Chapter 7
How to Deal with Epidemic Disaster in Buildings: Introduction to the Epidemic Prevention Design Standard of Residential Building

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Abstract The outbreak of COVID-19 has brought new challenges to architectural design: how to reduce the impact of epidemic disasters through architectural design. The paper compared the number of casualties caused by epidemics and geological and meteorological disasters in history, and analyzed the ways of transmission of novel coronavirus and the building response strategies, concluding the necessity and importance of compiling epidemic prevention standards, and suggesting building epidemic prevention standards be taken as one of the basic standards for urban and building disaster prevention, to provide a safe barrier against epidemic disasters for a

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A. Cheshmehzangi et al. (eds.), *Resilience vs Pandemics*, Urban Sustainability,
https://doi.org/10.1007/978-981-99-8672-9_7

higher living environment in the future. And the paper introduced the starting point, positioning and thinking of compiling *Epidemic Prevention Design Standard Of Residential Building* (T/ASC27-2022), including the general principles, chapter division, epidemic prevention level of building and epidemic prevention design measures of different specialties providing a safe barrier against epidemic disasters when the next epidemic strikes. Finally, the specific case application of the epidemic prevention design of the Qianxihui project in Putian, Fujian Province is elaborated in detail.

Keywords SARS-CoV-2 · COVID-19 · Disease Disaster · Building Regulation · Design Standard · Epidemic Prevention Level

1 Introduction

It has been three years since the outbreak of novel coronavirus pneumonia (COVID-19) at the end of 2019, but with the constant variation of COVID-19, the epidemic situation is still grim. By the end of September 2022, the global cumulative infection has exceeded 600 million cases and death has exceeded 6.5 million cases (WHO, 2021).

According to *the Classification and specifications for natural disasters (GB/T28921-2012)*, natural disasters can be divided into five categories, including meteorological and hydrological disasters, geological and seismic disasters, marine disasters, biological disasters and ecological environmental disasters and the COVID-19 belongs to epidemic disasters in the category of biological disasters (NDRCC, 2012). According to the reference (Meng & Helang, 2009; Jeremy, 2020; Barry, 2021; Joshua, 2021; William, 2010; Nathan, 2014; M'ikanatha, 2020; Ahmed, 2013; Frank, 2019), the number of deaths caused by ten highly influential epidemic infectious disease disasters in human society in the past 250 years is shown in Table 1. According to rough statistics, more than 250 million people have died from epidemic disasters in the past 250 years.

According to the death toll statistics, as shown in Table 2, the death toll caused by 10 major geological earthquake disasters and meteorological and hydrological disasters is about 3.5 million (Meng & Helang, 2009).

Compared with Tables 1 and 2, the number of deaths caused by epidemic disasters in history is much higher than that caused by other natural disasters, such as geological earthquake disasters and meteorological and hydrological disasters.

Earthquakes, tsunamis, floods, fires, etc. can cause direct damage to the physical environment, while the physical interface and spatial correlation caused by epidemic disasters are vague, and their propagation paths are hidden, lasting for a long time, affecting a wide range of space, causing many casualties, and making prevention difficult, so that it is very easy to form a social- economic-environmental super disaster chain. However, there is no consensus between the global scientific community and the government on the specific measures to deal with such a huge disaster as COVID-19.

Table 1 Death toll of global epidemic disasters in recent 250 years

Number	Epidemic disaster		Outbreak time	Death toll (10,000 persons)
1	Smallpox		seventeenth and eighteenth centuries	15,000
2	The third pestis		1800–1950	1500
3	Cholera in the nineteenth century		1817–1823, 1827–1837, 1846–1863, 1863–1875, 1881–1896, 1899–1926	5000–10,000
4	Influenza	Influenza in Spanish	1918–1919	2500–4000
		Influenza in Asiatic	1957–1958	100–200
		Influenza in Russian	1889–1890	100
		Influenza in Hong Kong	1968–	100
5	Yellow fever in Philadelphia in 1793		1793	0.5
6	West Nile fever virus		1937–	0.1884
7	Poliomyelitis		twentieth centuries	100
8	Ebola		2014	1.1
9	SARS		2003	0.0908
10	COVID-19		2019–2022.6	650

Source Data from Meng and Helang (2009); Jeremy (2020), Barry (2021), Joshua (2021), William (2010), Nathan (2014), M'ikanatha (2020); Ahmed (2013); Frank (2019)

People spend 90% of their time inside buildings (Mohamad, 2021). The outbreak of the epidemic has changed people's production and lifestyle, raised new demands and challenges for the construction industry. The construction industry began to think: What natural disasters are more serious than the "COVID-19" epidemic? More than 85% of COVID-19 infection occurs in construction, and how does the construction industry respond? Is building epidemic prevention technology a healthy building or environmental sanitation or building disaster prevention? How can the construction epidemic prevention technology become the consensus of the engineering community and be effectively implemented?

With the emergence and evolution of architectural space changes caused by the COVID-19 pandemic, more and more scholars began to combine architectural design to achieve epidemic prevention by improving the architectural environment. Flexible (Bettaieb & Alsabban, 2020) and healthy, safe and sustainable architectural design application principles (D'Alessandro et al., 2020; Putra, 2021) have become the key qualities of anti-virus buildings. In addition, the design standards for building epidemic prevention are also constantly being explored (Gong et al., 2021; The IMMUNE Building Standard, 2021), providing building epidemic prevention design

Table 2 Death toll of 10 major geological earthquake disasters and meteorological and hydrological disasters in history (Meng & Helang, 2009)

Number	Geoseismic disasters and meteorological and hydrological disasters	Outbreak time	Death toll (10,000 persons)
1	Byzantine Antia Earthquake	526	25
2	Eastern Mediterranean earthquake	1201	110
3	Rainstorms and floods on the Yellow River in Zhengzhou	1887	90
4	Kanto Earthquake in Japan	1923	10
5	Drought in sub Saharan Africa	1968–1974	20
6	Tropical Storm Bora	1970	30
7	Tangshan Earthquake	1976	24
8	Indian Ocean tsunami	2004	20
9	Earthquake in northern Pakistan	2005	8.6
10	WenChuan Earthquake	2008	8.7

Source Data from Meng and Helang (2009)

(Fawwaz et al., 2021) by improving the layout of entrances and exits, space division and internal design, so as to reduce the virus transmission area. The influence of the contact distance between residents on the diffusion of respiratory droplets has been studied, improving the efficiency of ventilation strategies of existing buildings (Villafruela et al., 2016; Liu et al., 2017; Cortellessa et al., 2021) to effectively dilute and/or remove pollutants in the air (Li et al., 2007; Nielsen, 2009; Morawska et al., 2020; Kissler, 2020). Or the improvement of ventilation could effectively control the spread of viruses and other pollutants and reduce the risk of infection (Li, 2005; Bin et al., 2003; Jiang et al., 2009). However, in a bad outdoor air environment, the use of natural ventilation would cause outdoor virus carrying air to enter the room, increasing the risk of infection. When mechanical ventilation is used, viruses and bacteria attached to the filter screen will be brought into the room, further polluting. Ventilation is the main means to optimize the air environment inside the building, but it still has potential health risks (Wen et al., 2020; Ding et al., 2015).

