On the afternoon of January 25, Wuhan government decided to build the Leishenshan Hospital on the south of the Yangtze River within half a month, which is larger than the Huoshenshan Hospital standing on the north of the river. The gross building area of the Leishenshan Hospital has been adjusted up for three times, and the final scale is determined as: 79,000 m² gross building area and 1,500 beds. The hospital can accommodate about 2,300 medical staff. At 8:00 p.m. February 8, Wuhan Leishenshan Hospital was completed and handed over, and received the first batch of COVID-19 patients.

The overall scale of Leishenshan Hospital doubles that of Huoshenshan Hospital, but its construction schedule is tighter than that of Huoshenshan Hospital. In addition to the split-second round-the-clock selfless work of participants, and scientific and reasonable design & construction organization, this article will, from another perspective, illustrate the three important guarantee factors for the rapid construction of Leishenshan Hospital, i.e. modular design, standardized production, and prefabricated construction, as shown in Figure 1.

Figure 1 Hook-ups: Three Stages for Construction of Leishenshan Hospital

I. Modular Design:

The concept of Modularization has been applied throughout the design of Leishenshan Hospital and can be summarized into three major levels: macro planning framework, meso-level functional layout, and micro room design.

1. Modular Planning Framework:
Leishenshan Hospital is divided into three major modules: isolation medical area, living area for medical staff, and support area, of which the isolation medical area provides the main function, as shown in Figure 2.

The isolation medical area in the fishbone layout is divided into the north area and south area according to the terrains. Each area takes the medical staff passage as its central axis, and ward units and test and imaging units are connected to the central axis as functional modules. The north area and south area each have 15 ward modules, and these modules are spaced at a distance of 12 m. Other functional modules include: the 30-bed ICU modules (each for the north area and south area), clinical lab module, operating room & CT room module, pharmacy and drug store module, and centralized sanitary passage modules (each for the north area and south area). In total, the north area has 20 functional modules, and the south area has 17, as shown in Figure 3. Among them, ward modules are the main part of the isolation medical area, and each ward module accommodates 50 beds. All ward modules have universal and consistent design, and follow the air distribution design principles of "three areas and two passageways" critical for infectious disease wards, as shown in Figure 4.

Each module has a clear boundary and independent functions, and is connected with each other through the central axis. This facilitates simultaneous design and separate construction, and saves the design and construction time.
2. Modular Functional Layout:

At the meso level, the medical function process can be quickly realized through the modular functional layout. For the purpose of reducing the types of functional modules, minimizing construction differences, and improving construction efficiency, 95% medical area of Leishenshan Hospital is mainly composed of three basic functional modules, namely:

1) Basic ward module (i.e. functional module for negative pressure wards in the contaminated area), consisting of two wards and a shared front buffer room.

2) Medical staff working area (i.e. functional module for semi-contaminated area), composed of the sanitary passages for male and female medical staff, nurse station, dispensing room, doctor's office, and transfer room.
3) Auxiliary medical area (i.e. functional module for hygienic area), composed of the duty room, restroom for medical staff, drug store, instrument store, consumables store, and distribution room.

The three basic functional modules are assembled into 30 ward areas as per unified internal standards. The three basic functional modules also map to three important basic areas in treatment of infectious diseases: **contaminated area, semi-contaminated area, and hygienic area**. Through the fine design of the three basic functional modules, the medical process, construction method, and E&M pipelines of each functional module can not only meet the high-standard process requirements of infectious disease hospitals, but also facilitate simple and quick construction and E&M installation. Only when the basic modules at the bottom are properly completed, can the large-scale Leishenshan Hospital maintain a high overall quality in the rapid construction process, and meet the high-standard medical process requirements of infectious disease hospitals, **as shown in Figure 5**.
3. Modular Room Design:

The design is broken down to each room. For convenience of standardized production, the whole isolation ward area (including the pharmacy, drug store, and centralized sanitary passages) is divided into two skeleton modules A and B for container-type prefabricated house via modular partition, in which module A has a size of 3 m x 6 m x 2.9 m (W*L*H) and a total number of 1918 (970 in the north area and 948 in the south area); module B has a size of 2 m x 6 m x 2.9 m (W*L*H) and a total number of 990 (495 in the north area and 495 in the south area), as shown in Figures 6 and 7. All modules are prefabricated in factory, transported to the roads around the site for assembly, and hoisted in place on site. Small pipelines inside the ward module are reserved and embedded simultaneously. Some special functional rooms (such as pharmacy and drug store) are built in box units to form spacious use space through different combinations in horizontal and vertical directions.
Furthermore, modular design focuses on major functional rooms, especially the rooms closely related to the use of medical functions and processes in infectious disease hospitals, which mainly includes: 1) basic ward modules, as shown in Figure 8; 2) distribution rooms, small built-in restrooms, and other equipment rooms, as shown in Figure 9; 3) sanitary passages connecting different areas, and other critical hospital infection-control rooms, as shown in Figure 10.
Figure 8 Basic Ward Modules – Satisfying Doctor-Patient Shunt, Buffer Passage, and Airflow Distribution

