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Research on the Design of Prefabricated Framework System Based on Spatial Needs in the Context of Urban Renewal

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Abstract: The problem of functional deficiencies in residential areas that occur in the process of urban renewal in our country can to some extent be described as insufficient or imbalanced urban basic metabolism. The optimization and solution measures for this type of urban disease mainly rely on the adjustability of prefabricated buildings and multi-point placement methods as the driving force for organic circulation within residential areas. The development of prefabricated buildings in the field of research abroad is constantly expanding, mainly in Germany, the United Kingdom, and the United States. It is also translated as a type of "prefabricated building" and has implemented interdisciplinary research from various aspects such as steel structures, wood structures, concrete structures, and new material technologies. Prefabricated buildings in our country have appeared in the early stages, such as the beam and column installation form of Jinggan style residential buildings. Since the 1980s, organic renewal cases of using prefabricated buildings for urban architectural design have also laid a certain foundation. This article comprehensively proposes a framework scheme for matching prefabricated buildings with different types of missing problems within urban residential areas through literature review. Combined with analysis and research on POI interests, the basic forms of prefabricated frame joints and steel plate structures are demonstrated, and a prefabricated frame system design scheme suitable for organic renewal methods is proposed.

1. Introduction

The structure and material usage of basic residential buildings in our country are mostly suitable for reinforced concrete structures. Due to the increasing economic foundation of the population and the disposable time outside of work and study, the architectural forms that can be put into various environments to provide the needs of the population are becoming increasingly limited. Since the development of prefabricated buildings, their historical guidance has made the use of building materials and budget more suitable for various emerging types of landscape points with missing functions, which can provide the needs of the venue population at low energy consumption and high

efficiency. Therefore, this article summarizes the research prospects of prefabricated building types and proposes a prefabricated framework system that is suitable for diversified site needs, making prospects for the development breakthroughs in the field of prefabricated building.

1.1. Organic Renewal

The research on organic renewal in foreign countries began with Howard's "Tomorrow's Pastoral City", which proposed the existence of a contractual relationship between nature and the city, and hoped to restrain the phenomenon of population spreading outward through green belts. Later, it was applied and extensively studied in various fields. Lewis Mumford mentioned in "The History of Urban Development" that he hoped to restore urban diversity through small-scale updates. The concept of organic renewal in China was proposed by Academician Wu Liangyong based on the Beijing Old City Renovation Project and combined with his research on Western urban development history. The theory of organic renewal advocates the use of appropriate scale and methods for transformation to promote the improvement of the overall environment and the construction of organic cycles.

1.2. Prefabricated building

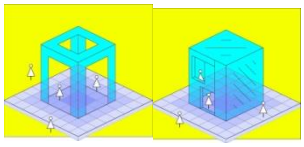
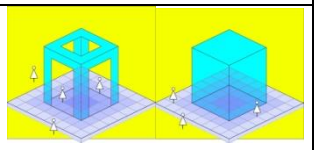
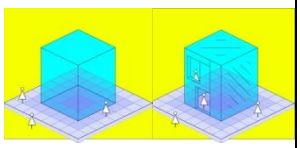
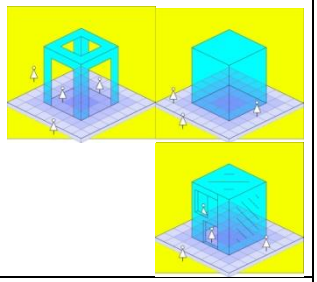
The research on prefabricated buildings abroad began in Germany in the 1920s, and the shortage of housing after World War II was the main reason for mass production of prefabricated buildings. Between 1958 and 1961, prestressed concrete steel and concrete technology were improved, and concrete was gradually replaced by wooden frames. By the early 20th century, led by Le Corbusier, many architects had made great contributions to prefabricated construction and the construction industry. Japan already has over 40% of its prefabricated building stock and well-established regulatory regulations. Developed countries also attach great importance to the development of new green assembly structures and component systems based on composite materials, light metal materials, light metal/polymer plastics, biomaterials/paper, and wood. The research on prefabricated buildings in China is still in development. Compared with foreign research fields, a mature production system for structural components has not yet been formed, making it difficult for China to achieve mass production of a large number of components. But currently, research results in related fields are gradually increasing. For example, Zhang Yi et al. explored the prefabricated residential design of a residential building in Xinzhou District, Wuhan City through modular design, which not only meets the individual characteristics of the residential building but also continues the traditional architectural features [1]. Secondly, if prefabricated buildings want to demonstrate their superiority in the current popularity of cast-in-place construction in China, they must demonstrate technical advantages such as earthquake resistance, convenient installation, and green environmental protection [2]. Modular design itself has advantages such as multiple changes in the environment, flexibility and efficiency. If used in construction, it can reduce damage and negative impacts on the environment, facilitate the disassembly, reassembly, maintenance, replacement, and recycling of waste modules [3]. In summary, on the one hand, China's prefabricated buildings inherit traditional architectural structures, and on the other hand, follow the development regulations of foreign prefabricated buildings with the characteristics of the times, gradually realizing the "sinicization" and "localization" of prefabricated buildings.

