Problems and Improvement Methods of HVAC Design of Building

Ruan Xiaolong
CHONGQING INFORMATION TECHNOLOGY DESIGNING CO.LTD
Chongqing 400000 China.

Abstract: Construction industry is the pillar industry of country. Its development reflects the level of national economic construction. Quality of construction is also directly related to urban development. HVAC design is an integral and important part of architectural design. Comfort, durability and energy efficiency of construction project will depend on quality of HVAC design. Therefore, HVAC design has always been the content of interest in architectural design. In the actual process of HVAC design, there are some problems that hinder the smooth progress of HVAC design which affect the overall quality of building. Based on this, this study mainly focused on analysis of the existing problems in HVAC design of building and proposed corresponding improvement measures. Hopefully this can provide suggestions as reference for current HVAC design and improve the conditions of HVAC design of building, in achieving the ultimate rationalization of HVAC design.

1. Introduction
Economy and level of technology of contemporary society are in rapid development. Construction industry which acts as the pillar industry of country is in advancement by leaps and bounds. As housing demand of people continues to increase, number of buildings is also increasing. To improve the quality of buildings in meeting people's high requirement for living environment has become the major concern of construction industry. HVAC design of construction projects mainly includes three parts: (1) heating, (2) ventilation, and (3) air conditioning. These three parts are essential residence requirements for most residential building users. The main function of heating part is to provide indoor heat according to the corresponding indoor area. Ventilation is mainly to accomplish input and output of indoor air. At the present, two main ventilation methods are mechanical ventilation and natural ventilation. Air conditioning involves more wide-ranged content, which includes adjustment of indoor air temperature, humidity and others, to ensure the quality of indoor air. Therefore, HVAC design can provide a comfortable living environment for people through control of the overall quality of indoor space environment. It thus has important practical significance for building construction. Many problems exist in construction work of HVAC design, and corresponding improvement measures should be taken for enhancement in order to optimize the overall environment of building space.

2. Problems in HVAC design of building

2.1 Improper design of heating system
In the aspect of heating system design for high-rise building, there is often improper planning between high and low areas. As the results, heat exchanger capacity and pressure are unable to meet the actual needs of building, and re-adjustment and correction of deviation are necessary. Usually, designers will
use separate heat exchanger to minimize the occurrence of such situation, to properly adjust the heating system demand for hot water supply. In addition, control of hot water temperature is an issue that requires extra attention during design process of geothermal heating system. Too high temperature of water not only causes the occupants to feel hot and dry due to high indoor temperature, it will also affect service life of the system. Usually, it is appropriate for water temperature to be controlled below 60 °C. Designers also choose to install radiator system at lower end of house to achieve aesthetic requirement of house. This however is disadvantageous for thermal energy consumption of the system, and it is not conducive for house heating. This needs to be improved in future design.

2.2 Calculation parameter of air do not meet specification requirement

The "Design Specification" clearly specifies the calculation parameter of winter indoor air temperature for reference. But in the actual construction process, different construction site and environmental characteristic require different parameter. Under normal circumstances, range of temperature parameter of washroom and toilet is about 12°C, and the minimum temperature parameter for bathroom is 25°C. On this basis, corresponding adjustment is made according to different construction environment. HVAC design is an important part to ensure indoor temperature of building, and the “Design Specification” provides important references for it to avoid major errors in engineering construction. Heat load is an important factor that affects indoor temperature. It is a parameter obtained by adding cold air which enters room through gaps of door and window during winter, with indoor heating temperature. However, many construction projects do not take this factor into consideration during design, probably due to disregard of this factor, or to reduce the difficulty of project, or choose to neglect it in order to shorten construction period. Either case, this ultimately results in insufficient indoor heat load of building, and the indoor temperature is not able to meet standard requirement.

2.3 Non-standardized fire damper setting

Setting of fire damper is a double-edged sword. It is an important design for protection of people's lives and properties. However, failure of fire damper can occur and cause safety accidents which seriously threaten normal life of people, if there are non-standardized procedures during the setting process. The reality is that, relevant personnel do not carry out fire damper setting strictly according to specifications and requirements during the actual design process. This poses a huge safety hazard for future practical use and threatens the safety of people's lives and properties at all times. Therefore, it is necessary to standardize fire damper setting.

2.4 Insufficient scientificity of exhaust system design

Exhaust system of building mainly refers to air conditioning and ventilation systems. Unscientific design of building is mainly reflected in the following aspects. (1) Installed refrigeration capacity is too large. This is because calculation deviation by designers exceeds the normal range. As the results, installed refrigeration capacity per unit of air-conditioning area is much higher than peak value under normal operation, which increases investment cost of exhaust system. (2) Inappropriate selection of air volume. As mentioned above, design parameters in “Design Specification” only serve as reference. In the actual design process, parameters must be adjusted according to the actual condition of building. However, there are often cases in which selected fan air volume is low. This is because designers carry out design according to parameter values set by the relevant specification, which is not able to meet the actual requirement of building exhaust. (3) Inappropriate selection of insulation material. Aluminum foiled glass wool products have drawback as thermal insulation material, its water absorption is too strong which affects its heat preservation effect. Moreover, fan is usually installed at the outer wall. This is not conducive for exhaust effect of roof fan and extension of service life of the fan.

