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Research on Rapid Construction Technology of Changsha Shelter Hospital Based on Ontainer-Mold Combination

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Abstract: Natural disasters, especially serious infectious diseases, have brought a very heavy disaster to mankind. The outbreak of novel coronavirus pneumonia at the end of 2019 has spread to many countries around the world. As COVID-19 is spreading faster, more insidious and more contagious, the medical Administration of the National Health Commission pointed out in a press conference on March 22, 2022 that the Integrated Group of the Joint Prevention and Control Mechanism of The State Council require each province to have at least two to three shelter hospitals. Combining with the main rapid construction technology adopted in the construction of shelter hospital, this paper puts forward the design concept of "container-mold combination". Parallel construction is adopted to facilitate the coordination of resources and ensure the maximization of construction progress. The main process of rapid construction technology is introduced, which mainly includes sample road guide, subcontractor approach, work face handover, coordination of public service units, and final stage. The construction deployment of anti-epidemic medical buildings and supporting rapid construction technology is summarized, and the deployment principle, construction organization, construction deployment and professional task arrangement are emphasized. The speed target of completing the drawing design in 24 hours, constructing the temporary facilities in 36 hours, and pouring the first bottom plate in 5 days was achieved, with a total of 28 days to complete the shelter hospital.

Keywords: Modularization, The COVID-19 Pandemic, Container Building, Fire Resistance, Corrosion Resistance

1. Introduction

The natural disaster, especially the earthquake brings the disaster to the humanity is very heavy. Because of the randomness and suddenness of earthquakes, the magnitude of the 2008 Wenchuan earthquake [1] was 8, with more than 70,000 people killed and 375,000 injured, while the magnitude of the 2010 Yushu earthquake was 7.1, more than 2,700 people were killed, 270 were missing and 12,000 were injured. Nothing is more serious than a global pandemic. From the end of 2019 to the present, the new coronavirus pneumonia epidemic has made the world public health security to face the greatest challenge [2, 3]. Covid-19 has rapidly developed into a particularly severe epidemic worldwide. In the process of epidemic prevention and control, the system superiority and strong capital construction ability of our country's national governance system have been fully reflected, but on the other hand, it has also exposed the weakness of urban epidemic prevention, especially in countries with weak public health care systems. Without strong infrastructure capacity and coordinated control of emergency dispatch, the epidemic will get out of control in the country. The global epidemic overview on 31 December 2021 is shown in Figure 1.

The surge of COVID-19 infection cases has threatened the supply of global medical system resources and brought great pressure to hospitals. For the demand of nucleic acid testing for all, hospitals have no way to fully cope with it, mainly due to the limited space and equipment of hospitals [4, 5]. According to incomplete statistics, cities with a population of less than 5 million should complete nucleic acid testing for all employees within 2 days. According to the guidelines issued by the Joint Prevention and Control Mechanism of The State Council, cities with a population of more than 5 million should

complete nucleic acid testing for all employees within three days. In the long-term anti-epidemic process, the demand for nucleic acid testing has always been increasing due to rounds of nucleic acid testing. The on-site and experimental tests are shown in Figure 2.

