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Fermanto Lianto<sup>1</sup>

## ABSTRACT

Chinese architecture from time to time show a rapid growth, in the past times they used a wooden structure system and based on a local culture tradition to show aesthetics, value and nature but in the present times they begin to shift towards by modern technology, more creative, "free" and "unusual" forms, out of the structures system paradigms as seen as in the Central Chinese Television building, National swimming center, the Beijing Olympic stadium and many others.

**Keywords:** Geometric, Paradigms, Skeleton structures, Cantilever structures, Long span structures.

# INTRODUCTION

Chinese architecture in the past focused on architecture building with wooden structure system, which is show ethics, aesthetics, value and nature. The main characteristic of Chinese art building is based on the idea that based on local culture traditions of power and strict to hierarchy. Building groups prioritize spatial designs of homes with yards, symmetrical central pivot, balance, respect for nature, pay attention to the harmony with nature, and high aesthetic value.

The Chinese architecture continues to progress very rapidly, in technology and building materials that are able to realize the dreams of architects, primarily buildings with "not common" shapes, so that their design is much more creative and "free" with the concepts "that seem" do not follow the rules of the common structure systems to develop building designs with a very innovative, out of the paradigm of the existing structure systems of the building forms to break the limited of the geometric "rules".

## SOME CHARACTERS OF CHINESE ARCHITECTURE<sup>[1]</sup>

In the book written by Djin Su Gin (1964), it is explained that the character of Chinese architecture can be seen at:

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- 1. Layout pattern, the layout patterns of a building and the environment is a reflection of the harmony with nature. Confucianisme is manifested in the form of balance and harmony to the dual concept. The balance between formal and non-formal. Formality is achieved with a sketch of the house or the laying of a symmetrical building. Non-formality is achieved in the dynamic and asymmetric arrangement of the garden. Both form a balanced and harmonious unity.
- **2.** The existence of the stage and the front terrace/balcony, stage and front terrace/balcony is used as a transitional room.
- **3. Building structure system,** the structure system is a typical frame system and the main structure to supports the weight load of the roof. The weight supported routed through the columns of the main structure. The series of column and beam system is a specific thing. Generally, building structure system is made of a wooden frame structure, the frame receives roof weight load and are passed down through the columns. Doors and windows are just a filler, therefore it will be flexible, while the doors and windows on the patio use the system Removable (knock down).

Roof structure system is a typical Chinese architecture, the rectangular easel. The top floor is generally planks floors supported by beams. Concrete slab is also used for lisplank and roof. Moving weight load and dead load received by the floor is forwarded to wall and to the foundation. All proportion and rules depends on standard systems of wooden dimension and standard division.

The buildings in Chinese are generally designed in modules and standard modular of absolute variable size, correct proportions properly protect and maintain harmonious relationship regardless of the magnitude of the structure.

- 4. **Tou-Kung,** the part of front roof construction is a typical form of Chinese architecture and its uniqueness, is called tou-kung. It is a buffer system console cantilever patio section so that its presence can be seen from the outside. Tou-Kung ornaments will be clearly visible on the palace buildings, temples or places of worship and houses of a rich family. Beam ends are decorated with lion heads that serve to counter the influence of evil spirits.
- **5. Roof forms,** there are several types of roofs, tien wu, Han Hsieh, hsuah Ngang shan han and ti. Archaeological study explains that there're two kinds of wooden structures that make a huge difference in the placement of columns and roof support system differences. Two earlier construction systems are Tai Liang and Chuan Dou.

The structure of these two systems, according to archaeologists, was originated from two ways to build homes. Tai Liang was originated from primitive caves that weredeveloped in North Chinese and Chuan Dou came from a house on a tree (Knapp, 1986: 6-7). Tai Liang structural system is a system of columns and beams where the lowest beam is placed on the column to the width of the building. The second structural system is called Chuan Dou. This system has columns established towards each other tranvesaly and connected to each other.

6. The color, the color in Chinese architecture is also very important because certain types of colors symbolize certain things. This relates to beliefs associated with good and bad orientation. The basic principle is to harmonize the color composition that supports the beauty of its architecture.

Commonly used colors are the primary colors like yellow, blue, white, red and black that are always associated with natural elements such as water, wood, fire, metal and earth. White and blue colors are used for the patio, red for columns and buildings, blue and green for the beam, elbow support, and roof.

The colors here give a special meaning, blue and green are in a east position and gives the sense of peace and timelessness, the red color is in the south and gives the sense of happiness and good fortune, while the yellow color symbolizes power, wealth, and power. White color is in the west with the meaning of suffering and peace. Black color is in the north that symbolizes destruction.

These colors include:

- a. The red color symbolizes happiness.
- b. The yellow color symbolizes happiness and glory.
- c. The green color symbolizes prosperity, health, and harmony.
- d. The white color symbolizes death and mourning.
- e. Black is a neutral color and is used in everyday life, and
- f. Dark blue is also the color of mourning.
- 7. Gate, Gih Djin Su categorizes the gate as the characteristic Chinese architecture, especially residential buildings. The gate is usually dealing directly with road facing south (good and bad orientation). The gate serves as a transitional space between the outside of the building and the inside of the building. At the gates are usually installed occupant identification and also images of gods or characters in Chinese Myth or writings that serve as a repellent from bad lucks.
- 8. Details of balconies, balcony detail or winds typically use artificial forms or shapes of chrysanthemums or tortoises, with the meaning of longevity.

