large room beside the block form house. The large room is the main living space.(Fig.63)

The biggest difference between these two types is the location of ancillary buildings. In the block form,

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ancillary buildings are next to the main houses, but in the apartment style, ancillary buildings and the main houses are separated. The main houses include living room, bedroom, storeroom and kitchen. Ancillary houses include utility room and animal house.

Although the structure of the house is clay arch structure, but the arrangement of houses is unrestricted, the direction of the room may be parallel to each other or to be perpendicular to each other. The width of span is from 2.7m to 3.6m, the depth is usually 5 meters.

The clay arch house does not have dome roof. The roof is flat roof and majority don’t have parapet. It’s because they like to sleep in the roof in summer. In addition, many families set the toilet in the roof, they don’t rinse it with water, only bury it with sand. It is used as fertilizer after air-dry. It’s an example that the clay-arch house adapt to the local habits, customs and climate.
Construction technique of clay-arch house

It is similar to the construction of separate cave-dwell. The back wall is the basis of arch; generally it is 1.5m high, 3m-3.6m wide, just the same as the width of span. Note that vaults and domes are built with compressed stabilized earth blocks which are laid in “Free spanning” mode, meaning without formwork. The most important feature of this method is simple and fast.

First build the back wall and the load-bearing wall, and then began to build the vault. People draw a circle on the end wall; the radius is half of the span. Workers stand on staging, stick mud outside the circle and construct adobe form the bottom to the top of the circle. The size of adobe brick is generally 30x16x7 centimeters. The vault was built arch after arch and therefore the courses were laid vertically. After the construction of an adobe brick circle, workers squeeze mud and finger stone to the arch to make it stronger. (Fig.64)

3.2.2.3 Wood and earth construction system.

The characterized of this system is that the load carrying structure and the building envelope are made of loam and wood. This is the most common system of construction. It can take advantage of these two kinds of building materials.
Fig. 64. Construction of a vault with support arch. According to Gernot Minke’s *Building with Earth: Design and Technology of a Sustainable Architecture*, 2009. PP. 124
### 3.3 CONCLUSION

There are many kinds of traditional architectural forms of different building materials in China. Today many of them are already in the edge of being eliminated. Throughout the 20th Century, Western-trained Chinese architects have attempted to combine traditional Chinese architectural forms into modern architecture, with only limited success. Moreover, the pressure for urban development throughout contemporary China required higher speed of construction and higher floor area ratio, which means that in the great cities the demand for traditional Chinese buildings, which are normally less than 3 levels, has declined. The rise of the technology of steel and concrete at that time has changed the face of architecture of the world. The architecture gradually developed from a low-tech era into high-tech era. The emergence of reinforced concrete buildings changes the appearance of architecture, but also caused a lot of problems, the homoplasy of cities is one of them. To solve this problem, we can look to vernacular architecture which has been ignored. The study of the traditional forms and low technology of Chinese architecture can revive people's enthusiasm for the traditional architecture. Maybe the combination of traditional Chinese architectural forms and the design method of modern architecture is the key to solve this situation.
4. LOW TECHNICAL ARCHITECTURAL PHYSICS

The building directly exposes to the natural environment, it is damaged by rain, snow, storm, fire and earthquake. For architecture, the climate is an important environmental factor; it affects the use of material, the forms and the space of buildings. Whether the cave or the vernacular architecture, they all adapt to the climate and the surrounding. It has been recognized that live in caves is harmful to health in the Neolithic Age; the building has developed from the cave of underground to the ground house, the window for ventilation and lighting also appeared.

To the slavery period, the high-platform building of rammed earth enhances the moisture resistance of the ground; the adobe enhances the winter proofing of the external wall; the tile enhances the drainage and waterproofing of the roof. The use of wood frame improves the earthquake resistance of the building, expands the building space. Buildings can be relatively free of set windows, lighting and ventilation is improved, it is an important progress of the development of China's ancient architecture.

For the ventilation, china's ancient architects design it from two sides, the site and layout of the building and the form of the building. In the south, buildings are more built toward southeast; they design a patio in the center of the building, so that between the window and the patio, it can form draught. Doors and windows are the major channel for the ventilation; therefore they create a wide variety of doors and windows to improve the effect of ventilation.

In terms of lighting, Chinese ancient buildings create favorable conditions for the lighting from the design of section; they control the proportion of width and length, the proportion of eaves and height of column in order to achieve the best lighting effects.

There is much low technology adapted in Chinese ancient architecture. In this chapter I will introduce the main low-tech, such as ventilation, lighting, to see how it is adapted and what can we learn from it.
4.1. VENTILATION AND LIGHTING

4.1.1. Ventilation

Ventilation has important significance for good indoor environment of traditional houses. Ventilation includes both the exchange of air to the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. “With an increased awareness of the cost and environmental impacts of energy use, natural ventilation has become an increasingly attractive method for reducing energy use and cost and for providing acceptable indoor environmental quality and maintaining a healthy, comfortable, and productive indoor climate rather than the more prevailing approach of using mechanical ventilation. In favorable climates and buildings types, natural ventilation can be used as an alternative to air-conditioning plants, saving 10%-30% of total energy consumption.” [15]

For the design of ventilation, china's ancient architects design it from two sides, the site and layout of the building and the form of the building.