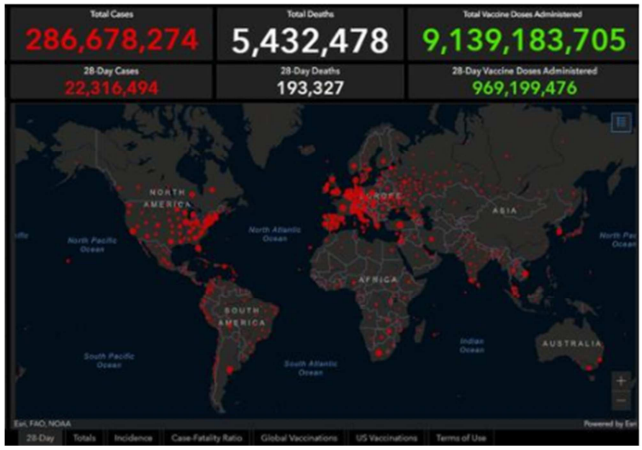

Figure 1. *Global epidemic overview (Source: Johns Hopkins University).*

Figure 2. *The on-site and experimental tests.*

In view of the fact that Covid-19 is spreading faster, more insidious and more contagious, the medical administration of the National Commission of Health said at a press conference on March 22, 2022, the joint defense and control mechanism integrated group of the State Council requires each province to have at least two to three shelter hospitals. Even if the construction of some local shelter hospitals is not completed, the construction programme provided should ensure that they are built and operational within two days when they are needed. Through the emergency effect of the built shelter hospital, we can know that it can play a very good role in the process of the treatment of the epidemic pneumonia patients, and it can cause great danger of pollution In addition to the strict requirements for airflow control, negative pressure environment, cleanliness and so on, the detection of nucleic acid of pathogenic microorganisms in sudden infection often requires high-level bio-environmental safety requirements [6]. There are many bottlenecks, such as high construction cost of traditional laboratory and negative pressure air-conditioning system, long construction period, difficult installation and transportation, and difficult to realize convenience in remote and backward areas, which need to be broken through [7, 8].

2. New Concept of Container-mold Combination in Shelter Hospital

2.1. Project Overview

The Changsha Shelter Hospital project of Hunan province is located at the southwest corner of Kaifu Avenue and Beltway Highway in Kaifu District, Changsha Province. It covers an area of about 110,000 m^2 and has building area of about 48,000 m^2. The aerial image is shown in Figure 3. There are 2450 beds, including 60 in the emergency ward. It was designed in strict accordance with the concept of "Doctor-patient division", combined with the health safety level, it is divided into "Three zones and two channels" (three zones are clean zone, semi-polluted zone and polluted zone; two channels are medical channel and patient channel). The staff living area is set on the north side, and the isolation ward area is set on the south side. There are 14 isolation wards for mild cases and 1 emergency ward. Since entering the site, the progress of the project has been measured by hours, with 24 hours to complete the design of the drawings, 36 hours to complete the temporary road, site clearing, site leveling, silt removal and filling, 48 hours to complete the construction of temporary electricity and water access, 5 days to build the first floor pouring key nodes. During the peak period, more than 300 managers, more than 2000 workers, and 120 large-scale machinery and equipment were put into the field.

Figure 3. *Aerial image of shelter hospital.*

The Shelter Hospital is one of the important carriers in the construction of epidemic prevention medical buildings during the epidemic period [9]. The first design concept of the hospital is a kind of field mobile medical platform which can be rapidly deployed. The medical shelter is the main carrier of the hospital, which integrates the support function of medical

treatment and medical technology. The components of the shelter hospital generally include ward units, medical function units, technical support units and so on, and it is a kind of usable modular medical buildings for epidemic prevention [10]. The utility model has the multi-functional characteristics of medical and surgical treatment, emergency treatment, clinical examination, easy transportation, simple construction, safety and high efficiency and so on. The rapid construction and operation of the epidemic prevention medical buildings can solve the problem of the detection and treatment of patients in time, effectively relieve the pressure of the existing infectious disease hospitals, and reduce the risk of cross infection. It embodies the concept of"People-oriented, life first" in epidemic prevention in our country.

2.2. The Architectural Design Concept of "Container-Mold Combination"

In order to guarantee the construction progress of airport epidemic prevention medical building and supporting emergency engineering, the project adopts EPC general contracting management. The design and construction of the modular concept, select prefabricated container-type board room, integrated bathroom, finished resin linear drainage ditch, plastic inspection wells, prefabricated finished scaffolding and other rapid construction technology. 20 days to complete the construction of the project, to ensure that the airport epidemic prevention concentrated residential areas put into use. This project adopts modular and standardized modular container assembly, that is, the design concept of "container-mold combination" is put forward, so as to achieve the standardization of architectural design, modular factory production, clean area, semi-contaminated area, contaminated area three areas and isolation ward, medical work area, medical function unit and so on are completely made into standard units, and try to combine similar items. To minimize the number of units, a standard container with a basic unit size of 3mx6m is adopted [11, 12].