2. Prefabricated framework system based on spatial requirements

2.1. Space demand analysis

The structural component systems of prefabricated housing and prefabricated buildings are visible as a continuation of safety, environmental protection, energy conservation, and sustainable development, while also aligning with the theory of organic renewal. Guided by this theory, in order to fill the functional gaps in the venue environment, add necessary facilities, and popularize the basic functions around the venue, this article proposes a flexible and adaptable prefabricated framework system. The design starts with conducting sufficient site research and investigation, summarizing different types of spatial requirements, and then building a prefabricated framework system based on the types and presentation forms of the space. The basic space requirements are shown in the table below (See Table 1):

Table 1: Table of Types of Basic Space Requirements Corresponding to Prefabricated Frames.

Basic space types	Target audience	Population needs	meet the conditions	Presentation form (Adjust according to season)	Sketch Map
Snack stalls, outdoor sales, trade shows, mini concerts, etc	Per capita suitability	Resting and chatting, Small scope, Suitable for circulation, Can add insulation layer	Window trading, In store rest, Sitting at the entrance	Open space, Semi open space	
Exhibition display and installation interaction	Residential residents, mobile population, students	Circular exhibition, Short stay	More spacious space, Planning streamline closed-loop	Open space, Enclosed space	
Capsule residence, short-term internet cafe, homestead, internet famous homestay	Niche enthusiasts, Popular internet celebrity check-in	Medium and long-term stay, Short term stay	Having a private space, Strong security measures, High demand for water and electricity	Enclosed space, Partial opening	
Learning and communication, community activities, and accommodation related cultural and tourism projects	Per capita suitability	Communication and exchange, Self study, Free activity space	With activity space, Having a private space, Learning and self-study space	Open space, Enclosed space, Partial opening	
Temporary warehouse, any functional attachment area, idle space	Party A, such as the community, who is responsible for organizing local events or organizing certain types of meetings	Temporarily stored, Count the goods	Unfixed	Unfixed	

As shown in the table, the specific presentation form of space serves as the basis for modular

combination in the prefabricated framework construction form. The special placement environment created by the flow of people and the round-trip between venues allows for flexible and flexible implementation of low loss and low efficiency functional supplementary forms in different functional areas. At the same time, it can also serve as an emerging industrial model to provide fun.

2.2. Prefabricated frame design based on spatial requirements

Prefabricated buildings have the following advantages: 1) Flexible layout and high integration of buildings; 2) It has a light weight and good seismic resistance effect; 3) Can control ground subsidence; 4) High quality and short construction time; 5) Realize industrialization and industrialization; 6) The comprehensive benefits are relatively high. It is worth mentioning that the selection of building materials and the construction process reduce the cost of the building, increase its performance, and improve the cost-effectiveness of the building[4].

Given the existence of a certain amount of urban land parcels in China that are difficult to interfere with through building construction and other behaviors, they are generally suitable for the deployment of modular prefabricated frame systems. The types of prefabricated frames proposed in this article should also maintain a safety factor not exceeding the vertical and horizontal assembly process, and regular maintenance and safety measures should be taken according to factors such as the climate and environment of the placement area.

