Tsinghua Green Building Research Center

——A Low Energy Demo Building

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1. Introduction

'Green Olympic' is a promise made by Beijing Olympic Organizing Committee to International Olympic Committee. Green building should be one of the most important tasks in 'Green Olympic'. Furthermore, China has become the largest construction site in the world, and it was predicted that by 2015, more than half of building floor area in China is built after 2000. Therefore, green building development is significant to China sustainable development as well as to global environment protection.

Sponsored by Ministry of Science and Technology (MST) of China, a green building assessment system for Beijing Olympic 2008 named GOBAS (Green Olympic Building Assessment System)[1] was issued in August 2003. This assessment system was developed on extracting the merits from CASBEE of Japan[2] and LEED of USA[3], and combining the situation of China urban construction development.

As a part of the project of GOBAS, a Low Energy Demo (LED) building was designed and is under constructing as an experimental environment and the new building technologies demonstration workbench. This LED building is not only for the project of GOBAS, but also was assigned as the workbench of the follow-up larger project sponsored by MST — 'Research on the pivotal technologies of green building'. LED building is an office building of 2920 m^2 floor area designed by architects and engineers from School of Architecture, Tsinghua University. New green building technologies will be used, tested and demonstrated on it.

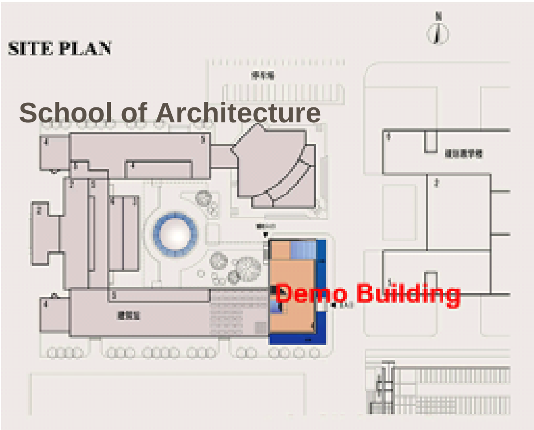


***Fig. 1** Location of the LED building*

LED building also will be used as the office and laboratory of Tsinghua Green Building Research Center. Integrated energy efficient technologies used in the building design include energy saving, energy callback and renewable energy utilization.

This paper introduces the design concept and principles of LED building. Details of some special technologies are described, and further relevant literatures are provided.

2. Design Concept and Principles of LED Building

The LED building is located in the campus of Tsinghua University. Its west façade is attached to the main building of School of Architecture, see Fig.1. It is a 4-story overground building with 1-story basement. Fig. 2 shows the ‘green’ technological strategies applied to this building.

