Proceedings of the 2nd International Conference on Mechatronics and Smart Systems
DOI: 10.54254/2755-2721/62/20240408

Information management and optimization methods in architectural construction drawings: A case study of the "coconut forest settlement" in Hainan

Zi'ang Zheng

China Academy of Urban Planning & Design, Research Branch of Landscape Architecture and Landscape Studies, Beijing, 100044, China

zheng18519752668@163.com

Abstract. This paper investigates information management and optimization methods within architectural construction drawings, using the "Coconut Forest Settlement" project in Hainan as a case study. Five key categories of methods are explored: clarification, structuring, standardization, precision, and lightweight. These methods address issues such as the lack of case-based analysis, the need for better information management, and the reduction of information redundancy. By classifying and discussing these strategies, the study highlights the enduring relevance of construction drawings in the digital age. Furthermore, it envisions the transferability of these methods to different contexts due to their emphasis on logical commonalities and the ever-present need for efficient information management. Practical examples from other fields, such as Revit, Rhino, and Grasshopper, are cited to demonstrate the potential applicability of these methods beyond traditional construction drawings. This paper contributes to the enhancement of information management in architectural design, fostering innovation and improved efficiency across various applications.

Keywords: Construction Drawing, Rhino, Grasshopper, Digital Architecture, BIM.

1. Introduction

1.1. Opportunities and challenges of construction drawing under the development of digital technologies

The development of digital technologies has brought about a revolutionary transformation in the field of architecture [1]. Within this context, various aspects of the construction industry and traditional means of conveying information have been significantly impacted [2]. Construction drawings have long been the primary method for expressing architectural design information, but digital design technologies have the potential to shift the process from traditional hand-drawn lines to model-based image exports, allowing for precise adjustments and annotations, thereby greatly improving the efficiency of construction drawing production [3, 4].

However, against the backdrop of nonlinear architectural forms becoming mainstream in design [5-7], construction drawings are beginning to exhibit a certain degree of inadequacy in terms of information representation. Specifically, for nonlinear architectural components, their dimensions

© 2024 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/62/20240408

cannot be accurately conveyed through traditional plans and elevation drawings. Even when employing unfolded surface representations for precise dimensioning, a level of abstraction becomes evident in guiding construction execution [2, 8].

Furthermore, a closer examination of the practical applications of construction drawings in construction projects reveals that the information conveyed in these drawings is primarily intended for on-site construction by construction teams. In contrast, manufacturers of prefabricated components utilizing computer numerical control (CNC) machining typically require digital models from the design team to serve as the basis for component dimension information [2]. Despite this, construction drawings remain an indispensable technical adjunct in the administrative management procedures of construction projects. They are subject to drawing reviews prior to construction commencement, and, upon project completion, they are used for final acceptance procedures within the project management framework. Additionally, construction drawings continue to serve as the basis for cost estimates in today's construction projects [9].

Hence, it can be argued that the development of digital technologies has gradually shifted the role of construction drawings from technical guidance to a type of administrative document emphasizing project management. However, it is precisely due to this evolving role of construction drawings in the digital technology landscape that information representation within these drawings has garnered significant attention. A complete set of construction drawings contains a wealth of information about the building project, with variations in spatial scales, information accuracy, and types of construction objects. Therefore, to ensure clear information representation in construction drawings, efficient management and optimization of the information within them becomes paramount.

1.2. Research gaps in construction drawing information management and optimization methods

Through a review of existing literature, this study identified several research gaps in the field of construction drawing information management and optimization methods:

1. Lack of case-based analysis: Existing scholarly work on construction drawings has predominantly focused on teaching construction drawing techniques to university students [10-11]. However, there is a lack of practical analysis by architecture and construction professionals based on real project experiences, both in terms of the techniques employed and the challenges faced. This abstraction in the analysis of construction drawings diminishes its applicability to actual construction drawing practices.

2. Neglect of information management and optimization: Scholarly attention has primarily concentrated on the technical aspects of construction drawing, including considerations for interdisciplinary collaboration in construction drawings [12], the role of construction drawings in construction projects [13], and drawing standards for construction drawings [10-11]. However, there is a notable absence of dedicated research on information management and optimization methods within construction drawings.

