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(Research Article)

Collaborative design and construction analysis of building structure and foundation of subway overlying complex

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Abstract

With the acceleration of urbanization, land resources are becoming more and more precious, especially in densely populated urban centers. As an efficient land use model, the subway overlying complex can not only optimize the urban spatial layout, but also promote the integration of public transportation and urban development. This paper aims to discuss the collaborative design and construction technology of the building structure and foundation of the subway overcover complex, in order to provide theoretical support and technical guidance for the practice in related fields. Based on the literature review of domestic and foreign subway overcover development projects, this paper reviews the research status and development trend in this field, and identifies the main problems in structural safety, foundation stability and construction efficiency. On this basis, the paper puts forward the design principle of the subway overcover complex, and emphasizes the key role of the synergistic relationship between the structure and the foundation to the success of the whole project. The paper further analyzes the construction technology of subway overcover complex, including specific construction technology, reasonable construction sequence and project management measures. Through comparative analysis of success and failure cases, it reveals the problems that may be encountered in the actual operation and its coping strategies.

Keywords: Subway overcover complex; Collaborative design; Foundation; Construction technology; Urban space utilization.

1. Introduction

As the process of urbanization becomes progressively faster worldwide, the task of sustainable growth becomes an important consideration for urban development, especially in large populated conurbations. This is because as the populations of the urban areas continue to expand, the core issues of management of land and means of transport to meet the needs of the people, existing Business enterprises, and other activities within the urban setting become a crucial consideration to address in the most sustainable manner possible. Competition for and availability of land is progressively becoming limited and this is most apparent in the fundamental zones of major urban cities. This scarcity has led to the emergence of new-generation urban development strategies that seek to provide maximum land utilization that accommodates various urban activities. Of these models, the subway overlying complex has become one of the most favorable solutions that can combine the transport terrestrial construction with residential, commercial, and recreational facilities, thus, creating the most productive use of the urban territory [1].

The idea of the subway overlying complex also called the Transit-Oriented Development (TOD) model uses the locations of subway stations and offers multi-purpose facilities that improve the connectivity of urban areas. This model not only supports the linkage between the public transportation system and urban planning but also enhances the disposition

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of limited urban land resources for sustainable development. TODs, where residential, commercial, and/or recreational facilities are built above, or near, subway stations, are another distinctive characteristic of the city that also has several benefits that including: The need to acquire large pieces of land to accommodate these facilities and programs is greatly reduced hence limiting the spreading out of the city's infrastructure and saving the environment from further strain through traffic-related emissions [2].

Originally, the papers on the TOD and the subway overcover emerged in the 1980s due to the rising traffic jams and efficient utilization of land in the developed countries including the United States, Japan, and Singapore. For example, Singapore has adopted TOD as a global best practice in which well-coordinated land-use planning and extensive public transport connectivity form the basis of linking urban spaces. These projects go a long way in the qualitative changing of the face of cities while also improving the quality of life by providing modern living conditions around stations. Researches reveal that out of all the completed and ongoing TOD projects that are currently in Singapore, the Marina Bay Sands and the Changi Business Park are the most efficient in terms of the space that is being used and also the economic and social value that they bring [3].

In China, the TOD model has also taken place due to the pressure that is exerted by the rapid expansion of cities. Large and developed cities including the capital city Beijing, economic powerhouse Shanghai, Guangzhou, and Shenzhen among others have initiated construction of the subway overcover complex in appreciation of both issues of population density and transport network flow. Such complexes have been used in the transformation of urban areas through the delivery of integrated human settlement facilities, which include residential, commercial, and entertainment, within proximity to transit stations. However, the use of the reference subway overcover complexes in China has its specificity due to the complexity of constructing in urban space and the use of specific construction technologies that make it possible to guarantee the reliability of the structure and the stability of the foundation of a transit structure during construction work with actively functioning subway stations [4].

This investigation pertains primarily to the intents and purposes for examining the technologies of design and construction collaboration that are foundational to effective subway overcover complex construction. Specifically, it addresses three key challenges: protection of the subways' structural integrity as well as the safety of the buildings constructed over them, determination of the most appropriate type of foundation that would suit the overlying complexes and their loads, and supervising construction projects to the highest standards and within the stipulated time frame. Solving these issues implies the inefficiency of the work of a structural engineer, a professional in geotechnical matters, and sophisticated approaches in construction management. These approaches are important in avoiding the confusion that comes with combining above- and below-ground systems so that integrity of the both systems is not adversely affected [5].

Preservation of the subway's normal functionality and the safety of the overlying constructions is a challenging task to solve. The use of the subway involves several vibrations and heavy loads which compromise the structural stability of buildings above the subway. Consequently, these complexes' design requires reliable structures capable of withstanding these forces; the application of sophisticated seismic design and load control methodologies are used. This is more so in the areas that are capable of being affected by natural calamities such as earthquakes in this case since the dangers are escalated. For instance, Liu pointed out the fact that there is a necessity to adopt superior seismic isolation systems in subway overcover complexes to reduce the effects of ground motion.

