

## **Low Carbon Building Design Method Based on the Digital Technology**

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**ABSTRACT:** With more and more extensive and wider application of the digital technology which offers not only a new drawing tool or performance means for building design, but also an innovation of building design idea, process and result assessment, namely the totally new digital architecture concept. Nowadays, the level of applying the digital technology into architecture and architectural design industries is still overall low, the whole working process is still rest in the manual working model which far cannot satisfy the demands of the new time. This paper combines the development of the digital technology in today's architectural design industry with the trend of promoting the low carbon building worldwide, on the basis of studying the British BEDZED zero carbon residential area and of being familiar with the related software, through the comparison data of the digital analysis of British BEDZED with the traditional design methods, further obtaining a more scientific and more logical design method, for exploring the design method of low carbon buildings. Having some reflections and concerns for future digital trend according to the current development status.

**KEYWORDS:** BIM technology; Digital technology; Low carbon buildings; Low carbon building design method.

### **INTRODUCTION**

As everyone knows, the traditional building design method, process and characteristics are belong to one-way linear architecture design concept, the traditional design method mainly based on the graphic information exists different levels of abstraction according to different design stage and different specific object. Nowadays, digital technology development is in its full swing, by means of different methods such as the powerful digital modeling technology, general integration model and network collaboration, the digital technology offers a new start for architects. Using this technology can truly make the design back into the three dimensional space and the integrity of information model, only on this level, the digital technology can truly perform as aided design not the aided display. Like the design methods of master architect Frank Gehry, the digital technology was not only adopted into their design process, but is dramatically changing the design process. In those masters' design, the CAAD technology which is represented by the computer graphics has entered the core place of the design, the spatial forms of architecture somehow are difficult to represent by the traditional flat, vertical and profile maps [1-3].

Such as the design method of master architect Frank Gehry, the digital technology is not only adopted into his design process, but also is dramatically changing the design process. In those masters' design, the CAAD technology which is represented by the computer graphics has entered the core place of the design, the spatial forms of architecture somehow are difficult to represent by the traditional flat, vertical and profile maps. That's can be seen that the digital technology, especially the emerging BIM technology which is changing many aspects of the traditional design method and process in an inexorable trend, it will provide us a higher working efficiency. With the rapid development of the digital technology, the urban buildings are constructed in an exponential speed, while the cost is that our living environment didn't get much improvement. All things happened need us to have a deep thinking, for improving living environment and constructing more green and low carbon buildings, we should contribute our own strength. This requires that the architects on the one hand, to be familiar with the low carbon technology for architecture and perform low carbon building design, on the other hand, under the background of the prosperity of digital technology, it seems that the architectures can make use of advanced technologies such as BIM to promote the implementation of low carbon building construction [4].

### **THE DIGITAL TECHNOLOGY FOR ARCHITECTURAL DESIGN THINKING MODEL**

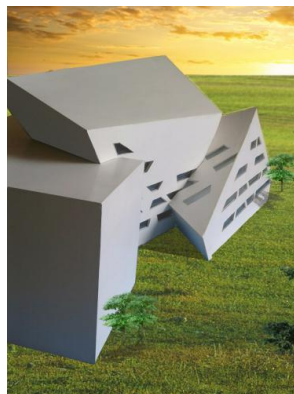
For a long time, the design and expression of architectural space are all used graphical information as the main media, which plays an important and irreplaceable role in the process of idea construction, analysis and professional expression of the building construction scheme. While the technological means and tools which are used to carry variety of professional graphical information are usually become the important factors affecting the design thinking. Different design tools brought by different levels of technology development also influence or even determine the different design thinking model [5].

#### The Graphic Thinking and its Limitations in the Traditional Building Design

The traditional graphic thinking of design model usually uses hand-drawn sketch (as shown in Figure 1), entity model (Figure 2), two dimensional flat, vertical and profile maps, perspective drawing, axonometric drawing and so on to realize the communication and expression of the design content. In a sense, the graphic thinking model is an inevitable result of these traditional medium instruments and of the graphic information carried by these tools. The practicality in the inspection and evaluation of the traditional graphic design lies on transforming the abstract image into a specific and real images. On the one hand, it makes the abstract concept map transform from the abstract image into a specific and real image, especially the spatial image, such as the architecture space perspective sketch observed from special positions [6].