The prefabricated container-type board house is shown in Figures 4-5. The container body is the basic unit, and the structure of the container body is made of special cold-formed galvanized steel structural, which is mainly made of flame retardant and insulation materials. Including plumbing, electric, decoration and supporting equipment. All are prefabricated in the factory according to the modular requirements of architectural design. There is no need for secondary processing in the transportation process or material processing on site. It can be used for assembly or overall lifting on site. It can also be combined into a larger space through different directions of horizontal and vertical. The main body of container-type board house is container-type movable board house structure, and the roof is steel structure +0.5mm thick laminated steel tile. Structure design service life is 5 years, the roof and wall pressed steel plate 5 years, which can meet the current bearing capacity, wind pressure and fire resistance requirements [13].

Prefabricated container-type board house has the advantages of simple structure, convenient installation, convenient relocation and many turnover times. Because the product is basically undamaged, there's no construction waste, prefabricated, flexible, energy saving and environmental protection. It is called a new "green building". The main construction process is as follows: modular design → construction preparation → foundation construction → on-site assembly of prefabricated container-type board building → modular integral (sanitary ware) construction → construction of outdoor rain sewage pipes and plastic inspection wells → installation of finished resin linear drainage ditch → construction of supporting facilities.

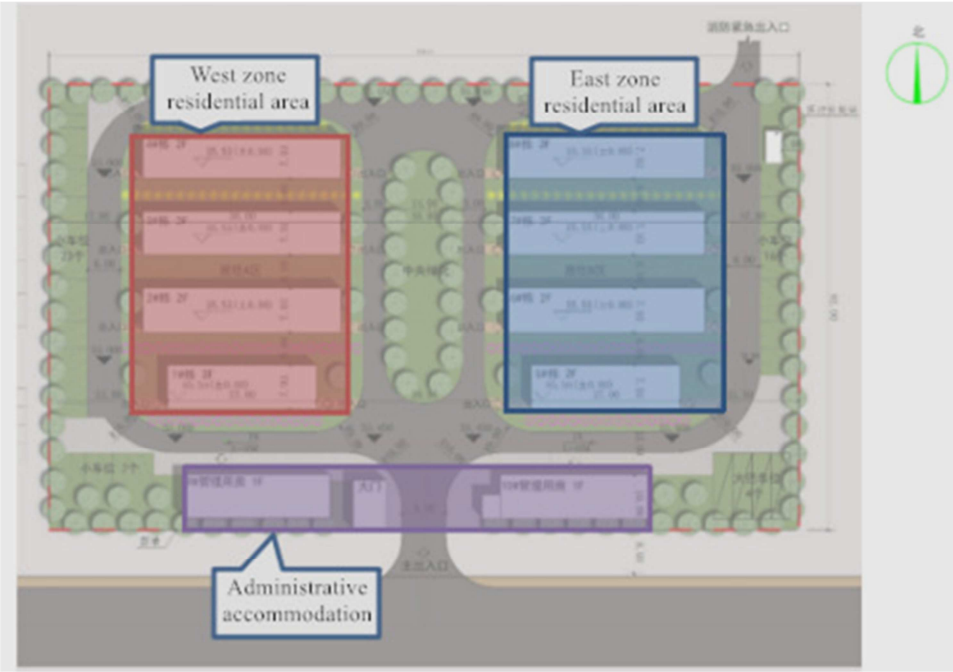

Figure 4. *Modular design of the general plan layout.*

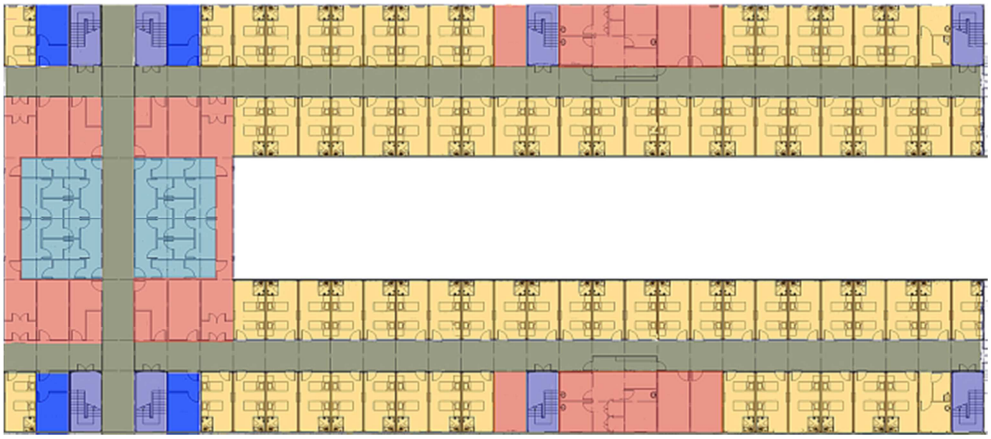

Figure 5. *Schematic diagram of residential unit module.*

3. Rapid Construction Technology of Shelter Hospital

3.1. Construction Organization of Rapid Construction Technology

In order to facilitate the coordination of resources [14, 15], maximize the construction progress, maximize the utilization of material resources, and maximize the construction mechanical efficiency, the research team divided the project into three zones, namely A-B-C, with parallel construction between and within each zone, as shown in Figure 6. The main elements of the phased construction deployment were as follows:

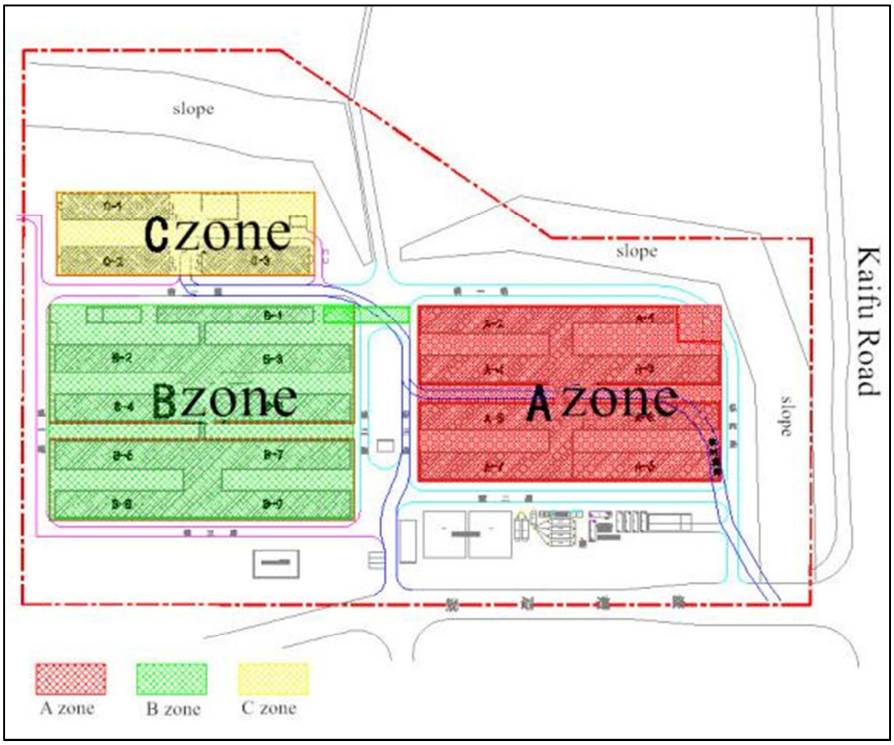

Figure 6. *Project partition Diagram.*

(1) Field leveling stage. According to the original topography and design plan, the site can be divided into two excavation areas and three filling areas. The other side is a slope area with a height of 3m to 18m on the north and east sides. The total amount of large earthwork excavation is about 120,000 cubic meters, the total amount of balanced backfill in the site red line is about 70,000 cubic meters, and about 50,000 cubic meters of earthwork needs to be transferred to the outside of the western slope outside the red line. The earthwork calculation does not consider the amount of stone replacement used in foundation treatment. Considering the tight construction period, the whole area synchronously carries out 24-hour uninterrupted

operation without organizing flow construction. The soil bearing capacity of the field before the dynamic rammer is weak, and the carrying car cannot reach the place. The schematic diagram of earthwork transfer at the site is shown in Figure 7.