3. Absence of categorized analysis for specific methods: Many studies related to construction drawings merely provide lists of specific methods, often in a fragmented manner [13-15], without categorizing these methods at a logical level. While enumerating specific issues and analyzing them is essential for addressing immediate problems, a more comprehensive impact can be achieved by classifying these methods according to their corresponding technical categories. Such classification would enable future scholars and practitioners in construction and design to expand their thinking based on this framework, offering a more forward-thinking perspective on construction drawing techniques.

To address these three key issues, this study utilizes the "Coconut Forest Settlement" (CFS) in Hainan as a case study to provide detailed, category-based discussions of the information management and optimization methods evident in its construction drawings. This research aims to illustrate the technical value of construction drawings in the context of current developments in digital design technology, emphasizing their role as administrative documents in engineering management processes. Additionally, this study offers insights into the potential transformation and application of these

DOI: 10.54254/2755-2721/62/20240408

summarized construction drawing information management and optimization methods in various technological scenarios, thus enhancing the technical core of construction drawings for future advancements.

2. IMOMs in the construction drawing of the CFS

2.1. Introduction to the CFS project

The Coconut Forest Settlement is located on Dongyu Island in Boao, Qionghai City, Hainan Province, China. The architectural clusters are situated near the island's lakeside (Figure 1). The architectural design draws inspiration from the harmonious blend of traditional tropical coconut forest village architecture and natural vegetation (Figure 2). The individual forms of each building unit are derived from the traditional Hainan straw hat, while the overall spatial layout of the buildings references traditional village settlements, giving the impression that they have naturally grown from the coconut grove, emphasizing the inseparable relationship between humans and nature.

The Coconut Forest Settlement utilizes high-performance and environmentally friendly bamboo and wood as the structural framework. The architectural design promotes natural airflow from the bottom to the top, achieving passive cooling effects. The outer surfaces of the roofs of each building unit are covered with 1,518 photovoltaic panels, which collect and convert solar energy to supply garden lighting, thereby reducing energy consumption and carbon emissions.

Some of the construction drawings for the Coconut Forest Settlement are presented in Figures 3-6. This study will conduct a categorized analysis of the drawing representation and the specific information management and optimization methods used in the AutoCAD drawing process.



Figure 1. The "Coconut Forest Settlement" in Hainan.

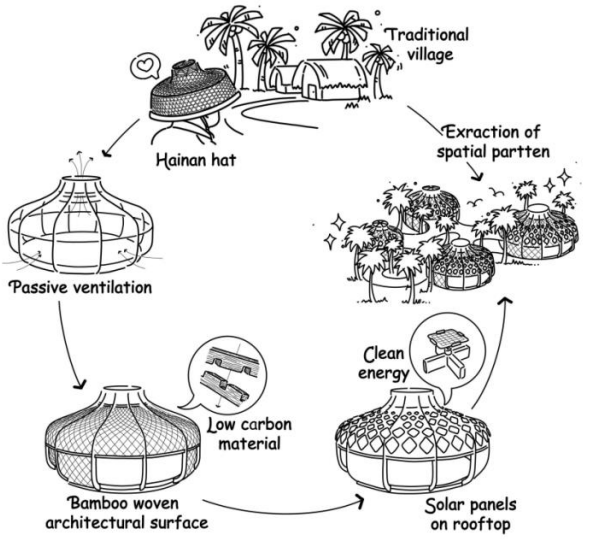


Figure 2. The conception of the CFS.