**Figure 1.** The design model uses hand-drawn sketch.



**Figure 2.** The design model uses entity model.

#### From the Graphic Thinking to the “Digital Thinking”

Digital media has provided us with accuracy, efficiency, integration, intelligent and many other advantages. The digital technology involved into the traditional space graphic method, making the architects’ abstract minds to become more intuitive and more real, while the more important potential is that can break through the habit and design pattern formed due to the limitations of representation methods, thus can truly make the architects to probably find the poetic pursuit of modeling on technologies, making the conception of architectural space can have the freedom and random character of the sculpture. Meanwhile, it also provides the possibility of updating the design thinking and method - the overall integrated architectural digital information model which can be used as basis to realize the dynamic participation and widely horizontal cooperation during the design process. This new type and multi-dimensional design thinking model has been long restricted by T-square and triangle tools on the design table [7].

Aimed at the disadvantages of the classical formalism, the modernism of architecture theory has proposed the slogan “form obeys function” and the design model “from inside to outside” to replace the excessive pursuit of the one-way linear thinking model of “from outside to inside” by formalism, with consideration of the social, environmental, technological and some other factors, treating the architectural design as a two-way operation process combined “from inside to outside” with “form outside to inside” concepts. The thinking model from one-way to two-way, with the help of the digital technology -- such as a wider range of information sharing, integrated professional information model, multi-angle network collaboration and so on -- is possible to overcome the limitations of the traditional graphic thinking, changing toward to a more diverse and multi-dimensional design thinking.

RESEARCH METHOD

Through the investigation and study of the British Beddington community (world's first zero energy consumption community), getting almost 10 low carbon building design methods, as shown in Table 1.

Table 1. Low carbon building design methods.

1	Self shadow of building	6	Adoption of sun room
2	Tightness of building	7	Using solar energy
3	Prefabricated construction	8	Using rainwater recycling and reclaimed water reusing
4	Roof afforestation	9	Passive using of wind energy
5	Super heat preservation of the maintenance structure	10	Active using of wind power generation

It can be found through the comparison, firstly, the using of digital means can make the architects have more rational consideration of the design factors, such as: through the digital method, the research information of the early stage can become more rational, and are more conducive for buildings to carry out thinking on natural resources utilization. Meanwhile, it seems that the architects have a new set of design method when they are doing the low carbon building design, as shown in the below Table 2 which summarizes the similarities and differences of the traditional design method and of the digital design method by the architect during the different stages of the design process.

Through the above the table, we can clearly see that with the help of those digital software, we can at least have a simulation to various performance of the building before the completion of the building, meanwhile, we have already used BIM technology to virtual the different situations of the real building, and having a simulation and estimation on CO<sub>2</sub> emission of the building in advance. It can be seen that the most important role of digital assistant on designing low carbon building is to construct a powerful “virtual model library” and to have “performance simulation”. These two aspects can be concluded into the following several couples of categories.

Construction of Building Assembly System and Digital Architecture Component Cluster Library

The adoption of assembly system for low carbon building and the selection of suitable building materials can reduce a large amount of CO<sub>2</sub>, but the “structure rationalization” should be firstly considered on a macro level, Beijing National Grand Theater costs 3 billion yuan, the average cost of each seat is nearly 500000 yuan. The architectural design includes a repeated construction of a super large outer shell structure outside the opera house, concert hall and theater, the roof area of the whole dome is three times of Shanghai Grand Theater, with the energy consumption during the operation, making a quite large whole CO<sub>2</sub> emission. With the digital technology, the above problems in the architectural project can be virtually constructed through the Informationalization model BIM which can be used to check if the structure is reasonable, it asks for the architects to accumulate the virtual model library of assembly components during the project operation, it is “cluster” in Revit, if there is a long time of accumulation, not only the construction efficiency of the virtual building will be higher, but also those “clusters” will go through the test of time and have communication with factories in real life, the low carbon building components of different parts will become more reliable and mature.

