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Application of compound ground source heat pump system in contemporary MOMA building design in Beijing

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Abstract: *As a technology using renewable energy, the composite ground source heat pump system has the advantages of energy saving, high efficiency and environmental protection, and has developed rapidly. In the area of unbalanced cooling and heat, the use of composite ground source heat pump system can effectively alleviate the problem of soil heat accumulation caused by the operation of single ground source heat pump system. In this paper, the development status and development trend of the compound ground source heat pump system are discussed, the advantages and disadvantages of the ground source heat pump system and the working principle are compared with the traditional technology, and the important position and future development trend of the compound ground source heat pump in building energy conservation are expounded.*

Keywords: *Compound ground source heat pump system, ground source heat pump system, relationship with architectural design, Working principle and classification, development status and trend*

1. Basic Overview

As the world is seriously affected by the rapid climate change and the novel coronavirus pneumonia, "energy conservation and emission reduction" has become an increasingly important issue. The "double carbon" goal is to raise the deep energy saving and emission reduction of the construction industry to a new height, and the architect will organically combine the resource-saving and environment-friendly ground source heat pump technology such as energy saving, water saving, land saving and material saving with the building design process.

With the rapid development of modern science and technology, radiation drives the upgrading and updating of ground source heat pump technology. It puts forward higher requirements on how human beings create their own living space and environment, and on the design and construction of modern architecture. In order to make people live more comfortable, in order to protect the earth's resources and environment, it is the duty of every architect to design livable green buildings relying on advanced ground source heat pump technology. Beijing Contemporary MOMA takes green ecological sustainable development as the concept, creating a green building with constant temperature and humidity, high comfort and low energy consumption.

Beijing Contemporary MOMA is designed by the famous American architect Steven Hall. The contemporary MOMA is known by architects as the Connecting Complex [1]. With a total floor area of 221,462 square meters, it provides 689 apartments for residents with an area of 135,000 square meters, including a cinema, kindergarten, gallery, shops, fitness gym, cafe and underground parking with 1,000 parking Spaces. The whole building is composed of residences and hotels, the buildings are relatively closed, but open to each other, around the diamond shaped cinema; The cinema is open to the public and there is a small bookshop below. On the ground floor, a number of public passageways connect the surrounding shops, schools, kindergartens and cinemas; The cinema is surrounded by a large pool that reflects the surrounding buildings. On the middle level, there is a communal roof garden. On the 12th to 18th floor, there is a multi-functional skybridge with swimming pool, fitness room, cafe, gallery, auditorium and small salon; A looped skybridge connects the residential buildings to the hotel, creating a horizontal connection between the buildings. The skybridges between these buildings are translucent glass, through which visitors can get a bird's eye view of the surrounding city, the people, the traffic, the buildings, in the words of the architects, like watching a moving "urban film", while people below

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can also look up and imagine the scene of life in the sky - the aerial galleries, reading rooms, restaurants and clubs. The bridge and cantilever parts are equipped with glowing colored film, whether it is day, or night under the reflection of the light, emit a flowing and flowing brilliance. In the apartment, "hinge space" is widely used. There is no fixed door or wall, and mobile door and wall panels can be opened and closed at any time. Residents can change the spatial pattern as they like, creating a free, flexible and flowing space [2] (figure 1, figure 2).

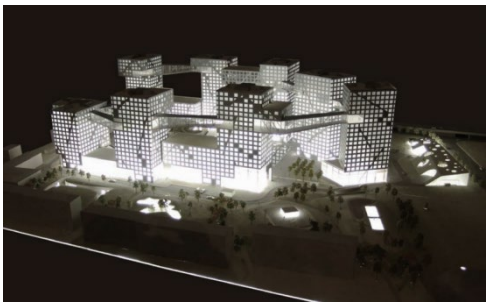

Figure 1: Aerial view of contemporary MOMA (self-drawn) *Figure 2: Contemporary MOMA model (self-drawn)*