This work also suggests that good foundation design is a critical factor that contributes to the success of subway overcover complexes. Due to the increase in geological variations that may be present in urban areas, there will always be variations in the foundation type to be used depending on the site conditions. This involves geomorphic mapping and evaluation of soil conditions, aquifer conditions, and bearing capacity to identify areas that require augmentation by service such as grouting, piling, or soil compaction. This implies blending information from rock and soil mechanics in foundation design to enable structures to bear the loads resulting from the 'weight' placed over them by the overlying buildings while at the same time avoiding differential settlements [7]. New developments in Geotechnical advancement and technology like jet grouting and deep mixing have been most beneficial as regards improving the foundation stability of such complexes as it help to provide counter force to the settlement cause due to imposing loads of trains and dynamic operation of subways [8].

Also, building subway overcover complexes requires complex project management, which requires efficient planning, and operation of high-quality work from different entities at the right time. Construction management plays a vital role in enhancing the efficiency of construction projects to complete within the specified timeline and cost affixed to it alongside safety and quality constraints. This study focuses on an assessment of measures applied in construction projects such as prefabrication and modular construction which have been widely adopted to improve construction productivity and minimize the need for labor at work sites. project planning and execution are eased by the Building Information Modeling (BIM) technologies that offer better visualization through detailed 3D models enabling project teams to easily coordinate [9]. Due to incorporating the use of BIM in these projects, space available in the construction projects can be well handled, and determining appropriate construction sequences that will not interrupt the running of the subway.

The importance of this method is in its ability to give possible insights into the design and construction of the subway overcover complexes that are commended for a collaborative effort. The objective of this study is to engage both literature review and case analysis and interviews with subject matter experts to evaluate the state of existing practice and to set out courses of action for future projects in this field. The results of this research would help the designer, the constructor and the decision maker who are interested in the subway overcover complexes design and construction for the progression of urban planning and sustainable development. This research also aims to address some gaps found in the literature in relation to the relationship between structural design and foundation stability, topics that have received limited attention given the landscape of TOD projects [10].

By discussing the options concerning structural safety, foundation conditions, and construction effectiveness, this paper aims to point out the interrelation between design and construction as key factors to the successful implementation of subway overcover complexes. Through analyzing the problems and potentials of this new form of urban development model, this research hypothesis expects to contribute to the further subproject development and improvement of subway overcover projects that create sustainable and effective urban spaces. The rising concerns about sustainability in the development and management of cities add more value to this research given that TOD projects such as subway overcover complexes can play a major role in lowering the carbon footprint of cities through enhanced land use and integration of public transit.

This therefore means that as urban centers continue to expand and develop, the traditional methods and approaches towards the management of space are more and more becoming incongruent with the task at hand which therefore makes the issue of efficient use of land even more crucial. The subway overlying complex is a vision for the modern development of large cities as a necessity and successful use of limited sq.m. to create a more connected and comfortable environment for citizens. It is shown that meaningful and effective integrated design and construction processes are essential to benefit from the potential of subway overcover complexes and overcome the technical, managerial, and environmental issues of the projects. Consequently, the results of the presented study will be highly beneficial for the further development of vast and multiscalar urban spaces in the course of the pursuit of a sustainable urban agenda.

2. Literature review

Since the 1980s, with the increasing pressure of urban traffic, many developed countries have begun to explore a new model of rail transit and urban land comprehensive utilization. The United States, Japan, Singapore, and other places took the lead in the implementation of subway overcover development projects, which not only improved urban traffic conditions, but also greatly improved the efficiency of land use [2]. Singapore's TOD model, for example, is considered one of the most successful in the world, connecting communities through an efficient public transport system that allows urban space to be properly planned and used. Foreign research mainly focuses on the following aspects: structural design and safety, research on how to build buildings above the subway without affecting the normal operation of the subway, focusing on the safety and stability of structural design; Foundation treatment, exploring how to treat the foundation above the MTR tunnel to ensure the stability of the building and reduce the impact on MTR facilities; Construction technology and management, analysis of advanced construction technology and management methods to improve construction efficiency and ensure project quality.

In China, with the acceleration of urbanization, the development of subway cover has gradually become a hot topic. In recent years, Beijing, Shanghai, Guangzhou, Shenzhen and other big cities have carried out the construction and research of subway overbuilt complexes [3]. Although it started late, the research and practice in China have made rapid progress and achieved certain achievements. Domestic research concerns mainly include: comprehensive benefit evaluation, evaluation of the social and economic benefits of subway overcover development, including the positive impact on urban traffic, land use and other aspects; Technical specifications and standards: to formulate technical specifications and standards applicable to the development of subway roof to guide the smooth progress of the project; Environmental protection and sustainable development, considering the impact of subway overcover development on the environment, put forward the design concept of green building and sustainable development.

2.1. Theoretical basis

Structural engineering: Structural engineering is a discipline that studies the design, analysis and construction of building structures [4]. For the subway overcover complex, the structural design needs to consider the following points: load analysis, including dead weight, live load, wind load, snow load, etc., to ensure that the structure can withstand these loads without damage; Seismic design, considering the possibility of earthquakes, the structure must have sufficient seismic performance to ensure the safety of personnel and property; The connection design ensures that the connection between the structural components is firm and reliable to avoid safety hazards caused by improper connection.