Therefore, a "epidemic prevention" space simultaneously meeting the needs of preventing epidemic outbreaks now and in the future is designed, and accurate design indicators and space standards are established to enhance the building's resistance to potential epidemics, becoming a key challenge for the current architectural design.

Based on such thinking, at the beginning of the COVID-19 in March 2020, *the Guidelines for Epidemic prevention design of residential building* was approved by the China Architectural Society. After 18 months of preparation and four expert reviews within 8 months, the standard are released in September 2022 (http://www.chinaasc.org.cn/news/128931.html). Due to no ready-made design standard for building epidemic prevention at home and abroad for reference, the standard preparation process is also a process of exploration. This paper introduces the ideas and main contents in the standard preparation process for reference in the future standard compilation and revision.

2 Challenges and Plans for Epidemic Prevention of Building

2.1 Challenges

The development history of architecture is the history of resisting natural disasters and constantly creating a safer and more comfortable living environment for human beings. Buildings are constantly developing in response to natural disasters such as earthquake, flood, lightning, fire, high temperature, and cold. With the gradual formation of industry consensus, national and industry standards have been established, including the Specification *for Seismic Design of Buildings (GB50011-2010)*, the *Specification for Fire Protection Design of Buildings (GB 50016-2014)*, the *Specification for Design of Urban Flood Control Engineering (GB/T 50805-2012)*, and the *Design specification for protection of structures against lightning (GB50057-2010)*, to effectively reduce losses caused by natural disasters. But how to deal with natural disasters such as the COVID-19, the construction industry is facing enormous challenges, triggered profound and extensive thinking in the industry.

The Diagnosis and Treatment Plan for Pneumonia Caused by novel coronavirus (Tentative Ninth Edition) issued by the National Health Commission of the People's Republic of China has identified three ways of novel coronavirus transmission (Gonhc, Osatcm, 2022):

(1) Respiratory droplets and close contact transmission are the main transmission routes;
(2) Aerosol propagation in a relatively closed environment;
(3) Contact transmission. People could also be infected after contacting with items contaminated by viruses.

The building is a relatively closed space environment, and is the place with the highest frequency of droplet propagation and close contact with personnel. Therefore, buildings have all three ways to transmit COVID-19. As shown in Fig. 1, according to the analysis of the survey data of 816 people infected with COVID-19 in Shenzhen from January to June 2022 (SMHC, 2022), 693 of them were infected in buildings, accounting for 85%, which indirectly indicates that buildings are related to the spread of the epidemic, and buildings have become an important link in epidemic prevention.

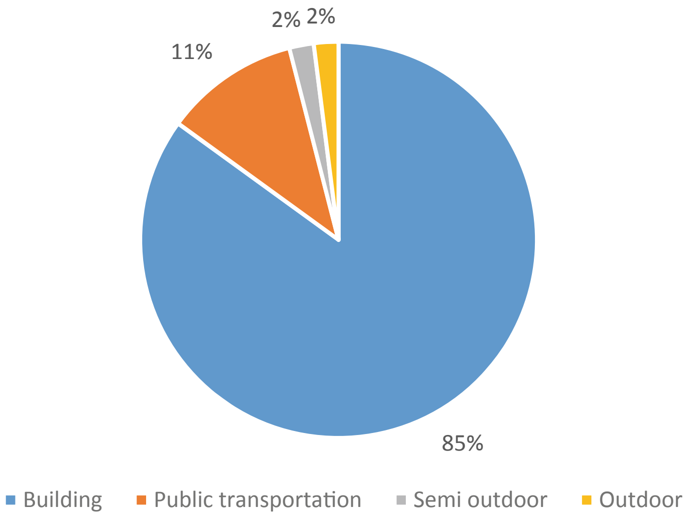


Fig. 1 Statistics of infection sites of confirmed cases in Shenzhen from January to June 2022. *Source* The data comes from the Shenzhen Municipal Health and Health Commission, and is compiled by the author.

2.2 Overall Solution for Epidemic Prevention of Building

Since the SARS epidemic in 2003, effective exploration has been made in the theoretical research of building epidemic prevention at home and abroad, including some feasible schemes, isolation wards, module hospital and other engineering practices (Wang et al., 2020; Tang, 2021), especially through the analysis of actual cases of infection transmitted by buildings (Kai, 2003; SCIHSARSOGHA (2003), providing a certain theoretical research for building epidemic prevention. However, these research papers, cases, lessons learned and technical measures are too scattered and lack the media of design standards, so they are difficult to be applied to other practical projects.

In addition, the design and construction of construction projects must be based on government regulations and industry standards, specifications and manuals, but research papers or reports are difficult to be used as the basis for design and construction. At the same time, the construction project is a systematic project, involving planning, architecture, structure, water supply and drainage, HVAC, electrical intelligence and other disciplines, and the coordination between disciplines has its own logic. While research papers or reports are mostly made by one person or several people based on one problem, they seldom consider the coordination with other majors. Building epidemic prevention involves basic medicine, clinical medicine, public health and preventive medicine, architecture, civil engineering and other disciplines. The research perspectives of different disciplines are relatively independent and single, resulting in a large number of research papers, but the research directions are scattered, the quality is uneven, and the information is mixed, making front-line engineering and technical personnel at a loss.

Therefore, the technical standards for the design of building epidemic prevention need to be prepared. By gathering the wisdom and opinions of experts from multiple disciplines, the research results at home and abroad involving various disciplines of building epidemic prevention will be summarized, refined and screened, and the contradictions between disciplines will be unified and coordinated to form an industry standard that can be applied and implemented by engineering technicians.