The site and layout of building

They often choose the site before mountains to build their village, facing the water. It is warmer and much sunny; this will help the formation of thermal nature ventilation. The mountain and a windbreak of evergreen trees can mitigate cold winter winds that tend to come predominantly from the north, the water can keep the wind blowing to the village cooler in summer. The picture shows a common traditional southern Chinese village. The streets composed by traditional courtyard houses are very structured; the streets parallel to wind flow prevails of summer rather than perpendicular to it. In front of

the village are fields and ponds; behind the village are the dense woods and hills. Houses are arranged along the slope from lower to higher. When the wind blows, the cool wind blows to the village along the street. When there is no wind, since the sun shines on the roof of the village, causes a high temperature, the hot air rises, so that the cooler air flows from fields and mountains to the village. (Fig. 65)

**The form of the building**

Wind causes a positive pressure on the windward side and a negative pressure on the leeward side of buildings. To equalize pressure, fresh air will enter any windward opening and be exhausted from any leeward opening. Natural ventilation systems rely on pressure differences to move fresh air through buildings. Most often natural ventilation is assured through operable windows but it can also be achieved through temperature and pressure differences between spaces.
Fig.66. Fig.67. The window in traditional building in Suzhou.

Windows and doors are the main channel for the ventilation of building. The form, position and size have a direct impact on the effect of ventilation. There are lots kinds of windows and doors in the ancient building. For example, as shown in the picture, this kind of window can easy to open and close, it can adjust the area of opening flexibly. (Fig.66. Fig.67). Horizontal window on the door is a special window of ancient building of china. In some buildings doors and windows cannot be opened too high because of construction limitations, so they create this kind of combination of window and door to increase the amount of ventilation and lighting. Such combination may allow air to enter from the door, come out from the top window. Such an arrangement is also found in the cave house. The cave house can only ventilate through the entrance, in order to increasing the ventilation and lighting, usually they use horizontal window. Another common window is the grille window. In the Ming and Qing Dynasties, grille window is widely used in gardens and residential buildings. The traditional building of china often has a courtyard; the use of grille window can promote air circulation between the various courtyards.

There is a special earth house in the northwest of china; the wall and the window are not distinguishing. The wall is built with adobe, between each two adobes there is a slit. The roof is made of wood frame, reed and rammed earth. Area of the room is from 10m2 to 40m2, the height is 3m to 4m. this is used to dry grapes, the ventilation is very good among the adobe building.(Fig.68. Fig.69)
The best design of ventilation is the combination of windows and doors to the patio. In this system warm air in the building can be allowed to rise and flow out upper openings to the outside (stack effect) thus forcing cool outside air to be drawn into the building naturally through openings in the lower areas. The picture shows two kinds of residential buildings of Guangdong province. In the first house, there are two small patios between three rows of buildings, the window and the patio can form draught to bring fresh air into the room. In the second house, there is a corridor in the south, the interior partition walls are all use grille window and door, and they form the stack effect with the window in the stairwell. (Fig.70)
4.1.2. Lighting

The lighting and ventilation are often linked in ancient building of china. The lighting depends on the door and window. In addition, they control the proportion of width and length, the proportion of eaves and height of column in order to achieve the best lighting effects. (Fig.71)

Generally the height of eaves of the south-facing room of traditional residence of north is usually high enough to let the sun light shines into half of the depth of the room in winter. The height of the front eaves and the back eaves are different, the front eaves are higher, which is to let more light can shine into the interior. It is also one of the reasons that the roof of traditional building of china is curved. In addition to the lighting area, the lighting is also related to the reflectivity of the wall. In some residential building of the south, in order to reflect more sun light to the interior, people whitewash the patio and the facade of courtyard with lime to increase their reflectivity (Fig.72)
Fig. 72. High reflectivity of the well.
4.2. HEAT PRESERVATION

People all wish that their house can be warmer in winter and cooler in summer. In winter, they use fire for heating and in summer they use shading device to prevent sun heated the room. Therefore we can consider the heat proof and winter proof together to see what they have done in the traditional residential building.

The heat proof and winter proof of architecture depend on three aspects, building envelope material, building envelope mode and some physical methods.

Building envelope material

Each building envelope material has its own characteristics, strength, density, fire resistance, thermal resistance, etc. Among them the thermal resistance is related to the heat proof and winter proof of architecture. For buildings, the higher the thermal resistance, the better. For the same material, the thicker, the better. The cave house is the representative of this type of building. They are free-standing buildings cut from soil and hollowed out. Neither additional air-conditioning nor heating is required, due to natural thermal lag kept in the soil mass.