# STRUCTURAL SYSTEMS OF CHINESE ARCHITECTURAL BUILDINGS IN THE PAST TIMES.

- 1. Wood frame structure system: this structure system has been domination since 2,000 years ago and there were 2 (two) rules (regulation or standard) on the wooden construction system developed specifically for the carpenters at that time, the Ying-tsao fa-shih (building standard) in the Sung Dynasty in 1103, which was renewed by Ch'eng Kung-tso-fa-fa tse tse-li (structural regulation) in the Ching Dynasty in 1734 (A Historical Pictorical History of Chinese Architecture Liang Shu-Ch'ng in 1984).
- 2. Multilevel structure beam system: This structure system is formed from the columns of the building that stands on the foundation by placing beams across the top in a certain size. Small pole are placed on top of the beam, by adding several beams on top. Wooden frame is structured in layers until the roof top. The parallel beam system is connected to a square beam and a round pole (bamboo) that lie at the end of the beams crossings on the pole, which is called gording system. While rafters are laid in accordance with specified size and location on the gording. Two wooden frames, which are joined together and supported by four columns, the system is called "trave" system, and is the most basic system of structures and construction of Chinese buildings.

Wooden material for building structures such as poles with 'tou-kung' system gives the freedom to evolve in different directions.



Figure 1. Example of 'Tou-kung' system.



The main features that the wooden beams frame system of Chinese architecture lies in the structure that can be developed in many directions with no restrictions.

Figure 2. Examples of logs systems that can be developed into various directions.



Figure 3. Examples of building system with wooden blocks that can be developed into various directions <sup>[7]</sup>



Figure 4. Longhua Pagoda in Shanghai, Sample Building with wood beam system that can be developed into various directions <sup>[8]</sup>

Poles have a crown as called as pole bracket (dou-gong), round or four sides, and consist of 5 kinds:

- a. Roof pole
- b. Pole of gold (golden post)
- c. Inside pole
- d. The center pole
- e. A short pole.

Poles are generally protected with plaster made from lime fibers which are painted with different colors or are varnish.

In Chinese architecture, especially for the sacred buildings, the roof is one of the components of the architecture that gets the attention. The shapes of the roof on the building of the temple are not always the same. There are various forms of the roof on the building of Chinese architecture, and in this case the shapes of the roof on the temple are included in them. Generally, the shape of the temple's roof is flat. The arch of the roof is supported by wooden construction in the crutch by the ranks of pillars made of solid beams,

round and square forming the roof of the horses. It has bright colors such as yellow, green, blue and black, and is covered or coated with glazed or colored tile. Then it is supported by pillars that use a system of wooden poles crowns that looks very complicated. There are five types of roofs, they are:

- a. Pitched roof (Wu Tien).
- b. Gable roof supported by wooden truss at the ends (Hsuan Shan) roof .
- c. Gable roof with solid walls at the ends (Ngang Shan).
- d. Half-pitched and gable roof and half (Hsuan Shan), or a combination of pitched roof with gable roof.
- e. Half-pitched roofs (Tsuan Tsien), or pyramidal roof.

Chinese buildings are also have five types of rooftops:

- a. End of Straw or pointed tip.
- b. Geometric.
- c. Rolling wave or curling cloud type.
- d. Curling wave or choppy cloud type.
- e. Curling end.

# BUILDING STRUCTURE SYSTEM OF CHINESE ARCHITECTURE IN THE PRESENT TIMES.

The development and rapid growth of technology and building materials as well as the existence of sophisticated computer software enable the architects to develop design and more diverse forms of buildings, as seen in some of buildings constructed in China.

#### 1. Chinese Pavilion, Shanghai Expo 2010.

Chinese Pavilion, Shanghai Expo 2010 looks like it goes "back" to the old concept of Chinese building structure system, the structure of the multi-storey blocks piled in every direction, but it is usually done at the ends of poles or building columns, while in the Chinese building Pavillion building, the multi-storey blocks form a very large room and cantilever structure system formed out of the shaft building.

Chinese pavilion building consists of 4 pieces of main columns as the support pole of cantilever beams, to establish a balance in all directions, so that the building can stand up straight.



Figure 5. Chinese Pavilion, Shanghai Expo 2010<sup>[9]</sup>

2. Central Chinese Television (CCTV Headquarters Building), Beijing – China.

The CCTV Headquarters building, designed by Rem Koolhaas and Ole Scheeren, uses the outside framework structure system (skeleton) of steel building materials, which power in the structure "outside the framework" of the building and the floor plates that are united into a rigid unit that allows to hold the "cantilever" at the top with the podium section below it and foundation specifically designed to withstand the "pull of" cantilever and moments associated with logging by cantilever floor of the building at the top of the building.