DOI: 10.54254/2755-2721/62/20240408

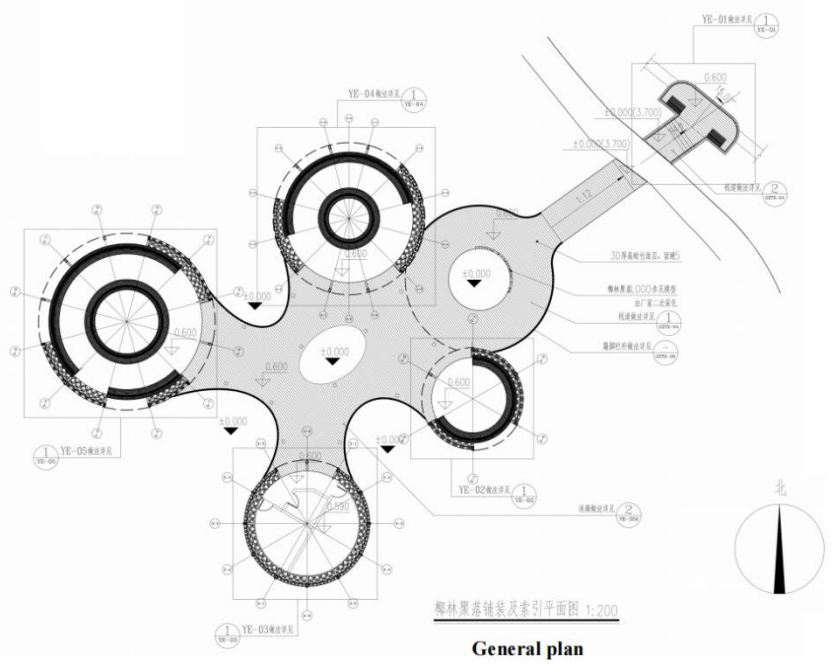


Figure 3. The general plan of the CFS.

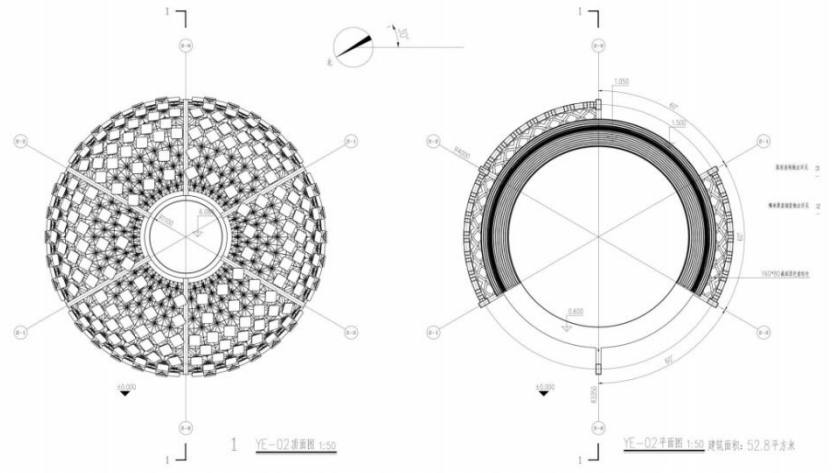


Figure 4. The rooftop and plan view of the CFS.

DOI: 10.54254/2755-2721/62/20240408

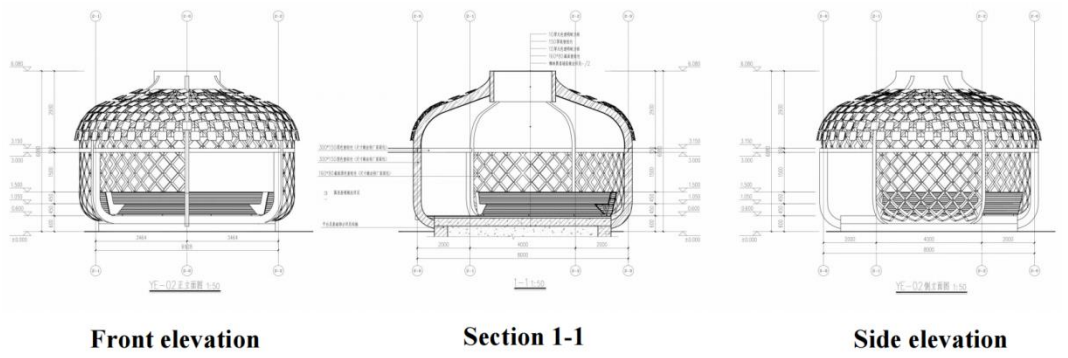


Figure 5. The elevation and section of the CFS.