Construction of Low Carbon Building Material and Virtual Material Depot

The importance of low carbon building materials for low carbon building is self-evident, besides a good selection of the main building structure, the retaining structure is also very important, because it relates to the good or bad thermal performance of building. Referring to the definition of green building material, the low carbon materials can be roughly

**Table 2.** Comparison of the traditional design method and the digital design method.

Design stage	Traditional design method	Digital design method
Research stage	Field survey on topography	Field survey on topography
	Questionnaire distribution on the site	Google Earth map research
	Questionnaire recycle and arrangement	Web 2. 0 technology online questionnaire survey, using SPSS to have statistical result analysis
Project design	Conception and having consideration on design sketch by architect, totally follow the assignment of the design work	Analyzing research result by using rational statistics method, deepening the assignment of the design work, forming the design planning proposal
	Standardization of the site design	Considering the influence of urban design and space (space syntax software, such as Depthmap to have research on the path and on view shed integration degree)
	Combined standardization of construction drawing performance analysis diagram	Considering the influence of sound, light, heat to building design (Ecotect software for building performance feedback)
	refining and completing the building's flat, vertical and profile map, offering information drawings of structure, water, heat and electricity, having repeated and several times of communication	Constructing BIM model, giving flat, vertical and profile map, having real-time communication with different professions in the information model, having the collaborative design
	Expression: Autocad two-dimensional drawing of flat, vertical and profile maps, intentional photograph, finally giving the design sketch to the company	IFC: Expression: Sketchup basic modeling, Boolean,morphing non-linear modeling of 3Dmax and so on, outputting IFC General format and rendering itself, using material color to deliberate the appearance style
Energy consumption evaluation	using PKPM software to calculate the energy consumption	Using informationization model, calculating the energy consumption report and the CO <sub>2</sub> emission

classified into four categories, as shown in Table 3. Low carbon building materials, in addition to the emphasis on environmental characteristics of the material itself like the definition of green building material, it also needs to know the thermal parameter and construction method of the material, the acquisition of these information can make the architects to have simulation for energy consumption the building.

**Table 3.** Low carbon material classification.

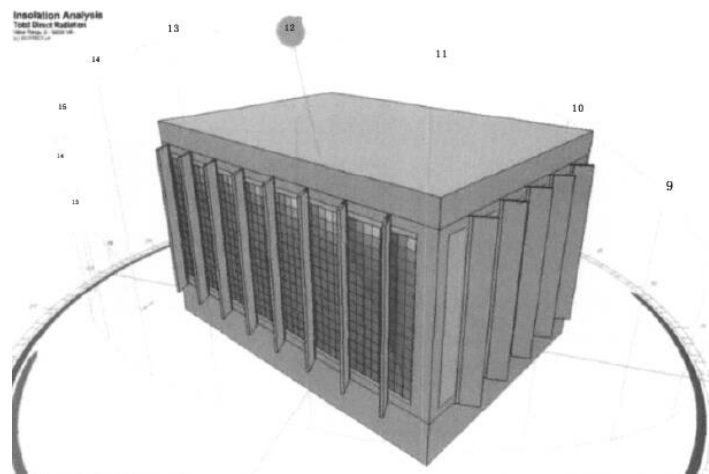
1	Building materials of low dissipation and low pollution
2	Natural materials without shortage crisis
3	Building materials of recycle usage
4	Recycled building materials from waste materials

#### Utilization of Solar Radiation Energy and Analysis of Digital Solar Radiation

Low carbon building has a very strong emphasis on relationship between the solar radiation with the building construction, not only the solar photovoltaic panels can be seen on the building roofs, the shape of building itself is designed for fully making use of the solar energy, so these buildings have a similar “slope roof”. While the angle of these “slope roofs” may not the optimal ones, most of the time they were judged according to the sketch and experience of the architects. At this time, Ecotect can optimize these slope angles. The case shown in Figure 3 shows the determination of best shade angle (rotation angle change to have 10 °as basis) by using Ecotect, Table 4 shows the sunshade effect of shutter at different angles [8].