Building envelope mode

Sun Control and Shading Device

Well-designed sun control and shading devices can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of building interiors. In the south of china, the ancient architects use a big roof as sun Control and shading device. The big roof is very effective at shading south-facing windows in the summer when sun angles are high, but in winter, when sun angles are low, it will not affect the sun light shine the interior.
4.3. CONCLUSION

In a word, the research of low technical architectural physics can help us to learn how they solve the ecological problem of architecture in ancient time. It can help us to improve our design of our city and create a comfortable living environment.

“We learn that many audacious "primitive" solutions anticipate our cumbersome technology; that many a feature invented in recent years is old hat in vernacular architecture- prefabrication, standardization of building components, flexible and movable structures, and, more especially, floor-heating, air-conditioning, light control, even elevators. Or we may find that long before modern architects envisioned subterranean towns under the optimistic assumption that they may protect us from the dangers of future warfare, such towns existed, and still exist, on more than one continent.” [16]
5. THE PRACTICE OF LOW TECHNICAL ARCHITECTURE

The use of low tech in architecture has been accompanied by human construction activities from the very beginning. Human beings summed up a lot of useful experience during long-term practice of construction. They use a variety of natural forces to achieve their goal for a building: a comfortable place to live.

Build a shelter and refuge against the beast is the primary motivation of human construction activities. People often use local materials which are most likely to achieve from the surrounding, as well as their original technology, to construct their buildings. Due to climatic conditions and geographic factors, the construction method is diverse. Today, there are still a large number of primitive buildings retained in the world. The architect Louis Kahn, when he came back from Africa, once said: “I saw lots of local huts, they are all the same and all easy to use, and there is no architect. I was moved that humans could be so clever to solve the problem caused by the sun and the rain.” There are many simple scientific principles in traditional vernacular architecture, but these are different from modern science, these principles can be achieved easily.

For example, In the Middle East, it is customary to build windcatchers. A windcatcher is a traditional architectural element to create natural ventilation in buildings in the Middle East, where the climate is very hot. A windcatcher can make a house much cooler and more comfortable. It’s open side faces the prevailing wind, thus "catching" it, and brings it down the tower into the heart of the building to maintain air flow, thus cooling the building interior. It does not necessarily cool the air itself, but rather relies on the rate of airflow to provide a cooling effect. When the cool air goes through the interior space, it can absorb heat, and then rise to the outdoors through the inner courtyard due to the chimney effect. In this kind of building, it only uses natural forces, without any mechanical ventilation, relies on traditional low-tech to obtain a good ventilation. (Fig.73. Fig.74)
There are also some examples that use traditional low-tech to improve indoor environmental quality in ancient Chinese traditional houses. We all know that groundwater is always kept at a constant temperature state. The digging of the well is probably the earliest use of groundwater, but mainly in order to solve the drinking water problem. After then they found the nature of a constant temperature state, so they use the well to adjust the indoor temperature. For example, in one of famous garden of Suzhou, The Garden of Cultivation, the master dug a well in the southwest of the meeting hall and added a stone cover. When the hot summer came, he can open the cover to reduce the indoor temperature with the well. It became an air conditioning.

Today, although the human society has entered the high-tech information age, these seemingly primitive low-tech skills still play an active role, this economy, harmony with nature, convenience low-tech, with a clear local characteristic, is receiving more and more attention. Between 1960-70 years, Thousands of Americans choose local materials to build their own houses in low-tech and low-cost way, with non-professional construction. It is called Natural building. Natural building tends to rely on human labor, more than technology. As Michael G. Smith observes, it depends on "local ecology, geology and climate; on the character of the particular building site, and on the needs and personalities of the builders and users." [17]

In addition to relying on natural building materials, the emphasis on the architectural design is heightened. "The orientation of a building, the utilization of local climate and site conditions, the emphasis on natural ventilation through design, fundamentally lessen operational costs and positively impact the environmental." [18]

Until now, there are many architects practice this architectural design principle. In the late 1980s, Matts Mohrman and Judy Cox founded "Out On Bale" in the southwestern United States, is committed to promoting Straw Bale Building. During the same period Ianto Evans and Linda Smiley, inspired by British tradition Cob buildings, founded "the Cob Cottage Company" in Western Oregon. Robert Laporte set up workshops in Iowa to teach the lesson of the combination of the European traditional wooden frame construction with light-clay. Rob and Jaki Roy established "Earthwood Building School" in New York State to teach cordwood masonry and earth-sheltered housing. Architect Nader Khalili founded the center of "Cal-Earth", which is committed to the development of the earthbag construction system. As time goes on, there are two different trends of the development of low-tech architecture between the developed and developing countries. In highly developed areas, people fully enjoy the benefits brought by the development of the society, but also begin to bear the consequences of over-exploitation, therefore some people have started to think about the influence of industrial revolution on the modern life. They choose to use more environmentally friendly materials and technology to build their home. They go back to learn from the nature, return to a nature life. They improved the design of low-tech building to be more sustainable.