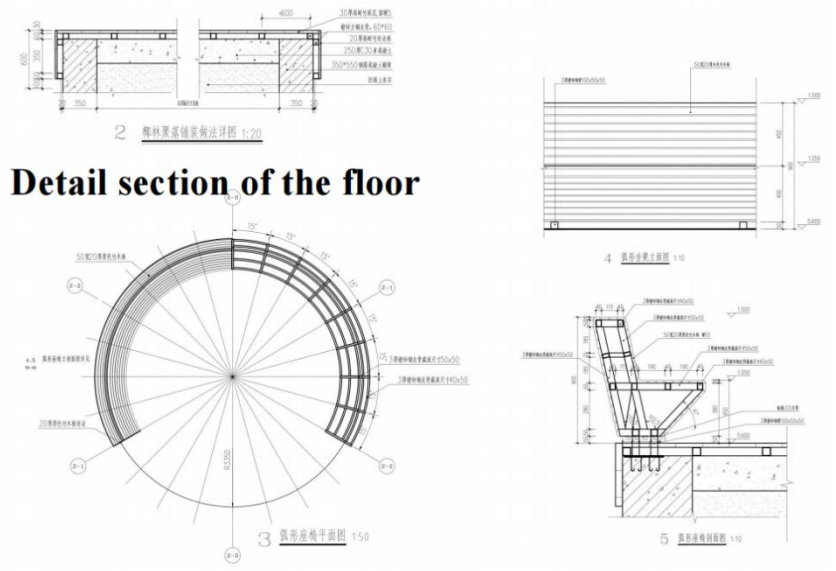


Figure 6. The detail of the CFS.

2.2. Clarity: enhancing visual information communication

Construction drawings serve as a set of engineering practice illustrations with the purpose of guiding construction personnel in the actual processing and installation of construction objects according to the specified drawings. To achieve this purpose, it is essential that construction personnel can accurately recognize and interpret the information presented in the drawings. Therefore, the expression of information in construction drawings should be clear and legible to enhance the efficiency of information communication.

2.2.1. Layout of construction drawing sheets. To clearly convey the design information contained in the drawings, the process of creating construction drawings involves the layout of drawing sheets to ensure that the information is presented clearly and legibly while maintaining a certain degree of aesthetic appeal. When performing sheet layout, the following points are considered:

a. Sheet spacing: This refers to the arrangement of various graphical elements and annotations related to different construction aspects within the same construction drawing. Adequate space is left

DOI: 10.54254/2755-2721/62/20240408

between these elements to visually distinguish and separate them, ensuring clarity for construction personnel.

b. Sheet alignment: This involves emphasizing the logical relationships between drawings on the sheet. For instance, in architectural drawings, elements like the roof, floor plans, various elevations, and cross-sections are expressed. When multiple types of drawings are present on the same sheet, they are aligned according to their respective axis numbers to clearly convey the corresponding relationships between different architectural drawings.

c. Feature distinction: Construction drawings use specific line styles, colours, and line widths to describe different elements of the construction. For example, in architectural construction drawings, blue lines may represent the elevations, light grey may signify the fill materials, yellow indicates the building sections and red dashed lines represent the building axes. Specific colours and line widths are designated for printing to visually distinguish the various meanings of lines in the final printed paper drawings. It is important to note that while the specific colours may vary, the underlying principle remains the same.

2.2.2. Annotation in construction drawings. To provide a clear explanation of construction methods, materials, and dimensions, the process of creating construction drawings involves annotating the drawing content with specific points to offer more detailed explanations. The following considerations are made during the annotation of construction drawings:

a. Annotation scale: When annotating different aspects of the same drawing with detailed explanations, an annotation scale matching the final viewport is used. This ensures that the size of annotation text and numbers for different explanatory objects remains the same in the final drawing, even if the drawing scale for various objects on the same sheet varies.

b. Annotation placement: Annotations are systematically placed within the drawing according to specific conventions. For example, in architectural construction drawings, elevation and cross-section annotations typically include elevation information combined with vertical dimension details on the right side of the drawing, while construction materials and practices information is annotated on the left side. This alignment conforms to the reading habits of construction personnel and complies with drawing standards, ensuring clear communication of annotation information.