Rock and soil mechanics: Rock and soil mechanics mainly studies the mechanical properties of rocks and soil and their interaction with the foundation of buildings [5]. As for the design of the foundation of the subway overlying complex, special attention is needed. The analysis of geological conditions requires a detailed investigation of the geological conditions of the project site, including soil type, bearing capacity, groundwater level and other factors; Foundation strengthening technology, according to the geological conditions to choose the appropriate foundation strengthening methods, such as grouting reinforcement, pile foundation, etc. Settlement control, taking measures to prevent cracking or other damage to the building due to uneven settlement [6]

2.2. Existing issues and challenges

Although remarkable achievements have been made in the development of subway cover at home and abroad, there are still some problems and challenges that need to be solved: coordination is difficult. The subway overburden complex involves many departments and specialties, so how to realize the effective coordination is a big problem. The technical complexity is high, the technical requirements of structural design and foundation treatment are high, and professional technical support is needed. Construction risk may affect subway operation during construction. How to ensure construction safety is also an important issue. [7].The Auxiliary Role of Artificial Intelligence Applications in Mitigating the Linguistic, Psychological, and Educational Challenges of Teaching and Learning Chinese Language by non-Chinese Students. *The International Review of Research in Open and Distributed Learning*, *25*(3), 116-133.)

Zhao et al. focus on the use of Digital Twin in intelligent subway tunnels and stress the importance of Digital Twin technology for improving the performances, safety and operation of urban rail transit systems. In their work, they discuss how Digital Twin has been implemented together with IoT, AI, and big data analytics to form 'living' models that are updated continuously to reflect the physical and functional environments of the subway tunnels. The existence of this integration results in better effectiveness in predictive maintenance, lesser time of disruption, and efficient usage of energy hence giving easier and economical means of running subway systems. The study, however, indicates the following IM implementation issues include; high implementation costs, data security concerns and lack of homogeneity because of the variance in protocols in different systems. They suggest that in future initiatives to advance the application of Digital Twins there should be an emphasis on strengthening cybersecurity, increasing the interoperability of the data and carrying out some experimentation to demonstrate the utilization of Digital Twins in various subways. This research recommends more research to overcome these difficulties, and therefore realize the full potential of Digital Twin in the subway tunnel system [12].

Borrmann et al. examine synchronous collaborative tunnel design with consistency-preserving multi-scale models: the authors underscore the importance of improving the design process with the help of new tools in engineering informatics. There is a particular concern with the question of how the dynamics of design decision-making and model changes are coordinated across multiple stakeholders, and how changes at one scale are synchronized with those at another. They found that the application of consistency-preserving multi-scale models helps to address this problem, improves the efficiency of coordination and communication, as well as decreases the likelihood of errors, and speeds up the design decision-making process during tunneling projects. This approach is shown by Borrmann et al to greatly enhance the quality and reliability of tunnel designs since it ensures that different levels of design remain well aligned right from conception to the detail planning level. Nevertheless, it acknowledges that there are issues like the issues related to model integration that need the amalgamation of different models or powerful computational infrastructure for processing huge amounts of data for synchronized computing. The following is the list of future recommendations: incorporation of more elaborate software systems, improving user interface for increased stakeholder interactions, and practical testing of benefits of synchronous collaborative design for tunnel engineering projects [6].

Zhang and Ying focus on synthesizing low-carbon urban rail transit stations and cities using ideas of BIM and sensor fusion while highlighting sustainable city development. In their studies, they explain that the integration of BIM with the sensor technology can increase the effectiveness of the URT EMS through the conservation of energy, less emission, and optimum management among others. The study finds out that through this integration, there is enhanced surveillance and regulation of station surroundings in as much as there is encouragement for practices like efficient lighting and heating systems. Zhang and Ying used video-based sensors and they concluded that they enhanced real-time information processing and they enhanced the managerial feedback loops for timely and responsive action. However, the research finds some limitations such as the requirement of a relatively large amount of initial investment in technologies, and the integration of multiple sources of data. The authors suggest more investigation on cost-benefit comparison, elaboration of the standard integration procedure, and research on case examples to confirm the efficiency of BIM and sensor fusion for low-carbon construction for urban rail transit stations [14].

Based on the research by Ye et al., this study examines the deformation and safety of existing metro tunnels under the impact of adjacent foundation pit excavations and emphasizes the importance of coordinated safety analysis in urban construction. Based on the research study, it is pointed out that foundation pit excavations may lead to stress and deformation in the nearby metro tunnels thus compromising their structural and operational safety. Using modeling and simulations, Ye and the authors can study the deformation characteristics of the target structure and major factors that affect the tunnel stability comprising of the nature of the soil, depth of excavation and closeness of the tunnel. The research reveals that there is a need to constantly monitor and predict such risks, and that it is possible to use state of the art monitoring tools to monitor deformation and establish safety measures during trenching operations. Some of the issues mentioned include; the fluctuating geological environment and imprecision of current prediction models in estimating deformation results. Future recommendations include improvement in the performance of existing prediction models and planning of advanced monitoring techniques together with rigid construction regulations to ensure the safety of metro tunnels during the excavation of adjacent structures [15].

Li and Yuan proposed a safety control system of shield tunneling on the operating subway tunnels, the concerns are near-proximate construction in urban environments. It also remotely supports the proposal of proper assessment and evaluation of structures dealing with tunnels that already exist while another tunneling process is carried out nearby. The study explains how shield tunneling might present certain hazards in mainland China such as ground settlement, and tunnel deformation, and hence why safety control measures have to be employed. The research provides a framework that discusses the process of real-time observation, risk assessment, and application of construction techniques that have been enhanced to reduce the occurrence of these risks. Evaluation results presented in this manuscript reveal that the use of this framework can help to manage movements of the ground and safeguard nearby subway tunnels. This study also reveals some issues like the requirement of continuously accurate monitoring systems and the difficulty in applying safety measures corresponding to the differences in the geology. As for further developments, it is recommended to improve the framework by adding new elements of high-order data analysis, apply the framework to different media environments of big cities, and perform more field tests to increase the efficiency of protecting subway tunnels from shield tunneling [16].