But in less developed areas, due to the lack of science, modern technology and money, people are forced to improve their living conditions with natural materials and traditional construction. The natural material, for example, wood, stone and earth, is very cheap, and very easy to get, they use those materials to build for thousands of years, they have accumulated a lot of experience about how to

The primary school of Gando of Diébédo Francis Kéké construct with it, and therefore now there are two kinds of strategy of development of low-tech buildings. The first is full use of local building materials, construction techniques and local labor. The work of the architect is to combine the design of modern architecture with local conditions. They improve the construction technique, use modern design to improve the living environment of local people. This situation mainly occurs in Africa and Asia. Now more and more architects go to there to practice their design. Combining local solutions with the most appropriate Western ideas, solving the problem with the low tech building, among them the most famous architect is Diébédo Francis Kéké. He is a German-trained architect from the small African village of Gando in Burkina Faso. In the system of architecture of Francis Kere, he focuses on the use of traditional materials and techniques and the participation of local people. His goal is to make his hometown to be educated. "Help to self-help" is his basic philosophy. His modernism of clay is a good combination of traditional construction, modern technology and local building materials. (Fig.75)

Similar design and works also appeared in under developed areas of China. In the Loess Plateau region, several Hong Kong architects had accomplished one project: Maosi Ecological Demonstration Primary School. This is practical study of ecological architecture based on traditional construction technology. "The project of "Maosi Ecological Demonstration Primary School" contributes a significant
study. Meanwhile, they demonstrate one feasible way to charitableness for the poor rural region.” [19](Fig.76).

The second is that architects use modern building materials to design their works, but they treat the new material as old material, with which the local people are familiar. The construction is simplified through professional design. People can build the house themselves using hand tools under professional technical guidance, which will significantly reduce the cost of labor. The system of Architect's design is an open system; the owner can adjust the size and space of the building according to their actual needs. We can see this strategy in the project Quinta Monroy Housing of Alejandro Aravena. “We had to work within the framework of the current Housing Policy, using a US$ 7,500 subsidy with which we had to pay for the land, the infrastructure and the architecture. Considering the current values in the Chilean building industry, US$ 7,500 allows for just around 30 sqm of built space.” [20]


Therefore, to settle the 100 families of the Quinta Monroy in 5,000 sqm, the architect rebuilt the structure and 50% of each unit’s volume, the other 50% will eventually be self-built. This design method solved the lack of capital and land, and also made the owner have a voice in the update of the community. (Fig.77)

Another architect that I appreciate, Hsieh Ying Chun, carries out this strategy more exhaustively. Hsieh Ying Chun is a Taiwanese architect, who has deployed his talents in rebuilding their houses in rural areas where have been decimated by earthquake for over a decade. “Hsieh Ying Chun Architects & People’s Steel have been a leading force in developing and promoting sustainable lightweight steel
houses in rural & ethnic areas since 1999”. [21]

He develops simplified building techniques based on earthquake-safe steel-frame structures, the lightweight steel structure, which can be adapted to all over the world from the remote villages of China to the sufferers of the South East Asian Tsunami. “They combined traditional construction techniques with 'new' technology, such as bamboo screens covered in a thin layer of cement, to make spaces appropriate to the community's involved.” [22](Fig. 78)

I will introduce the practice of Francis Kere and The project of “Maosi Ecological Demonstration Primary School in this chapter to analyze the strategy of combining the design of modern architecture with local conditions.

5.1. THE PRACTICE OF LOW TECHNICAL ARCHITECTURE OF DIEBEDO FRANCIS KERE

5.1.1. Diébédo Francis Kéré

Africa is the world's most underdeveloped regions, but since the independence of most African countries in 1960, African countries embarked on the path of independent development. Now Africa is a place of rapid decline in poverty, increasing investment, and young populations. “It seems only fair that Africa’s rich cultures and growing population (predicted to reach 1.4 billion by 2025) finally take the stage, but it's crucially important that Africa’s future development is done right.” [23]

More and more African architect began to practice in Africa. Combining local solutions with the most appropriate Western ideas, solve the problem with the low tech building, the most famous architects in Africa is Diébédo Francis Kéré.(Fig.79)

Diébédo Francis Kéré is a German-trained architect from the small African village of Gando in Burkina Faso. As the first son of the leader of his village, he was the only child allowed to attend school. After

excelling in his studies, he worked as a carpenter and Kéré received a scholarship of "Carl Duisberg Gesellschaft" for a practice in Germany. He then attended the Faculty of Architecture of the Technical University of Berlin, where he earned his degree in architecture and engineering. In 1998 he created the Schulbausteine für Gando association with the aim of supporting the development of their country, combining the knowledge gained in Europe with typical construction methods of Burkina Faso. In 2004 he founded his own architecture office, Kéré Architecture, based in Berlin. He has won many awards, for example, "the Aga Khan Award for Architecture", "the Global Award for Sustainable Architecture", "the BSI Swiss Architectural Award", "the Marcus Prize", "the Global Holcim Gold Award" and "the Schelling Architecture Award ".

