The Impact of Architectural Layout on Low-Carbon Design in High-Level Bio-Safety Laboratories

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Abstract. At present, low-carbonization has become the main development trend in China's construction engineering field. Against this backdrop, this article explores whether there are more reasonable layout forms in the design phase to reduce the energy consumption of high-level bio-safety laboratories, focusing on the architectural layout. By controlling variables, this article investigates the impact of building layout on high-level bio-safety laboratories, starting with the predefined laboratory standard module. Based on this, the article explores the relationship between architectural spatial layout and low-carbon design by changing the position layout of the standard module, the layout of supporting rooms, and the setting and layout of internal intelligent facilities. The article aims to identify low-carbon design strategies that are compatible with the spatial layout.

Keywords: Low-carbon concept; Laboratory building; Architectural layout; Spatial design.

1 Introduction

In recent decades, many architectural trends have emerged that have adopted the concept of sustainability under different names but with convergent contents that point in the same direction. It focused on the principles, features, dimensions and elements of sustainable design, but it lacked a comprehensive framework approach to the subject. [1] Globally, buildings are responsible for 40% of all waste generated (by volume), 40% of all material resource use (by volume) and 33% of all human-induced emissions (United Nations Environment Programme, Citation2012; World Resources Institute, Citation2016). At the same time, a great amount of all materials ever extracted in human history are located in the built environment (Sanchez & Haas, Citation2018a), suggesting that buildings will become a major temporary material stock to supply future demand. Continued inefficient use of non-renewable materials will almost certainly cause significant natural-resource depletion (Hossain & Ng, Citation2018). Consequently, the European Union aims at net zero (emissions) buildings by 2050 (European Commission, Citation2019b). [2]

Thus designers are exploring the methods to achieve green and sustainable building, including the laboratories. Over the past decade, bio-safety laboratories system

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construction has undergone a profound transformation due to advancements in technology. The emergence of low-carbon design prompts the need for in-depth investigation. The demand for laboratories is increasing, which has resulted in the original construction layout and management capacity can no longer fully meet the needs of the new situation. Despite the significant progress made in low-carbon aspects of bio-safety laboratories, there are still a critical gap in energy-saving and emission-reduction designs for high-level bio-safety laboratories. The primary objective of this research is to elucidate how the architectural layout affects the heat load of laboratory space in order to reduce the energy consumption of bio-safety laboratories. The study seeks to provide a comprehensive analysis of the relevance of architectural space layout to low-carbon design. The findings of this study can inform policy makers and practitioners in related fields of low carbon. Employing the approach of controlling variables, this research investigates the relationship between different building layouts and laboratory energy consumption as well as carbon emissions in different contexts. Unlike previous studies that primarily focused on the building equipment level, our approach emphasizes the impact of changes in architectural layout on energy consumption in bio-safety laboratories. In the following sections, we will first provide a comprehensive review of relevant research background and state the purpose of this study clearly in Section 2. Section 3 describes specification basis and implications of low-carbon Design for high-level bio-safety Laboratories. Then, in Section 4, we present our research methodology and optimization strategy of laboratory module layout. Finally, Section 5 offers analysis of the obtained results and presents prospects for the sustainable design of bio-safety laboratories in the future.

2 Research background and significance of laboratory low-carbon design

2.1 Research Background

In the High-level Bio-safety Laboratory System Construction Plan (2016-2025) issued by the National Development and Reform Commission and the Ministry of Science and Technology in 2016, it is mentioned that: "As the international bio-safety situation becomes increasingly complex and changeable, China's strategic emerging industries are booming, the demand for laboratories is increasing, and the original construction layout and management capacity can no longer fully adapt to the needs of the new situation." [3] Therefore, it is necessary to fully grasp the new requirements of economic and social development under the new situation, and accelerate the construction of a national high-level bio-safety laboratory network system with reasonable layout, complete functions, overall management and efficient operation." Various related industries have gradually accelerated the process of building bio-safety laboratories. After the baptism of the epidemic, the world economic pattern has undergone major changes, the rise of emerging markets, and the bio-economy has been brought into the mainstream of development. As a result, the construction of bio-safety laboratories is in full swing. Due to the late start, there is still a huge construction demand in the field of bio-safety, and more high-level bio-safety laboratories will be built or expanded in the future.

In 2021, the state announced the "Carbon Peak Action Plan before 2030", which requires "strengthening the research and development and promotion of energy-saving and low-carbon technologies applicable to different climate zones and different building types, and promoting the large-scale development of ultra-low energy consumption buildings and low-carbon buildings." [4]. The Ministry of Housing and Urban-Rural Development recently issued the "14th Five-Year" building energy conservation and green building development Plan "(hereinafter referred to as the" Plan ") put forward the overall goal: "Building energy consumption and carbon emissions growth trend to be effectively controlled, basically form a green, low-carbon, circular construction and development mode, for urban and rural construction before 2030 carbon peak laid a solid foundation." The plan also proposes to "promote government investment in public welfare buildings and large public buildings to improve energy efficiency standards, and strictly control the construction of high energy consumption public buildings." "Build a market-oriented building energy efficiency and green building technology innovation system, organize key links in key areas of scientific research and project research and development" [4] and other specific tasks.