3. Overview of the subway overtop complex

3.1. Definition and classification

The subway overlying complex refers to a complex of buildings with multiple functions built above or near the subway station. Such buildings usually include but are not limited to residential buildings, office buildings, shopping centers, hotels, entertainment facilities, etc., aiming to improve land utilization, promote efficient use of urban space, and enhance the vitality of the city by integrating multiple functions such as transportation, commerce and residence.

The subway overcover complex can be divided according to different classification criteria: according to the combination of functions, it can be divided into single functional type (such as pure business district), multi-functional mixed type (such as commercial and residential dual-use) and comprehensive type (including multiple functions); According to the scale, it can be divided into small complexes (such as single buildings), medium complexes (such as groups composed of multiple buildings) and large complexes (such as whole blocks or larger areas of development); According to geographical location, it can be divided into downtown type (located in the core area of the city), sub-central type (located in the secondary commercial center of the city) and marginal type (located in the edge of the city).

References are cited in the text just by square brackets [1]. (If square brackets are not available, slashes may be used instead, e.g. /2/.)

3.2. Function and value

The main functions of the subway overcover complex are reflected in the following aspects: traffic function, through seamless docking with the subway station, to provide convenient public transport services, reduce travel time, improve traffic efficiency; Commercial functions, the complex is usually equipped with shopping centers, restaurants and other commercial facilities to meet the consumer needs of residents and tourists; Residential function, part of the complex includes residential areas, providing residents with convenient living conditions; Office function, with office area, attracting enterprises to settle in, forming industrial agglomeration effect; Leisure and entertainment functions, providing entertainment places, such as cinemas, gyms, etc., to enrich people's leisure life.

The social and economic value of subway overlying complex is mainly manifested in: promoting urban development, optimizing urban spatial layout, improving land use efficiency, and promoting urban sustainable development; Enhance the image of the city, enhance the attractiveness of the city through modern architectural design and high-quality service facilities; To increase employment opportunities, the construction and operation of the complex can create a large number of jobs and drive the development of the surrounding economy; Improve traffic conditions, alleviate urban traffic congestion, reduce private car travel, reduce environmental pollution; Enhance community vitality, provide diversified activity space, promote community exchanges, and enhance community cohesion.

3.3. The advantages and challenges of subway roof development

The advantages of subway overlying development can not only realize land saving, that is, make full use of land resources around subway stations to maximize the utilization of land, but also realize convenient transportation and facilitate people's travel. In addition, it also has huge economic and social benefits: through intensive development, the value of the property is increased, bringing a higher return on investment; We will improve people's living environment and promote harmonious social development [9].

In addition to solving complex engineering and technical problems, such as structural design and foundation treatment, the development of subway cover also faces the problem of difficult coordination. Because the development area of subway cover involves multiple stakeholders, a good coordination mechanism is needed to ensure the smooth progress of the project. Moreover, due to the huge investment in the early stage and the long cycle, long-term stable financial support is needed. Safety risks are the top priority of the challenges, during the construction from all sides of the security risks are always present, everywhere, in order to ensure the safety of personnel and subway operation is not affected, safety production needs to ring the alarm bell and make unremitting efforts. In addition to the uncertain factors, the building itself also has a certain risk.

3.4. Cooperative design principle

3.4.1. Structural design principle

Accurately calculate the various loads of the building, including dead loads (such as the weight of building materials), live loads (such as people, furniture, etc.), wind loads, snow loads and earthquake loads, etc., to ensure that the structure can be safe and stable under various working conditions. Considering the potential threat of earthquake to buildings, seismic codes should be adopted in the design to strengthen the seismic capability of the structure, such as setting appropriate isolation layers and using shock absorption devices. In the design process, it is necessary to ensure a good match between the superstructure and the foundation to avoid the uneven settlement or tilt of the foundation caused by unreasonable structure. Pay attention to the connection design between structural members to ensure that the connection parts have sufficient strength and stiffness to prevent stress concentration. Reasonable selection of building materials, balance the relationship between cost and performance, the use of lightweight high-strength materials to reduce self-weight and reduce the foundation burden. Through computer simulation and optimization algorithm, the most economical and reasonable structural design scheme is found to reduce unnecessary material waste.