2.5 Insufficient energy-saving design

With the strengthening of environmental awareness, modern architecture has also begun to focus on energy-saving aspect of design. As an important part of architectural design, HVAC design should
incorporate energy-saving design concept into it. However, conventional design patterns still presently exist in contemporary architectural design. Relevant designers still retain conventional design concept, they are lack of innovation and their consciousness of energy-saving design is relatively low. Their final design solutions are not able to accomplish energy-saving function of building. Energy consumption of HVAC system is relatively high and it accounts for a high proportion of the overall energy consumption of building. Ways to improve energy-saving measures of HVAC system in order to improve energy-saving efficiency have become the current focus.

3. Improvement measures

3.1 Improve the level of design specification
High standardization of design scheme can ensure standardization of HVAC engineering design, and also effectively guarantee the overall quality level of construction project. In order to improve the practical effect of this method, designers must first have a macro planning for the overall construction condition before carrying out specific design work. Subsequently, to gradually carry out detailed design according to framework of the macro planning, to ensure orderly and rational design process for better realization of estimated design effect. Second, relevant personnel must strictly abide by requirements of various regulations in the process of carrying out design drawing. They must correct their attitude and continuously improve quality of their professional skills.

3.2 Appropriate selection of various design parameters
In addition to relevant standard requirement, selection of design parameter must also involve consideration of characteristics of specific object of HVAC engineering design, to achieve rationalization of different design parameters. First of all, basic construction engineering data should be collected and sorted out, and analyzed and adjusted according to standards. Final appropriate design parameters are subsequently determined to ensure the overall quality of construction project and at the same time accomplish effective cost control of the project. Secondly, special attention should be given to two factors: fresh air volume and noise parameter. During the design process, full consideration is required with regard to layout of indoor space setting, so as to select the most appropriate fresh air volume and to set the most reasonable limit of equipment noise.

3.3 Implementation of green energy-saving design concept, and emphasis on energy-saving and consumption reduction of HVAC system

3.3.1 Cold and hot source
Most buildings especially public buildings use a cold and hot source combination of electric cooling water-cooled chiller and boiler. Meanwhile, direct fired lithium bromide absorption chiller/heater and air-cooled heat pump boiler/chiller are less frequently used. Some of the more promising cold and heat source energy-saving technologies, such as cogeneration and water source heat pump are also less frequently used in actual engineering construction. During the design process, relevant designers should pay more attention to accurate calculation of cold and heat load and select number and capacity of cold and heat source according to the actual requirement of installation capacity, to improve the overall operation efficiency of the unit. Based on a study which carried out survey and analysis on 36 large public buildings, results of cold source type and the corresponding seasonal average primary energy efficiency (OEER) data are shown in Table 1.

| Type        | Number | Percentage (%) | Seasonal average OEER |
|-------------|--------|----------------|-----------------------|
| Water cooling unit |       |                |                       |
| Centrifugal | 8      | 22             | 1.186                 |
| Screw      | 12     | 33             | 1.094                 |
| Piston     | 5      | 14             | 1.034                 |
Combined & 3 & 8 & \\
Direct combustion unit & 4 & 11 & 0.95 & \\
Air-cooled heat pump & 2 & 6 & 1.069 & \\
Water source heat pump & 2 & 6 & \\
Total & 36 & 100 & \\

3.3.2 Water system

Energy-saving measures of water system are inefficient at transitional season and low-load phase. Therefore, it is necessary to make targeted design and matching. In the specific adjustment process, combination of large and small cooler unit and chilled water pump can be implemented. Chiller unit with small cooling capacity can be turned on during low load, while both units can be turned on at the same time during the hottest period in summer to improve heat dissipation efficiency without excessive energy consumption. In addition, energy-saving efficiency of variable flow system is also widely recognized by the public. At present, variable flow secondary pump system is mainly used because variable flow primary pump system will pose certain effects on performance of refrigerator, and its usage effect remains to be investigated. Also, it is not appropriate for cooling water pump to take frequency conversion measure in variable flow primary pump system.

A hotel had installed frequency conversion equipment for both chilled water pump and cooling water pump. We performed tests on this for two consecutive days. Figure 1 shows the 24-hour flow rate of chilled water of the hotel and power consumption of air conditioner water pump. It can be seen from the figure that during low load phase at night time, power consumption of cooling water pump increased although power consumption of chilled water pump reduced due to decreased flow of chilled water. Total power consumption of water pump was not reduced, but increased instead. This can be seen clearly in Figure 2.