2.3 Domestic and Foreign Standards Related to Building Epidemic Prevention

There are few standards related to building epidemic prevention at home and abroad. *IMMUNE Building Standard* issued by Belgium Health by Design Building Institute (HDBI) in June 2021. During the epidemic, China issued two epidemic prevention related standards, including *Guidelines for office buildings to* deal with "new coronavirus" operational management emergency measures (T/ASC 08-2020)(CADG, 2020) and *Operational Guide for Epidemic Prevention Design of Office, Residential and Medical Environment and Environmental Protection during the Epidemic Period* (MHURDPRC, 2020), a*s* well as other epidemic prevention standards related to buildings led by the National Health Commission of the People's Republic of China. However, its government functions decide that these standards can only focus on the requirements of health indicators and the protection and disinfection in the construction operation and maintenance stage. However, from the perspective of the whole process of the construction project, the front-end planning and design epidemic prevention standards are missing. Therefore, the compilation of the design standards for building epidemic prevention is an important and urgent work to improve the standard system for building epidemic resistance.

3 Compilation Idea of Building Epidemic Prevention Design Standard

3.1 Components of Disaster Prevention Standards

Is building epidemic prevention an integral part of building health or building disaster prevention? This involves the division of functions among government departments and the centralized management and positioning of standards.

As for the standards for healthy buildings, there are *Assessment Standards for Healthy Buildings (T/ASC 02-2021)* and *Evaluating Standard for Healthy Housing (T/CECS 462-2017),* etc. in China. As for the standards of sanitation in buildings, there are *Hygienic Management specification for Public Places (GB 37487-2019), Hygienic Standard for Hotel (GB 9663-1996)* and *Hygienic Standards for Dining (GB16153-1996),* etc.

Is it necessary to revise the existing health building standards and hygienic standards to add epidemic prevention content, or to prepare the building epidemic prevention standards separately? The following aspects can be analyzed:

(1) Epidemic disasters are both public health events and natural disasters. A separate standard system should be established to deal with major natural disasters. (2) Epidemic disasters are emergencies, the same as earthquake and fire, while health building technology and hygiene requirements are normal routine requirements, different in practice and requirements. (3) Building epidemic prevention involves many disciplines and contents, difficult to be covered in healthy building technology and sanitation technology. (4) The existing health standards focus on the requirements of health indicators and health services after the construction, while the health building standards are the evaluation standards. Therefore, the construction industry lacks the standards to guide engineering technicians in the technical link of building epidemic prevention design, so the health indicators and requirements related to epidemic prevention cannot be implemented. (5) As previously analyzed, the damage caused by epidemic disasters is huge, and its importance is far greater than the general health and hygiene requirements.

Therefore, the design standards for building epidemic prevention should be prepared separately by referring to the practices of buildings in dealing with natural disasters, from the aspects of harmfulness, nature of use, convenience, and collection of research results and experience on building epidemic prevention, and together with the existing disaster prevention specifications, form the basic standard system for building and urban disaster prevention, to protect the health and safety of residents.

In order to reduce technical risks, the design standards for building epidemic prevention are divided into two parts: *Standards for Epidemic Prevention Design of Residential Building* and *Standards for Epidemic Prevention Design of Public Building*. First, the standard of residential buildings with fewer building types and more people involved was compiled. Then, the research results of epidemic prevention were continuously absorbed in the process of use. After several years of use, the standard was finally combined into a *Design Standard for Epidemic Prevention of Building*. Based on the epidemic prevention design standards, the planning, design, construction, installation, acceptance, testing, evaluation, product, operation and maintenance and other standards of building epidemic prevention will be gradually completed, so as to establish a relatively complete standard system of building epidemic prevention, and minimize the threat of pandemic diseases mainly transmitted through air to cities and human beings.

3.2 Compilation Idea and Technical Measures of Standards

Different from the temporary documents such as management regulations issued during the epidemic, the *Standards for Epidemic Prevention Design of Residential Building* does not rely solely on administrative management, but uses a systematic approach to control the epidemic through the combination of construction technology and management. The control of epidemic situation should start from the architectural design, and then continue to improve. Therefore, epidemic prevention design standards can be used as the carrier for accumulating epidemic prevention research results and become the basis for epidemic prevention design of front-line engineering technicians.

3.2.1 General Rules for Preparation

There are many types of infectious diseases with different transmission routes. This standard focuses on COVID-19 and similar respiratory infectious diseases to guide and standardize the design of various architectural design disciplines and property services after completion, aiming to use architectural technology to block the transmission of viruses through droplets, aerosols and contacts, but it is not applicable to infectious diseases such as cholera transmitted through water bodies, AIDS transmitted through body fluids and blood.

On the one hand, the design of building epidemic prevention can reduce the risk of infection of people in the building; on the other hand, if people are infected, they can get relevant medical and health services nearby, quickly diagnose, isolate and treat, and reduce the probability of infecting others. Therefore, supporting medical and health care and services are also considered in the standard.

3.2.2 Division of Standard Sections

Building epidemic prevention technology involves many disciplines such as Building, general Plan, HVAC, water supply and drainage, electrical intelligence, as well as medical and health services, operation and maintenance after the building is completed. Therefore, in chapter division, in addition to an independent chapter for each discipline of architectural design, a separate chapter for medical and health services, operation and maintenance, plus general principles, terminology and basic provisions, a total of 10 chapters are set up.

In the process of standard preparation and standard review, whether the chapter of operation and maintenance is set in the design standard is controversial. The review expert group finally thinks it is necessary to retain it after many discussions. The reasons are as follows: (1) The operation and maintenance of buildings are really important. During the epidemic, every person isolated at home deeply felt that property services were indispensable and an important part of the epidemic prevention work; (2) The requirements related to epidemic prevention design are not completely expressed in the design chapter, and need to be implemented in the operation and maintenance chapter; (3) Design is a phased work, while operation and maintenance is a continuous work. The design only needs to meet the current standards. After completion and delivery, the main work of the design is basically completed. The construction operation period will face a series of uncertainties such as the revision of standards and specifications, the decoration and change of buildings, so the operation and maintenance is the continuity of design services.

3.2.3 Design Level of Building Epidemic Prevention

During the epidemic, due to the complexity of building types, the risk of infection of personnel in different buildings is different, and the consequences of infection are also different, resulting in different losses. Therefore, the design level of building epidemic prevention is proposed to deal with different building infection risks.

Level I: for buildings with dense population, more close contact and weak immunity, once some people are infected, the consequences are relatively serious. Therefore, this type of building is defined as Level I epidemic prevention design level. Other places with special needs for epidemic prevention, such as infectious disease hospitals, barracks and command posts of chemical prevention forces, could also refer to the requirements of Level I. Kindergartens, nurseries and nursing homes are typical Level I epidemic prevention design buildings.