(2) Foundation reinforcement stage. It is mainly carried out according to the partition construction in the special construction scheme of dynamic compaction. After reaching the completion surface of dynamic compaction, 150 mm paving crushed stones for rolling. Within the range of 15m from the current slope, it is strictly prohibited to use dynamic ramming construction, and real-time monitoring of the slope should be done when it is near the slope construction.

(3) Foundation and board house installation stage. After the completion of the dynamic compaction of the foundation in each district, the concrete can be poured by laying and filling the crushed stone according to the set elevation and binding the reinforcement with the support mold. The slab house can be installed 1 day after the completion of the foundation construction.

(4) Outdoor pipe network construction stage. 2 to 3 days after the completion of the foundation construction of the slab house in each district, and the construction of the outdoor pipe network, the construction shall be organized according to the depth first, then the shallowness, and the road under the road first, then the road outside.

(5) Road and indoor electromechanical construction stage. After the construction of the outdoor pipe network, especially the under-road and over-road pipe network, the road construction will be carried out. At this stage, when 40%-50% of the board house installation is completed, the indoor mechanical and electrical installation will be carried out. Considering the tight schedule, the whole district will carry out 24-hour uninterrupted operation simultaneously, and the steel structure roof frame construction of the board house roof will be carried out simultaneously.

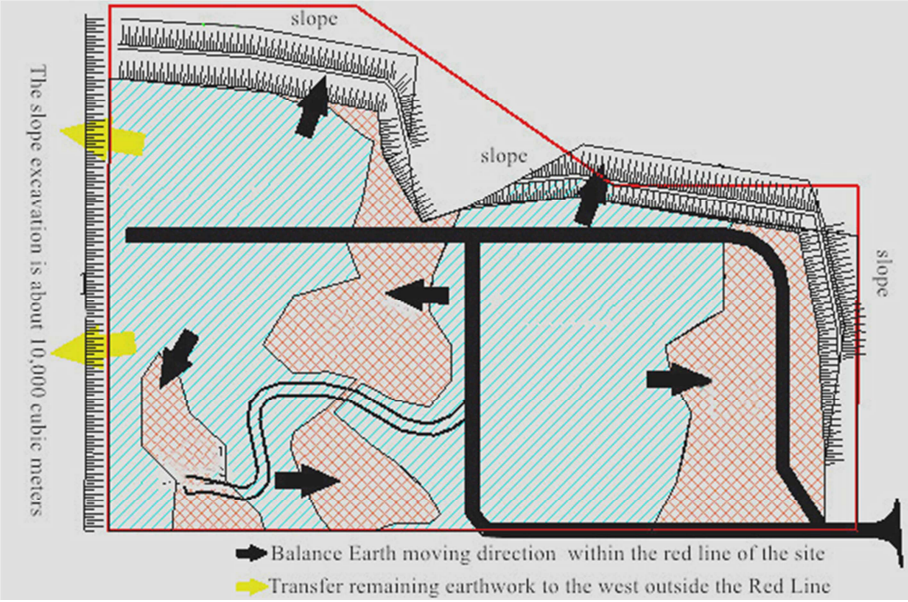

Figure 7. *The schematic diagram of earthwork transfer at the site.*

(6) Outdoor garden construction stage. After the outdoor road construction is completed, and the construction of the stone along the road, synchronous garden ground leveling and landscaping construction at the same time.

