Study on Key Technologies of Chinese Residential Structures—A Case Study of Mei sheng Education Harbour

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Abstract. Against the backdrop of growing housing demand and rapid urbanization in China, the study of key technologies for residential structures has become increasingly important. High-rise residential buildings in China still face great challenges in terms of construction efficiency, safety and environmental sustainability. Using the Zhengzhou Mei sheng Education Port project as a case study, this paper examines the practical applications of construction management, architectural design and structural engineering through an in-depth literature review and analysis of the case study, emphasizing the effectiveness of the key technologies such as concrete technology, masonry construction and reinforcement engineering.
In addition, the thesis proposes a sustainable development strategy and discusses innovative methods and technical applications in residential structural design, providing valuable insights and lessons for the future development and construction of residential buildings in China.

Keywords: high-rise residential structures, construction organization design, architectural design, structural design, sustainability.

1 Introduction

China's rapid urbanization and modernization has led to a surge in demand for construction. China accounts for almost 50% of the world's annual building completions[1]. Over the past 40 years, the share of residential buildings in the annual completed floor area of all houses in China has been around 65%-80%[2].High-rise buildings are increasingly becoming a significant feature of modern urban landscapes. Statistics show that the number of high-rise buildings worldwide has risen by over 50 percent in the past decade. In China alone, the number of high-rise buildings is projected to reach 700,000 by 2030, presenting unprecedented challenges for construction technology and man

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agement. Among these challenges, structural safety, energy conservation, environmental protection, construction efficiency, and intelligent management stand out. A notable example is the foundation settlement incident in a hotel in Quanzhou City, Fujian Province, in 2020, which stemmed from a design flaw. This incident resulted in casualties and substantial economic losses, severely impacting public safety and eroding trust in the construction industry.

In the field of materials science, high-rise buildings demand exceptional material performance. For instance, high-performance concrete (HPC) significantly enhances the durability and safety of structures, boasting strength and crack resistance that surpasses traditional concrete. Additionally, advancements in construction techniques, such as Building Information Modeling (BIM) technology, have streamlined the construction process, greatly improving efficiency. A prime example of this is the construction of the Guangzhou Tower, where BIM and modular construction methods led to substantial efficiency gains. Moreover, the adoption of green building technologies has become a prominent trend. The BEAM Plus certification system in Hong Kong, for example, encourages the use of renewable energy and energy-efficient technologies to reduce environmental impact.

In this context, Mei sheng Education Port serves as an exemplary case study that illustrates the potential for innovation and application in building technology. This paper aims to conduct a comprehensive analysis of the project's experiences in overcoming the technological challenges associated with high-rise buildings, thereby fostering the continuous development of building technologies. Ultimately, this study seeks to offer new insights into the advancement of key technologies for residential buildings in China.

2 Development and Construction Problems of Urban Housing in China

2.1 Accelerated Urbanization

Accelerated urbanization refers to the rapid increase in rural-to-urban migration, along with the swift expansion of cities and urbanization levels over a relatively short period. Many rural residents move to cities in search of better employment opportunities and improved living conditions, with migration largely concentrated in first- and second-tier cities. This influx has fostered a vibrant urban culture and diversified economic activities, enriching the economic, cultural, and social landscape of these cities.

2.2 Housing Supply and Sheltered Housing

In recent years, both the government and developers have accelerated residential construction to meet the rapidly growing housing demand. The marketization of China’s housing supply has steadily progressed, leading to a broader variety and greater number of commercial housing units available to cater to different income groups. Simultaneously, the Chinese government has intensified efforts to address the housing needs of low-income families by implementing policies aimed at promoting shantytown renovations and expanding the construction of affordable housing.

2.3 Existing Construction Problems

Amid rapid urbanization, some construction projects have been rushed to meet deadlines, or undertaken by builders with inadequate qualifications, resulting in irregular construction practices, substandard materials, and shoddy work. Despite the existence of building standards, regulatory enforcement is often weak, particularly in the inspection and acceptance stages, leading to safety risks in residential developments. Additionally, many high-rise residential designs are overly homogenized, lacking individuality and diversity, and fail to adequately address the varied needs of residents. And high-rise housing is overcrowded with people getting on and off the elevator. If the height of residential buildings is lowered in the design and the number of households on each floor is reduced, the shortcomings of high-rise residential buildings, which are characterized by a large number of people and congestion pressure, can be weakened[3].While the green building concept is being promoted, its adoption has been slow due to high costs and insufficient technical support, with many projects still relying on traditional construction methods that neglect energy efficiency and environmental protection. Relevant research shows that China's current residential building life is no more than 38 years, which is much shorter than the national standard of 50-60 years[4].