The reason why kindergartens and nurseries belong to Level I epidemic prevention design buildings is: (1) crowded: children's study and life are basically limited to one activity room, with an average student area of only 1.5–3 m^2. If a child is infected with an epidemic disease, the probability of transmission to other children is high. (2) More close contact and long time: children in a class spend 8–10 h playing, studying and living together. (3) Weak immunity: children have not yet completed all the vaccinations required by the state and have not established a complete immunity. Therefore, the kindergarten requires morning check every day when going to school, and the children's activity room requires daily disinfection. The existing norms and management systems have already taken some measures for building epidemic prevention.

Once the epidemic situation breaks out in nursing homes, it will have serious consequences. There are many elderly people, and their physical functions are degraded and their immune capacity is weak. Once they are infected with COVID-19 or other epidemic diseases, they may cause other complications. Therefore, the nursing home is a first-class epidemic prevention design building. In fact, in the early stage of the pandemic, infection in nursing homes would spread rapidly, with a high mortality rate (14–33%), and up to half of COVID-19 patients died in nursing homes (Ochi et al., 2021; Lau-Ng et al., 2020; White et al., 2020). In November 2020, 99 of 114 residents of Little Mountain Place Nursing Home in Vancouver tested positive for COVID-19, and at least 41 died (Amy, 2021).

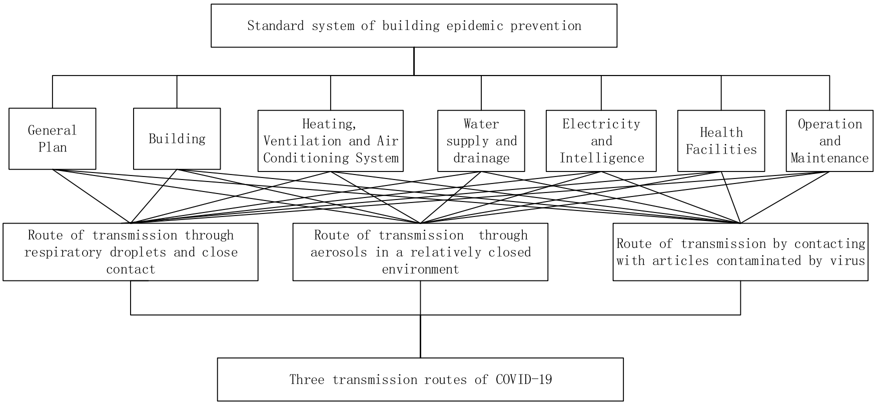


Fig. 2 Correspondence between epidemic transmission route and standard system. *Source Epidemic Prevention Design Standard of Residential Building* (T/ASC27-2022)

Level II: Ordinary houses, apartments, dormitories, etc., with low population density and relatively strong overall immunity, are classified as Level II for epidemic prevention design of building.

In consideration of practicability, economy and applicability, corresponding epidemic prevention design measures should be taken for buildings with different epidemic prevention design levels.

3.2.4 Technical Measures for Building Epidemic Prevention Design

The construction epidemic prevention measures in this standard aim at three transmission routes of COVID-19 and other epidemics, including respiratory droplets, aerosols and contact. Each construction discipline takes different design technical measures, as shown in Fig. 2 and *Epidemic Prevention Design Standard of Residential Building (T/ASC27-2022)* for details.

3.2.5 Safety of Epidemic Prevention Technology

The construction epidemic prevention measures must be safe to avoid other damage to the health of personnel due to epidemic prevention technology. From the perspective of the whole life cycle of the building, the epidemic situation is short, and the combination of epidemic prevention and control must be considered. The function and use of the building cannot be affected by the epidemic prevention measures, and the health performance of the building can be effectively improved through the epidemic prevention measures, such as improving the secondary pollution of the air conditioning and ventilation system during normal operation.

(1) Avoiding Ozone Generation

Different environmental disinfection technologies would be used in hospitals, kindergartens and some special places, but these technologies should avoid generating ozone. At the beginning of 2015, the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) released the *Position Paper on Filters and Air Purification Technologies* (ASHRAE, 2015), comprehensively reviewed the effectiveness of eight purification and disinfection technologies, including media filtration, electrostatic filtration, adsorption, ultraviolet light, photo catalysis, air purifier, ozone and ventilation, as well as their impact on indoor personnel's health, long-term effects and limitations, clear that: (1) mechanical filtration or porous media filtration has a very obvious filtering effect on particles, beneficial to human health; (2) The indoor environment should not use ozone for air purification. If the purification device generates a large amount of ozone during operation, it must be highly vigilant. In addition, ultraviolet ray has certain effect on inhibiting the activity or killing of viral microorganisms, but the possible ozone must be alert.

This standard adopts the viewpoint of ASHRAE and adopts more filtration purification methods. Although environmental disinfection measures have been designed for some functional rooms in the buildings of the first level epidemic prevention design level, the mode of "coexistence of human and machine" should be avoided for disinfection measures that may produce ozone.

(2) Improving Air Conditioning and Ventilation System

The actual use of the ventilation and air conditioning system in residential buildings exposed the problem of excessive microorganisms. The fresh air system designed for some residences is installed in the ceiling of the toilet or kitchen to save space, but these places are narrow and humid, and the filter is difficult to replace, often causing mildew and becoming a health hazard. And the experiment shows that the air conditioning system would have an aggravating effect on indoor air microbial pollution. The dynamic changes of microorganisms in the indoor air before and after the operation of the air conditioning system. Within 5 min after the operation of the air conditioning system, the number of indoor bacterial colonies rises sharply, which is 3 times that when the air conditioning is not running. After the operation is stable, the number of indoor bacterial colonies is stable at about 2 times that when the air conditioning is not running (Ding et al., 2015).

The pipes and filters of air conditioning and fresh air systems are suitable places for microorganisms to breed. Therefore, the standard proposes to adopt mold proof filter screen or other mold proof measures in the filter screen of the fresh air system to reduce the secondary pollution of the fresh air system. At the same time, according to the current national standards such as *Antibacterial and cleaning function for household and similar electrical appliances—Particular requirements of air cleaner (GB 21551.3-2010)* and *Antibacterial and cleaning function for household and similar electrical appliances-Particular requirements of air conditioner (GB 21551.6-2010)*, filter products with antibacterial and mildew resistant functions shall be selected, or fixed air purification function sections shall be set in the fresh air system to inhibit the breeding and transmission of germs in the air conditioning and fresh air system.

