RESEARCH PLAN

Architectural Engineering Graduation Studio

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(I) Introduction

Personal fascination

Megastructure buildings are always my interest. This kind of buildings became a trend in 1960s, and most of them used much heavy concrete to create a large volume. But this kind of massive concrete buildings are facing many problems in function, energy performance and so on nowadays. So, I started to think what will the heavy concrete buildings be in the future? What will the new materials bring to them in the renovation?

Problem statement

In the past, we always highlighted the beauty of 'huge'. As everyone knows, hugeness tends to be surplus, and it brings a lot of waste of resources and energy. This waste is not short-lived, but long-term.

In the 20th century, with the increasing shortage of natural resources and the deterioration of the ecological environment, people began to pay attention to the sustainable development of society and the protection of the ecological environment. Relevant data show that the energy consumed by contemporary construction activities accounts for more than 50% of the total global energy consumption, and construction activities are also the most important source of environmental pollution. Among them, the environmental performance of concrete buildings is the worst, and most of the concrete buildings have high carbon emissions, not only in the construction phase, but also in the entire life cycle of the building. For these old concrete buildings, they will also have new functional requirements in the future. How to efficiently transform them without demolishing them has become a very important issue.

The National Archives of the Netherlands in The Hague, which was built in the 1970s using a reinforced concrete structure, faced similar problems. This kind of large-scale buildings that used a lot of concrete are not only eliminated by this era in terms of environmental protection, but also need to face the innovation of function, use experience, and space experience. This kind of buildings are always rigid and not flexible, which means hard to undergo the reconstruction project. Besides it, considering the large volume of them, this kind of buildings are always losing connection with society and urban context.

Relevance & Relation with the Overall Design question

The overall design question is how to use lightweight structure transform an old massive concrete building into an efficient and flexible building in order to meet new requirements in the future, so the most important point is starting with the material. By comparing several different building materials, based on various properties of these materials, the conclusion

can be made to choose timber as the main structure, especially considering its good performance in sustainability and light-weight.

After analysing the building's current situation and future requirements, besides the bad energy performance, the most vital issue is lacking space which can be used to face the digital age's requirements. Based on the site research, the strategy is using a new structure system to create more space above the current building. Therefore, combined with the material analysis, the research question can be determined: how to use timber structures to create large-span architecture space?

Timber is a renewable building material with low environmental load. Its scientific use can reduce the burden on the natural environment due to human construction activities. In the future, wood as a building material will have a broader stage. In addition, the advancement of industrial production technology has brought about changes in material properties and advancement in structural technology, which has promoted the development of modern large-span timber structures. Wood, which was only used in smaller-scale buildings in the past, can now be used by architects in large-span structures. The prefabrication of the timber structure also makes it suitable for use in renovation projects and large-scale public building projects, which can reduce construction periods, reduce costs, and reduce production pollution. These characteristics will be used in the future development of architectural design. The purpose of this research is to find ways to quickly and efficiently construct large-scale public buildings, and to provide new ideas for the reconstruction and addition of many old concrete buildings.

Research questions

How to use timber structures to create large-span architecture space?

(2) Research framework

Key terms: Timber structure, large-span, typology, sustainability, production, joint construction

Concepts & Theories

In general, the whole research and design process will focus on two main concepts – light-weight structure and sustainability.

First of all, the research starts with the analysis of timber's properties. As an environmentally friendly building material, timber is more popular in this era. However, in addition to the characteristics of environmental protection, wood itself has many properties that other building materials do not have. Therefore, a reasonable and indepth analysis of the material characteristics of wood can fully help architects use wood more rationally, maximize strengths and avoid weaknesses, and make the best use of it.

Renovating and adding to the volume of the original building through the timber structure will bring about the connection problem between the old and the new structure.

How two different structural systems coexist in the same building requires in-depth research. In addition, one of the design goals is to make the original building visually light. This requires studying the strength, rigidity, ductility and other aspects of the wood structure system, using the finest and lightest structure to complete the large-span space required by the architectural space requirements. Considering the research question, the focus of the research should be the timber large-span structure – which means the definition of it should be determined at first. After that, the research focuses on the typology of various timber structure systems, starts with classifying of various structure systems, by analysing the force diagram, structure form, applicable situation and so on.