3 Field Survey of High-Rise Buildings in China: Mei sheng Education Harbor

3.1 Project Overview

The Mei sheng Education Harbor project is located in the Jin shui District of Zhengzhou City, and is a large-scale integrated community that combines education and housing. The project focuses on providing families with quality educational resources and a comfortable living environment, and is aimed at families of different income levels. The residences are of various types and are equipped with a wealth of community and educational facilities to meet the living and educational needs of families. The building structure is reinforced concrete structure, and the project is expected to be handed over by the end of December 2025 for the second phase of 12 buildings with main floor area up to 34 storeys. This building has a site area of approximately 61,008 square meters, a plot ratio of 5.99% and a greening ratio of 25.01%. There are 20 construction buildings and 553 underground parking spaces. The location of Port Mei sheng on the map is shown in (Fig 1).

Fig. 1. The location of Port Mei sheng Education on the map (Image source:https://zz.loupan.com/)

3.2 Survey of Construction Conditions

Jin shui District is situated in a plain depression characterized by the Yellow River alluvial plain. The terrain is elevated in the west and low in the east, with higher elevations in the southwest and lower ones in the northeast. The area boasts good quality surface and groundwater, classified as calcium carbonate water type. The annual surface water runoff depth is 90 millimeters, resulting in a total runoff volume of approximately 21.798 million cubic meters. The average annual temperature is 14.8°C, with annual rainfall measuring 586.1 mm.

In order to study the corrosiveness of groundwater and site soil to construction materials, 2 groups of groundwater samples were taken from 6# and 35# boreholes within the site, and 2 groups of underground soil samples were taken from 49# and 60# boreholes to conduct the water analysis test and soil corrosivity test, respectively, and the results are shown in Tables 1 and 2 below.

Table 1. Table of water quality analysis test results

form / number	K^++Na^+ Mg/L	Ca^{2+} Mg/L	Mg^{2+} Mg/L	NH_4^+ Mg/L	CL^- Mg/L	SO_4^{2-} Mg/L	HCO_3^- Mmol/L
6#holes	53.62	89.10	36.90	0.00	77.36	112.32	5.68
35#holes	60.85	93.65	33.21	0.00	74.19	130.52	4.59

(Source of table: Record of site survey)

Table 2. Table of soil corrosion test results

Form / number	K^++Na^+ Mg/kg	Ca^{2+} Mg/kg	Mg^{2+} Mg/kg	CL^- Mg/kg	SO_4^{2-} Mg/kg	HCO_3^- Mg/kg	CO_3^{2-} Mg/kg	PH
49#holes	26.35	239.25	78.65	187.32	359.49	411.29	0.00	8.45
60#holes	71.28	131.24	75.64	146.32	286.96	324.23	0.00	8.31

(Source of table: Record of site survey)

According to the results of indoor wet subsidence test of soil samples from exploratory wells in this site, the coefficient of wet subsidence by weight is less than 0.015, and the soil samples with coefficient of wet subsidence greater than or equal to 0.015 are listed in the following table.

Table 3. List of loess wet subsidence test results

Holes number	Depths δ_{zs}	Self-weight wetting factor δ_s	Test-pressure200KPawetting factor	Wetting Initial pressure-P_{sh}
7	2.2	0.003	0.022	124
	3.2	0.008	0.023	115
57	1.2	0.001	0.018	152
	2.2	0.006	0.016	163

(Source of table: Record of site survey)

Powdery soil has wet subsidence, and the self weight wet subsidence coefficients of the proposed site are all less than 0.015, and the maximum wet subsidence coefficient is 0.023, and the wet subsidence starting pressure is 115~163kPa, and the site is wet subsidence with self weight. Since the coefficients of wet subsidence below the base are all less than 0.015, and the original soil under the miscellaneous fill is close to the groundwater level of the site, there is no need to consider the problem of wet subsidence of the site, and the proposed building can be designed according to the regulations of general areas.

3.3 Pit Foundation and Superstructure

A pit is a temporary trench excavated for the construction of a foundation or underground structure. Excavation of pits is usually accompanied by the design of support structures to prevent the surrounding soil from collapsing or affecting the surrounding buildings. Foundation is the lowest load-bearing part of the building, located at the bottom of the pit, usually including shallow foundation (e.g. bar foundation, raft foundation) and deep foundation (e.g. pile foundation). Its main function is to transfer the load of the building to the foundation below to ensure the stability and safety of the building. The pit and foundation base work together to determine the stability of the building structure, which is an important part of building construction that cannot be ignored. For environmental friendliness, environmentally friendly materials and energy-saving technologies should be adopted to support sustainable development. The foundation construction process is shown in (Fig 2).

Fig. 2. On site foundation
(Image source: Photo taken on site)

The project adopts a number of advanced foundation treatment technologies and construction methods, such as deep mixing method and pile foundation technology, which possess high technical innovation and are suitable for in-depth exploration of their application and effect in complex foundations. Monitor building settlement, pit deformation and changes in groundwater level during foundation construction. The monitoring data are processed using statistical analysis software (e.g., Excel or MATLAB) to assess the effectiveness and safety of construction measures.