4 Design Case of Building Epidemic Prevention

Qianxihui Project, as shown in Fig. 3, is located in Xiuyu District, Putian City, Fujian Province, China, with Xiuyu Avenue in the east, planned road in the south, Houjing Road and planned land in the west, and planned road and Central Avenue green control belt in the north. The project covers an area of 154,359.07 m^2, with a total building area of 473,504.54 m^2. It belongs to the land for commercial, urban residential, education and service facilities, and is divided into three plots. Plot 1 is a commercial street, plot 2 is a residential area, and plot 3 is a residential area and a kindergarten. The project is designed in June 2021 and constructed in 2022. It is currently under construction. After the outbreak of COVID-19, the project development company Ligao Group issued the enterprise standard *Design Standards for Epidemic Prevention of Healthy Building* in March 2020. This project is designed according to this standard. Therefore, this project is selected as a case study of the design of building epidemic prevention.

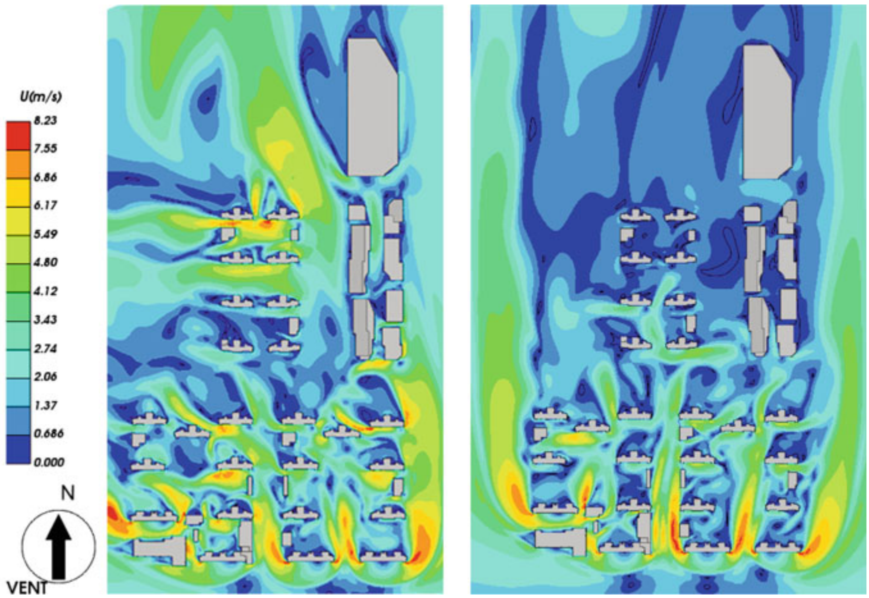
Fig. 3 Aerial View of Qianxihui Square Project. *Source* Provided by Ligao Group

4.1 Design Principles and Measures for Epidemic Prevention

During the epidemic prevention design of the project, the following three principles shall be strictly followed: (1) The epidemic prevention design measures shall not conflict with the current design specifications; (2) It has little impact on the construction cost; (3) Optimize and improve the epidemic prevention function of the building, so that residents can feel the sense of security brought by epidemic prevention technology. Therefore, the following measures shall be taken in general plan design, building unit and house type design, electromechanical supporting technology and supporting services.

4.1.1 Epidemic Prevention Design of General Plan

(1) The natural ventilation of the site is optimized. Quanzhou is a hot summer and warm winter area, so the natural ventilation of buildings is particularly important for improving the living environment. The general layout design focuses on simulating and optimizing the natural ventilation of the building site, ensuring smooth ventilation in the areas where people walk and move in the residential area, avoiding vortex areas or windless areas, and providing reference for landscape design and activity site layout, as shown in Fig. 4.
(2) Suitable building density. The average building density is 26.38%, and the average floor area ratio is 2.49. The distance between high-rise residential buildings is large. The average distance between high-rise buildings in the dominant wind direction in spring is 30m, and the average distance between other buildings is 17m.
(3) Building blocks. The total building area of the project is large. In order to facilitate the control and service during the epidemic, four building blocks are divided from the south to the north, with an average land area of 35,000 m^2 for each block. As shown in Fig. 5.
(4) Non-contact community system. The main entrances and exits are designed with face recognition systems and intelligent infrared temperature measuring devices. Through the entrance-road-lobby-elevator-vestibule, you can enter the building non-contact throughout the whole journey home, which is convenient for owners and avoids cross contact of crowds, as shown in Fig. 6.
(5) Residential roads and communication and activity spaces are designed to reduce cross infection. The width of the road in the residential area is 2.5–4m, ensuring a safe distance of more than 1m when walking. Within 50m of the communication and activity space, there are public toilets and hand cleaning facilities.
(6) Reservation of epidemic prevention and service space. The entrance and the block are designed in combination with the landscape, and the collection and release places for non-contact takeout and express delivery are reserved to meet the requirements of nucleic acid detection and other services during the epidemic.



（a）Summer（SSE，4.2 m/s） （b）Transition season (S，3.6 m/s)

Fig. 4 Ventilation Simulation Diagram of Overall Building Layout in the Community. *Source* The picture is exported by the author according to the software simulation

4.1.2 Epidemic Prevention Design of Building Unit

(1) Combined with the natural ventilation simulation results of the general plan, the indoor ventilation of building unit is optimized to ensure good natural ventilation, as shown in Fig. 7.
(2) The entrance lobby and elevator on the first floor of each building are densely populated places. Therefore, the lobby on the first floor is designed with external windows for natural ventilation, and the elevator shaft is designed with louvers on the top floor that directly lead to the outside to ensure that the air supply in the elevator car is outdoor fresh air. Then the elevator car is equipped with a double speed fan, increasing the air supply volume in the car during the epidemic situation, and an epidemic prevention purifier, be opened for use during the epidemic situation. Finally, the elevator adopts touch free floor selection to reduce the chance of contact and infection.
(3) The three bedroom apartment has two bathrooms, one of which forms an independent suite with the bedroom. The external windows of the toilet are directly outward, and the distance between the external windows or exhaust outlets of the adjacent toilet is greater than 1m and they do not look at each other.
(4) The exhaust fan in the toilet is equipped with a check valve to prevent the outdoor air from back filling. The sanitary ware and floor drain in the toilet are all deep