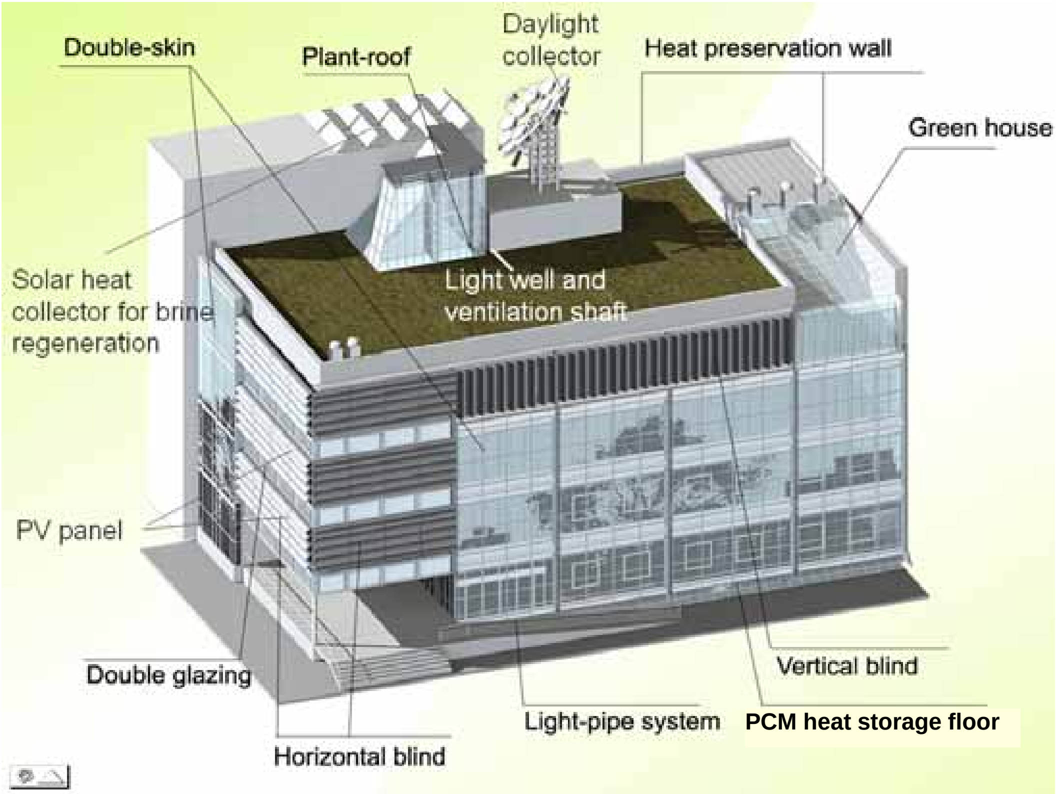


Fig. 2 *Southern and eastern façade of LED building*

Green building technologies are selected for this building considering that those should be available in China. Therefore, updated technologies and new products available in Chinese market and new technologies developed by Tsinghua University and research partners are adopted in the environment and energy system. They include:

(1) Steel structure and double skin façade with controllable shading and hybrid ventilation paths are adopted as the frame and main envelope of the building. High performance glazing fabrics can keep low annual cooling/heating load.
(2) Controllable daylight reflectors are built inside the east double skin façade. A daylight collector on the roof traces the sun and collects the daylight then transfers through the reflector system in the light well to the basement.
(3) Rising floor with shape stabilized phase change material is used as the thermal storage mass of the building. It storages heat from the night electric heating in the off peak price period and keeps space warm in the daytime.
(4) A new brine desiccant system with high efficiency was developed to realize independent humidity control. Outdoor air is dehumidified to very low dew point to remove the indoor latent heat gain, and the sensible heat gain is removed by cool ceiling with underground water or chilled water at temperature higher than 18 °C.

(5) The solar heat collecting system collects solar heat for regenerating the brine of the desiccant system.
(6) Natural ventilation strategies are design by simulation. The light well is also used as the ventilation shaft to promote natural ventilation at night or in the intermediate seasons.
(7) The power is from BCHP with gas engine and fuel cell. The rejected heat is recovered for brine regeneration.
(8) Some PV panels will be installed in the lower part of the double skin facade of each floor.
(9) Personnel air-conditioning system and fan-coil units blowing emulated natural wind are used for office and lecture room.

3. Building Energy Efficency in Building Fabrics Design

The main purpose of the building fabrics design is to reduce the cooling/heating load and lighting energy consumption. The environment impact from the building materials is also considered as well as the environment impact from the consumed energy.

(1) Structure and materials

From the view point of life cycle analysis, as less as possible unrenewable materials are used in this building. Steel structure is used because it can be easily recycled and reused. Glazing curtain wall is the main type of fabrics. It is not only for the sake of its renewability, but also for the sake of that glazing fabrics are always architects' favorite in commercial building design. Choosing glass as the main fabric material in this building is to show them how glazing curtain wall should be designed in a better way.

(2) Double-skin facade and shading

There are three main types of glazing façade in south and east façade. Well insulated light solid wall with overall U value 0.35 W/m^2K and double panel windows are the main form of north and west façades. Part of south and east facades use double-skin facades with built-in controllable blinds. The remains parts adopt adjustable louvers as the external shadings. Based on the solar altitude analysis, horizontal louvers are used on the south facade and east corner, and vertical louvers are installed on the upper part of the east façade. Fig. 3 shows the adjustable horizontal louvers installed at the south-east corner. Both the width of a louver and the space between horizontal or vertical louvers are 600 mm.

Fig.3 *Adjustable horizontal louvers*

The structure of southern double-skin façade is shown in Fig. 4. The external glazing unit is double panel with one low-e coating, and the interior glazing is single panel unit without any coating. The space between interior and exterior glazing unit is 200 mm, so mechanical ventilation is necessary for removing the solar heat gain from the blinds. The overall U value of the curtain wall is 1.28 W/m^2K, and SHGC<0.1 if ventilation system works. As to the curtain wall with the external shading, the overall U value of it is 1.28 W/m^2K as well when external louvers are open. There are openable parts on the two side-walls of this double-skin façade so that natural ventilation can be realized during the intermediate seasons.