3. Design of prefabricated frame system Equations

3.1. Basic preparation work

In terms of constructing a prefabricated framework system, field research combined with data analysis methods should be used to analyze the missing functionalities within the research site. For example, POI facility point analysis, Baidu thermal analysis, GIS spatial analysis, and other methods should be used to deduce the placement area. Point of interest (POI) comes from the term used in geographic information systems to identify geographic objects. The reference case selected the author's thesis, using POI data from Baidu Maps. By obtaining Baidu developer permissions and using EasyPOI software to crawl administrative boundaries and retrieve POI data, it was imported into platforms such as ArcGIS for analysis. Within the study area, a total of 155 relevant POI data entries were obtained, including information on companies, enterprises, and commercial residential properties. Research has shown that hotels, tourist attractions, and commercial buildings are missing in this area, and prefabricated frames should be chosen for placement in these areas.

3.2. Prefabricated frame construction

In terms of the construction method of prefabricated frames, emphasis was placed on referring to the construction sequence of wooden structures and shaft style buildings. In the construction sequence of the "flat seat" wooden house of the Nu ethnic group, the steps include disassembling and assembling prefabricated components, transporting them to the construction site, connecting the lowest level components to the ground ridge, building in the order of fire pit room, auxiliary room, floor slab, central column and side column, beams and floor ridges, etc.[5]. In terms of materials, 3D printing technology is used to construct a frame and bottom plate composed of prefabricated building components (Figures 1 to 2). The plate includes steel structure reinforcement, and the interior is filled with material walls. The four corners and inner four fixed points of the prefabricated plate can be inserted into fixed load-bearing columns. When two or more layers of prefabricated buildings are used for grafting, the load-bearing shaft is in a four point interlocking

form at both ends, and the material interface is sealed with iron wire or rubber rings through plug-in connections. The more sturdy interface has higher durability and is easy to maintain. The prefabricated foundation includes (1) A drainage outlet; (2) Pouring layer; (3) Waterproof layer. From the current overall use of prefabricated PC buildings in China, many cases use the "cast-in-place" method. The "cast-in-place" mode has significant shortcomings in many aspects and has a significant impact on the quality of the entire project. Applying aluminum alloy formwork technology to prefabricated buildings can better solve the problem [6].

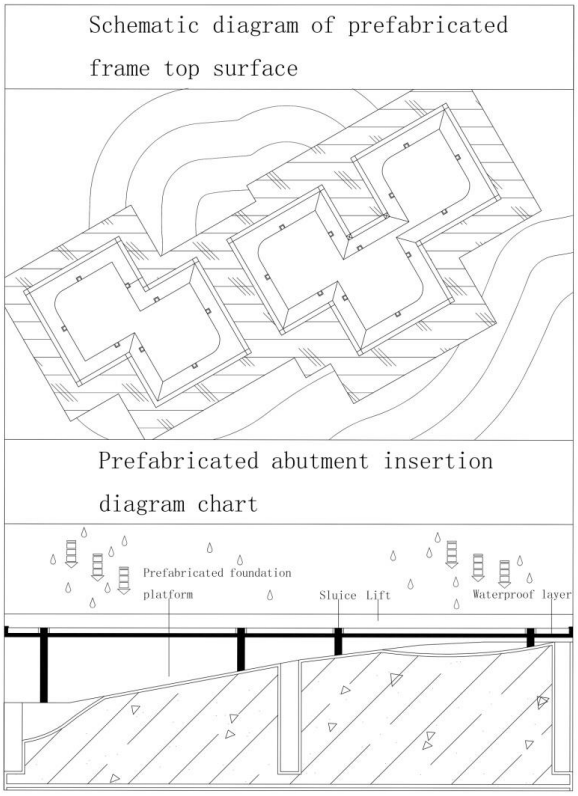


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Figure 1: Prefabricated Frame Top and Foundation Section.