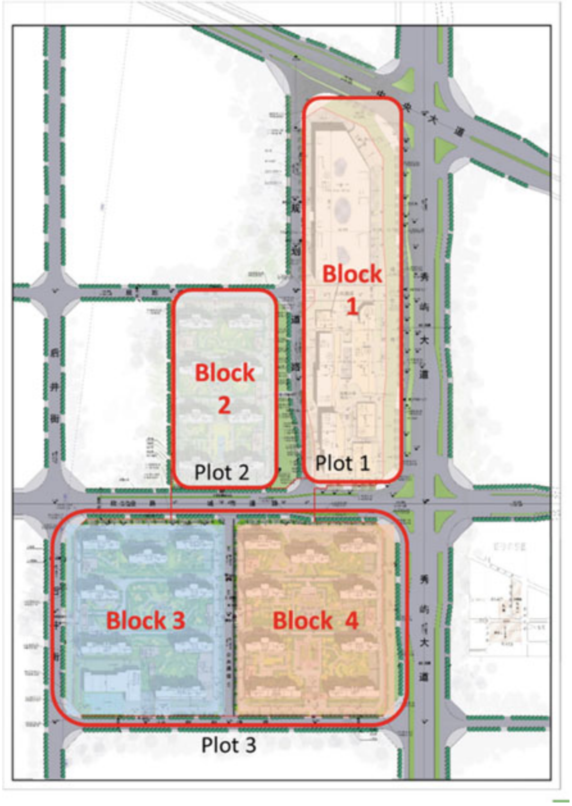


Fig. 5 Block division diagram. *Source* Provided by Ligao Group

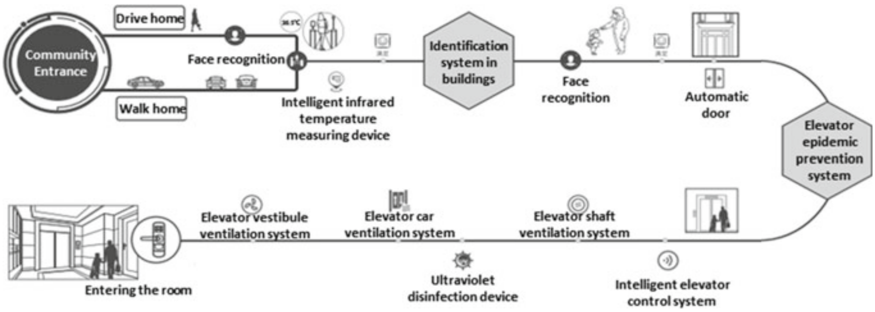


Fig. 6 Non-contact community system. *Source* Provided by Ligao Group

water sealed traps, and the water seal height is greater than 50mm. The toilet drainage riser is set in the tube well and separated from the water supply riser to prevent pollution caused by leakage. The roof vent pipe is 2m higher than the floor of the accessible roof to prevent the pollution in the drainage from being inhaled by personnel.

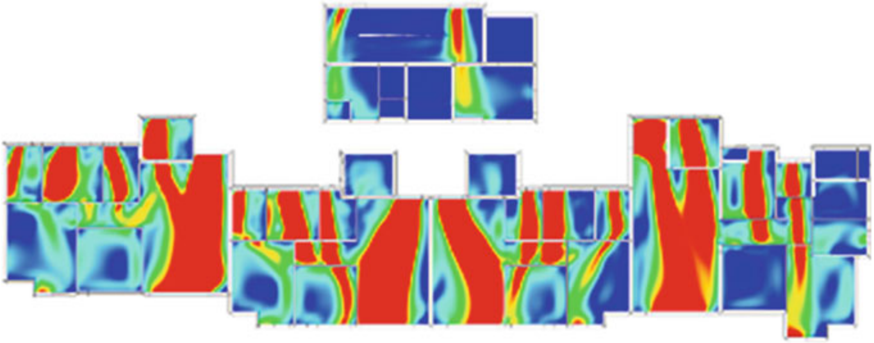


Fig. 7 Natural ventilation simulation of typical house type. *Source* The picture is exported by the author according to the software simulation

(5) The garbage room is equipped with disinfection, sterilization and deodorization devices, and the garbage point is equipped with a garbage container overflow monitoring and alarm system.

4.1.3 Health Supporting Facilities and Community Operation Services

(1) The project is equipped with a 150 m^2 community health service station and a 750 m^2 home care service station. Health management center, children's health insurance center, elderly care center, national health care center, sports rehabilitation center, neighborhood activity center and lifelong growth center are set up, and a telemedicine system is set up to provide medical security and home health care services for residents.

(2) Supporting fitness room. Provide fitness conditions to improve the immunity of community residents. The indoor sports and fitness space is well ventilated. The total area of the indoor fitness room is 510 m^2, and the total area of indoor and outdoor sports and fitness space is 5107 m^2, accounting for 1.08% of the project building area. The outdoor sports ground covers an area of 4195 m^2, accounting for 2.72% of the total land area. The bicycle parking space is set and the electric bicycle charging system is matched.

(3) The community has a smart health management platform. Various sensing equipment for environmental monitoring shall be set in the residential area to monitor the environmental quality of air, water, soil, CO, microorganism, etc. in the community, and integrate with the community digital operation platform to achieve linkage control with property stewards and health stewards, and maintain the healthy living environment of the community in real time.

5 Summary of Technical Measures for Epidemic Prevention of Project Buildings

The epidemic prevention design measures and technology of the Project are summarized in Table 7.

Since March 2020, Ligao Group has implemented healthy building and building epidemic prevention technology in more than 20 projects. From the application practice, the construction cost of building epidemic prevention technology is low, and the epidemic prevention design does not conflict with the existing building and residential design specifications. Market research shows that customers are sensitive to building epidemic prevention technology and have high acceptance.

6 Concluding Remarks

The epidemic has brought disasters to human beings and promoted the development of architectural design. Looking back on the epidemic situation in the past 100 years, the only certainty is that there will be new plagues and epidemics in the future. Plagues may not be predictable, but we should know that they will come again (Nathan, 2014).

Based on the research results and experience of building epidemic prevention, referring to the practice of building response to natural disasters, the design standards of building epidemic prevention were compiled, including the general principles, chapter division, epidemic prevention design level division, and epidemic prevention design measures of different specialties. Together with the existing disaster prevention specifications such as the Specification *for Seismic Design of Buildings (GB50011-2010)*, the *Specification for Fire Protection Design of Buildings (GB 50016–2014)*, the *Specification for Design of Urban Flood Control Engineering (GB/T 50805-2012)*, and the *Design specification for protection of structures against lightning (GB50057-2010)*, it forms the basic standard system for building and urban disaster prevention, protecting the health and safety of residents.