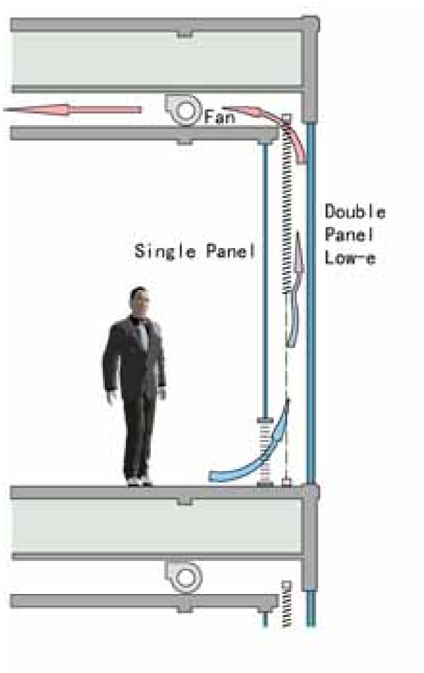


Fig. 4 Southern double-skin façade

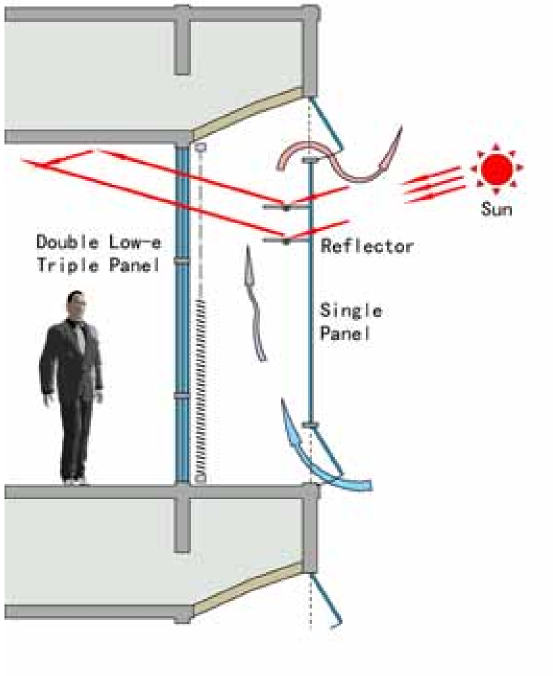


Fig. 5 *Eastern double-skin façade*

Fig. 5 shows the structure and principles of eastern double-skin façade. It is difficult for eastern façade to get the balance between reducing solar heat gain and well utilizing daylight, because solar altitude is rather low in this orientation. This design uses rising blinds to prevent the direct solar radiation on the working space. Two daylight reflecting panels located on the upper part of the curtain wall reflect direct sunlight to the ceiling, which can diffuse the daylight over the space. The distance between interior and exterior glazing units is about 700 mm, so that natural ventilation is sufficient to keep the façade away from being overheated. The central part of the interior glazing unit can be opened so that natural ventilation can be used in the intermediate season. The exterior glazing is a single panel while the interior unit is triple panel with two low-e coatings. The overall U value of this curtain wall is 1.0 W/m^2K, and SHGC<0.1.

Based on the annual thermal simulation result, the cooling load from fabrics is 5.2 W/m^2, heating load from fabrics is 2.3 W/m^2, and the average heating load from fabrics in the whole heating season is only 0.7W/m^2. In fact, when internal heat gain is considered, there will be 0.0 heating load in the winter.

(3) Daylight utilization

In order to save lighting energy, daylight collector system was designed to collect daylight and transfer it to the laboratory in the basement, see Fig. 7. There is a solar tracing daylight collector located on the roof. The collected sunbeam is reflected by a group of reflectors, through a light well which also be used as a ventilation shaft to the basement. Then the sunbeam will be distributed by reflectors or photic fibers to different areas of the basement.