Figure 9 Distribution Rooms, Small Built-in Restrooms, and Other Equipment Rooms
Left: small restrooms for medical staff, totally 7 in north and south areas
Right: distribution rooms, totally 16 in north and south areas

Figure 10 Sanitary Passages Connecting Different Areas, and Other Critical Hospital Infection-Control Rooms
II. Standardized Production

On the basis of modular design, the standardized production of components has been carried out simultaneously in many factories across the country, amid the field processing of terrace and embedded pipe network. Except for foundation treatment, main pipe network embedment, and concrete exterior wall of CT room, all works on the site are subject to dry operation. Over 95% building materials of Leishenshan Hospital are prefabricated in factory, such as buttresses of prefabricated houses in the medical area, steel structure box-type modular houses (as shown in Figure 11), doors and windows, steel structure components (as shown in Figure 12), finished restrooms and shower rooms, inner wall partition in test and imaging area, sterile wallboard for operating rooms and clinical labs, and all bathroom products and E&M facilities.

Based on unified technical specifications, standardized and industrialized production, and satisfactory factory environment and processing precision, operators can control the quality of components, minimize defects, and ensure the overall construction quality during rapid field assembly. Reducing wet operations on site allows simultaneous installation of multiple services. Moreover, standard prefabricated components can be recycled, disassembled and reassembled, thus saving energy and protecting the environment.

Figure 11 A Manufacturer from Jiangsu Province Providing Aid by Building the Container-Type Prefabricated House for Leishenshan Hospital
III. Prefabricated Construction

The biggest challenges in the construction of Leishenshan Hospital are its tight schedule and heavy task, which requires completing a 2-3-year construction task within a dozen of days. Prefabricated construction is an inevitable choice for project construction. This project incorporates three different prefabricated construction methods according to different building functions and floor height requirements for the inpatient department and test and imaging department in the isolation medical area, and living area for medical staff.

1. Prefabricated Construction Method for Inpatient Department:

The inpatient department in the isolation medical area has the most functional rooms in the whole project, accounting for about 70% of the total quantities. All these rooms are built into mature steel structure box-type modular houses (container-type prefabricated house) as the basic construction units. Compared with traditional color steel prefabricated houses, container-type prefabricated houses perform better on fire prevention, earthquake resistance, sound insulation, sealing, waterproofing, and heat preservation. All modular components are subject to standardized production in factory, and building components are quickly installed on site with standardized connectors to complete the overall building, as shown in Figure 13.
2. Prefabricated Construction Method for the Test and Imaging Department:

The Test and Imaging Department in the isolation medical area mainly includes ICU, CT room, operating room, and checkout room. The test and imaging building, as a comprehensive building for examination, diagnosis, and treatment, serves as the "brain" of Leishenshan Hospital, which holds complicated functional rooms with large span and floor height, and non-uniform plane column grid. The structural span reaches over 7 m, and local span 18 m, and floor height over 4.2 m. The steel-frame structure system is used because it's difficult for box-type house and plate-type house systems to meet the requirements. Steel structure design and detailed node design are carried out simultaneously, and steel structural components are prefabricated in factory and transported to the site for assembly, as shown in Figure 14.
3. Prefabricated Construction Method for Living area of Medical Staff

The living area for medical staff is of a two-storey light-steel prefabricated house system differing from the ward area according to the plane and space requirements of the building. The plane layout of building takes the wall board width - 1820 mm as the module, and the plane size of a standard room is 3640 mm x 5460 mm. The main structure of the light-steel prefabricated house is a light steel frame with cross stay cables to ensure structural rigidity and stability. With mature technology, standardized modular design and convenient assembly and disassembly, prefabricated houses show obvious advantages like flexible plane layout when serving as indoor temporary buildings, and can satisfying functional requirements of the building, as shown in Figure 15.
Figure 15 Light-Steel Prefabricated House Area and Construction System for Living Area of Medical Staff