In addition, the low-carbon design concept is mainly the effective use of resources, and reduce waste in the use of low-carbon design concept in construction projects, it is necessary to fully implement the concept in every detail of construction not only to save the use of resources, but also pay attention to the idea of sustainable development, and enhance the harmonious development relationship between human beings and the ecological environment. [5]

The concept of low-carbon green is one of the most important guiding ideas for the development of the construction industry at present. Construction enterprises are actively conducting research on low-carbon design, responding to the national call for green and low-carbon development, and improving the level of engineering construction.

2.2 The purpose and significance of the study

China is now vigorously developing bio-safety-related industries, especially stepping up the construction of high-level bio-safety laboratories. Due to the particularity and sensitivity of the functions of high-level bio-safety laboratories, the energy consumption of such buildings to achieve safety performance indicators is much higher than that of other types of public buildings. At this time, the whole society needs to contribute to energy conservation and emission reduction. As a high-energy building, the high-level bio-safety laboratory needs designers to study how to implement energy conservation and emission reduction design on the basis of meeting the experimental needs and ergonomics. Numerous past studies have addressed barriers to particular forms of ‘green building’ or ‘sustainable building’. Some of these studies take broad definitions of sustainability, incorporating economic and social factors (e.g. Williams & Dair Citation2007), whilst others have focused specifically on the environmental aspects of sustainability. [6] The author aims to find an effective way to reduce energy consumption and carbon emission by rationalizing building layout.

This research can mainly reduce carbon emissions, save energy, improve the efficiency and safety of the laboratory, promote the sustainable development of the laboratory and improve its economic efficiency. It aims to provide scientific basis and guidance for laboratory construction and design, achieve efficient, safe and sustainable laboratory operation, while reducing carbon emissions and energy consumption, and contribute to environmental protection and sustainable development.

2.3 Research content and path

The research of this paper comes from the experience and thinking in the actual project design work, starting from the relevant content of architectural design, mainly studies the impact of building layout on energy consumption and carbon emissions of high-level bio-safety laboratories.

According to the development goals proposed in the "Plan", although the high-level bio-safety room focuses on the construction of the goal, the overall layout of the four-level bio-safety laboratory is 5-7, and the three-level bio-safety laboratory "on the basis of making full use of the existing three-level laboratory, a new batch of three-level laboratories (including mobile three-level laboratories), To achieve the goal of having at least one Level 3 laboratory in every province." Therefore, according to the content of the "Plan", although the number of level 4 bio-safety laboratories has increased greatly, the overall number is small; Level III bio-safety laboratories not only increase greatly, but also have a certain number of bases. Therefore, the author believes that it is more appropriate to take the three-level bio-safety laboratory as the starting point and adjust the layout of the bio-safety laboratory with different levels of radiation up and down. In addition, the laboratory streamline and scale will be adjusted according to the size of animals, but the purpose to be achieved in the design of the laboratory is similar to that of the microbial bio-safety laboratory, so this paper only takes the microbial bio-safety room as the research object.

This paper intends to explore the influence of building layout on high-level bio-safety laboratories by means of control variables. The three-level bio-safety laboratory standard unit module was first developed to explore the relationship between laboratory layout and energy consumption based on this standard unit. By changing the location layout of standard modules, the supporting layout of computer rooms, and the setting of internal intelligent facilities, the correlation between building space layout and low-carbon design is sorted out, and low-carbon design strategies for space layout are found out.

3 Basis and enlightenment of low-carbon design specifications for high-level bio-safety laboratories

3.1 Standard basis for energy conservation and emission reduction in high level bio-safety laboratories

In view of the fact that there are no existing standards for low-carbon design at this stage. Reference to the "Carbon peak carbon neutral standard system construction Guide" issued by the National Standards Commission and other departments in the "standard key construction content" of the "carbon emission reduction standard subsystem" in the "energy saving standards" and "production and service process emission reduction standards" respectively mentioned the public building energy conservation and green buildings and other content. Therefore, the current relevant standards "public building energy saving design standards" and "green building evaluation standards" are used for reference.