The *Standards for Epidemic Prevention Design of Residential Buildin*g is a start, providing a guarantee for higher residential environment requirements of the future city through building epidemic prevention technology, and a safety barrier against epidemic disasters when the next epidemic strikes.

Table 7 Technical measures for building epidemic prevention of Quanzhou Yulongzhuang Project

Number	Specialty classification	Examples of epidemic prevention measures
1	General plan	(1) Carry out special analysis on natural ventilation in the general layout design to optimize the building layout; (2) The building density design of the project is appropriate, the average building density is controlled at 20%, and the building floor area ratio is 1.8; (3) The project is divided into 4 building blocks according to the site, high-rise and multi-storey building types; (4) The main pedestrian road in the residential area is 2.5m–4m wide, and there are public toilets and hand cleaning facilities within 50m of the communication and activity space; (5) The entrance and the neighborhood are designed in combination with the landscape, and non-contact takeout and express delivery places are reserved; (6) The main entrances and exits of the residential area are equipped with personnel information verification system and infrared temperature detection device
2	Building unit	(1) Special analysis on indoor natural ventilation; (2) The entrance lobby on the first floor of each building is designed with natural ventilation; The elevator shaft is connected to the atmosphere, and the elevator car ventilator is set with high and low gears, equipped with a car specific purification sterilizer; (3) The three bedroom house is equipped with two bathrooms, one of which forms an independent suite with the bedroom; (4) The sanitary ware and floor drain in the toilet are all equipped with deep water sealed traps, and the water seal height is greater than 50mm; (5) The toilet drainage riser is set in the tube well, separated from the water supply riser; (6) The roof vent pipe of the accessible roof is 2m higher than the floor to prevent the pollution in the drainage from being inhaled by personnel; (7) The garbage room is equipped with disinfection, sterilization and deodorization devices
3	Operation and maintenance	(1) The Internet platform for remote diagnosis and property services has been set up to reduce contact and facilitate medical treatment; (2) During the epidemic, the nucleic acid testing site was naturally ventilated; (3) The outdoor landscape water body and tap water are equipped with an online water quality monitoring system; (4) The outdoor air environment microorganism monitoring system is set; (5) The garbage container overflow monitoring alarm system is set at the garbage point

Source Prepared by the author

Acknowledgements This research is financially supported by Practical Research on Low Carbon and Healthy Building System in Fujian and Guangdong for China Construction Fangcheng Investment& Development Group Co., Ltd. (CSCECFC-2022-KJZX--06), Research on Intelligent System of Healthy Residential Buildings for Smart Building Research Center of China Real Estate Association, and Research and Verification of Epidemic Prevention System of Residential Buildings (Shenzhen science and technology plan project in engineering construction field in 2021).

References

Ahmed, A. K. (2013). Spillover: Animal infections and the next human pandemic. *The Yale Journal of Biology and Medicine, 86*(1), 107–112.

Amy, J. (2021). Administrator resigns at care home that was site of B.C.'s deadliest COVID-19 outbreak. Global News Posted February 19, 2021 https://globalnews.ca/news/7651253/administrator-resigns-little-mountain-place-covid-19/.

ASHRAE. (2015). ASHRAE Position Document on Filtration and Air Cleaning. NE • Atlanta, Georgia: 1–26. https://www.iaq-cpr.com/newsroom#:~:text=ASHRAE%20Position%20Document%20on%20Filtration%20and%20Air%20Cleaning,the%20health%20consequences%20of%20filtration%20and%20air%20cleaning.

Barry, J. (2021). *The great influenza: A story of the deadliest pandemic in history*. Penguin Books.

Bettaieb, D. M., & Alsabban. (2020). R. Emerging living styles post-COVID-19: Housing flexibility as a fundamental requirement for apartments in Jeddah. *Archnet IJAR, 15*, 28–50.

Bin, Z., Zhao, Z., & Xianting, L. (2003). Comparison of biological particles distribution in different ventil ated rooms. *Heating Ventilating & Air Conditioning, 30*(3), 179-182. (in Chinese).

CADG. (2020). Guidelines for office buildings to deal with "new coronavirus" operational management emergency measures: T/ASC 08–2020 Beijing: China Architectural Society: 1–8. (in Chinese).

Cortellessa, G., Stabile, L., Arpino, F., Faleiros, D.E., van den Bos, W., Morawska, L., & Buonanno, G. (2021). Close proximity risk assessment for SARS-CoV-2 infection. *The Science of the Total Environment, 794*, 148749-148749.

D'Alessandro, D., Gola, M., Appolloni, L., Dettori, M., Fara, G. M., Rebecchi, A., Settimo, G., Capolongo, S. (2020). COVID-19 and Living space challenge. Well-being and Public Health recommendations for a healthy, safe, and sustainable housing. *Acta Biomedica, 91*, 61–75.

Ding, L., Zha, X., Deng, K., & Yan, H. (2015). Wet-processing characteristics and inactivation dynamics model of indoor air microorganisms under air-conditioning system.

Fawwaz Alrebi, O., Obeidat, B., Atef Abdallah, I., Darwish, E.A., & Amhamed, A.I. (2021). Airflow dynamics in an emergency department: A CFD simulation study to analyse COVID-19 dispersion. *Alexandria Engineering Journal, 61*, 3435-3445.

Frank, M. S. (2019) Epidemics and Society: From the Black Death to the Present (Ji S,Cheng X,Trans.) Beijing: Central Compilation and Translation Press.2022. (in Chinese).

Gong, X., Liu, J., Wu, L., Bu, Z., & Zhu, Z. (2021). Development of a healthy assessment system for residential building epidemic prevention. *Building and Environment, 202*, 108038.

Gonhc, Osatcm. (2022). *Notice on printing and distributing the diagnosis and treatment plan for novel coronavirus Pneumonia (Trial Version 9)* (Guo Wei Ban Yi Han [2022] No. 71) (March 14, 2022) (October 17, 2022) http://www.gov.cn/zhengce/zhengceku/2022-03/15/content_5679257.htm. (in Chinese).

Jeremy, B. (2020). *Influenza: The hundred year hunt to cure the deadliest disease in history (Wang C, Trans.)*. Social Science Literature Press, Beijing. (2018) (in Chinese).

Jiang Y., Zhao, B. Li, X. Yang, X. Zhang Z., & Zhang Y. (2009). Investigating a safe ventilation rate for the prevention of indoor SARS transmission: An attempt based on a simulation approach. *Building Simulation, 2*, 281–289.