5.1.2. The concept of design of Diébédo Francis Kéré

While still a student, he established his charitable foundation Kéré Schulbausteine für Gando (Bricks for Gando) in 1998. He began to raise money to build a school in his hometown. Despite the financial and logistical challenges, Kéré put his focus toward reinvesting his knowledge back to his communities in Burkina Faso. Using his formal training as an architect, he developed innovative strategies for building by combining traditional construction techniques of Burkina Faso and materials with methods of modern architecture. For the realization of its objective, Francis Kéré closely associated with the community, demonstrating to them the possibility and potential of innovation that could benefit its people in the coming years.

Now his projects locate throughout the whole world, the idea of his work is that "se basa en el respeto de las estrategias climáticas- tanto en edificación como en urbanismo- integrando en sus propuestas mano de obra y técnicas constructivas locales, así como materiales sostenibles". [24]

24. APUNTES DEL FORO Segunda Edición Abierta. Foro para la Edificación Sostenible Comunitat Valenciana
So his buildings are different with the buildings in developed countries. In the twentieth century, with the development of society, reinforced concrete as a building material started to applicate in urban construction. In 1903, the residential building in the Rue Franklin, Auguste Perret used the first time the structure of reinforced concrete as supporting structure. (Fig. 80) This is the beginning of modern architecture, and has a great influence on the later of the modern architecture of Corbusier. Since then, the foundation of modern urban construction is the use of reinforced concrete. This model of
development of the city is suitable for developed countries; they have the technical and economic to build a world of concrete. But if this development model is extrapolated to another context, such as the African, in the case of Burkina Faso, the homeland of Diébédo architect Francis Kéré, a country where 80% of the population is illiterate, a country that is one of the poorest countries in the world, the question is whether to follow the same path as in a developed country, or to have to change strategy emerges.

In the practice of Diébédo Francis Kéré, he chooses a sustainable path. In the country which has not yet industrialized, unfriendly construction methods, such as reinforced concrete and brick, have not yet begun. In the system of building Kéré, the use of concrete beam and adobe is a method of low industrialization. Use of clay as building material, first it is very cheap, second, it can be produced locally, it is traditional building material, people familiar with its properties, it is very easy to build, and for locals, it is very easy to learn the construction technology.

The association "Bricks for the school of Gando" is committed to the training of locals. They build schools and other buildings through their hands, with the aim of acquiring technology of construction. Through doing it, they not only get a new construction technology that can be applied to the construction of their new homes, but also get a skill that helps them to find a job. In this impoverished country, the important thing is not to build a school or a few houses for the people, but to teach them how to use traditional materials and construction technologies to solve urban problems.

In the architecture system of Francis Kere, it focuses on the use of traditional materials and techniques and the participation of local people. His goal is to make his hometown to be educated. "Help to self-help" is his basic philosophy. "People are the foundation of each piece of work." He says. (Fig.81. Fig.82)
Fig. 81. Architects work with local people

Fig. 82. Architects work with local people
5.1.3. Several projects of Kéré

Most of its projects are in his country. Some projects which can reflect his idea are in his village, Gando. Gando, where Kéré grew up, is a typical rural village in West Africa. Now the architect has design an primary school, the house for teachers, an extension of the school, a sports field, and a library which is at the corner of the school and the extension.

Primary school/ Gando / Burkina Faso

With a population of 3,000 inhabitants, Gando is a small village in the southern plains of Burkina Faso, located 200 kilometers far away from Ouagadougou, the capital of the country. In Gando, the villagers still live in small mud huts with thatched roofs, and there is no access to electricity or running water. In 2011, according to the Development Index of the UN, the lack of education, low income and life expectancy means that Burkina Faso is the seventh least developed country in the world.

In 1998, Francis Kéré Diébédo, started the construction of a school. In the country of Burkina Faso, 80% of the population is illiterate; it is one of the poorest countries in the world, with an income of $1,200 annually. Due to the poor infrastructure, it is not easy to access school, and it is also a very painful thing that has class in an original school, because in this country it is very hot, the original school is like an oven during the day. Therefore, the architect must solve these problems.

Kere has considered all design factors for this project, such as climate, cost, resource availability, and construction feasibility. At last he chooses the clay/mud hybrid construction for the school. Clay is abundantly available in the region, and is traditionally used in the construction of housing. Heat-resistant properties of the clay is very good, it provides thermal protection against the hot climate. "Concrete buildings are not well suited to the climate in Burkina Faso, as the interior becomes intolerably hot, making it difficult for pupils to concentrate." The clay is processed with modern method of construction in order to create a more structurally robust construction in the form of bricks. But
Fig. 83. Primary school of Gando
Fig. 84. Classroom of Primary school
Fig. 85. The roof of Primary school
Fig. 86. Heat exchange of Primary school
villagers were concerned that a mud brick construction would not survive the rain season. Therefore the architect needs to provide a solution to solve this problem. He uses a wide, raised tin roof to protect the walls from the rain, at the same time it allows air to circulate underneath in order to keep the building cool. “The roof of the Primary School was pulled away from the learning space of the interior though, and a perforated clay ceiling with ample ventilation was introduced. This dry-stacked brick ceiling allows for maximum ventilation, pulling cool air in from the interior windows and releasing hot air out through the perforated ceiling.” [25] (Fig.83. 84. 85.86)

The entire population of Gando took part in the construction of the school. Traditionally, all members of the whole village work together to build and repair their houses. They were trained in low-tech and sustainable construction techniques which they can use to find jobs in future. Women prepared the floor while the men pressed earth for the brick walls and children collected stones for the foundations. More and more people are trained, so the new cultural and educational projects were constructed.