Based on the provisions of "Public Building Energy Saving Design Standard" GB50189-2015, the author combined with the content of "Green Building Evaluation Standard" GBT50378-2019 as a reference for analysis. The basic low-carbon strategy for laboratories as public buildings is as follows:

According to Article 3.1.4 of the "Energy Saving Design Standards for Public Buildings", "building design shall follow the principle of giving priority to passive energy saving measures, make full use of natural lighting and natural ventilation, and combine thermal insulation and sunshade measures of the enclosure structure to reduce the energy demand of the building." And Article 3.1.5: "The shape of the building shall be regular and compact, avoiding excessive convex and convex changes." [7] It is not difficult to conclude that due to the particularity of its use nature, the high-level bio-safety laboratory itself needs to consider its airtightness, and it cannot adopt natural ventilation and other ways to save energy and reduce emissions, but in addition to the supporting public Spaces outside the laboratory can follow this specification, such as public Spaces such as foyers, verandas, offices and so on. Such as office space and other resident space as far as possible arranged on the external wall, not only can make full use of natural lighting and natural ventilation to provide users with a comfortable building physical environment, but also can reduce energy consumption, less carbon emissions, so as to achieve a low-carbon strategy. In addition, designers weigh the functional needs of the laboratory, architectural modeling and other factors, reasonably determine the building form, comprehensive control of the building's shape coefficient and facade form is more conducive to reducing energy consumption, low carbon emission reduction. Especially in cold and cold areas, the less the area of the outer envelope of the building, the smaller the energy consumption.

3.2 Basis of high level bio-safety laboratory layout design code

Starting from the function and nature of the bio-safety laboratory itself, the author mainly combined with "General requirements for laboratory Bio-safety" GB19489-

2008 and "Technical Code for Bio-safety laboratory construction" GB50346-2011 for high-level safety laboratories to carry out targeted low-carbon key points analysis.

Articles 6.3.1.3 and 6.3.1.4 of the "General Requirements for Laboratory Bio-safety" GB19489-2008 correspond to article 4.1.3 of the "Technical Code for Bio-safety Laboratory Construction" GB50346-2011, which limits the scope of the protection area and auxiliary experimental area of the tertiary bio-safety laboratory: "Class a laboratory protection area should include the main laboratory, buffer room, etc., buffer room can double as a protective clothing replacement room; The auxiliary working area shall include cleaning clothes changing room, monitoring room, washing room, shower room, etc. bl laboratory protection area should include the main laboratory, buffer room, protective clothing change room, etc. Auxiliary work areas shall include cleaning and changing rooms, monitoring rooms, washing rooms, shower rooms, etc." [7][8] Later, detailed environmental requirements are put forward for these areas, resulting in energy consumption in these areas is much higher than that of ordinary public buildings. Therefore, in the case of the unchanged requirements for the room environment, in addition to the energy saving and emission reduction measures started by the mechanical and electrical profession through the system design and equipment selection, the construction profession can also pass the main experimental functions.

The room and its supporting parts should be rationally arranged to shorten the energy transmission distance as far as possible, and energy conservation and emission reduction should be considered from the inherent energy consumption caused by the building design.

Article 4.1.3 of the Technical Code for Bio-safety Laboratory Construction GB50346-2011 also points out that "the main laboratory should not be directly adjacent to other public areas." (Article 6.3.1.5 of the "General Requirements for Laboratory Bio-safety" GB19489-2008 also has the same requirements for b1 laboratories) In addition, Article 4.1.12 also requires: "The containment structure of the protection area of the tertiary and quaternary bio-safety laboratories should be away from the external wall of the building; The main laboratory should be located in the middle of the protected area." [7] This article is mainly for bio-safety considerations, it is recommended that the laboratory envelope should be as far away from the external wall as possible, and it also guides us to further explore, triggering the consideration of whether the laboratory maintenance structure has an impact on carbon emissions by the outer envelope and the inner envelope.

4 Influence of building layout on energy conservation and emission reduction of high-level bio-safety laboratories

4.1 Laboratory module volume optimization strategy

The energy consumption of the laboratory itself usually includes the energy consumption of the experimental equipment and the energy consumption of the electromechanical system to meet the requirements of the laboratory environmental parameters. The energy consumption of the experimental equipment will change according to the different content of the experiment, so it will not be discussed for the time being. In order to meet the requirements of laboratory environmental parameters, the energy consumption of electromechanical system is mainly divided into three parts: water supply and drainage, HVAC and electrical. The largest proportion is the energy consumption of HVAC professionals. In the case of specific laboratory location and fixed index requirements, the main influence on laboratory energy consumption is the volume of the laboratory use part.

Therefore, based on the communication and experience of practical projects and experimental personnel, the theoretical basis of ergonomics and relevant laboratory specifications, as well as the description of typical level 3 bio-safety laboratories in WHO's Laboratory Bio-safety Manual, the author set up bio-safety cabinets and other equipment. According to the standard unit modules, the minimum module layout is arranged to meet the basic requirements of the tertiary bio-safety laboratory (Figure 1).

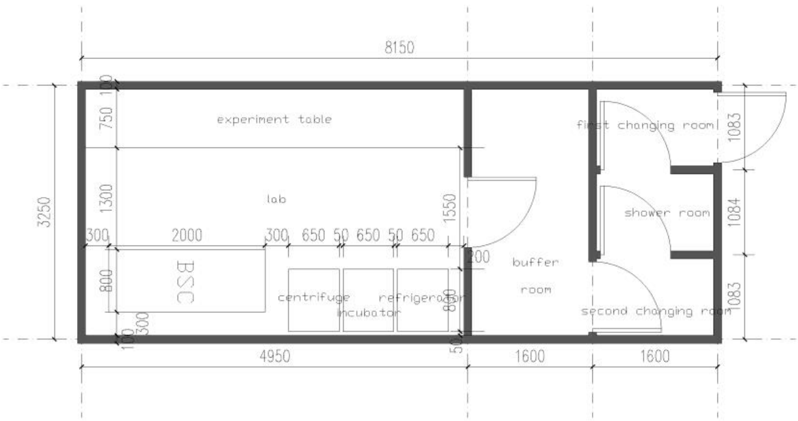

Fig. 1. Laboratory unit module layout.