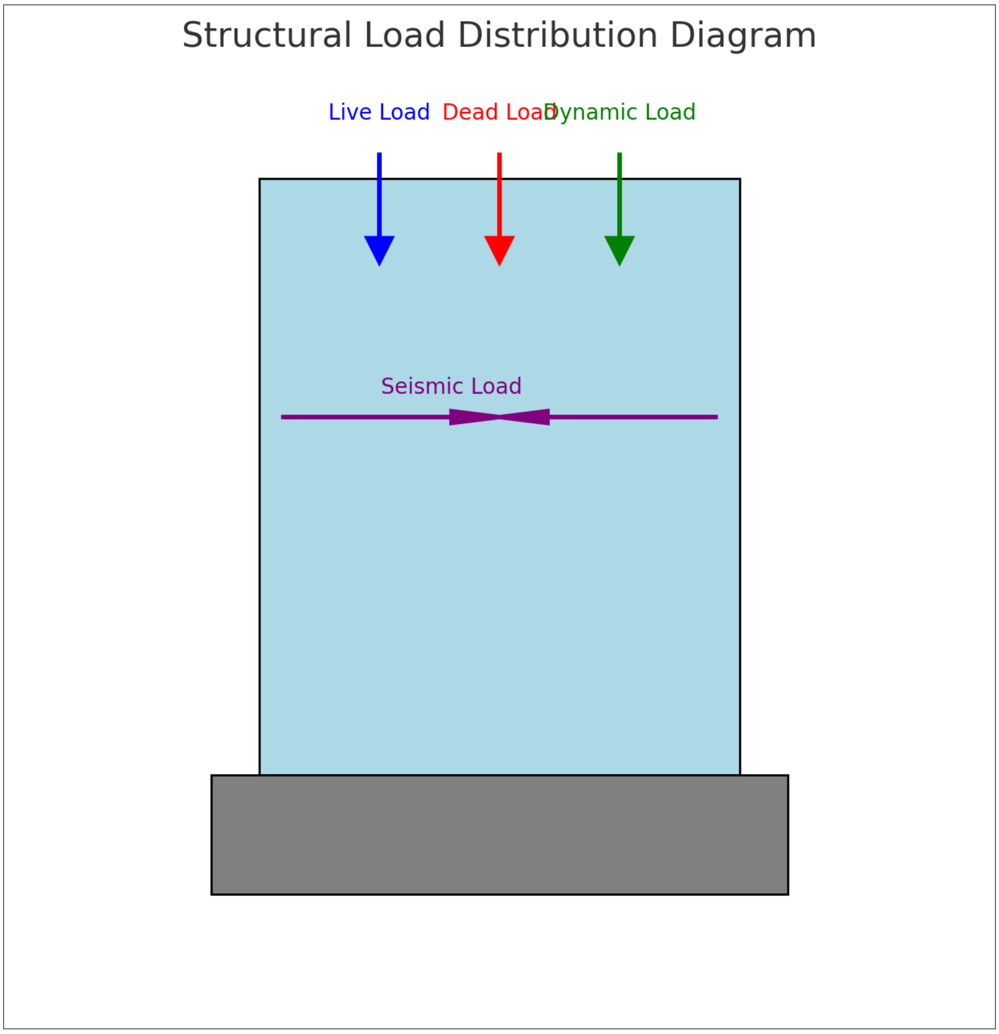

Figure 1 Structural Load Distribution Diagram

The diagrams demonstrate how the structural loads and the seismic forces are controlled in case of subway overcover complexes. The load distribution diagram indicates dead, live and dynamic loads The seismic isolation diagram depicts how isolators can help in minimizing the effects of seismicity on a structure increasing it's stability and safety.

3.5. Foundation design requirements

When designing the foundation of the subway overcover complex, it is necessary to carry out comprehensive geological exploration and obtain detailed geological data, including soil type, bearing capacity, groundwater level and so on. This series of preparatory work is the basis to ensure the rationality and safety of the foundation design. Through systematic geological exploration, detailed geological data can be obtained to evaluate the bearing capacity and stability of the foundation, which provides a reliable basis for the subsequent foundation design. Geological exploration usually includes drilling sampling, in-situ testing, laboratory tests and other means to ensure the accuracy and comprehensiveness of the data.

Choosing suitable foundation form is a key step in foundation design. According to different geological conditions, shallow foundation, deep foundation (such as pile foundation) or composite foundation can be selected. Shallow foundations are suitable for soil layers with high bearing capacity, while deep foundations are suitable for areas with low bearing capacity or complex geological conditions. Because of its high bearing capacity and stability, pile foundation technology is particularly common in the construction of subway overburden complex. When selecting the foundation form, it is necessary to comprehensively consider the geological conditions, the load characteristics of the building and the construction conditions, so as to ensure that the selection of the foundation form can meet the safety requirements of the building and ensure the feasibility of the construction. In some cases, the foundation conditions may not be sufficient to support the weight of the building, which requires foundation reinforcement measures. Common foundation reinforcement methods include grouting reinforcement, replacement reinforcement and so on. Grouting reinforcement is to fill the pores by injecting cement slurry or chemical slurry into the soil layer to improve the compactness and bearing capacity of the soil. Replacement reinforcement is to remove the weak soil layer and replace it with higher strength materials, such as sand, gravel, etc., so as to improve the bearing capacity of the foundation. These measures can effectively improve the conditions of the foundation, improve the stability and bearing capacity of the foundation, and ensure the safety of the building.