c. Annotation alignment: Annotations in construction drawings are aligned within the drawing. For instance, in dimension annotations, equal distances are maintained between annotation lines and material annotations are aligned with the end of the annotation lines, ensuring that dimension lines are aligned on the same straight line, creating a neat appearance, and making it easier for construction personnel to access drawing information.

d. Annotation simplification: In a single drawing sheet, annotation information, especially for construction materials and practices, is consolidated and streamlined. Construction drawings typically achieve this in two ways. The first method involves adding annotation points along annotation lines to represent multiple identical parts on the same straight line. The second method employs a single annotation line that branches out to point to multiple non-collinear locations. However, the latter approach may result in intersections between construction method annotations and other types of annotations, affecting aesthetics and the clarity of information communication to some extent.

2.3. Structuring: distinguishing the hierarchy of drawing information

Architectural construction drawings contain information related to different spatial scales and varying levels of information precision. Moreover, the design content that needs to be conveyed through drawings encompasses various categories. To enhance the efficiency of information representation, construction drawings employ a structured information management approach to differentiate and categorize various types of information.

2.3.1. Indexing relationship between master plans and detailed plans. Construction drawings are divided into master plans (Figure 3), node detailed plans (Figure 4-5), and practice detail plans (Figure

DOI: 10.54254/2755-2721/62/20240408

6) based on their content. These three categories are hierarchical, with master plans providing an overview of the overall layout of the building, node detailed plans further elaborating on each individual building within the architectural cluster, and practice detail plans explaining the specific aspects of construction practices at the level of individual building components. To express this relationship, construction drawings use indexing symbols on larger-scale drawings to refer to more detailed drawings, creating a logical hierarchy of information explanation from the general to the specific.

2.3.2. Layer management of construction drawing files. In architectural construction drawings, differentiation of information types is achieved through the use of layers, aligning with the discussion of feature distinction in Section 2.2.1 of this study. Construction drawings establish standard layers based on the types of information to be conveyed. These layers typically include architectural elevations, architectural floor plans, architectural section lines, and architectural pavement and fill patterns. In addition to layer differentiation, various colours and line styles are used to further distinguish content. During the drawing process, design content is placed on the corresponding layers for rendering, ensuring that when electronic drawing files are completed, information can be individually displayed during actual construction based on different layers. This enhances the efficiency of information communication.

2.4. Standardization: reducing redundant expression of repetitive information

Standardization focuses on the consistent expression of identical information in architectural construction drawings. To facilitate modifications and management in construction drawings, various methods are employed for information management to reduce the independence of the same information and enhance data connectivity. From a logical perspective, standardization is an optimization method aimed at addressing the issue of "information islands," with the goal of establishing relationships between identical pieces of information.

2.4.1. Common details. Common details fall within the category of detail plans discussed in Section 2.3.1. Depending on the uniqueness of the content, detail plans can be divided into special practice detail plans and common practice detail plans, the latter referred to as "common details." Common details in architectural construction drawings represent architectural details that can be reused and appear repeatedly, such as connection nodes used in building roofs, standard-sized photovoltaic panel components, and the use of railings in buildings. Common details express these recurring components through a single drawing, which is then indexed for use in drawings of individual buildings. This reduces information redundancy within the entire set of construction drawings, optimizing information representation. In other words, for the construction team, the specific content of common details informs them that the building requires a certain number of identical building components, and these components share the same dimensions. This effectively and clearly enhances the construction team's understanding of the construction object and reduces the likelihood of errors resulting from misinterpretation.

2.4.2. Blocks. The use of blocks is also applied to repetitive objects in construction drawings, such as the elevation representation of structural columns and the side view of benches. By creating blocks using the "block" command to represent the content in these drawings and copying and using them at different locations, any modifications to the content in one block can be applied to all identical blocks, improving the efficiency of drawing.

2.4.3. Standard sections. Standard sections are typically applied to the repetitive, large-scale construction parts that appear uniformly in drawings, such as building boardwalks and railings. In the representation of standard sections, only one repeating unit is expressed, and the content on both sides is omitted using dashed lines. This conveys the modular pattern of the construction object in terms of

DOI: 10.54254/2755-2721/62/20240408

dimensions and materials, thus simplifying the explanation of the construction object using concise information.