There are many factors affecting laboratory energy consumption. In order to prove the impression of laboratory layout on energy consumption, this paper analyses this module based on the basic laboratory module, that is, the internal conditions of each experimental unit are the same, and only explores the influence of building layout on energy consumption of high-level biosafety laboratories.

4.2 Laboratory module layout strategy

4.2.1. Simulation method.

On the basis of the above standard modules, the author tries to explore the influence of the attribute change of laboratory module layout on its energy consumption and carbon emission. Mainly explore the following two aspects:

(1) The influence of the form of laboratory envelope structure and its area ratio on carbon emissions.

According to Article 3.1.4 of GB50189-2015, "Building design should follow the principle of passive energy saving measures, make full use of natural lighting and natural ventilation, and combine thermal insulation and sunshade measures of the enclosure structure to reduce the energy demand of the building." [9] To explore the impact of standard laboratory maintenance structures - outer envelope and inner maintenance structure - on carbon emissions.

(2) The impact of different locations of laboratory projects on carbon emissions.

Buildings are located in different climatic zones, and the corresponding requirements of the code should achieve different coefficients and properties of materials. Therefore, this paper further studies the influence of climate on laboratory performance. According to the zoning of building thermal design of Public Building Energy Efficiency Design Standard GB50189-2015, this paper selects a representative city in each climate zone to analyse a total of five cities, including the cold region -- Harbin, the cold region -- Beijing, the hot summer and cold winter region -- Hangzhou, the hot summer and warm winter region -- Guangzhou, and the mild region -- Kunming.

According to the provisions of GB50189-2015, the author selected the thermal parameters of different climate zones in accordance with the provisions of various climate regions in the "Energy Saving Design Standard for Public Buildings", as follows in Table 1:

Table 1. Major parameters for cities represented by climate region.

Climatic zone	Example city	K value				Solar heat gain coefficient
		Outer wall	Interior wall	Single elevation exterior window	Roof	
Temperate region	Kunming	0.8	0.4	5.2	0.5	/
Cold zone A	Harbin	0.38	0.4	2.7	0.28	/
Cool zone A	Beijing	0.5	0.4	3	0.45	/
Hot -summer and cold -winter Zone	Hangzhou	0.6	0.4	3.5	0.4	/
Hot-summer and warm-winter Zone	Guangzhou	0.8	0.4	5.2	0.5	0.52
Winter to wall ratio		0.11				
Figure coefficient		≤0.3				
Thermal inertness of enclosure structure		D≤2.5				

4.2.2. Simulation results and analysis.

(1)Enclosure structure.

The author first explores the influence of the relative position of laboratory standard modules on energy consumption and carbon emissions. Three laboratory standard unit layouts are set up, namely: two external wall standard laboratory units (standard).

Both sides of the unit are in direct contact with the outside. The enclosure structure is composed of two inner walls and two outer walls. From Figure 2, left for the schematic diagram. One external wall standard laboratory unit (one side of the standard unit is in direct contact with the outside, and the enclosure structure is composed of three inner walls and one outer wall, the schematic diagram is shown in Figure 2); The standard laboratory unit with four inner walls (the standard unit is not in direct contact with the outside, and the enclosure structure is composed of four inner walls, as shown in Figure 2 on the right).

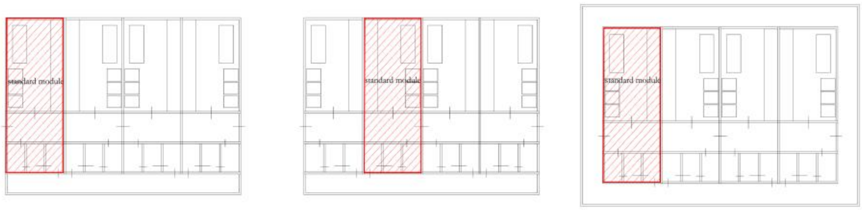

Fig. 2. Standard unit layout: Two exterior walls (left); An outer wall (center); Four interior walls (right).

In the process of exploring the influence of relative layout position on carbon emissions, the control variable method was adopted because there were many factors that could affect it. In other words, during the experiment, the lab shape, size (length and width) and height of the standard laboratory remained unchanged, and only the influence of maintenance structure changes (outer protective structure and inner maintenance structure) on laboratory energy consumption was considered. Based on the above three standard laboratory unit arrangements, the paper use Tianzheng load calculation software to calculate load values of the standard unit in winter and summer were calculated respectively, and the data obtained were shown in Figure 3. The specific calculation process and control variables take the calculation process of winter in Beijing as an example, as shown in Table 2 and Table 3. The data show that in the same area, the factors of temperature and external wall K value coefficient will lead to great changes in the laboratory demand load value. In summer, cold load and experiment.