School Extension / Gando / Burkina Faso

The capacity of the primary school built in 2001 soon became too small to meet the rapidly increasing demands. The building had been designed to accommodate 120 students, but by 2007 the number of pupils had reached 300. Therefore an extension was needed to meet the need of the village. Like its predecessor, the extension is also built with hand-made compressed stabilized earth blocks. “Los muros se construyeron de acuerdo a la tradición local pero, en vez de recurrir al adobe (que tras la temporada de lluvias queda muy dañado y debe repararse), se optó por utilizar ladrillos fabricados in situ por la propia comunidad. Con estos ladrillos se erigieron los muros de carga del edificio (una estructura que se complementó con vigas perimetrales de hormigón armado) y se resolvieron asimismo las bóvedas tabicadas que cubren las aulas (otra referencia a la tradición).” [26]

26. The Architect is Present
Fig. 87. The school extension of Gando
Fig. 88. Classroom of school extension
Fig. 89. The roof of school extension
Fig. 90. Heat exchange of school extension.
As same as the primary school, the extension school also uses a big overhanging tin roof to protect the wall and bricks from the rain and sun. But the difference is that the first primary school uses a flat roof, but the extension school uses a rounded vault roof. Cooling breezes circulate through the shutters and hot air is drawn up through the vaulted ceiling and dissipated into the roof space through the stack effect. The vault roof has better ventilation than the flat roof. (Fig.87.88.89.90.91)

**School library / Ganado / Burkina Faso**

Another interesting project of Kere is the School Library, in the library he also chooses bricks for the building material, but for the roof, he chooses a widely-recognized handicraft--locally produced earthenware pots. The clay pots were sawed in half and then cast into the ceiling. These circular openings create a playful pattern and introduce natural light and passive ventilation in the interior spaces. (Fig.92.93.94.95)
Fig.92. Women with clay pots
Fig.93. The roof
Fig.94. Constructional process.
Fig.95. The indoor of library
In another project, teacher’s housing, he chooses to build a vault roof with stabilized earth blocks. This construction method previously is never heard before in this region. “En Burkina Faso, no existe normativa de edificación que garantice unos márgenes de seguridad estructural en las nuevas construcciones. Para que la gente confíe en que las estructuras resisten hay que probarlas. La mejor forma es subir a ellas, y demostrar que funcionan.” This is the status of work of Dièbédo Francis Kéré. In this project, the villagers climbed up to top of the dome to demonstrate the strength of the structure. Interestingly, this project is similar with China’s Clay-arch structure system, and the feature of the dry-grapes houses.

In a word, Kéré’s clay modernism is a good combination of traditional construction, modern technology and local building materials. During the construction process, machines are rare used; the people involved can learn construction skills. “El proyecto de Gando siempre estuvo conectado al entrenamiento de la gente, porque deseo que el día que me desgaste y muera, al menos una persona de Gando continúe haciendo este trabajo. Y mi pueblo ahora puede usar sus habilidades para ganar dinero por sí mismo.” So the future of his method of construction is not only building a few schools for locals, but also is a system of building in future in his country, even in Africa.
Fig. 96. Overview of the Maosi Ecological Demonstration Primary School
5.2. THE PRACTICE OF LOW TECHNICAL ARCHITECTURE OF EDWARD NG YAN YUNG AND MU JUN

5.2.1. The background

Maosi Ecological Demonstration Primary School is located in the village of Maosi in the Loess Plateau region of West China. “In the past, classes had been conducted in dark caves located a long distance from the children’s homes, requiring children to walk for an arduous two hours to reach school. The conditions in the caves were cramped and overcrowded and there was danger of the caves collapsing. To address the need for schools nearby, the government had provided new school buildings built of concrete and brick, but these buildings did not perform well in the extreme climatic conditions, with the result that they were too hot when the weather was warm and were very cold in winter.” [27](Fig.97).
So the architects decided to design a new primary school in the village.

Due to limited resources, extreme climatic conditions, soil erosion and other factors, it is one of the poorest regions in China especially in rural areas. For thousands of years, local residents have learned how to adapt to the nature and take advantage of the nature to build their house. The representative building of this area is cave dwelling building. But in recent years, with the change of habits, these local traditional construction technologies have gradually been abandoned. Lots of buildings built with brick and concrete appear. But subject to the limited resources, economy and construction technology, those self-built buildings cannot fit in with extreme climatic conditions, therefore it not only cannot provide a truly comfortable living environment, but also exacerbates the deterioration and pollution because of the use of modern material. In the past, the government provided a new school buildings built of concrete and brick for children, but these buildings did not perform well in the extreme climatic conditions, with the result that they were too hot when the weather was warm and were too cold in winter. But those problems can be solved perfectly in traditional

27. UNESCO Asia-Pacific Awards for Cultural Heritage Conservation
building of this area. Earthen architecture has been the method of construction for buildings for a long time in the Loess Plateau region. Local people have used earth and mud to create dwellings and other buildings for centuries. Earth is a widely available, low-cost and sustainable resource, and utilizing it in construction has minimal environmental impact. So the architect decided to build the primary school with earth in a sustainable manner, hoped to improve these poor conditions and meet the children’s need for a comfortable learning environment.