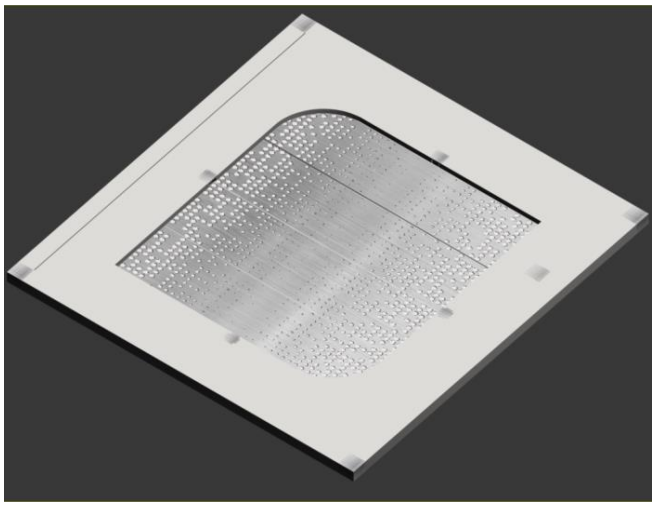

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Figure 2: Demonstration of 3D max model for prefabricated building frame foundation slab.

The fixing method and socket model demonstration of prefabricated frame load-bearing columns are shown in Figure 3. In this way, the single-layer frame structure is fixed by inserting the load-bearing shaft into the top plate, adding sealing material, and inserting the load-bearing shaft interface sealing element. Prefabricated frame with upper and lower grooves, single-sided groove sizes equal to 1/2 thickness or 1/2 diameter, while strengthening the ends [7]. If continuing to stack upwards, a bi-directional protruding sealing element needs to be inserted into the load-bearing shaft interface. At the same time, the fixing of the four corners of the prefabricated panel assembly mouth is done using the insertion method of the original component, and the reinforcement is also done using the plug-in connection form. The lower back of the four corners of the groove mouth under the prefabricated frame is also equipped with a load-bearing shaft, which is a type of prefabricated frame buried inside the U-shaped frame.

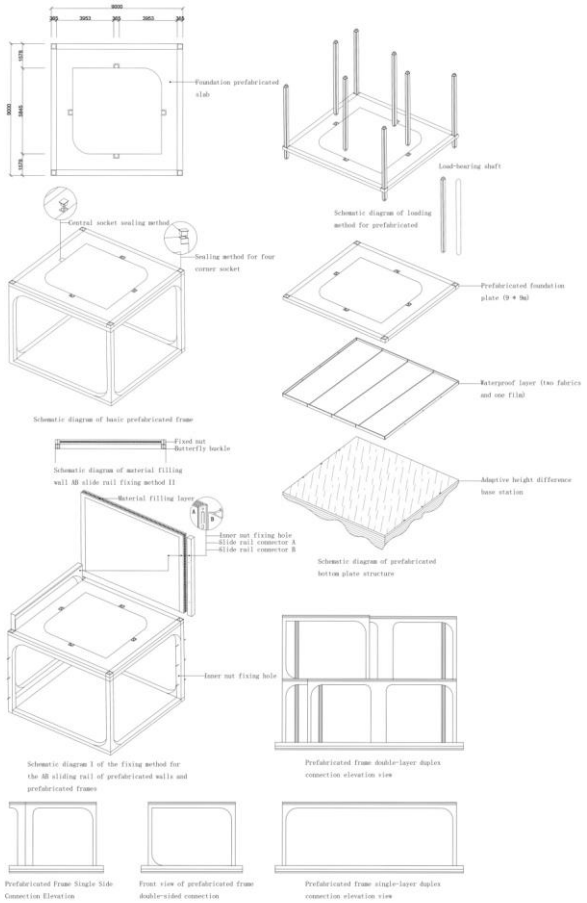

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Figure 3: Design diagram of prefabricated frame system.

Prefabricated frame foundation is divided into (1) Suitable height difference abutment; (2) Waterproof layer (two fabrics and one film); (3) 900x900 (m) foundation prefabricated slab; (4) Prefabricated frame single double compound structural components; (5) Passenger axle; (6) Central passenger entrance sealing components; (7) Sealing components at the four corners. The framework foundation is built through the connection method between the bottom plate, load-bearing axis, and prefabricated panel. The prefabricated panel has a material wall sandwich in the middle, which is interlocked with the load-bearing axis through slide rail connector A, slide rail connector B, and

double-sided nut fixing holes. The functionality of single prefabricated frames can be used for exhibition halls, porches, vendors, counters, and other purposes. Prefabricated frame combinations that connect four or more prefabricated panels can be used as basic prefabricated buildings. Composite prefabricated frame combinations require special attention to filling and sealing the gaps between prefabricated panels (in Figure 4-Figure 7).