2. Ground source heat pump system overview

2.1. Definition of ground source heat pump system

Ground source heat pump air conditioning system is a kind of energy exchange air conditioning system that extracts geothermal resources from the earth surface by using part of high energy, namely electric energy. It is a branch of the application field of heat pump, usually only need to input a small amount of high energy, through the use of heat pump unit equipment can be stored in the soil of low-grade energy into useful heat energy in daily life. It can realize the mutual conversion of winter heating and summer cooling conditions. In winter, the unit extracts heat from the soil for indoor heating. In summer, the unit releases excess indoor heat into the soil to achieve the effect of cooling [3].

2.2. Advantages of ground source heat pump system

(1) Ground source heat pump system belongs to renewable energy.

Ground source heat pump (GSHP) is an air conditioning system that uses shallow geothermal resources on the earth's surface as a cold and heat source for energy conversion. This almost unlimited renewable energy stored in shallow layers of the earth's surface makes ground sources a form of clean renewable energy.

(2) High efficiency, energy saving and stable operation.

Because the ground source temperature is relatively stable throughout the year, it is higher than the ambient air temperature in winter and lower than the ambient air temperature in summer, The fluctuation range is far less than the change of air, the ground source temperature is relatively constant characteristics of the ground source heat pump than the traditional air conditioning system operation efficiency is 40% higher, so more energy saving, and there is no air source heat pump in winter defrost and other difficult problems, while making the heat pump unit operation more reliable and stable.

(3) Green environmental protection.

The operation of the ground source heat pump unit does not have any pollution, it can be built in the residential area, there is no burning, no smoke exhaust, no waste gas, no need to stack fuel waste sites, and no long-distance heat transmission.

(4) Application Flexible and versatile.

The ground source heat pump system can be used in new projects or expansion and reconstruction projects, which can be gradually constructed in stages, and the heat pump unit can be flexibly placed anywhere, saving space, safe and reliable. Ground source heat pumps can also provide dual-use air-conditioning systems for buildings, and can also provide domestic hot water at the same time.

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2.3. Disadvantages of ground source heat pump system

(1) The initial investment is large and the occupied land area is large.

Because the thermal conductivity of the underground rock and soil layer is very small, the heat capacity is very large, and the thermal diffusion capacity is very poor, the heat extraction from the underground requires a large amount of buried pipe, the initial investment is large, and a large area of land is required. At the same time, in the case of unbalanced winter and summer loads, underground energy accumulation will be caused, and auxiliary energy is needed.

(2) The groundwater well recharge technology is not mature.

In terms of groundwater system drilling technology, the recharge problem has not been well solved, and many projects have not actually reached l00% recharge. There are still conflicting views on the quantity allocation of recharge Wells and production Wells, whether winter and summer should be exchanged, whether single-well recharge is reasonable and effective, and whether underground aquifers will be destroyed. At present, in the actual use of domestic groundwater ground source heat pump system, many projects have the situation that groundwater is discharged directly from the surface because the problem of recharge plugging is not fundamentally solved, which will aggravate the impact of ground settlement on the surrounding environment.

(3) The groundwater loop sealing system is not mature.

At present, the groundwater circuit of the domestic groundwater source heat pump is not strictly a sealed system, and the negative pressure generated in the recharge process, the negative pressure generated in the water circuit and the settling pond will make the outside air contact with the groundwater, resulting in groundwater oxidation, which will produce a series of physical, chemical and ecological problems. In addition, the current domestic groundwater loop materials do not do strict anti-corrosion treatment, groundwater through this system, the water quality will be affected to a certain extent. At the same time, the groundwater may be pumped out and then recharge, which may bring bacteria and viruses in the operating pipeline back to the aquifer, causing bacterial or viral pollution, endangering the health of humans and animals.

(4) The special evaluation standard of ground source heat pump system is not perfect.