(7) Slope and foundation pit supporting stage. The foundation pit support of this project includes the slope on the north side of the site and the elevation difference of the site caused by the lowering of the elevation of the site on the west and south side, and the deep foundation pit support project formed by the construction of the rainwater sewage collection and treatment system in Zone A; which is designed and constructed synchronously with the main body of the project.

(8) Decoration stage. The construction organization of the decoration stage is synchronously interspersed with the electromechanical indoor construction.

Overall construction sequence: The overall construction sequence of the project follows the foundation first, then the base; First board house installation, then outdoor pipe network; First indoor mechanical and electrical installation, then outdoor garden and decoration; In the installation and construction stage of foundation and slab house, civil construction is mainly carried out, and installation is reserved and embedded interspersed. In the outdoor and decoration construction stage, all works of different professions and civil construction are crossed in space and synchronized in time.

3.2. Main Process of Rapid Construction Technology [16]

(1) Model guide. Before the formal mass production of the packing container room, the standard room model must

be made, ask the owner to confirm on site. Furniture and other equipment samples, household appliances and other items with large consumption, should be determined in advance of the specifications and models, so as to facilitate the market to find enough supplies or factory order processing in advance.

(2) The subcontractor enters the site. According to the overall progress plan, define the entry time of each subcontractor, so that each subcontractor can organize personnel and materials in advance. The general contractor shall pay close attention to the resource organization of the subcontractor, timely understand the existing difficulties, coordinate and help the subcontractor to solve the problems.

(3) Work handover. As the construction period of the epidemic prevention building is very tight, only the reasonable interpenetration of the professional subcontractors can ensure the overall progress of the project, ensure that workers and materials are adequate and timely. The main contractor shall hold general contractor meetings regularly to coordinate the work handover of each subcontractor, ensure the protection of finished products, and ensure the orderly progress of the project.

(4) Co-ordination of public service units. The normal construction of the project needs the assistance and participation of all public service units, which can ensure the timely access of water, electricity, network and gas according to the project schedule.

(5) The final stage.

a. Household acceptance, after the completion of the last process of construction, clean up the room and lock the door, the main contractor shall organize the relevant subcontractor to conduct a comprehensive inventory of each room, make a list of problems and submit them to the subcontractor to require them to deal with the problems one by one.

b. Separate acceptance of each specialty. In addition to the general foundation, main body, roof, water supply and drainage, electrical, energy saving, decoration, intelligence and fire-fighting, the sub-projects involved in epidemic prevention buildings shall be added special acceptance of epidemic prevention based on the requirements of epidemic prevention. The special acceptance of epidemic prevention is mainly to check whether regional isolation, personnel movement lines, epidemic prevention testing equipment, epidemic prevention and disinfection facilities, and medical waste disposal meet relevant epidemic prevention requirements. The main contractor will organize relevant medical experts, government health departments, Party A, supervisors and other units to participate in the acceptance inspection.

c. Completion acceptance. After the completion of all works of the project and the acceptance of each specialty item, relevant units shall be organized to carry out the completion acceptance.

d. Data archiving. After the completion and acceptance of the project, the data of each subcontractor shall be uniformly handed over to the main contractor, and then handed over to the construction unit by the main contractor.

e. Maintenance services. It is from the date of delivery of the project. After the project is put into use, the main contractor and each subcontractor shall sign the Quality Guarantee Letter with the owner, stipulating the responsible person and contact information of the project maintenance.

3.3. Construction and Deployment of Anti-epidemic Medical Buildings and Supporting Rapid Construction Technologies

(1) Deployment principles.

As an epidemic prevention building, the general schedule is very tight, very strict requirements for the schedule. In view of the characteristics of epidemic prevention buildings, we should take into account all the factors affecting the overall layout of tasks, human resources, machinery, time and space. Construction units of all professions shall obey the unified command and deployment of the general contractor.

In space deployment principle: the main consideration of three-dimensional cross operation, scientific interspersed construction procedures. In order to implement the principles of full space, continuous time, balanced and rhythmic construction, and leave room for subsequent construction as much as possible, ensure that the project is completed according to the general schedule.