5.2.2. Design and Methodology

The project aims to explore an ecological construction mode under limited economic and resources in this area, and can play a positive exemplary and guiding role for the construction of villagers. “Condition analyses in economy and resource for building, climate, and vernacular architecture deduce that thermal design for this region is the most effective approach towards ecological architecture”. [28]
Based on the theory of ecological architecture and the local condition, the design principles of this project can be summarized as follows:

**Minimum embodied energy.** As far as possible to avoid the use of high energy-consuming, high polluting materials, such as brick and cement. Reduce the energy consumption and pollution during the construction. For the school building, it should decrease the energy consumption the whole year on the premise of a comfortable indoor environment.

**Use natural energy resource.** To reduce the consumption of fossil fuel, such as coal, oil and natural gas, the school building should use natural energy(solar and wind) as far as possible.

**Use local materials; reduce the damage to the surrounding.** On the one hand, the building should conform to the terrain, avoid excessive dig to the original site; on the other hand, use the local renewable material as much as possible.

**Low cost and ease of construction.** Use and improve local traditional construction techniques and local material to minimize the construction cost. The construction technique should be simple enough for the local people to handle it in order that they can build their own house.

### 5.2.2.1. Local traditional construction techniques and materials

Over the past thousands of years, earth has been widely used as the main building material in the traditional building in the region of the Loess Plateau. It forms traditional vernacular architecture of this area, the adobe building. Adobe building of the Loess Plateau has some advantages, such as it is simple to construct and is very cheap. “Mud bricks are easy to make and can be produced by compressing wet earth in wood moulds. No chemicals or heating are required in the process, nor does the manufacture of mud bricks result in atmospheric pollution. The materials can also be reused both for new buildings and as an additive for croplands.” [29]

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29. UNESCO Asia-Pacific Awards for Cultural Heritage Conservation
So far, local villagers still maintain the tradition of self-construction of their own houses: the owner collects and prepares all materials for the construction, and then he invites some friends and relatives to help him to make adobe or dig the cave, finally they build house together. After long-term accumulation of experience of construction, locals know that each material has its own specific features and construction techniques. For example, compact damp loess into a block in the mold, and after about 40 days, the block gets dry and strong, it will become the main envelope material of the building—the adobe brick.

For example: A damp loess compaction into a block in the mold, after about 40 days to dry, it will become the main material envelope structure - adobe brick. The wheat straw mud can either be used as part of the adobe brick, or be used as the surface layer of the wall, the straw in the mud can be effective against the crack of the adobe brick. Given its good characteristics of resist compression and moisture proof, the stone has been used for the foundation. All of these materials are local materials and can get easily; the cost is also extremely low. More importantly, compared with brick and concrete, the adobe brick has superior thermal properties and provides a flexible building form that adapts well to the surrounding landscape, and the cost is only 1/15 of concrete, 1/3 of brick. This performance makes that the adobe building can be effective against both the outdoor weather changes in cold winter and hot summer, it only requires a little fuel to keep a comfortable indoor environment. Overall, compared with conventional construction techniques based on reinforced concrete, the construction technique with adobe and other natural material has the advantage of low cost, non-polluting, low energy consumption and simple construction, it is an ideal construction technique and it is worth to be refined and used in the practice of low-tech building in the region of Loess Plateau.

5.2.2.2. The combination of traditional low-tech architecture with modern design.

The objective of this project is to build a school for approximately 400 students to replace four existing primary schools located in the village of Maosi. The school needed ten classrooms and twelve offices for the teaching staff as well as restrooms, playgrounds and other facilities. Following the topography,
Fig.98. Drawings of site plan

Fig.99. Playground
Fig. 100. Interior view of the classroom

Fig. 101. Partial view of the internal
10 classrooms are planned into 5 units at two levels. (Fig.98). This is not only that helps to maximise daylight and solar heating for the winter, but also can increase natural ventilation in summer, and reduce the impact caused by the north wind in winter. “A tree-based landscape helps to create a desirable campus for children. The classroom form is derived from local traditional houses with timber structures so as to be constructed easily by villagers. Thermal mass and insulation are employed in the forms of mud - brick walls, insulated traditional roof, double - glazed windows, etc. The semi - buried form at the north side together with the direct - gain mode of passive solar system can further upgrade the thermal performance.” [30](Fig.99,100,101,102)

30. Maosi Ecological Demonstration Primary School, Department of Architecture, The Chinese University of Hong Kong
The project relied on a balance between traditional and contemporary construction techniques. For example, architects designed a new light-weight roof, they improved the traditional single slop roof of the local earthen housing in the new school building. They used a light steel structure and polystyrene insulation combined with traditional timber purlins and straw to block solar heat in summer and reduce the heat loss in winter. Another example of contemporary additions was the newly-designed angled openings for the windows, through it daylight can be maximized into the indoor space.