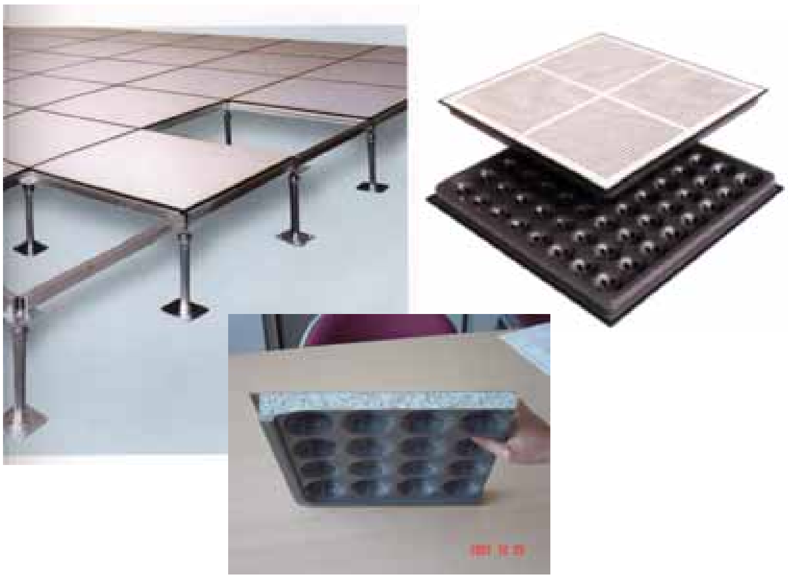


Fig. 6 *Rising floor and shape stabilized PCMs*

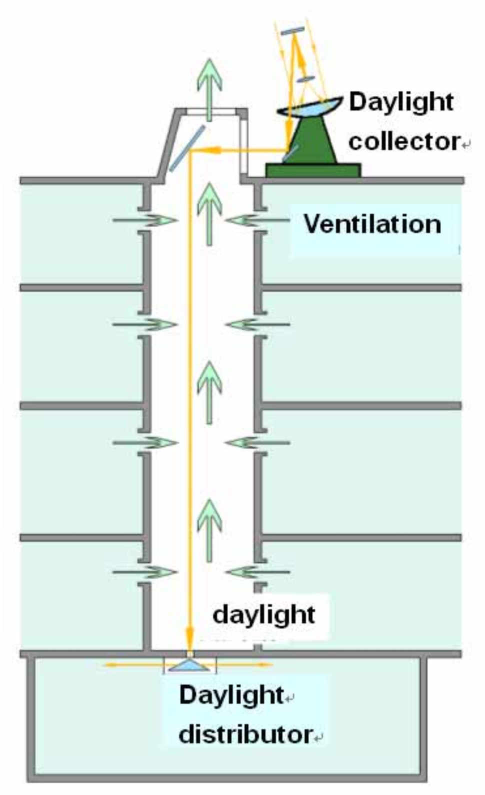


Fig. 7 *Daylight collector system*

(4) PCM rising floor

Considering the low thermal mass steel structure, 1300 m^2 PCM (Phase Change Material) rising floor is designed in this building so that the thermal properties can be improved. For example, direct solar radiation can be stored by PCM so that the indoor temperature will not vary too much. In the winter night, the off peak low price electricity can be used to heat the PCM floor, and then in the daytime, the indoor environment can be kept warm without any daytime heating. Therefore, the bill of electricity can be saved.

In order to avoid the high thermal resistance of the encapsulation materials for solid-liquid PCMs, a kind of shape stabilized PCM are adopted. Its phase change temperature is 20~22°C, and the phase change latent heat is 120~160 kJ/kg. The PCM granules are mixed with concrete and filled in the cavum under the rising floor, see Fig. 6.

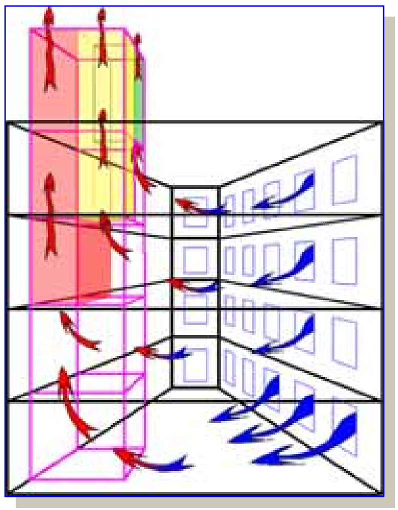


Fig. 8 *Natural ventilation Design*

(5) Natural ventilation design

In order to save cooling energy during intermediate season, natural ventilation paths were designed by detailed analysis with simulation. A natural ventilation shaft with glass attic was designed to promote buoyancy ventilation when outdoor air temperature is lower than indoor set point. Outdoor air will go first through the opens on the exterior glazing unit of the double-skin façade, then through the opens on the interior glazing unit, and finally cross over the indoor spaces and cool the space down. Fig.8 gives the sketch of the natural ventilation paths of LED building.