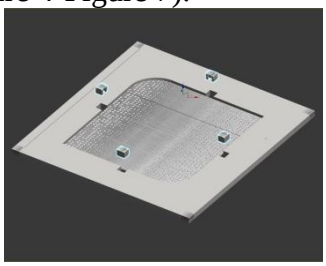

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Figure 4: 3Dmax Model Demonstration of Slot Insertion Form.

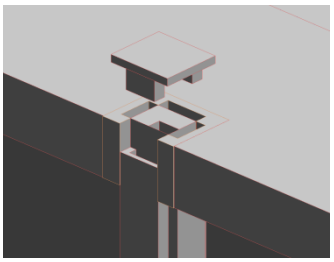

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Figure 5: 3Dmax Model Demonstration of Prefabricated Frame Insertion Direction.

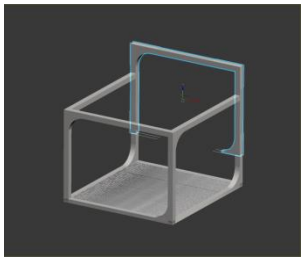

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Figure 6: Prefabricated Frame System Design Diagram [5].

Based on a single frame assembly, multiple units can be assembled to build larger buildings. The frame structure of the residence is constructed using 3D printing technology (in Figure 7), and the material is 3D printed concrete, which can be recycled. The floor and steps are also made of 3D printed concrete. After use, the material can be disassembled and reapplied to the next project. This article is based on 3D printing concrete technology, combined with the provisions of the "Technical Standards for Well Dry Wooden Structures", and adopts a modular concept to print concrete building materials with wood shapes. Based on the regional characteristics of Changchun and combined with the existing homestay building models, the prefabricated scheme design is carried out, and the construction process is shown in reference [7]. In terms of splicing form, research has been conducted on: 1. Jinggan style residential buildings in Fusong County, Changbai Prefecture; 2. Lahaqiang Residential Buildings in Heilongjiang Province; 3. Yanbian Sandwich Wall Residential Buildings; 4. Residential buildings in Qiongkushitai Village, Yili River Valley, Xinjiang. This type of modular prefabricated building can adapt to the required functional zoning combination mode under various functional mixing ratios, optimizing the cumbersome traditional residential

construction forms [8].

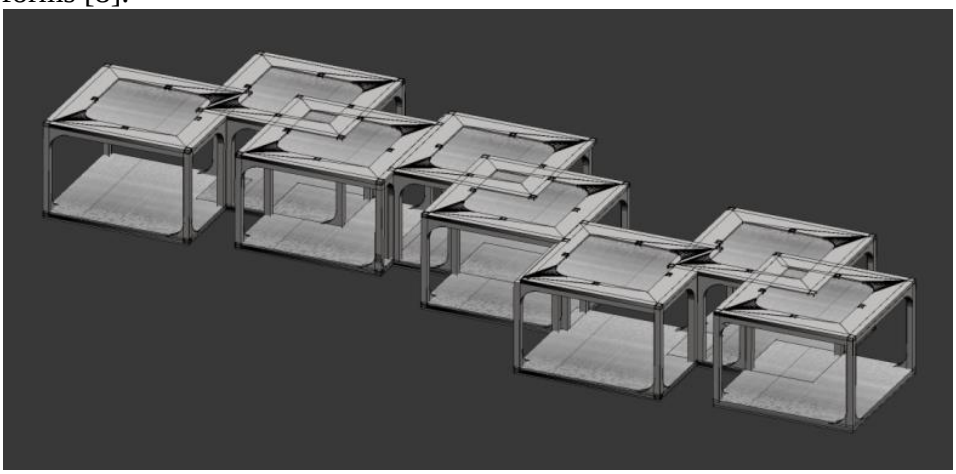

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Figure 7: Demonstration of 3D Max Model for Prefabricated Building Frame Retest Splicing.