**Table 4.** Sunshade effect of shutter at different angles.

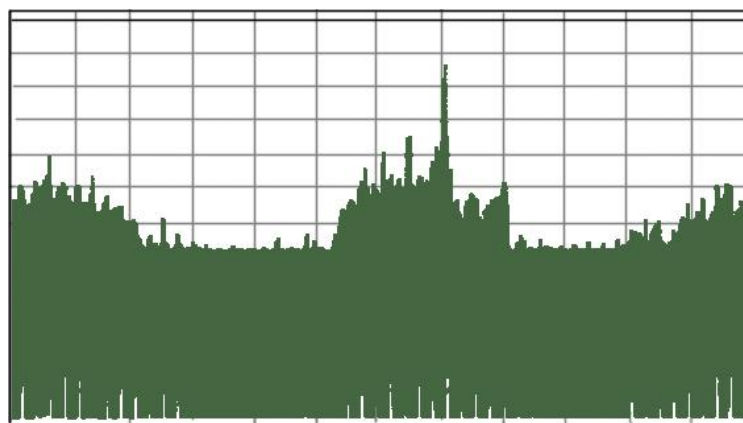
Direction Angle	East elevation		West elevation		South elevation	
	South	North	South	North	East	west
0 Degree	82685204.3		61498941.82		201101797	
10 Degree	8583812.12	78679156.2	66596406.18	57235612.97	194263885	204674961
20 Degree	85788104.7	74919821.64	71813207.4	54267147.42	196257925.9	2122264689
30 Degree	89337495	71097711.17	75190224.7	51538837.01	191875607.2	217195553



**Figure 3.** Determination of the best sunshade angle.

Carbon Emission Calculation of the Building and Energy Consumption Simulation Software

There has two-fold explanation for “carbon emission” of the building: first one is the carbon emission during the operation of the building, mainly is the energy usage of the building; second one is the carbon emission of the building’s life cycle, including the land utilization, material selection, energy system configuration and so on. During the whole life cycle of the building, the energy consumption and carbon emission during the operation period account for the most biggest part among all kinds of dissipation, therefore, the energy saving during the operation period of the building is the most important part for realizing the low carbon building construction. Here, the energy consumption simulation software intends to simulate the CO<sub>2</sub> emission of the construction project during the operation period, which can solve the above about the most important part of understanding on “carbon emission”, as shown in Figure 4.



**Figure 4.** Simulation result.

## RESEARCH SUMMARY

The above several couples of categories of low carbon building with the complementary with the digital building are some practice by author, dealing well with those categories is very important for using digital technology to assist low carbon building design. However, an architect who wants to complete a whole process of the low carbon building design, in addition to master the usage method of some software, it still needs to prepare a lot for the pre-stage of design. Besides, the architects should pay attention to the latest technologies and products on sustainable aspect, which can provides many ideas and related product parameters for designing the low carbon buildings. The methods of digital technology aided low carbon building design involve some very complex technological points and software, so this paper uses flow diagram to express the systematic methods of designing low carbon buildings based on digital technology, in order to give a more concise expression of the relationship between the design methods. (as shown in Figure 3) there has to be cleared that the software indicated in the flow diagram are the most commonly used ones by author's thought, the architects can choose the suitable ones according to the software classification during the design process (such as the Sketchup in architectural strategies can also be the volume scale derivation software Rhino, Cinema4D, etc.).

Here, the summary of the design process and method is based on some thoughts about BEDZED, and the summary and reflection on some digital software which are familiar by author, perhaps in the future due to the development of the social world, the "cluster" library of the architectural products may completed by architectural product manufacturer: such as the virtual material library will be gradually perfected by architectural product manufacturer, when the whole low carbon building industry forms into a industry chain related to digital technology, and the integration degree of the architectural software's different functions improves, I believe the low carbon building design flow chart will be more concise.

## REVELATION AND PROSPECT

New technologies from the digital age have brought many possibilities for building design, providing the architects with freer choices on form innovation aspects, making the "complex" no longer to be untouchable. Under the influence of the digital technology, the change of building materials' shape and characteristic making the architectural form "omnipotent", but to some extent, this "omnipotent" making the design trap into a misunderstanding of "digital instrumentalism" which pays too much attention on form itself, for pursuing the superficially new form to create new form, leading to the so-called "digital cortex" and disjointed architecture. Some eccentric buildings which have so many curved surfaces and are famous for their exaggerated and ugly design called themselves "digital architecture", with focus on pure, isolated and static details and on physical properties of the building materials, lacking of a comprehensively systematic thinking on interrelation among technological system, construction techniques and social culture. In practice, we encountered many technological barriers, but also accumulated precious experience on digital design. Now we have a updated understanding and knowledge on three-dimensional information model and on parameter design technology, and deeply feel the technological value and potential opportunity of digital technology which is about to have influence on building design and development of related fields. The true sense of digital area for architectural design is coming.

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