4. HVAC System and Cooling/Heating Plant System

The strategies of the environment control and energy system design are:

a) As to the indoor terminals, personal controllability and thermal comfort are considered as the most important factors. Therefore, personal air-conditioning, natural wind emulator, displacement ventilation and radiative panel are used.

b) Air-handling process should be compatible to the indoor terminals. Therefore, temperature and humidity controlled separately is the most important strategy.

c) Energy plant system should be compatible to the air-handling process while energy efficiency is considered.

Fig. 10 shows the indoor terminals used in office spaces. The personal air-condition terminals with natural wind emulator is the personal environment control measure. The ambient temperature is controlled by cool ceiling while humidity is controlled by the dried fresh air supplied from the displacement ventilation system.

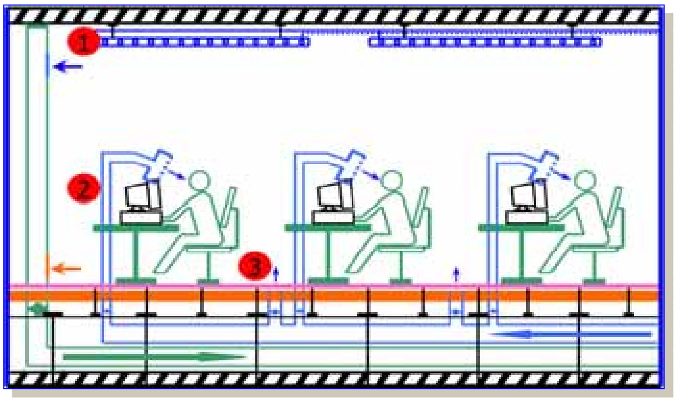
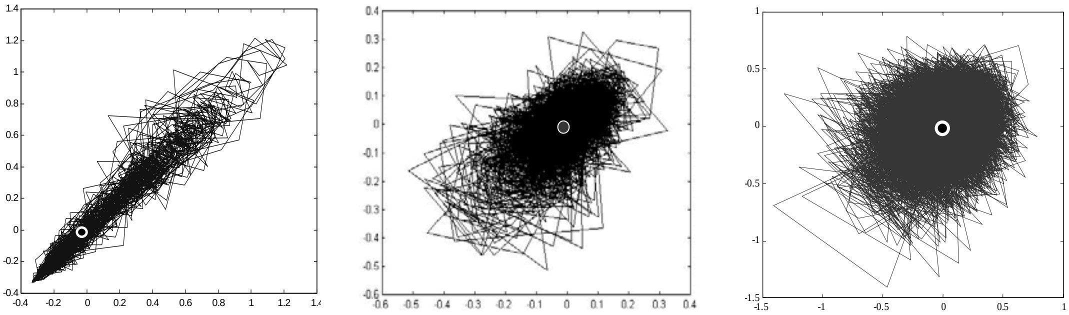


Fig.10 *Indoor terminals of LED building*

In the other spaces of LED building, similar strategies are used. For example, in the lecture room, fan-coil units with natural wind emulators operated only during the peak load periods take the place of personal air conditioning system.



Natural Wind　　Buoyancy Flow　　Mechanical Wind

Fig.11 *Phase space reconstruction curves of typical natural wind, buoyancy flow and mechanical wind* [4]

The principle of the natural wind emulator is based on the theoretical analysis to the fluctuation properties of the air velocity of wind from different kind sources. This research in Tsinghua University is started from 1998. It is believed that the differences between the air velocity fluctuation properties are the virtual factors to the human sensation. Fig.11 shows the differences between the phase space reconstruction curves of typical natural wind, buoyancy flow and mechanical wind. Besides phase space reconstruction, differences between fluctuation properties of different kinds of airflows include power spectrum, turbulence intensity, information entropy, information dimension, and so on. Based on the fluctuation properties analysis, a kind of air supply terminal utilizing a rotational pan to change the airflow distribution inside the air supply terminal was developed so that airflow with different power spectrum could be generated. Such a dynamic air supply terminal could be used to generate the 'quasi-natural wind' which agreed with most of the fluctuation properties of natural wind. Fig. 12 is the experimental results of voting to different kinds of airflows generated from this terminal. It was found that the airflow of which the spectrum close the most to the natural wind would be more pleasant to people than the other three[5].