Figure 6. CCTV Headquarters Building<sup>[10]</sup>



This is as shown in the schematic drawing systems outside the framework structure (skeleton) of the building below:

Figure 7. Schematic structure in CCTV Headquarters Building

Exterior building wall has certain angle against the force of gravity (not vertical with the floor buildings) further adds "beauty" and "uniqueness" beside her "cantilever" is quite prominent, it is possible with the "bracing-bracing" around the building that makes outside of the building frame structure in balance between drag and tap on both sides of the building on the principle that against like tube structure system. While the system of "core" building and building vertical transport systems remain are made vertical to the building floor (see picture below).



Figure 8. Zoning System Installation inside the CCTV Headquarters Building

In the picture below it can be seen details of the relationship between the structural system of steel frame floor beams, columns and bracing system. And can be seen also the dimensions of the steel material used in floor joists and the outside of structural wall frame (skeleton) which is tube structure system (note the scale between the steel beam and column construction workers below).



Figure 9. Installation of steel constructions on CCTV Headquarters Building

In the picture below shows a detail of the outside walls of the building structural system which is made of steel with special profiles as "steel box" to increase power but with a lighter weight compared to steel "massive".

Steel material is given a protective material that is fire proof to protect against fire or excessive heat, so it provides security in the event of a fire.

In the picture below is also visible the relationship/ connection between the aluminum frame and the glass window to main structure of the system.



Figure 10. Detail relationship steel construction with aluminum frame and glass on the CCTV Headquarters Building

In the images below shows the working methods and stages in the implementation of its development.



Figure 11. Most of the development process of CCTV Headquarters Building

# 3. Linked Hybrid

Linked Hybrid, which will be filled by 2,500 people up in 700 apartments covering 1.6 million square meters, is a residential-scale model of sustainable architecture.

This building is visible on the bridges connecting the buildings on certain floors with a relatively long stretch of distance, so that the necessary construction to span the width of a steel construction which tied with bracing-bracing.



Figure 12. Linked Hybrid<sup>[11]</sup>

## 4. National swimming center

The exterior of the building in the national swimming center looks very striking, the buildings was constructed for the Beijing Olympics and was dubbed "water cube", made by soft panels Teflon material which turn the building into a greenhouse environment as energy efficient. The building also uses solar energy to heat the pool.

Structure system of the building is made of steel with the frame system (skeleton), but the organic shape is unlike frame structure system that is generally used in other buildings.



Figure 13. National swimming center<sup>[12]</sup>

By using bubbles as a concept that served as the basis formation of organic forms of structure system has a special characteristics and supported by computer program to calculate the dimensions of the materials for construction and building structures that can be built.

The structure system is designed in a rigidity and strength to the relatively large expanse with a large box tied to each other, especially on steel structures in the form of organic, thestructural system resembles the structure of the system known as space frame system that is always balance between pull and push in the chassis frame.



Figure 14. Inside of national swimming center<sup>[13]</sup>

## 5. Beijing Olympic stadium

The stadium has followed the sustainable design of one of the worders of the world for along time, de Meuron beijing national stadium is an attempt to rethink the classic sports arena to be more ecological. Swiss architect (tate modern fame) wanted to provide natural ventilation for the structure of the 91,000 - seats, the largest "green" stadium has ever been built. To do this, they are trying to create a building that could use without a strictly enclosed shell, but also provide a constant shelter for the people and athletes.

In general, the form of the building as shown below use the skeleton structure of the system (framework), especially on the outside of the building (such as tube) is made such that going a perfect stiffness and is an integral form of the "whole" and not in a individual, and is in the balance pull and push using a relatively lighter materials such as carbon steel with a high level on the corresponding dimension.



Figure 15. Beijing Olympic Stadium<sup>[14]</sup>

Structure of these skeletons look like irregular shape resembles a bird nest, but if we observed carefully, there are some parts of the framework that have "unified whole" who constantly as its main framework. While other skeletons in welding into one entity with the main frame to all directions, crossing each other to provide strength and rigidity.

## CONCLUSION

Chinese architecture in the past times is full of concepts and specific meanings, developed to line rapidly advances in accordance with technology and building materials. Formbuilding varies greatly in the present are supported the advancement in technology, the use

of sophisticated computer software, and the "courage" of the structure experts to "get out" of the common rules, thus enabling the use of structural systems that can realize "dream" and "thirst" of the architect with "unusual" architectural forms.

The architectural style in Chinese at present times add the excitement of world architecture with lots of unique architecture is built, other than the other, as if vying with the architecture in the world to give a pride for the architect.

By studying the basic principles of a structural system can be a variation in the forms of "unusual" and interesting, but still concern to the safety standards regulation and comfort for building users as well as a trademark or identity for a country.

There are many other buildings that are very unique and interesting to discuss in China or other countries that also have a specific characteristic.

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- [13] Figure 14, Inside of national swimming center, *http://id.images.search.yahoo.com* downloaded on October 12<sup>th</sup>, 2012.
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