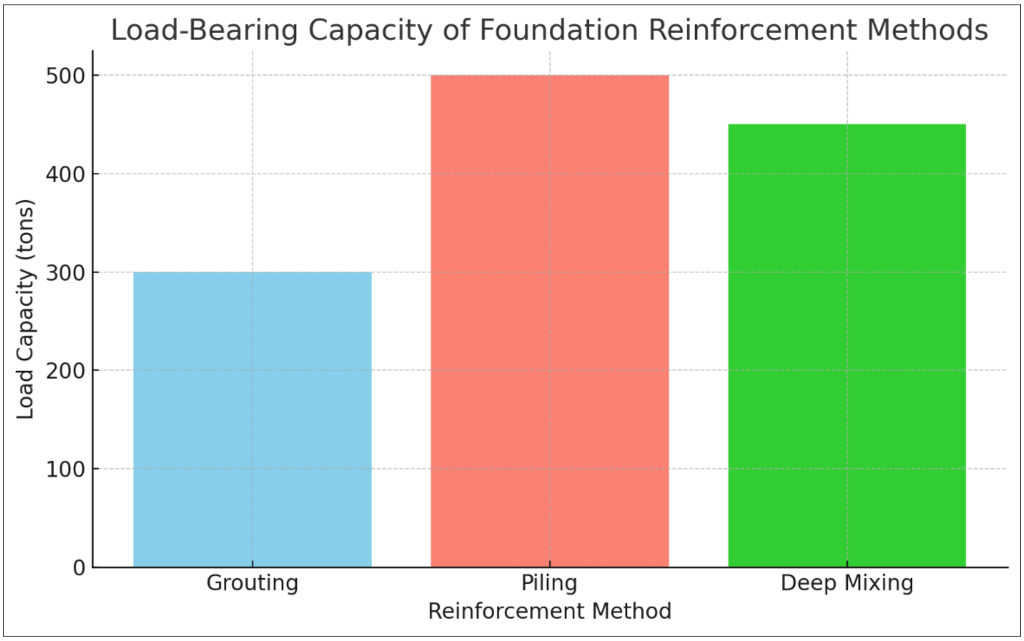

Figure 2 Load-Bearing Capacity of Foundation Reinforcement

The bar chart portrays the load-carrying capacities of overcover subway complexes foundation reinforcement techniques/technologies including grouting, piling, and deep mixing. Deep mixing and grouting are the second and third approaches in terms of construction capacity compared to piling. This kind of visualization suggests that reinforcement techniques should be chosen depending on the situation and grounds of the given project.

In order to predict the settlement of buildings, especially the risk of uneven settlement, theoretical calculation and numerical simulation are usually carried out. The theoretical calculation is based on the known geological data and the load condition of the building, and the method of engineering mechanics is used to estimate the settlement. Numerical simulation uses computer software, such as finite element analysis software, to build three-dimensional models for more accurate settlement prediction. These methods can help designers find potential settlement problems in the design stage and take appropriate measures to solve them. In the construction process, strict settlement monitoring is essential. By setting the settlement observation point and recording the settlement data regularly, the abnormal settlement can be found in time and the corresponding remedial measures can be taken. For example, if the local settlement is found to be too large, the settlement can be controlled by adjusting the construction sequence, adding temporary support and other means to ensure the safety and stability of the building. In the concrete design process, the structural design and foundation design must be regarded as a whole, and the interaction between them must be fully considered. Structural design should not only consider the load of the building itself, but also consider the bearing capacity and deformation of the foundation to ensure the overall stability and safety of the building. Designers need to flexibly adjust the design scheme at any time according to geological changes and construction conditions, to ensure that the design matches the actual situation, and to avoid safety hazards caused by the design and reality.

In addition, the choice of environmentally friendly building materials and the integration of energy saving concepts are also important aspects that cannot be ignored in the foundation design. In the selection of building materials, priority is given to environmentally friendly building materials, such as recycled aggregate, high-performance concrete, etc., which can reduce the impact on the environment. In structural design into the concept of energy conservation, such as the use of natural ventilation, natural lighting and other ways, not only can reduce energy consumption, but also improve the comfort of the building, to achieve the goal of green building.

Table 1 Comparison Table of Foundation Types

Foundation Type	Load Capacity	Cost	Construction Time	Suitability
Shallow Foundation	Moderate	Low	Short	Suitable for high-bearing soils
Pile Foundation	High	High	Long	Suitable for low-bearing or complex geological conditions
Deep Foundation	Very High	Very High	Long	Suitable for highly variable soil conditions

The cooperation of a multi-professional team is an important guarantee to ensure the comprehensiveness and rationality of the design scheme. Structural engineers, geotechnical engineers, architects, and other technical professionals need to participate in the design process and provide comprehensive design advice from their professional perspectives. Through the establishment of an effective information communication mechanism, to ensure that the information between the majors is unimpeded, timely solve problems, avoid information island phenomenon, and improve the overall level of design.

3.6. Construction technology analysis

3.6.1. Construction technology

First of all, the foundation treatment, including geological exploration, foundation excavation, foundation reinforcement and other work. By injecting cement slurry or chemical slurry into the foundation to fill the pores, the bearing capacity and stability of the foundation are improved. At the same time, the replacement method is used to excavate the weak soil layer and replace it with higher strength materials, such as sand, gravel, etc., to enhance the bearing capacity of the foundation. Finally, the pile foundation technology is adopted, and the pile is driven into the deep underground by the method of bored pile and prefabricated pile, so as to disperse the load of the superstructure and ensure the stability of the foundation. After the completion of the foundation treatment, the construction of the foundation structure, such as the main structure construction stage such as cap, pile foundation:, the construction of the superstructure, including the installation of columns, beams, plates and other components. In the installation technology of prefabricated components, the way of on-site assembly of prefabricated components is adopted to improve the construction efficiency and reduce the on-site operation time and labor demand. The proper formwork system is selected in formwork support technology to ensure the quality of concrete placement, and to facilitate disassembly and reuse. The welding and assembly of steel structure adopts high-strength bolt connection or welding technology to ensure the connection strength and integrity of steel structure. After the main structure is completed, indoor and outdoor decoration and installation and commissioning of mechanical and electrical equipment are carried out.