2.5. Precision: accurate conversion for controlling complex form dimensions

In the era of digital technology, nonlinear architectural design has become a prevailing trend. This nonlinear aesthetic leads to an increasing number of forms that are challenging to express directly through traditional architectural construction drawings, including plans, elevations, and sections. In response to this, construction drawings employ various information optimization methods to transform complex information, enabling precise dimension representation.

2.5.1. Accurate dimension representation of complex form elevations through unfolding. When the design content represented in architectural construction drawings exhibits curved lines in the plan or variations in slope in the vertical direction, the form dimensions cannot be expressed through traditional elevation drawings from a true perspective. In such cases, construction drawings use elevation unfolding drawings to represent the true dimension information and the variation trends on the elevation. In the process of representation, the total length of the curved lines in the design content is first measured in plan, and then an unfolding curve is drawn based on its actual length. Objects located on the curve are drawn according to their dimensions, providing accurate data for quantity calculations.

2.5.2. Expression of irregular dimensions in panels. For irregular surfaces, during the process of dimension representation in construction drawings, the surface is expressed in a flat, unfolded form. In addition, seam lines are set based on processing requirements. When representing the dimensions of each panel, a uniform grid (e.g., 100mm x 100mm grid) is used for dimension information, providing precise data for CNC manufacturers as a basis for production.

2.6. Lightweighting: reducing file volume by minimizing unnecessary precision

Lightweighting is an optimization method for construction projects in a multi-disciplinary context. Construction drawings, as core documents for conveying construction content in a construction project, are shared among different disciplines and companies. Therefore, compatibility issues, including file version compatibility and minimum computer performance compatibility, need to be considered. As a result, the process of creating construction drawings incorporates methods for reducing file volume.

2.6.1. External references. For architectural construction drawings, the use of external references is often seen in the architectural site plan. During the preparation of construction drawings, the design content is treated as a separate file, and the external reference command is used to import files containing site survey information provided by the surveying profession into the architectural design files as “background” information. This reduces the total amount of information contained within individual files, making it easier to understand and manage the information in each file. It also reduces the file lag issue that can occur during the transfer of construction drawing information due to computer performance problems, thereby enhancing drafting and reading efficiency.

2.6.2. Simplification of details in general plans using basic line types. Considering the analysis of the indexing relationship mentioned in Section 2.3.1 between construction drawings of different spatial scales and expression accuracy, it can be observed that in most cases, construction drafting simplifies the content indexed in the general plan. For example, in a general plan, elements like kickboards in a building corridor are represented simply as polylines with a certain line width (Figure 3), whereas in the common detail plan, the actual construction details of these elements are provided (Figure 6). This method ensures that the general plan provides an overview of the location of elements like railings while also offering specific details in the common detail plan. As a result, it avoids redundant expression of detailed practices in the general architectural site plan, achieving file lightweight.

DOI: 10.54254/2755-2721/62/20240408

3. Conclusion and perspective

In this study, using the construction drawings of the "Coconut Forest Settlement" project in Hainan as a case, we have categorized the methods of information management and optimization within architectural construction drawings into five types: clarification, structuring, standardization, precision, and lightweight. By combining these methods with specific practical scenarios, we have addressed three key issues in the field: the lack of analysis based on real case studies, the insufficient focus on information management and optimization methods, and the absence of method classification. This demonstrates that, in the current context of digital design technology development, construction drawings, as administrative documents in the engineering management process, still hold significant value for in-depth research.

Looking ahead to the five types of information management and optimization methods discussed in this study, we believe that these methods have the potential for cross-application in various contexts. The reasons for this include:

1. Emphasis on logical commonalities: Although we have discussed these methods in the context of architectural construction drawings, after classification, they form a logical framework for information management and optimization that goes beyond the specific application. Therefore, these five types of logic are no longer confined to the realm of architectural construction drawings and can be applied to other contexts.