Principles for resource deployment: Have sufficient human and machine resources, and ensure that useful resources are available. As the epidemic prevention project, the company will make every effort to provide adequate human resources, labor resources and professional subcontracting resources. All kinds of resources should meet the needs of the site construction, and must be prepared in advance of the backup storage, to deal with the rush and emergency.

General construction sequence deployment principle: The foundation first, then the main body, the civil construction first, then other professions, the main body first, then the subsidiary, from the far end of the project entrance to the entrance. After the completion of part of the base, an independent working face will be formed naturally. As long as the appropriate flow of rhythm, reasonable control of jet lag, equipped with adequate human resources and machinery, the tight lap of each process can be guaranteed to advance rapidly. In the initial stage, taking the construction of the main structure as the guide, the construction method of plane subsection and synchronous flow process of construction method was carried out. After the completion of the main body, ancillary works and outdoor works in accordance with the overall sequence of the advance fully launched. In the whole construction process, the reservation, embedment, installation and commissioning of the installation project should be fully compact lap with the civil construction in space and time.

(2) Construction organization.

Organizational structure and management mode:

1) Organizational structure, the project organizational structure is divided into four levels for hierarchical management: the first level is the command level (enterprise support level). Set up a project management committee with the company and owner as the core, allocate the source and direct the whole, and provide support from technology, resource, fund and manpower. The second level is the general contracting decision-making level. The team consists of project managers, project technical managers, production managers, business managers and mechanical and electrical managers. The decision-making level of the general contractor undertakes the planning, organization, coordination, control, supervision and other management functions. Implement the instructions of the headquarters and manage the subcontracting of all professions. The third level is the general management of general contracting, which is composed of six departments and one office, including engineering, technology, quality and safety, contracts, procurement, electrical and Mechanical Department and Integrated Office. The general management of the general contractor directly supervises and manages the quality, progress, safety and civilized construction of the project under the instruction of the project decision-making level, and is the executive level of the project. The fourth level is the subcontracting management of professions. It is composed of civil engineering project department and professional subcontracting project department. Under the instruction of the general contracting project Department, the subcontracting management of professions directly supervises and manages the quality, progress, safety and civilized construction of the project, which is the operation layer of the project department.
2) Management mode, implement the department responsibility system under the leadership of the general contracting project management department and the management system of engineering labor.

(3) Construction deployment.

Construction section division:

1) The overall construction sequence: foundation first, then board house installation, and finally road garden. After the board house foundation is completed, work handover to the board house installation. At this time, the board house installation and water and electricity pipeline, outdoor municipal pipeline road garden work are in cross-operation, synchronous construction. During the installation and construction of the board house, in order to make reasonable use of the interval time of the process, ensure the overall construction progress of the project, optimize the resources of labor, materials and equipment, organize parallel flow operation, reduce the idleness as far as possible, and let the operators of each type of work carry out continuous operation in an orderly manner. The general construction process is shown in Figure 8.

