Preliminary Study on Function Layout and Development Principle of Shanghai Soft Soil Deep Underground Engineering Test Base

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Abstract. By investigating the industrial function layout of underground engineering test bases under construction or operation at home and abroad, and analyzing the predefined function and industrial layout of deep underground test bases in soft soil area of Shanghai, this article proposes the "1 + 1 + 3" function layout, development and construction principle of deep underground test bases, that is, centered on the deep underground base planning and construction management committee, periodically planning the "2020–2040" strategic layout for integrated construction of deep underground base and taking into account regional planning, hierarchical planning and plane layout of base construction, and provides the construction management guideline for function layout and planning of test bases.

Keywords: deep underground test base · function layout · development planning · construction management guideline

1 Introduction

Underground space construction in Shanghai, with high land use intensity and project diversity, has reached a considerable scale. However, current development of underground space mainly focuses on the shallow and medium covering area within 30 m, and development and utilization of the space has become saturated. Development of deep underground space has become the inevitable choice of urbanization in future. The depth of deep underground space development is mainly 50–100 m. The stratigraphic structure difference and the environmental influence are more complex, which bring a lot of difficulties to construction of deep underground space and selection on the types of operation. Based on the study on deep underground engineering test base, engineering technology utilization and function layout planning of deep underground space are performed to provide theoretical and practical guarantee for the sustainable development of underground space utilization. Currently, with respect to the idea of underground engineering test base, there are cases in China and abroad. Based on the experience of successfully operated test bases, the study on function layout and development procedure of the test base in Shanghai soft soil area is conducted. According to the predefined

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function of the test base and the associated industrial development need, the test base development planning and site layout principle are proposed in combination with the surrounding environment.

2 Survey on Industrial Function of Domestic and Foreign Underground

According to the statistics of the underground engineering test bases or scientific laboratories that have been successfully operated or are under construction, the industrial function of test base mainly includes science education, engineering test, logistics & warehousing, infrastructure, and scientific innovation output. Analysis on industrial function of domestic and foreign underground test sites under construction or operation are illustrated in Table 1 (Table 2).

Among these deep underground test sites, Hagerbach Test Gallery, which is successful in engineering test and scientific innovation output, has built a 5.5 km long underground cavity and tunnel system with diverse cross sections over 30 years' development. Engineering tests such as material test, blasting test and tunnel fire control test, and scientific innovation output such as new materials, new machinery (shield machine) and new method (shotcrete technology) are available in test sites. Moreover, test sites also provide venues for study and discussion, dining halls and agricultural R&D tests. Figure 1 shows the inside of Hagerbach Test Gallery.

3 Analysis on Predefined Function of Underground Engineering Test Base

3.1 Analysis on Function Layout of Underground Space

According to the current research, the industrial functions of deep underground space in progress or expected to be necessary in future are as follows:

1) Underground agriculture: The underground space is utilized to develop underground agriculture to realize the crops production mode of high yield, high quality, green and health, and study and develop the technology of plant growth and intervention in artificial sunlight band and culture medium environment.
2) Underground tech lab: Science and technology lab for biomedical science, new material, AI, precise manufacturing and other frontier fields. Underground space can provide enclosed, safe and secure test environment.
3) Underground space base: The moon and Mars are not habitable. In order to explore the universe, humans need to build space bases. Deep underground space can be explored for research and development of life support system technology. The simulated space base can be built for associated technical research.
4) Underground data center: Deploying the critical data center of a city underground will provide a safety barrier against natural disasters such as typhoon and protect data center facilities from all disasters except extreme earthquakes.

Table 1. Analysis on industrial function of domestic and foreign underground test sites under planning, construction or operation

Name of test site/laboratory/ project	Industrial function					Industry type
	Engineering test	Scientific innovation output	Science education	Infrastructure	Logistics & warehousing	
Hagerbach Test Gallery, Switzerland	■	■				Industrial, in operation
Kentucky underground data center, USA				■		Industrial, in operation
Sheshan underground data center, Shanghai				■		Industrial, in operation
CTS deep industry base, Switzerland	■	■			■	Industry, under planning and construction
Suzhou River deepwater tunnel, Shanghai	■			■	■	Municipal, under planning and construction
Underground nuclear		■		■		Municipal,

(*continued*)

Table 1. (*continued*)

installation, Japan						under planning and construction
Underground neutron energy power station				■		Municipal, under planning and construction
Underground cemetery				■		Municipal, in operation
Josef Underground Research Centre (URC), C		■	■			Scientific, in operation
Sanford Underground Research Facility (SURF), USA		■	■			Scientific, in operation
Lantau deep underground physics laboratory, Hongkon			■			Scientific, under planning and construction
Boulby Underground			■			Scientific, in

(*continued*)