2. The demand for information management and optimization methods in other contexts: Through practical examples from other contexts, we find that the five types of information management and optimization logic summarized in this study are also applicable in the context of information technology used in other architectural designs. For instance, in Revit, the division of "families" essentially uses structured layers and standardized objects to enhance information management efficiency and clarity of expression. In the Rhino modelling process, the management of layers and the use of Instance objects are similar to the concept of "blocks" in construction drawings, reducing redundant expression of repetitive information and achieving lightweight files for delivery. In Grasshopper, the use of "Groups" for arranging connected components clearly demonstrates the logic of components, and the "Cluster" command allows for the overall packaging and reuse of components. These different contexts all reflect the five types of information management and optimization methods summarized in this study.

In conclusion, future research can be conducted based on the five logical patterns of information management and optimization methods extracted from architectural construction drawings in this study. This will allow the core technical principles of traditional construction drawings to be inherited and applied in new technologies, facilitating a more comprehensive update of architectural design techniques.

References

[1] Community Design. (2012). An Exploration of "Parametric Design" – An Interview with Professor Xu Weiguo from Tsinghua University School of Architecture. Residential Areas (05), 12-15.

[2] Lu Wanmei, Feng Jia, Ma Chen, & Ran Yang. (2022). Research and Application of Nonlinear Architectural Form Generation Using Parametric Methods. Architecture Inside and Outside (03), 21-27. doi:10.19940/j.cnki.1008-0422.2022.03.004.

[3] Li Xikun, Yu Shishi, Jing Jianxiong, & Ni Ni. (2023). A Review of Domestic Applications of Grasshopper Parametric Design Methods Based on Bibliometric Analysis. Packaging Engineering (S1), 34-41. doi:10.19554/j.cnki.1001-3563.2023.S1.006.

[4] Huang Yumeng. (2021). Analysis of Rhino+Grasshopper Plugin Functions and 3D Modeling in Architectural Design. Automation Technology and Applications (07), 167-169+173.

[5] Lv Junxing. (2019). Application of Parametric Design Methods in Landscape Architectural Form. (Master's thesis, Dalian University of Technology). https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD202002&filename=1020641806.nh

DOI: 10.54254/2755-2721/62/20240408

[6] Xing Lu. (2022). Research and Application of Parametric Methods in Landscape Architectural Form Design. Beauty and Time (Urban Edition) (08), 14-16.
[7] Luo Shanshan, Hou Binbin, Gao Huilin, & Yang Bo. (2023). Characteristics and Application Analysis of Parametric BIM-Based Architectural Design. Chinese Construction (05), 143-145.
[8] Liu Jianhua, Meng Qingyu, & Chen Jingjie. (2023). Application Research of Parametric Design Methods in Nonlinear Architectural Design. Engineering, Construction, and Design (01), 30-33. doi:10.13616/j.cnki.gcjsysj.2023.01.008.
[9] Yu Chunchun. (2015). Design Stage Cost Management Based on BIM Under LCC Theory. (Master's thesis, Lanzhou Jiaotong University). https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD201602&filename=1015448317.nh
[10] Chen Jingjing. (2021). Exploring Curriculum Reform Using Information Technology - Taking Understanding of Construction Drawing as an Example. Modern Communication (21), 13-15.
[11] Wu Guangli, Long Xiaobo, & Dai Xiu. (2022). Optimizing Architectural Construction Drawing Teaching Design Using Mind Mapping. Journal of Kunming Metallurgy College (02), 69-71+75.
[12] Huang Dan. (2022). Analysis of Key Points for Coordination in Architectural Construction Drawing Design with Various Specialties. China Housing Facilities (05), 104-105.
[13] Yang Yanan. (2021). Application of BIM Technology in Architectural Construction Drawing Design. Engineering, Construction, and Design (22), 116-117. doi:10.13616/j.cnki.gcjsysj.2021.11.237.
[14] Wei Jiafu. (2022). Discussion of Key Points in Architectural Construction Drawing Design. Technology and Market (04), 129-130.
[15] Xu Shu. (2022). Reflections on Common Issues in Architectural Construction Drawing Design. Sichuan Building Materials (05), 101-102+127.