There is no obvious relationship between the composition of enclosure structure. In winter, the thermal load of two external walls is significantly higher than that of one external wall and all internal wall maintenance structure. At the same time, the total interior wall maintenance structure is less affected by changes in external conditions, and the load required by the laboratory is relatively small.

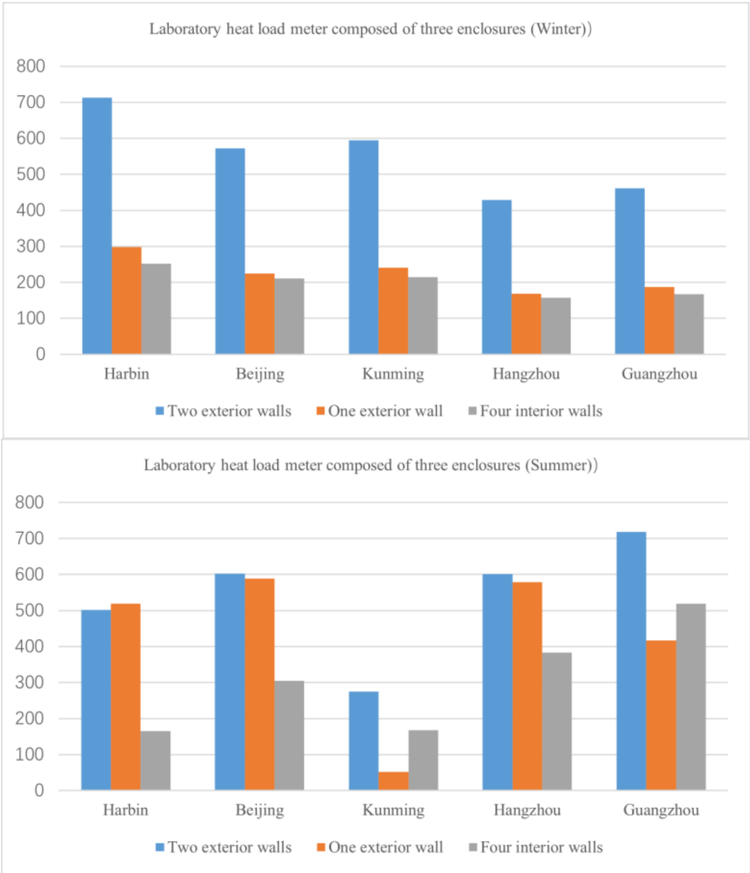

Fig. 3. The laboratory heat or cooling load of the three layouts in winter (top) and summer (bottom).

Table 2. Beijing cooling load calculation book (summary table)

	Floor	Lab	Lab room area	The value of each load at the maximum time of the project load (13 o 'clock)		Maximum room load
				Cooling load	Total cooling index	
			m2	W	W/m2	W
Bei-jing	Lab at first floor	Two exterior walls	15.28	602	39.4	602.02
		An outer wall	15.28	588.3	38.5	588.3
		Four interior walls	15.28	304.6	19.9	401.93
	Lab at sec-ond floor	Two exterior walls	15.28	602	39.4	602.02
		An outer wall	15.28	588.3	38.5	588.3
		Four interior walls	15.28	304.6	19.9	401.93
	Lab at third floor	Two exterior walls	15.28	660.6	43.2	660.62
		An outer wall	15.28	646.9	42.3	646.91
		Four interior walls	15.28	363.2	23.8	545.19
	Total		137.5	4660.5	33.9	4660.5

Table 3. Beijing cooling Load calculation form_Detailed table (taking Beijing - Winter - laboratory located on the first floor as an example)

	Load source		Hourly load value												
			8	9	10	11	12	13	14	15	16	17	18	19	20
Beijing-Two exterios walls	Room parameter		Area	15.28m2	Height	3.0m	indoor temperature	24.0℃	Relative humidity	50%					
			Person	0	Light	0W	Equipment	0W	Ventilation System	0.00m3/h					
	West exterior wall	Basic information	Length	4.93m	Width(height)	3.00 m	Area	14.8m2	Heat transfer coefficient	0.5(W/㎡·K)					
		Load value	47.3	41.1	37	34.2	34.2	35.6	39	43.8	52.1	64.4	80.9	98.7	115.8
	South exterior wall	Basic information	Length	3.27m	Width(height)	3.00 m	Area	9.8-1.8m2	Heat transfer coefficient	0.5(W/㎡·K)					
		Load value	16.3	14.1	12.6	12.6	14.4	18.1	23.7	30.4	37.8	44.1	48.9	51.9	53
	South exterior window_inlaid	Basic information	Length	0.90m	Width(height)	2.00 m	Area	1.8m2	Heat transfer coefficient	3(W/㎡·K)					
		Load value	41.4	85.2	160.5	242.2	286.5	320.8	249.7	141.6	91.3	75.2	58.1	36.7	31.9
	North interior wall	Basic information	Length	3.27m	Width(height)	3.00 m	Area	9.8-1.9m2	Heat transfer coefficient	0.4(W/㎡·K)					
		Load value	24	24	24	24	24	24	24	24	24	24	24	24	24
	North inner door_inlaid	Basic information	Length	0.95m	Width(height)	2.00 m	Area	1.9m2	Heat transfer coefficient	6.500(W/㎡·K)					
		Load value	106.2	106.2	106.2	106.2	106.2	106.2	106.2	106.2	106.2	106.2	106.2	106.2	106.2
	East interior wall	Basic informatio	Length	4.93m	Width(height)	3.00 m	Area	14.8m2	Heat transfer coefficient	0.4(W/㎡·K)					