Table 1. (*continued*)

Laboratory, UK						operation
Underground scientific test site, Singapore		■	■			Scientific, under planning and construction
Space base			■			Strategic, under planning
"Deep sea, deep earth, deep space and deep blue" strategy of China		■				Strategic, under planning and construction

Table 2. 2020–2040 Shanghai integrated construction plan for deep underground engineering test

Construction phasing	Industry type	Industry classification
5-year plan	Industrial	Transportation, data center, robot equipment, new material manufacturing, etc
10-year plan	Municipal	Energy power generation, resource storage, CO2 recycling, livelihood services, etc.
15-year plan	Scientific	Physics experiment, aerospace technology, marine technology, medical technology, etc.
20-year plan	Strategic	Special disaster protection, extreme agriculture, moon habit dwell, etc.

5) Underground cemetery: It satisfies the needs of the deceased for tombs in big cities, and also solves the problem of land scramble between the dead and the living, thus saving land resources. Ecological and future type underground cemetery is built with artificial light, greening and landscape technology to change people's traditional view of catacombs.

Fig. 1. Photos of the inside of Hagerbach Test Gallery

6) Underground energy city: Vigorously developing clean energy, reducing emissions of polluting gases and building energy reserves will become the major trends in maintaining energy safety and promoting sustainable energy development in the future. Deep underground space is used to explore the fields closely related to geoscience, such as geological storage of greenhouse gases and development and utilization of new energy resources such as geothermal energy and NGH. Underground neutron power station is a new type of power station in underground space, which bombards the fuel with high-energy neutrons and provides energy in the form of CHP.

3.2 Analysis on Predefined Function of Shanghai Deep Underground

The function layout of existing underground engineering test bases is investigated and surveyed. At present, according to the development prospect and expected return cycle of different industries, cargo transportation, underground data center, robot, new materials and new technology are the highest in terms of the urgency of demand for deep development of underground space and market. Industries that combine urban development with people's livelihood needs, such as energy power generation, resource storage and solid waste recycling, require early planning and long-term development due to the long planning and construction period and construction planning of at least 10 years will be necessary. Looking at the development of science and technology in today's world, every major breakthrough brings profound economic changes and great social progress. Science and technology has increasingly penetrated into every field of economic construction and human progress and become a decisive factor in the competition in overall national strength. Located deep underground, the underground tech lab is immune from cosmic radiation to a large extent and less affected by atmosphere, temperature and humidity, thus maintaining a relatively stable experimental environment [1]. As a result, global precedents have placed physics, aerospace technology, marine technology and medical technology laboratories underground. Thus, deployment of scientific industries

such as medical technology requires construction planning of at least 15 years. Industries with national development strategies such as disaster shelters, extreme agriculture and special equipment require construction planning of at least 20 years.

According to the function layout of the existing underground test base and the demand urgency and planning development law of different industries, the main industrial planning of deep underground engineering test base will be as follows: Industrial, Municipal, Scientific, Strategic.

4 Construction Layout Principle of Deep Underground Engineering Test Base

The function layout of base is planned on the basis of analysis on predefined function of underground test base. Zoning planning, hierarchical planning and plane layout of base are carried out in the field of construction space, and time planning of base is carried out in the field of construction phasing, so as to realize an all-round layout planning of test base in both space and time.

(1) Construction function layout
Zoning planning: The location factors considered in deep underground space development potential research project in Shanghai include thickness of geological layer, industrial potential area, traffic location and vertical function class. Zoning planning is required in the construction distribution planning of deep base. According to the above analysis, in terms of the importance of direct economic effects, development needs of various areas and national science and technology development plans, No. 1 deep underground industrial base, No. 2 deep underground municipal base, No. 3 deep underground scientific base and No. 4 deep underground scientific base are deployed [1]. It is a resource-specific deep underground industry base cluster, as shown in Fig. 2. Hierarchical planning (vertical planning): The functional isolation and structural discontinuity between deep underground space and shallow and medium underground space are beneficial to the independence of deep underground building, including the independence of development sequence and the independence of structural system. In the process of deep underground base planning and construction, vertical distribution planning is needed. Hierarchical planning is helpful for the independent development of the two development modes of special and specialized" deep underground facilities and traditional and popularized" shallow underground facilities, giving consideration to the traditional operation needs of the city and the future-oriented strategic development needs [2]. The functional division of deep base is carried out according to vertical depth, not only meeting the requirements of test functions, but also expanding from single function to different business models to explore the development of a variety of deep underground business models (Fig. 3).