In order to keep track of the construction progress at any time, a detailed construction progress plan should be prepared from the beginning of construction to the date of completion, and the implementation should be checked regularly to ensure that the project progresses as planned. And establish a strict quality control system to supervise and inspect every link in the construction process to ensure that the project quality meets the design requirements. Formulate safety management system, conduct safety education and training, and equip necessary safety protection facilities to prevent accidents. Make reasonable arrangements for the use of funds, control unnecessary expenses, and reduce costs through fine management. Case 1: Building a commercial complex on the subway in a city center. The project is located in the downtown area of the city, with busy traffic and complex geological conditions. Construction technology, using prestressed pipe pile technology for foundation treatment, combined with prefabricated components assembled on site to accelerate the construction speed. Through strict schedule management and quality control, ensure that the project is completed on time and with high quality. At the same time, effective measures should be taken to reduce the impact of construction on the surrounding environment. The final project was successfully completed, the building was stable and reliable, and was highly valued by the owners and users.

In the Gantt chart, the management indicates the various phases of construction such as foundation treatment, superstructure and prefabricated components' installation showing the intended sequence and time. The bar chart analyzes load-bearing capacity of reinforcement methods such as grouting, piling, and deep mixing with a focus on their applicability depending on the project.

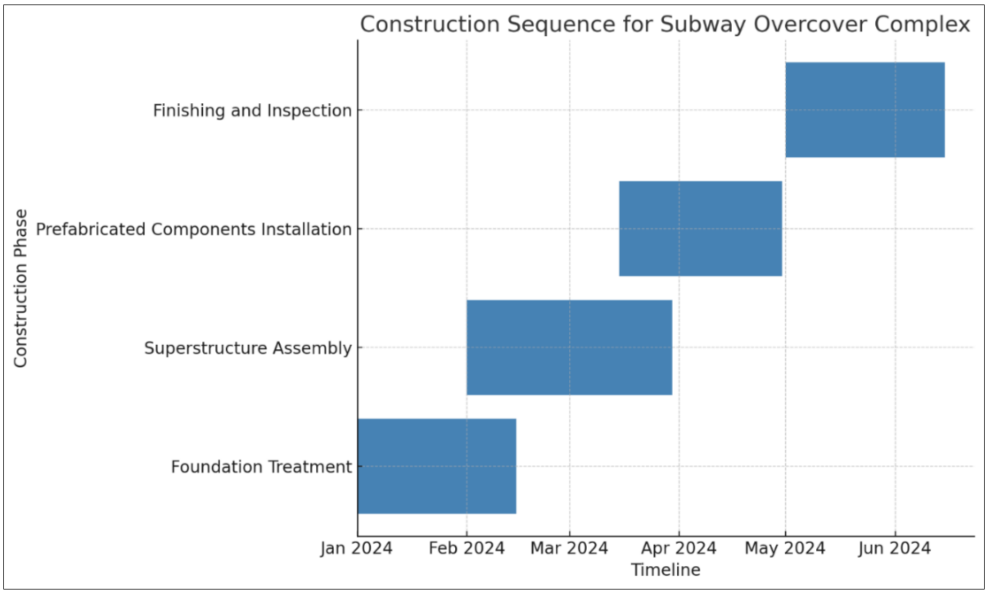

Figure 3 Gantt Chart

3.7. Problems encountered in construction and solutions

In the construction, the weak foundation and insufficient bearing capacity may lead to the settlement or inclination of the building. The deep mixing pile, high-pressure rotary jet pile and other technologies are used to strengthen the foundation, or the pile foundation is used to replace the shallow foundation to improve the bearing capacity of the foundation. Cracks appear at structural joints, affecting the overall stability of the structure. The solution is to strengthen the design and construction quality control of the connecting nodes, ensure the quality of welding, use high-strength bolt connection, and carry out the necessary reinforcement treatment. In specific construction, the lack of effective communication between different construction units often leads to the delay of construction progress. In order to solve this problem, a multi-party coordination mechanism has been established, and regular project coordination meetings have been held to clarify the responsibilities of all parties and ensure the smooth transmission of information. To solve the impact of a large amount of noise and dust on the surrounding environment caused by the construction process, noise barriers were built, noise reduction equipment was installed, and dust diffusion was controlled by wet operation. A series of measures such as reasonable arrangement of construction time and avoiding noisy operations during sensitive periods can minimize dust and noise pollution. Case 2: Building a residential community on the subway at the edge of a city. The project is located on the edge of the city, with relatively good geological conditions, but it is required to minimize the impact on the environment during construction. Construction technology, the use of advanced green construction technology, such as low noise equipment, wet operation, etc., to reduce environmental pollution. Take measures to strengthen site safety management to ensure the safety of construction personnel; Implement fine cost control and allocate resources rationally. Through scientific and reasonable construction technology and management means, the project not only reached the expected goal, but also made contributions to energy conservation and emission reduction.