		n													
		Load value	45	45	45	45	45	45	45	45	45	45	45	45	45
	ground	Basic information	Length	4.0m	Width(height)	3.82 m	Area	15.28m2	Heat transfer coefficient	0.35(W/m^2·K)					
		Load value	0	0	0	0	0	0	0	0	0	0	0	0	0
	West outer Wall	Basic information	Length	1.60m	Width(height)	3.00 m	Area	4.8m2	Heat transfer coefficient	0.5(W/m^2·K)					
		Load value	15.3	13.3	12	11.1	11.1	11.5	12.7	14.2	16.9	20.9	26.2	32	37.6
	West outer Wall	Basic information	Length	1.60m	Width(height)	3.00 m	Area	4.8m2	Heat transfer coefficient	0.5(W/m^2·K)					
		Load value	15.3	13.3	12	11.1	11.1	11.5	12.7	14.2	16.9	20.9	26.2	32	37.6
	East interior wall	Basic information	Length	1.60m	Width(height)	3.00 m	Area	4.8m2	Heat transfer coefficient	0.4(W/m^2·K)					
		Load value	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
	East interior wall	Basic information	Length	1.60m	Width(height)	3.00 m	Area	4.8m2	Heat transfer coefficient	0.4(W/m^2·K)					
		Load value	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
Total(Two exterior walls)	Cooling load (W)		340	371.4	438.5	515.6	561.8	602	542.2	448.6	419.3	429.9	444.7	455.7	480.2
	Ventilation System Cooling Load(W)		0	0	0	0	0	0	0	0	0	0	0	0	0
	Total cooling load(W)		340	371.4	438.5	515.6	561.8	602	542.2	448.6	419.3	429.9	444.7	455.7	480.2
	humidity load (kg/h)		0	0	0	0	0	0	0	0	0	0	0	0	0
	Ventilation System humidity load (kg/h)		0	0	0	0	0	0	0	0	0	0	0	0	0
	Total humidity		0	0	0	0	0	0	0	0	0	0	0	0	0

	load (kg/h)													
	Cold index (W/m2)	22.3	24.3	28.7	33.7	36.8	39.4	35.5	29.4	27.4	28.1	29.1	29.8	31 .4
	Ventilation System index (W/m2)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total cooling index (W/m2)	22.3	24.3	28.7	33.7	36.8	39.4	35.5	29.4	27.4	28.1	29.1	29.8	31 .4
	Total humidity index (kg/hm2)	0	0	0	0	0	0	0	0	0	0	0	0	0

(2)Vertical layout.

Based on the above analysis, four internal wall laboratories that are relatively more energy efficient are selected. In this experiment, the laboratory envelope structure was kept unchanged, and the variable was the number of floors where the laboratory was located. The laboratories arranged on the ground floor, the middle floor and the roof floor respectively to study the influence of their vertical positions in the building on carbon emissions, and the calculated data are shown in Figure 4. The data show that when the envelope structure types of standard module laboratories are the same, the heat load of the laboratory located in the middle layer is smaller than that of the laboratory located on the ground floor and the roof floor, that is, from the perspective of low carbon, the laboratory layout in the middle layer is better than that on the ground floor, and the ground floor is better than that on the roof floor.