5.2.3. The construction of low-tech architecture.

The construction of Maosi ecological demonstration primary school references local traditional model of construction. All workers are skilled craftsmen of the village and the surrounding area. Since the technology of construction is simple enough, during the construction it did not need large machine. In addition to the excavator which is used to dig the foundation, all the tools are commonly used in rural areas, such as shovels, mould of adobe brick and handsaw. The construction inherited the local traditional means. Therefore, the energy consumption and pollution of the entire construction is far lower than it in conventional construction. At the same time, in addition to a small amount of steel frame and glass, all adobe products and materials are locally. “Instead of buying and using cheaper factory made red tiles, we told the village head to go around to the homes of villagers to collect and buy un-used roof tiles to be recycled. Due to the involvement of these natural materials, little waste was generated during construction, Off-cuts were recycled back into construction, for example off-cuts rafter reused for children’s facilities, spare mud bricks mixed with straw mud for plaster. The construction has almost no environmental impact.” [31] (Fig.103.104.105.106)

31. Maosi Ecological Demonstration Primary School, Department of Architecture, The Chinese University of Hong Kong
Fig. 103. The construction of adobe
Fig. 104. The structure of roof
Fig. 105. The structure of roof.
Fig. 106. The construction of roof
5.2.4. Conclusion

The construction of the new school was completed in summer 2007. The construction cost is around 50 €/m², far cheaper than local conventional school building which is made of bricks and concrete. “The new school has been used by children and teachers since September 2007. According to field measurements last year, the indoor air temperature of new classrooms is always stable, cool in summer and warm in winter. Even in the uncommonly cold weather of last winter, the indoor ambience could still reach an acceptable level of thermal comfort with fresh air, without needing coal for heating.” [32]

“Our winter is extremely cold. But in this new school, not a single piece of coal was burnt to keep warm. We can save the money for books.” the school master said. It is a good example of the combination of low-tech architecture with modern design. The most important point is that the villagers can rethink and re-understand their own traditional construction “The school illustrates to the locals a feasible way towards an ecological architecture suited for the conditions of China’s Loess Plateau region. In this way, by selectively employing their familiar techniques and materials the villagers can easily build themselves their most effective and affordable ecological.” [33] Therefore this project and the practice of Francis Kere illustrate totally the strategy of full use of local building materials, construction techniques and local labor. They combine the design of modern architecture with local conditions. They improve the construction technique, use modern design to improve the living environment of local people. They are all successful.

32. Maosi Ecological Demonstration Primary School, Department of Architecture, The Chinese University of Hong Kong
33. Xi Fang, THE MAOSI ECOLOGICAL PRIMARY SCHOOL IN WEST CHINA
6 CONCLUSION

The concept of sustainable development was put forward since the last century seventy's, people pay more attention to the relationship between human and nature. Natural environment not only affects people’s way of life, but also deeply affects the future of human society development. However, even if the natural environment has got the attention of people alter decades of social development, but the deterioration of the environment news has never stopped. To realize the sustainable development of human society, people should not only concern about the future and technical measures, at the same time pay attention to the history, according to the reality of social conditions, combine geographical environment and social culture, create the ecological strategy, consisted with local sustainable development.

Low carbon and ecological architecture is the development direction of architecture industry in the future. China has a vast territory, the geographical environment in different places has the very big difference, so the development of ecological construction has different requirements in different places. The formation and development of traditional buildings are the results of local people adapt to the local climate and natural environment, which rich ecological construction experience has a great reference on the development of local ecological construction. Modern science and technology is more and more developed, we can be able to re-examine traditional buildings in dealing with the relationship between man and nature in terms of ingenious with new vision, get inspiration and create the ecological architecture, consisted with the local environment and the characteristics of regional culture.

I hope that by the study of low-tech construction systems of traditional architecture, and the combination of low-tech with modern design, I can find out a new way of modern architectural design.
NOTES.

24. APUNTES DEL FORO Segunda Edición Abierta. Foro para la Edificación Sostenible Comunitat Valenciana
26. The Architect is Present
27. UNESCO Asia-Pacific Awards for Cultural Heritage Conservation
28. *Maosi Ecological Demonstration Primary School,* Department of Architecture, The Chinese University of Hong Kong
29. UNESCO Asia-Pacific Awards for Cultural Heritage Conservation
30. *Maosi Ecological Demonstration Primary School,* Department of Architecture, The Chinese University of Hong Kong
31. *Maosi Ecological Demonstration Primary School,* Department of Architecture, The Chinese University of Hong Kong
32. *Maosi Ecological Demonstration Primary School,* Department of Architecture, The Chinese University of Hong Kong
33. Xi Fang, *THE MAOSI ECOLOGICAL PRIMARY SCHOOL IN WEST CHINA*
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