For the renovation project of old concrete buildings, how to reduce pollution as much as possible during the construction process and shorten the construction period is also an important issue. In the research phase, it is necessary to research and analyse the whole process of wood structure production, prefabrication, and construction, and determine a reasonable and efficient construction process.

Then, the research comes to the joint parts. It concludes the classification of different methods used in joint details for large-span timber structures. In the end, the energy consumption of wooden buildings is also a very important research object. Here the research focuses on the energy performance of different large-span timber structures.

Methodology

All in all, the entire research process starts with site research and cognition, through onsite investigation and literature review, the current situation of the site and building is analysed, including the history of the building and analysis of the site, and preliminary conclusions are drawn. Then, on the basis of these analyses and conclusions, the research questions are determined, and the directions and some key points of the follow-up indepth research are summarized.

Under the topic of large-span timber structures, five important elements constitute the main part of the research, namely, material properties, typology of large-span timber structures, production and construction of timber structures, joint detail construction and sustainable performance.

The structure selection part involves morphology and structural mechanics. For a largespan timber structure building, its structural form can truly reflect the force of the structure, thereby expressing the internal logic of the structure. Therefore, for the classification of large-span timber structure buildings, analysis should be conducted on the basis of structural mechanics and the book - *structural conception and selection of large-span buildings.* In the entire structural system, the loading state of one single component can be analysed separately, and under the action of different forces, the structural components show different morphological changes, and this morphological change is precisely the embodiment of mechanics logic. And for the sustainable performance, it involves the relevant knowledge of ecology. As a renewable material, wood has inherent advantages over other materials. Moreover, the performance of the whole life cycle of wood can not only regulate the natural environment during the growth process, but also requires very low energy consumption during the processing, production, and construction stages.

These five key factors have different sub-theories, and they together form the main framework of the entire research. In addition, these five elements influence and restrict each other in the selection of the final structure type and the determination of the structure form.

In general, this is a qualitative research. The entire research tries to understand the two concepts - timber and large-span building structures more clearly, and uses case studies, classification methods and other ways to explain the scope of application, various properties, and construction processes of large-span timber structures more clearly. At the same time, in some more specific research and problems, quantitative analysis methods are also used, and for quantifiable aspects such as wood strength and energy performance, graphs and data analysis and research are conducted as well.



Methods

The first part of the research is mainly site research. Recognize the site and the area where the building is located through field research. In addition, through consulting the literature, deeply analysed the history, former planning, population density, daily activities, land properties, traffic flows, circulation and other factors of this area, and then recognize it through methods such as maps, Google Street View, and computer modelling, which helps

to know more about the public space in the site and think about the relationship between existing buildings and urban context.

The second part is the analysis of the architecture. Through field investigation, map surveying, three-dimensional modelling, etc., an in-depth analysis of the building in the existing site, the National Archives of The Hague, is carried out from various perspectives such as structure, function, circulation, and spatial relationship. After that, some basic conclusions about the current situation of the building can be drawn.

The third part is to study the characteristics of wood as a material. By consulting literature and data, studying the various physical properties of wood, through the Material property charts drawn by Professor Mike Ashby, "Chart created using CES EduPack 2019, ANSYS Granta © 2020 Granta Design", to further compare wood with other materials, such as foam, metal, clay, concrete, plastic about strength, density, thermal conductivity and other properties. Then further quantify the "light" feature of wood as a building structure, calculate the structural weight of wood structure and steel structure, bamboo structure, and concrete structure under the same circumstances, and compare and analyse the advantages of wood to produce new types of timber, and the characteristics of timber as a building material like seismic resistance, sound insulation, sound absorption and mechanical stability should also be further analysed.

The fourth part is mainly to conduct in-depth research and classification of large-span timber structure systems. First, the classification standard, namely force, is clarified. Under this standard, several typical large-span timber structure systems are cited. After the classification and sorting are completed, in terms of the number of consumables, connection characteristics, and cost, these different large-span timber structure systems are horizontally compared and studied, and finally summarized.