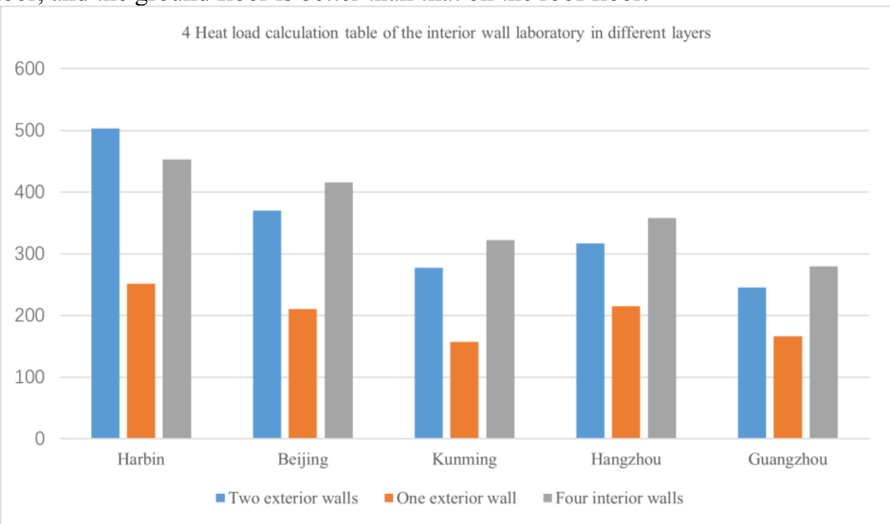

Fig. 4. Four interior walls layout of heat load in different layers in laboratory.

In the building climate zone, the average temperature in January is less than -10°C, and the average temperature in July is less than 25°C. In 2022, July 7 in Harbin is the hottest day in a year, and the temperature is usually between 18°C and 27°C. January 15 is the coldest day of the year, with temperatures ranging from -24°C to -13°C. Therefore, it is inferred that the ground layer in the cold zone A is at a disadvantage in the perspective of low carbon insulation because the surface temperature is too low.

(3) Geographical area.

At the same time, we deeply explored the carbon emissions of laboratory module layout in different climate zones. According to the zoning of building thermal design in the "Design Standard for Energy Efficiency of Public Buildings" GB50189-2015, we selected a representative city in each climate zone for analysis, and a total of five cities were selected, including the cold region -- Harbin, the cold region -- Beijing, the hot summer and cold winter region -- Hangzhou. Hot summer and warm winter area - Guangzhou, mild area - Kunming.

As can be seen from Figure 4 and 5, generally speaking, as A region with a large temperature difference throughout the year, cold region A is at a disadvantage in terms of energy saving and low-carbon, and the extremely hot and cold region is not as good as the temperate region in terms of energy saving and is better than the extremely hot and cold region in terms of energy saving. From the perspective of the overall big strategy, the geographical location of the laboratory shows a trend of warmer, more energy-saving and low-carbon, but it still needs specific analysis in specific regions.

4.3 Layout strategy of laboratory equipment room

The bio-safety code of conduct of high-level laboratories has been given higher requirements, so the corresponding supporting equipment rooms have more special requirements. The layout of fresh air units is crucial for high-level laboratories. The relative position relationship between the fresh air unit and the laboratory can be roughly divided into two categories: same layer or different layer. The machine room with different layout is usually equipped with a special machine room layer, which is connected to the experiment area through the vertical well, and the machine room with the same layout is connected to the experiment area through the horizontal air duct. (Figure 5)

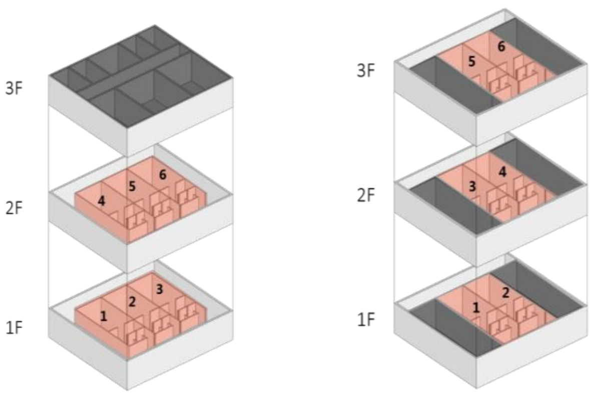

Fig. 5. Two machine room layout diagram (left: different floor layout; Right: same floor layout).

Based on the research in Section 3.2, Kunming, a specific region, was selected as the control variable to study the energy consumption of the cross-floor and cross-floor computer rooms. In this section, a three-story building is simulated as the experimental object. The geographical location, construction area and number of laboratories of the building are quantitative, and the variables are the arrangement of laboratories and computer rooms (same floor arrangement and different floor arrangement). Six laboratories were set for each arrangement, and the types of laboratory envelope structures were as follows in Table 4.

Table 4. Distribution of laboratory rooms under two machine room layouts.

	Two exterior walls (ground floor)	Two exterior walls (middle floor)	One exterior wall (ground floor)	One exterior wall (middle floor)	Four interior walls (ground floor)	Four interior walls (middle floor)
Mechanical rooms and labs lay out in different floors	2 rooms	2 rooms	1 room	1 room	/	/
Mechanical rooms and labs lay out in same floor	/	/	/	/	3 rooms	3 rooms

The heat load value of the equipment room layout in different floors is (697.1x2) + (595x2) +343+240.8=3168, and the heat load value of the equipment room layout in the same floor is (317x3) + (214.8x3) =1595.4. The results show that the equipment room layout in the same floor is superior in low-carbon aspects. When the computer room and the laboratory are arranged on the same floor, the route is relatively short and the energy consumption is relatively low. Whether it is connected to the experimental area through the shaft or through the horizontal air duct, the location of the experimental area should be considered according to the building plan. In the case of meeting the needs of later maintenance and repair work, reasonable layout should be adopted as far as possible to reduce the resistance of the ventilation system air duct and achieve the goal of low-carbon operation.