3.4 Construction Organization Design

Effective construction organization design is key to managing the complexity and scale of high-rise residential projects. Arditi et al. developed a database for example-based structural design systems[5], while Baiky and Smith out developed CADRE, a structural design system based on engineering examples[6]. Ensuring construction quality requires the use of advanced technologies to improve durability. At the same time, environmental responsibility is becoming increasingly important, and environmental practices and compliance with environmental regulations should be used to minimize the impact of construction on the environment.

3.5 Concrete Engineering

Cement concrete is a versatile building material used in a wide range of applications, including structural elements like beams, columns, slabs, and foundations, as well as non-structural uses such as pavements and landscaping. It is also widely utilized in precast components like pipes, pavers, and sewer systems. Its primary benefits include strength, durability, and fire resistance, along with being low-maintenance and easy to repair. However, concrete can be heavy, prone to cracking, and susceptible to damage from adverse weather conditions. The strength of concrete is greatly influenced by factors such as mix design, material quality, and curing methods, making quality control and testing essential.

The concrete construction at Mei sheng Education Port involved a variety of structural types, including foundations, shear walls, floor slabs and beams and columns, which demanded high levels of concrete performance and construction techniques, providing a typical example of concrete construction in a complex project. High Performance Concrete (HPC) was used on the project to improve the durability and crack resistance of the structure. The application of this material is suitable for exploring its specific construction techniques and quality control measures in high-rise buildings. During the construction of mass concrete, the internal temperature changes of the concrete were monitored in real time by temperature sensors to prevent temperature cracks. Data analysis software is utilized to process the temperature data and assess the effectiveness of temperature control measures. At the same time, finite element analysis is used to simulate the stress distribution of mass concrete to explore the impact of temperature changes on structural safety. Concrete cast-in-place continuous box girder construction process flow chart is shown in (Fig 3).

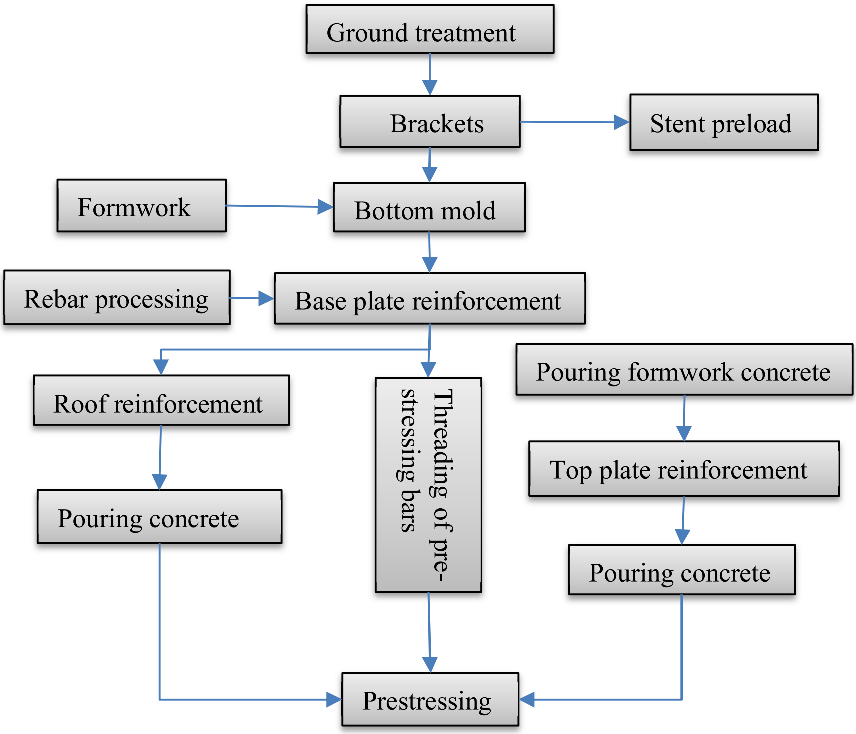

Fig. 3. Concrete cast-in-place continuous box girder construction process flow chart (Image source: Produced by project personnel)

4 Conclusion

This thesis discusses in depth the key technical issues in the design and construction process of high-rise residential buildings through a case study of the Mei sheng Education Harbor project.

Combined with the development of material science, construction techniques and green building technologies, we propose the following specific recommendations to promote future research and practical applications: residential buildings should be designed with a function-oriented and rational layout to meet the various needs of residents while ensuring building safety and durability; specific policies and incentives should be developed to support the development and use of renewable energy and energy-saving technologies to reduce building operation's impact on the environment. It is recommended that monitoring and quality control be strengthened during the construction of high-rise buildings, especially during the foundation and structural construction phases; advanced monitoring technologies, such as Internet of Things (IoT) devices, should be introduced to track key parameters in the construction process in real time. Promoting green building concepts and adopting environmentally friendly materials and energy-saving technologies will help reduce energy consumption and improve quality of life. By implementing the above recommendations, the industry can take a significant step forward in the research and practical application of high-rise building technologies, promoting innovation and development in the construction industry. This will not only improve the safety and sustainability of high-rise buildings, but also enhance public trust in construction projects and lay a solid foundation for future urban development.

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