The fifth part is mainly to investigate the entire process of the production process, transportation, installation, and on-site construction of the components in the large-span timber structure. The main research method is to consult the literature and case analysis to fully understand the construction process of the large-span timber structure system.

The focus of the sixth part is the joint construction in the large-span timber structure. Apart from doing research on the existing connection nodes between monomers, the methods of consulting literature and case analysis to classify these main node connection methods are used, and further research and discussion under each type of joint connection method are also done here.

The seventh part is the research on the environmental protection and sustainable performance of large-span timber structure system. Mainly using charts, data analysis and other methods to compare the sustainability performance, life cycle carbon emissions, environmental performance and other aspects of timber structure buildings with the buildings using other structures, which can be used to summarize the advantages of the sustainable

performance of the large-span timber structure system.

Finally, after summarizing all these contents, some conclusions about the large-span timber structure system are drawn, which can be applied to the subsequent design.

(3) Preliminary conclusions, choices and design strategies

Preliminary conclusions

For the site research, the preliminary conclusion that can be drawn is that the central area of Den Hague is a densely populated area with a lot of social interaction activities. Public buildings are concentrated, and there are many cultural public buildings. However, the public activity space in this area is relatively fragmented and small, and the urban space is too compressed. The National Archives, located at the end of the central axis of the city, has less connection with the urban space because of the blocking of the surrounding trains and highways. Therefore, in the subsequent design, how to deal with the relationship between the building and the site and enhance the publicity of the original building is an important issue.

For the building itself, the National Archives of Den Hague uses reinforced concrete as the main structure. In order to ensure the preservation of paper files, the building is relatively closed, and a large number of mechanical ventilations, air conditioning and other equipment are also used, which makes the building's energy performance poor. At the same time, most of the space in the current building is used as storage space for documents. The building space lacks flexibility and the size of the space does not meet the needs of the future digital age. Therefore, it is necessary to add more large-scale building space to meet future needs. At the same time, it is also necessary to consider improving the energy-saving performance of the original building and enhance its sustainability.

For large-span timber structure building, the selection of the structure can truly reflect the stress of the structure, thereby expressing the internal logic of the structure. Therefore, for the classification of large-span timber structure buildings, analysis should be conducted on the basis of structural mechanics. Considering that the purpose of the design is to use lightweight structures to efficiently create large-span spaces, it is necessary to choose a structure that can create a larger span and use as few consumables as possible. In addition, the entire structural system needs to be divided into primary and secondary structures. The main structure is connected with the original reinforced concrete beam-column structure, and the secondary structure is built on the basis of the main timber structure to form a complete structural system.

On the basis of the selected structural system, go deep into the node design, and use efficient and clear construction logic to solve the problem of the connection and ensure the stability of the overall structure. Finally, combined with the specific functional layout, streamline and other issues, combined with the structure itself, consider the enclosure system of large-span wooden structures, and at the same time give full play to the characteristics of wooden buildings to ensure the environmental protection and sustainability of the building.

Design strategies

First, the original building functions should be re-divided, and the most important file storage functions are placed on the lower floors of the building as much as possible, and then the newly added volume of the original building is divided into two major functional areas. The middle part is mainly used for public activities. It is a relatively open space. To some extent, it can be used as a part of the urban space and has a relationship with the square on the front of the building. The space on the top is a continuous large space, used as an exhibition hall function, and the entire space can be freely arranged. The purpose is not only to display the past with digital equipment, but also to show the future of the country and the city, and redefine the concept of archives.



Wooden components will become the main structure of the additional construction. In terms of structural design, the volume of the new building should have a sense of lightness, in contrast to the original building. A floating and light structural atmosphere is created inside the space. The supporting pillars and the roof structure are made as thin as possible. In addition to the main structure is prefabricated glulam, steel cables or carbon fiber structures can also be used as an auxiliary to create more structural possibilities.

In the next design stage, what also needs to be considered is how to reduce the energy consumption of the original concrete building through the additional construction, and strengthen the sustainability of the entire building, making the original building not only visually lighter, but also in terms of energy consumption lighter. At the same time, the connection between the original concrete structure and the new timber structure will also be the focus of the design.

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