4. Case study

4.1. Case 1: Kowloon Bay MTR Overhead Complex in Hong Kong

As a highly developed city, Hong Kong's land resources are very valuable. The Kowloon Bay MTR Overhead Complex is located in the East Kowloon area of Hong Kong, close to the MTR station. The project aims to create a multi-functional complex of residential, commercial and office use through efficient land use. The project covers an area of about 50,000 square meters, with a total construction area of more than 300,000 square meters, which is a typical large-scale subway development project. The project uses advanced structural design techniques to ensure that the building can withstand various loads, especially considering the earthquake risk in the Hong Kong region, and enhances the seismic performance. The design team used 3D modeling software to optimize the structure and detailed load analysis through finite element analysis software to ensure the safety and stability of the structure. In accordance with Hong Kong's seismic code, the design team increased the seismic rating of the structure, adopted high-performance seismic materials, and set up multiple seismic nodes to ensure the safety of the building under earthquake conditions. Through

3D modeling and finite element analysis, the design team optimized the structure several times to ensure structural safety under various load conditions. In view of the complex geological conditions in the Kowloon Bay area, the design team adopted the deep mixing pile technology, which mixes cement slurry with soil to strengthen the foundation and improve the bearing capacity and stability of the foundation. In the construction process, a number of settlement monitoring points are set up to monitor the settlement of the foundation in real time to ensure the stability of the foundation.

In the construction, the prefabricated component installation technology is used, which greatly shorens the construction period, reduces the amount of on-site work, and improves the construction efficiency. The specific approach is: the use of prefabricated component technology, most of the components are produced in the factory, and then transported to the site for installation, reducing the site construction time and work. Through the use of prefabricated components, the construction period is shortened by about 30% and the construction efficiency is improved. While fully implementing the scientific construction technology, a strict project management system has been established to ensure that the construction progress and quality are effectively controlled, and the project is promoted as planned through detailed construction schedule and regular progress inspection. A strict quality control system has been established to supervise and inspect every link in the construction process to ensure that the project quality meets the design requirements. And adopted a series of environmental protection measures, such as the adoption of sound barriers, noise reduction equipment and other measures to reduce noise pollution; Use wet operation to control dust diffusion; Reasonably arrange the construction time to avoid noisy operations during sensitive periods. The impact on the surrounding environment is reduced.

The project has successfully integrated the subway station with the upper building, which not only improves the efficiency of land use, but also provides a convenient living and working environment for local residents. The safety and stability of the building have been widely recognized as a successful example of MTR overcover development in Hong Kong.

4.2. Case 2: Singapore Changi Airport MTR overcover complex

The Singapore Changi Airport Metro Complex is located near Singapore Changi Airport, designed to provide passengers with convenient transport connections, and a combination of hotel, retail, office and other functions, aiming to create an international transport hub. The project covers an area of about 100,000 square meters, with a total construction area of more than 500,000 square meters, which is a large-scale subway overcover complex. The project uses a modular design that breaks down the building into several independent units for easy construction and maintenance, while also increasing the flexibility of the building. The specific approach is as follows: the building is divided into multiple independent units, each unit can be designed and constructed separately, improving the flexibility of design and construction; Through modular design, the design team carried out detailed structural optimization for each unit to ensure the safety and stability of the structure. Through accurate geological exploration and foundation evaluation, the foundation form suitable for local geological conditions is selected, and effective settlement control measures are taken. Firstly, detailed geological exploration was carried out, and detailed geological data including soil type, bearing capacity and groundwater level were obtained. According to the geological data, the bearing capacity and stability of the foundation are evaluated, and the foundation form suitable for the local geological conditions is selected. Then the bearing capacity and stability of the foundation are improved through grouting reinforcement, replacement reinforcement and other measures to ensure the safety of the building. In the specific construction, advanced BIM (building information model) technology is used. Through BIM technology, a detailed three-dimensional model is established, information management (such as visualization in the construction process) is realized, construction accuracy and efficiency are improved, and construction progress and quality are ensured. The project management team adopted lean management philosophy to ensure the smooth progress of the project by optimizing resource allocation and process control.

The Changi Airport Metro Complex project adopts a unique design concept, combining hotel, retail, office and other functions to not only become a landmark building in Singapore, but also provide a comfortable and convenient service experience for international travelers. Not only that, advanced construction technology and efficient scientific management, so that the project successfully completed within the scheduled time, to achieve the expected effect. Its unique design concept and efficient construction management make it one of the models of subway roof development in the world.

5. Conclusion and prospect

Through the in-depth discussion of the collaborative design and construction technology of the building structure and foundation of the subway overcover complex, we draw the following main conclusions: the structural design of the subway overcover complex must fully consider the safety and stability, to ensure that the building can withstand various loads, especially under the conditions of natural disasters such as earthquakes. The use of advanced structural design methods and technologies, such as 3D modeling and optimization algorithm, is helpful to improve the rationality and economy of the design. The design and treatment of foundation is directly related to the safety and stability of buildings. Through detailed geological exploration and foundation evaluation, selecting suitable foundation treatment technology (such as grouting reinforcement, pile foundation, etc.) and taking effective settlement control measures, the problem of uneven settlement can be effectively avoided. Structural design and foundation design should be regarded as a whole and coordinate with each other. Interdisciplinary cooperation and information sharing mechanism is an important guarantee to ensure the rationality of design and smooth construction. Advanced construction technology and effective management measures are essential to ensure project quality and schedule. The use of prefabricated component installation, formwork support and other technologies can improve the construction efficiency, and strict schedule management, quality management, safety management and cost control are the keys to ensure the success of the project. Through the analysis of successful cases, we can learn advanced design concepts and technical means; The failure case reminds us to pay attention to every detail, especially in the case of complex geological conditions, more careful treatment is needed. Although some achievements have been made in the design and construction technology of subway overpass complex, it is still worth further research in many aspects such as new materials and new technologies, intelligence and information technology, sustainable development and green building, and social and economic benefit assessment.

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