4.4 Intelligent design strategy

With the development of automation and artificial intelligence technology, some mature robotic arms have been applied in bio-safety experiments, such as liquid injection robotic arms and automatic DNA extractors. More mature robots have been applied in the medical industry, such as the Da Vinci surgical robot, which is widely used in laparoscopy and throat surgery. The development of these technologies allows us to see the possibility of the construction of intelligent unmanned bio-safety laboratories.

The construction of intelligent unmanned bio-safety laboratory has important research value. First, the robotic arm is located inside the laboratory to avoid the risk of virus spread caused by experimenters entering and leaving the main experiment area. The main experiment area is equipped with automatic disinfection robots, which can greatly reduce the probability of personnel entering the contaminated area and reduce the risk of infection of experimental personnel and cleaning personnel. Meanwhile, the operation of experiments with robotic arms can also reduce the risk of sample contamination. Secondly, the building space set up for personnel safety can be simplified, and more space can be used for experimental operation. Thirdly, the introduction of the concept of no one can reduce the heat gain inside the building, reduce the environmental requirements of the main experiment area, reduce energy consumption, reduce the number of ventilation and ventilation, and reduce carbon emissions, which is conducive to the energy saving and emission reduction operation of the building.

5 Conclusion

This paper compares and discusses the carbon emission values of three laboratory envelope structures, three laboratory vertical relative locations and two room layouts in five climate zones, and proposes the potential of low-carbon design strategies based on these results and the prospect of future intelligence.

Low-carbon design is a concept integrated into the whole life cycle of buildings. This paper puts forward the consideration of low-carbon design in the aspect of building layout. There are still many directions and methods for the low-carbon research of laboratory buildings. Based on the data analysis in this paper, under the premise of controlling variables, the following conclusions are drawn:

(1) The location of the laboratory project is conducive to low-carbon and energy-saving operation: the location of the laboratory project is located in the area with small temperature difference in four seasons, which has some advantages, such as Harbin and other regions with relatively cold winter, and the relative heat load of the laboratory is large, so it is recommended to avoid setting up the laboratory in the area with large temperature difference in four seasons.

(2) The envelope structure of the standard laboratory module also has a certain impact on the laboratory load: in winter, the larger the area of the envelope structure, the more detrimental it is to the low-carbon design of the laboratory. Based on this, the data analysis selected in this paper shows that the middle layer of the laboratory is better than the ground layer and the ground layer is better than the roof layer in the conventional laboratory in the temperate climate area. The layout of the laboratory

should be reasonably organized, and on the premise of meeting the building function, reasonable layout can reduce carbon emissions.

(3) The reasonable layout of the laboratory room is conducive to reducing energy consumption: the energy consumption of the laboratory supporting room is large, and the pipeline distance connecting to the laboratory unit should be shortened as far as possible. Taking comprehensive consideration, the reasonable layout of the supporting room is located, and the ventilation system duct resistance is reduced as far as possible through reasonable layout, so as to achieve the goal of low-carbon operation.

China not only emphasizes the green and low-carbon development of the building industry in urban and rural construction and special planning of green building, but also continuously improves and promotes the large-scale development of low carbon buildings in the code and implementation plan, and encourages the construction of low carbon buildings and near-zero energy consumption buildings. At the moment when the novel coronavirus epidemic swept the world, bio-safety laboratories, as the most critical technical facilities in the field of bio-safety, are increasingly valued by countries around the world, and China is also vigorously building bio-safety laboratories and other related industries. As a large energy consumer, laboratories will be built in the future under the premise of meeting the needs of laboratories. Efforts should also be made to reduce energy consumption from design, construction, operation and other aspects, construction companies are actively conducting low-carbon design research, in response to the national call for green and low-carbon development, which is an industry trend.

Laboratory buildings consume a lot of energy, and the realization of the low-carbon design of the whole life cycle of laboratory buildings is also of great significance for the low-carbon development of the entire construction industry. Green building refers to the design, construction, operation and maintenance of buildings that aim to protect the environment, conserve resources, reduce environmental impact, increase energy efficiency and improve indoor environmental quality.[10] To sum up, both low-carbon buildings and low-carbon experiments are the trend of future social development and the response of human beings to achieve harmonious coexistence with the natural environment. Cities are places with an increased urgency for sustainability transitions and system innovations, e.g. due to high energy consumption (ca. two-thirds of global energy demand), CO2 emissions (ca. 70%) or population growth (estimates suggest that by 2050 70% of people will live in cities). On the other hand, many new initiatives and interventions to counteract unsustainable behaviour and practices have originated in cities (IEA, Citation2011; UN (DESA), Citation2012).[11] Therefore, the low-carbon design especially the biosafety laboratories design is not only in line with the development of The times, but also coincides with national policies and the requirements of sustainable development.

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