At present, there is no systematic and special evaluation standard for ground source heat pump system in China, so it is urgent to establish an effective evaluation standard. Through the evaluation of the performance of the ground source heat pump system, the formation of effective industry constraints can curb the blindness in the promotion of this technology, and avoid the problems of many systems, such as recharge obstruction and abnormal operation of equipment.

(5) Strong dependence on local geological and climatic conditions.

The advantage of ground source heat pump is the balance between cooling and heating. If the local climate is hot in summer and cold in winter, and the cooling and heating load are equivalent, the outdoor heat exchanger of the ground source heat pump is utilized to the greatest extent, and the system design is relatively compact, which is conducive to saving costs and reducing the payback period of investment. If the local cooling and heating load difference is large, in order to meet the large cooling and heating load, it is necessary to design the ground source heat pump outdoor heat exchanger as the benchmark, which causes the imbalance of the outdoor heat exchanger heating and cooling load, the result is an increase in investment and a longer payback period.

3. Factors affecting the performance coefficient of ground source heat pump

It is of great significance to improve the performance coefficient of the ground source heat pump, and the key is to improve the heat exchange efficiency of the buried tube heat exchanger. The following factors have an important impact on the improvement of the heat exchange efficiency of the ground source heat pump [4].

3.1. Length of buried tube heat exchanger

In the case of other factors unchanged, the longer the tube length, the greater the rate of heat extraction from the soil, the higher the temperature at the outlet of the buried tube heat exchanger, the greater the temperature difference between the import and export liquid, the higher the heat transfer efficiency. However, the pipe length should not be too long, too long not only the initial investment is large, but also affects the overall layout of the underground pipeline, resulting in low utilization of

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underground soil.

3.2. Liquid flow rate in the buried tube heat exchanger

When the flow rate in the tube is too low and the flow is in laminar flow state, the convective heat transfer coefficient in the tube is very low, which will affect the heat transfer effect. When the flow rate of the fluid in the large tube makes the flow state turbulent, the convective heat transfer coefficient of the inner wall of the tube will be greatly improved, and the heat transfer efficiency will be significantly improved. However, the flow rate should not be too large, because when the tube length is certain, the flow rate is too large, which will reduce the heat absorption rate per unit tube length, resulting in the heat exchange efficiency of the heat exchanger.

3.3. Pipe diameter of the buried pipe heat exchanger

When the pipe diameter is smaller, the heat transfer capacity is stronger, but the pipe diameter should not be too small, too small will increase the flow resistance of the fluid in the pipe, which will increase the energy consumption of the pump, but will reduce the performance coefficient of the ground source heat pump system.

3.4. Spacing of buried tube heat exchangers

The distance between the two tubes of the U-shaped tube has a great influence on the heat transfer efficiency. The heat absorption capacity of the pipe near the liquid outlet is lower than that of the pipe near the liquid inlet. The soil temperature around the pipe near the liquid outlet is high, while the soil temperature near the pipe near the liquid inlet is low. If the distance between the two pipes of the U-shaped pipe is too small, the soil part with high temperature will transfer heat to the soil part with low temperature, which will affect the heat absorption efficiency of the pipe near the liquid outlet. Thus, the heat transfer efficiency of the buried tube heat exchanger is reduced.

3.5. Moisture content in soil

When the moisture content in the soil is high, the heat transfer efficiency outside the tube of the buried tube heat exchanger increases significantly, because when the moisture content is too low, the heat transfer outside the tube is mainly based on heat transfer. When the moisture content increases, there is not only heat conduction but also convective heat transfer outside the pipe. Long-term use of the ground source heat pump system will lead to a lot of water content in the soil, so the ground source heat pump system should be used intermittently in order to optimize the performance of the ground source heat pump.