Joshua, L. (2021). *Epidemics: The impact of germs and their power over humanity*. (Li K, Trans.). Social Sciences Academic Press, Beijing. (2020) (in Chinese).

Kai, Y. (2003), Analysis on Residential Problems through the "Taoda Garden" Incident/KAI Yan. *Planners, s1*, 49–52. (in Chinese).

Kissler, S. M., Tedijanto, C., Goldstein, E., Grad, Y. H., & Lipsitch, M. (2020). Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. *Science (New York, N.y.)*.

Lau-Ng, R., Caruso, L., & Perls T. T. (2020). COVID-19 deaths in long-term care facilities: A critical piece of the pandemic puzzle. *Journal of the American Geriatrics Society, 68*, 1895-1898.

Li, Y., Leung, G. M., Tang, J. W., Yang, X., Chao, C. Y., Lin, J. Z., Lu, J., Nielsen, P. V., Niu, J., Qian, H., Sleigh, A., Su, H. J., Sundell, J., Wong, T. W., & Yuen, P. L. (2007). Role of ventilation in airborne transmission of infectious agents in the built environment—A multidisciplinary systematic review. *Indoor Air, 17*(1), 2-18.

Li, Y. (2005). Engineering control of indoor infectious disease transmission—droplet diffusion and building ventilation Advances in New Technologies of Refrigeration and Air Conditioning. In: *Proceedings of the third symposium on new technologies of refrigeration and air conditioning* (pp. 18–22). (in Chinese).

Liu, L., Li, Y., Nielsen, P. V., Wei, J., & Jensen, R. L. (2017). Short-range airborne transmission of expiratory droplets between two people. *Indoor Air, 27*, 452–462.

M'ikanatha, N. M. (2020). The pandemic century: One hundred years of panic, hysteria and hubris. *Emerging Infectious Diseases, 26*(6), 1349. https://doi.org/10.3201/eid2606.191739.

William, H. M. (2010). Plagues and Peoples (Yu X, Bi H, Trans.). China Environmental Press, Beijing. (1976) (in Chinese).

Meng, L., & Helang, H. (2009). Major natural disasters in human history. *China Economic Weekly, 2009*(18), 2(in Chinese).

MHURDPRC. (2020). Notice of the General Office of the Ministry of Housing and Urban Rural Development on Printing and Distributing the Guidelines for Epidemic Prevention Design and Safety Guarantee of Indoor Air Environment in Public and Residential Buildings (Trial). http://js.xm.gov.cn/xxgk/zfxxgk/ml/gzdt/02/202006/t20200624_2457510.htm. (in Chinese).

Mohamad A., Burcin B.G., Simi H., et al. (2021) Ten questions concerning occupant health in buildings during normal operations and extreme events including the COVID-19 pandemic [J]. *Building and Environment,* 188: 107480. https://doi.org/10.1016/j.buildenv.2020.107480

Morawska, L., Tang, J. W., Bahnfleth, W. P., Bluyssen, P. M., Boerstra, A. C., Buonanno, G., Cao, J., Dancer, S. J., Floto, A., Franchimon, F. F., Haworth, C., Hogeling, J., Isaxon, C., Jimenez, J. L., Kurnitski, J., Li, Y., Loomans, M., Marks, G. B., Marr, L. C., Mazzarella, L., Melikov, A. K., Miller, S. L., Milton, D. K., Nazaroff, W. W., Nielsen, P. V., Noakes, C. J., Peccia, J., Querol, X., Sekhar, C., Seppänen, O., Tanabe, S., Tellier, R., Tham, K. W., Wargocki, P., Wierzbicka, A., & Yao, M. (2020). How can airborne transmission of COVID-19 indoors be minimised? *Environment International, 142*, 105832-105832.

Nathan, W. (2014). The Viral Storm: The Dawn of a New Pandemic Age (Shen J, Trans.). Hangzhou: Zhejiang People's Publishing House.2012. (in Chinese).

NDRCC, CMA, NMEFC. (2012). *The classification and specifications for natural disasters: GB/T 28921-2012* (pp. 1-5). General Administration of Quality Supervision, Inspection and Quarantine, National Standardization Administration, Beijing (in Chinese).

Nielsen, P. V. (2009). Control of airborne infectious diseases in ventilated spaces. *Journal of the Royal Society Interface, 6*, S747-S755.

Ochi, S., Murakami, M., Hasegawa, T., & Komagata, Y. (2021). Prevention and Control of COVID-19 in Imperfect Condition: Practical Guidelines for Nursing Homes by Japan Environment and Health Safety Organization (JEHSO). *International Journal of Environmental Research and Public Health, 18*(19), 10188. https://doi.org/10.3390/ijerph181910188

Putra, I. D. G. A. D. (2021). "Stay at home" for addressing COVID-19 protocol: Learning from the traditional Balinese house. Archnet-IJAR 2021, 15, 64–78.

SCIHSARSOGHA. (2003). Epidemic Investigation Report of Taoda Garden. Hong Kong. (in Chinese).

SMHC. (2022). COVID-19 daily update (2022–03–27) [2022–08–13]. http://wjw.sz.gov.cn/yqxx/content/post_9639496.html (in Chinese).

Tang, Q. (2021). The Huoshenshan Hospital Designing and Thinking of Construction of Post? Epidemic Medical Facilities. *New Architecture,2021*(1), 31-35. (in Chinese).

The IMMUNE Building Standard. (2021). Available online: https://immune-building.com/certification/ (accessed on 19 December 2021).

Villafruela, J. M., Olmedo, I., & José, J. F. (2016). Influence of human breathing modes on airborne cross infection risk. *Building and Environment, 106*, 340-351.

Wang, H., Jin, H., Chen, G., Ma, X., Xu, C., & Lu, X. (2020). Construction technology of negative pressure wards in Huoshenshan hospital. *Construction Technology, 49*(12):99-101. (in Chinese).

Wen, Y., Leng, J., Shen, X., Han, G., Sun, L., & Yu, F. (2020). Environmental and Health Effects of Ventilation in Subway Stations: A Literature Review. *International Journal of Environmental Research and Public Health, 17*.

White, E. M., Kosar C. M., Feifer R. A., Blackman C., Gravenstein S., Ouslander J., & Mor V. (2020). Variation in SARS-CoV-2 Prevalence in U.S. Skilled Nursing Facilities. *Journal of the American Geriatrics Society, 68*(10), 2167–2173. https://doi.org/10.1111/jgs.16752.

World Health Organization. (2021). WHO health emergency dashboard. World Health Organization, Geneva. https://covid19.who.int/.