In the case, as shown in Figure 8, the placement area of the prefabricated frame combination is located in the central southern part of the residential area, in front of the enclosed factory area. It lacks the balance of POI function mixing ratio and lacks commercial facilities, cultural facilities space, and other pedestrian flow lines passing through the core point. The purpose of the setting is to use a detachable prefabricated frame to carry functional requirements for different time periods; Attracting a stable flow of people through this area through the missing POI facilities in the entire block; To drive the purchase of surrounding POI facilities, the connection between harmonious and surrounding landscape nodes. It can be used as a medium for various functions such as snack stalls, exhibition halls, and book markets, achieving the effect of repeatedly involving the crowd in driving the vitality of the block and the frequency of POI facility usage.

Figure 8: Demonstration of the 3Dmax model of mixed function prefabricated building frame combination.

3.3. Building prefabricated buildings

The aspect ratio of the basic prefabricated building with the smallest footprint is 8:13 (m), as shown in the following figure (Figure 9- Figure 11). The insertion form is the same as that of the front prefabricated frame, but the original appearance is different. The appearance is derived from

the structuralist architectural form, and the top floor of the building can be planted with flowers and plants. As shown in the figures (Figure 9-Figure 11), the single building form can be improved in size and area according to needs. When the size is suitable, a 2-story mixed space with built-in stairs can be constructed.

Figure 9: Demonstration of 3Dmax Model for Prefabricated Buildings.

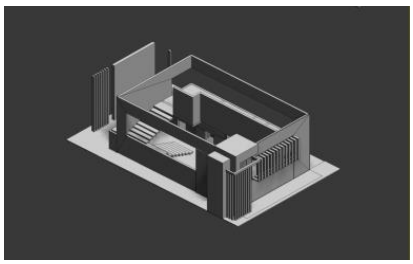

Figure 10: Demonstration of 3Dmax Model for Prefabricated Buildings.

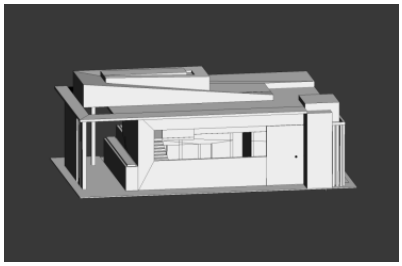

Figure 11: Presentation of 3Dmax Effect for Prefabricated Buildings.

Figure 12: Combination rendering of prefabricated buildings.

As shown in the figure (Figure 12), the combination form of the building is a composite prefabricated building where the lower level can pass through a branch and the upper level can be raised and widened. The functional investment of the prefabricated building here is to mix residential space with other missing items. In the process of gradual urban assimilation and improvement in adjacent residential areas, there will be many changes in the site. The functionality, appearance, and architectural form of prefabricated buildings can be adjusted according to the

actual situation. When the building size is sufficient, if it can be put into long-term use here, parking lots or other public activity spaces can be constructed underground according to demand. Through composite splicing of individual prefabricated buildings, the POI facility ratio is enriched, and the mixed ratio of business formats is balanced, allowing the crowd to regain vitality in limited and functionally lacking areas.

4. Conclusions and Prospectives

This article proposes a method of placing POI facilities on a site using a prefabricated frame system, hoping to use the flexibility and efficiency of a modular prefabricated frame system to adapt to changes in the surrounding environment and respond flexibly to various unexpected situations. On the one hand, there are problems in optimizing the mixed ratio of business formats by increasing POI facilities, and on the other hand, we hope to provide new ideas for plots that are difficult to adjust through building construction and other methods through the construction of prefabricated frame systems. There are also some theoretical and technical shortcomings in this article, which have not been able to conduct more in-depth research on the connection technology of prefabricated building structural components. It is expected that the author or other scholars will improve and supplement it in the future. In the gradual development of research in the field of prefabricated buildings in China, it is believed that more achievements will be proposed, and mature regulations will also emerge in the field of prefabricated buildings, which will be more valuable in the development process of industrial buildings in China.

Acknowledgements

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