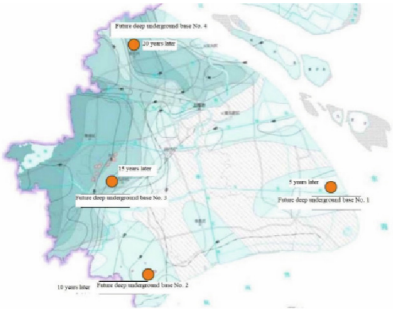

Fig. 2. Zoning planning of deep underground industry base cluster

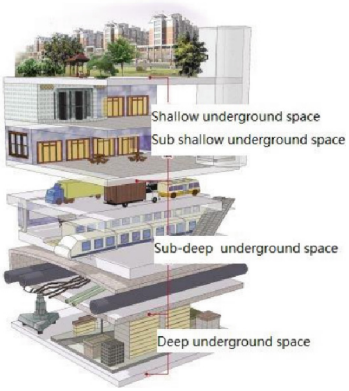

Fig. 3. Planning and utilization of deep and shallow underground spaces [3]

Plane layout: In an industrial base, it is necessary to carry out further plane zoning to improve the planning accuracy. For example, a wedge-shaped greenfield in Shanghai is selected as the site for test base and functional layout and floor planning in the base are carried out. Five shafts are arranged according to the estimated function, requirement and construction method of the test base. In order to maximize the utilization of test function of the site, different construction methods are adopted. For working shafts, the underground continuous wall, pneumatic caisson, open caisson method, reverse building method and VSM method are adopted. For tunnel construction, shield method, pipe-roof freezing and dark cutting, and pipe jacking method are adopted (Fig. 4).

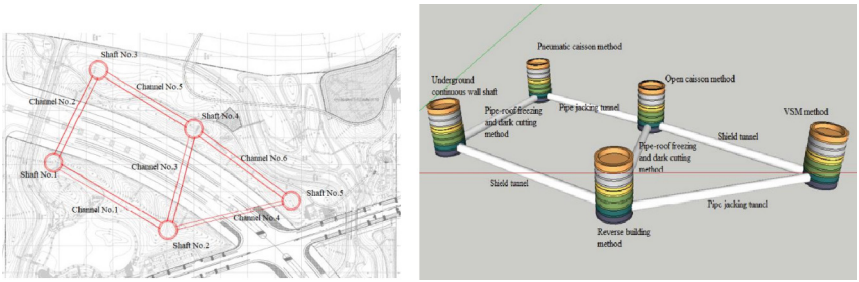

Fig. 4. Plane layout planning of wedge-shaped greenfield deep underground test base

(2) Time planning

From the project development experience of the invested deep underground industrial test bases, the construction phasing of future projects should be given great prominence. Based on the investigation and survey of the administrative department on underground space development in Shanghai, 20 years is a phasing node of urban construction management that fully grasps the administrative system of development and utilization of shallow underground space. The construction of Shanghai deep underground industry base cluster can be divided into four phases (5-year, 10-year, 15-year and 20-year). According to the importance of direct economic effects, the innovation of industry (such as equipment and materials) in deep underground bases is promoted in the first place to meet the most urgent problem in urban development of Shanghai. In addition, align with the world's leading industrial projects to produce ideal market return on investment of the first underground engineering test site. With the construction and management experience of industry, the municipal industries (such as energy and civil affairs) that serve the whole society are developed in deep underground bases for a long time. The scientific industry serves the scientific and technical development of the country, and the strategic industry serves the innovation of human livability, which are long-term construction planning. Based on the resource and asset oriented "construction distribution" planning, the strategic research plan of "2020–2040 Shanghai integrated construction plan for deep underground engineering test base" is proposed, as shown in the following table.

5 Set up "The Deep Underground Base Planning and Construction Management Committee"

A 20-year construction and distribution plan of deep underground engineering test base covering the whole city of Shanghai will lay an important foundation for scientific research innovation and institutional management for the establishment of the Shanghai global base of underground infrastructure. The large-scale economy of deep underground space related industries in Shanghai needs to be built on the basis that the key technical engineering test conditions and the administrative measures have reached certain stage of maturity. Therefore, it is necessary to set up Shanghai soft soil deep underground

engineering demonstration area in the whole city, and cooperate with the demonstration area to set up "the deep underground base planning and construction management committee".

6 Conclusion

By learning from the function layout and industrial types of the planned or successfully operated deep underground test bases at home and abroad, the study on function layout and development steps of test base in Shanghai soft soil area is carried out. According to the predefined functions of test base and the development needs of related industries, in consideration of the surrounding environment, the article proposes the view of centering at the deep underground base planning and construction management committee, planning the integrated construction of deep underground test base by phases, taking into account zoning planning, hierarchical planning and plane layout of base construction, and formulating the preliminary "1 + 1 + 3" guideline of function layout and development of deep underground test base to provide experience and reference for the planning and construction of Shanghai soft soil deep underground test bases.

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