Figure 1 Flow volume of chilled water and power consumption change of air conditioning pump flow in a hotel
3.4 Fresh air system operation control

Fresh air load can be reduced by maintaining the minimum volume of fresh air. However, this method has little effect for saving volume of manual cooling. New control method using enthalpy of return fresh air can be adopted to ensure reasonable enthalpy difference between indoor and outdoor during operation process of fresh air conditioning system. Main steps are as follows: (1) perform parameter examination to ensure accuracy of relevant parameter. This is because value of enthalpy depends on temperature and relative humidity; (2) to achieve flexible control of each component using automatic control equipment; (3) to determine and analyze enthalpy value. Calculation of corresponding enthalpy value can be done using formula (1). Based on calculation results, it can be determined whether it is within the design range. Thereby, appropriate indoor fresh air volume can be determined to ensure proper indoor environment.

\[ h = 1.01t + 0.001d(2500 + 1.84t) \]

In the formula: 
- \( h \) indicates enthalpy of moist air (kJ/kg of dry air)
- \( T \) indicates air temperature (°C);
- \( D \) indicates moisture content of air (g/kg dry air);
- 1.01 indicates average constant pressure specific heat of dry air (kJ/(kg.K));
- 1.84 indicates average constant pressure specific heat of water vapor (kJ/(kg.K));
- 2500 indicates the latent heat of vaporization of water at 0°C (kJ/kg)

During transitional season, fresh air system can be used in combination with multi-line system to compensate for the deficiency of system operation if a separate fresh air system is not able to meet the requirement of indoor air quality. It is also necessary to strengthen intelligent monitoring of system work process in order to effectively control abnormal situations in real time. In addition, this can allow centralized control management of each unit of the system, which is beneficial for subsequent operation and maintenance work.

3.5 Ensure compatibility of HVAC design

Although HVAC design is an important part of architectural design, all design aspects must be ensured to be carried out smoothly in order to improve the overall quality of building. Therefore, HVAC design of project should be compatible with other architectural design parts in addition to rationality of its own design. At present, application of BIM technology in architectural design can solve such problems well. It can provide reference model of specific building to designers at the beginning of design, thereby sparing sufficient space for project design and providing conducive support for other design work and subsequent construction work.
3.6 Enhance the overall quality of design unit
Department of design must clearly understand its important roles in HVAC design and must take up their own responsibilities. It is necessary to assign professional designers to carry out HVAC design and design control. At the same time, construction site inspection and investigation should be carried out. All relevant data should be understood before official designing through actual site visit and investigation and analysis methods to provide reliable data support for engineering design. For example, if there is difference between HVAC design and national technical standard due to limitations of the building which are impossible to resolve, it is necessary to perform design factor trade-off. It is necessary to start from macro perspective and proceed with details to eliminate contradictions and design planning. Trade-off and management should be well carried out to develop an optimal design plan, in order to create indoor space environment while ensure the quality level of HVAC design.

3.7 Establishment of strict review mechanism
Establishment of a strict review mechanism can prevent problem of unawareness in personnel and regulate problems which are attributed to some uncertain factors. Through effective supervision approach, the quality of HVAC design can be efficiently assured. At the same time, this can prevent under-performance of relevant responsible departments. Strengthening quality control and auditing of all aspects of design can also render good and solid foundation for subsequent overall construction project.

4. Conclusions
In summary, development of construction industry promotes social and economic progress. It promotes continuous development of urban construction. As an important design part, HVAC design should fully comprehend and grasp the current major problems, and adopt corresponding improvement measures to improve the quality of design. Based on analysis of inadequacy and drawback of HVAC design, this paper focused on assessment of measures related to standardization, rationality, compatibility and energy-saving efficiency. Hopefully this paper can provide valuable reference experience for various design problems for actual improvement, in achieving optimization of HVAC design to provide more comfortable architectural space environment for people.

References
[1] Wu Jiayan. Study on chimney effect and HVAC system design of super tall buildings[D]. Beijing University of Civil Engineering and Architecture, 2018.
[2] Zhang Yao. Study of application of BIM technology in HVAC engineering design and construction [D]. Jilin University of Architecture, 2018.
[3] Shang Jing. Design and operation analysis of HVAC system in a public building[D]. Beijing University of Civil Engineering and Architecture, 2017.
[4] Qiao Biao. Research on the overall performance evaluation method of "Energy Design Standard for Public Buildings" [D]. China Academy of Building Research, 2015.
[5] Guo Meiling. Analysis and summary of HVAC system of a specific building in Handan[D]. Hebei University of Engineering, 2014.
[6] Han Hao. Research on measure selection method and strategy for dual certification of green building and energy-saving and comfort [D]. Southwest Jiaotong University, 2013.
[7] He Zhiheng. Analysis of energy consumption status and energy-saving efficiency of large shopping malls in Xi'an [D]. Xi'an University of Architecture and Technology, 2009.
[8] Zhang Wei, Lian Wenzheng. Problems and improvement strategies of HVAC design in high-rise buildings[J]. Heilongjiang Science and Technology Information, 2015(30):207.