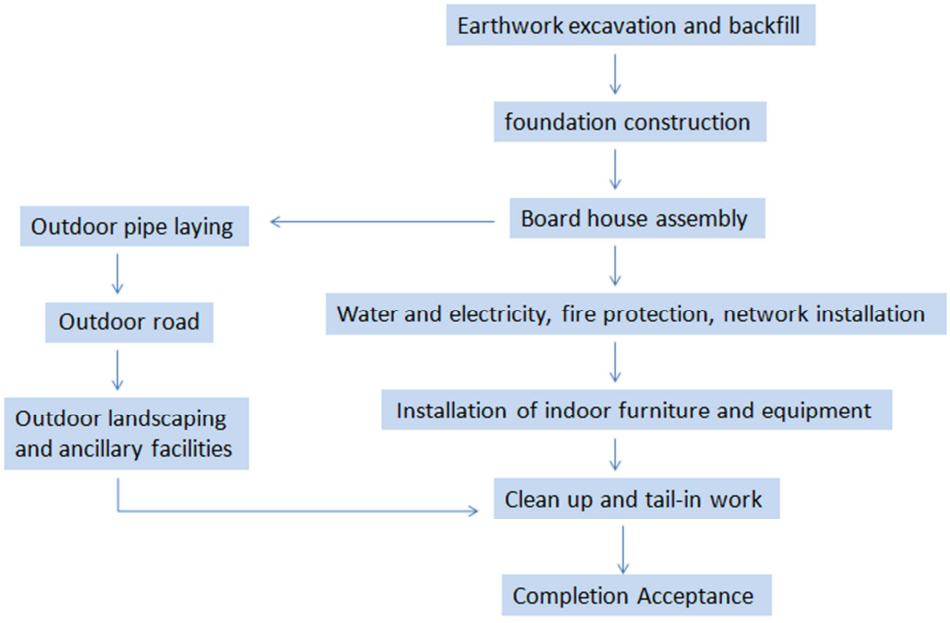

Figure 8. *General construction process.*

2) Foundation construction sequence. In the foundation construction stage, the construction section is divided to organize the flow construction. In order to facilitate the hoisting and installation of the board house, the construction is generally promoted in the overall sequence from far to near the relative entrance gate.

Foundation construction sequence: earthwork excavation or foundation treatment → cushion construction → installation of foundation reinforcement formwork → reserved and embedded → inspection and acceptance handling of hidden records → pouring bottom plate, bearing platform and foundation beam → maintenance.

3) Construction sequence of board house. Construction sequence of board house: hoisting bottom plate → assembly of vertical components → installation of top plate → Piping → installation of ceiling of wall panel → installation of doors and windows → installation of curtain wall → installation of sanitary ware → installation of indoor appliances, furniture and equipment → cleaning.

Division of construction tasks: Division of engineering tasks: equipped with comprehensive construction capacity, professional supporting main contractor labor team, in order to independently complete the engineering tasks undertaken independently. Mechanical and electrical reservation and embedded works, board room installation, indoor furniture and household appliances shall be constructed by professional subcontractors.

The main construction technical measures include: earthwork backfill and foundation treatment and board house assembly. For earthwork backfill, the foundation of the backfill site should be layered rolled by vibrating roller to ensure that the backfill soil reaches the compacting degree. For soft foundation, it is recommended to use dynamic compaction or grouting for treatment, then test to ensure that the bearing capacity to meet the requirements. The assembly of the board room adopts the crane to lift the container to the corresponding position for assembly. The board room assembly adopts the bolt connection, which can be connected by handheld electric tools.

4. Main Conclusions

According to the report "Human Losses Caused by Disasters 2000-2019" released by the United Nations, a total of 7,348 major disasters were recorded in the world from 2000 to 2019, causing 1.23 million deaths, 4.2 billion people affected and 2.97 trillion US dollars in economic losses. Take the COVID-19 as an example. The epidemic has lasted nearly three years and is still raging. According to the WHO report, as of July 2022, the cumulative number of confirmed cases worldwide is about 545 million, and the cumulative number of deaths is about 6.335 million. The world's public health security is facing great challenges.

In view of the fact that covid-19 is spreading faster, more insidious and more contagious, the medical administration of the National Commission of Health pointed out at a press conference on March 22,2022, the integrated group of the joint defense and control mechanism of the State Council requires that every province should have at least two or three shelter hospitals. In this paper, combined with the modular container hospital research, the main conclusions are as follows:

(1) Combined with the main rapid construction technology applied in modular container construction, the design concept of "box-mold combination" is put forward specifically;

(2) The research group adopted the parallel construction method, in order to facilitate the coordination of resources and ensure the maximization of construction progress;

(3) The main process of rapid construction technology is introduced, which mainly includes model guide, subcontractor approach, works handover, coordination of various public service units, and the final stage;

(4) Summarized the construction deployment of anti-epidemic medical buildings and supporting rapid construction technology, emphasizing the deployment principles, construction organization, construction deployment and professional task arrangement.

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