4. Development status of composite ground source heat pump system

The composite ground source heat pump system technology is the most popular technology in the application of geothermal energy at present, which is widely used in public buildings, such as schools, hospitals, stadiums, office buildings, residential quarters, villas and other places. In recent years, the Chinese government has given a number of preferential policies to the composite ground source heat pump system technology. The basic division of suitable area, basic suitable area and not very suitable area is given for ground water ground source heat pump system and ground pipe ground source heat pump system, which is convenient to reduce project risk. High-temperature geothermal power generation takes advantage of the volatility and intermittency of wind power and solar power, while shallow geothermal energy relies on the development and utilization of ground source heat pump system technology, which can provide high-quality services for building energy and meet the growing demand for heating, cooling and hot water supply, and is a clean and pollution-free energy [5].

5. Development trend of compound ground source heat pump system

The purpose of using the compound ground source heat pump system is to make full use of renewable energy, improve system efficiency and reduce operating costs. However, in practical projects, the system efficiency is not high, the operating cost is reduced less, and the system investment payback period is long. Therefore, it is necessary to study the load forecasting, the establishment of mathematical simulation, and the simulation of the optimization control of the composite system, so as to achieve the superior energy saving and economy of the composite system.

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Because the compound ground source heat pump system uses an auxiliary heat dissipation or auxiliary heating device to balance the heat discharged into the soil and the heat extracted from the soil, the design should accurately determine the specifications of the auxiliary heat dissipation device or auxiliary heating device, so that the unbalanced heat is discharged more accurately and the excess heat (or cold) does not accumulate in the ground. The auxiliary heat dissipation and heating devices of the compound ground source heat pump system need regular maintenance. Operating and maintenance costs will increase the cost of the entire system. Therefore, the initial investment and operating costs increased by auxiliary devices should be fully considered in the design. In addition to the accurate design of the auxiliary cooling device or auxiliary heating device specifications, the compound ground source heat pump system also needs to design the control conditions for opening and closing the auxiliary cooling device or auxiliary heating device in the entire system, and determine the operation control mode. Only these reasonable designs can fully demonstrate the advantages of using a compound ground source heat pump system in areas with unbalanced load throughout the year.

Since the efficiency of the building load and the auxiliary cooling device, that is, the cooling tower, changes with the outdoor meteorological conditions, the heat of the soil heat exchanger in the operation of the system changes time by time, and this fluctuation makes the temperature of the water supply and return of the geothermal heat exchanger change within a day range of 5.6℃ ~ 10℃. The COP value of the heat pump will be affected by the change of the temperature of the supply and return water, and the fluctuation of the system performance will have a greater impact on the operating cost in the area where the TOU price is implemented. Therefore, in order to design the most economical compound ground source heat pump system form and its operation control mode for specific buildings, it is necessary to calculate the operating costs under various system components and operation control mode, and carry out annual hourly energy consumption analysis for the operation of the entire compound ground source heat pump system. The system form and control measures with minimum initial investment and operating cost are determined under given climatic conditions and electricity pricing method.

6. Conclusions

The cooling tower assisted compound ground source heat pump (GSHP) system is an effective method to solve the imbalance of winter and summer load in the region where the cooling load is dominant. The research on the design and operation strategy of the composite system has not been widely promoted in China. At present, the research on the system is still aimed at the minimum initial investment and operation cost, and the solution of the soil heat balance problem is rarely considered. Therefore, the optimization design method and efficient operation strategy have far-reaching significance for the rational application and scientific development of the compound ground source heat pump system. For the compound ground source heat pump system, it should be in-depth and detailed study for different forms of compound ground source heat pump system according to different climate regions or project characteristics, and optimize the system design according to local conditions. For example, there is sufficient sunlight in Qinghai Province, so detailed and in-depth analysis and research can be carried out for the ground source heat pump and solar energy compound system, so as to make full use of solar energy and improve the energy saving and economy of the system. For example, the combination of ground source heat pump and energy storage system should be studied for system configuration and operation strategy to improve system performance, reduce installed capacity, and reduce investment and operating costs.

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