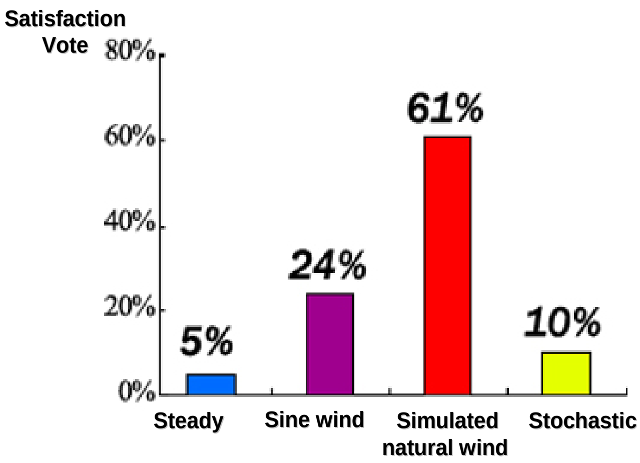


***Fig.12** Experimental results: Vote to different air flows*

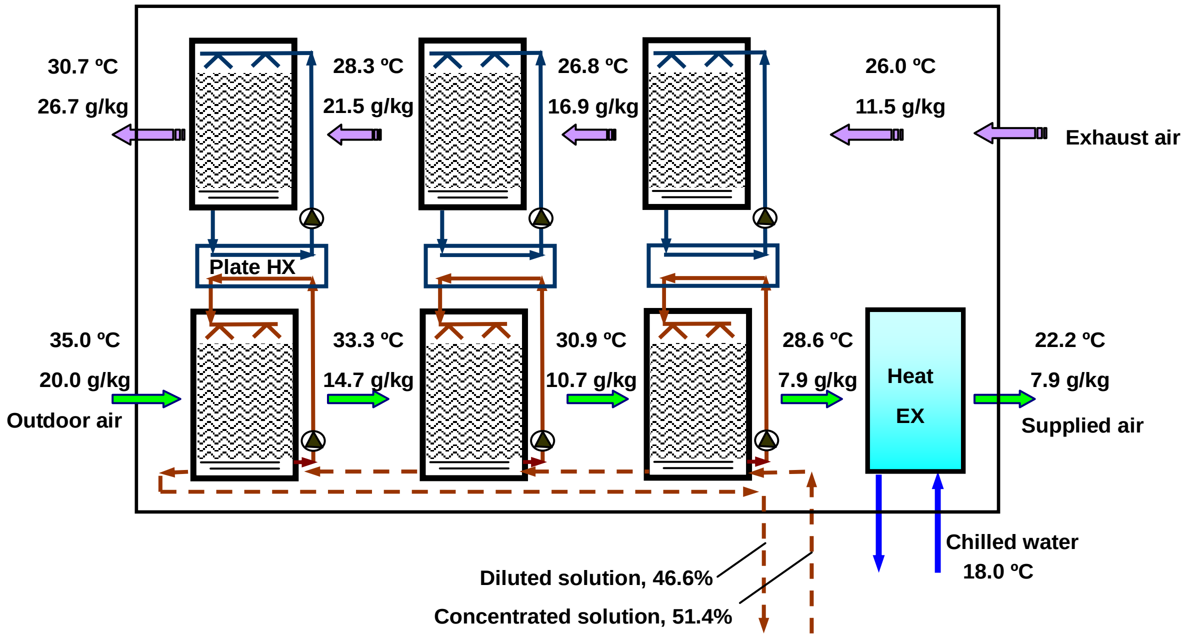


***Fig. 13** Outdoor air handling Unit (dehumidifier)[6]*

According to the environment control strategies, dried fresh air is necessary. Four brine-desiccant air handling units of 4000m^3/h air volume are installed to control the humidity of the outdoor air intake. Fig.13 and Fig.14 give the schemes of the brine-desiccant system [6]. It is a multi-stage brine desiccant system. Sensible heat and moisture are transferred from the intake outdoor air to the exhaust air. Then the outdoor air can be dehumidified to RH 35% (28.6°C, 7.9 g/kg), see Fig.13. In the winter, such a system is used as the total heat recovery system.

The outlet brine from outdoor air handling unit is diluted and has to be regenerated/concentrated in the brine regenerator. Fig.14 shows the scheme of brine regenerator. It is found that in this regeneration process, only hot water at 80°C is needed as the input energy. Furthermore, for the other air handling terminals such as cool ceiling or fan-coil units, only chilled water at temperature not lower than 18°C is necessary. Therefore, the majority of the cooling demand can be met by higher temperature chilled water and low temperature hot water. It is why waste heat, solar heat, underground water (about 15°C) and other renewable or natural energy can be used in this system.

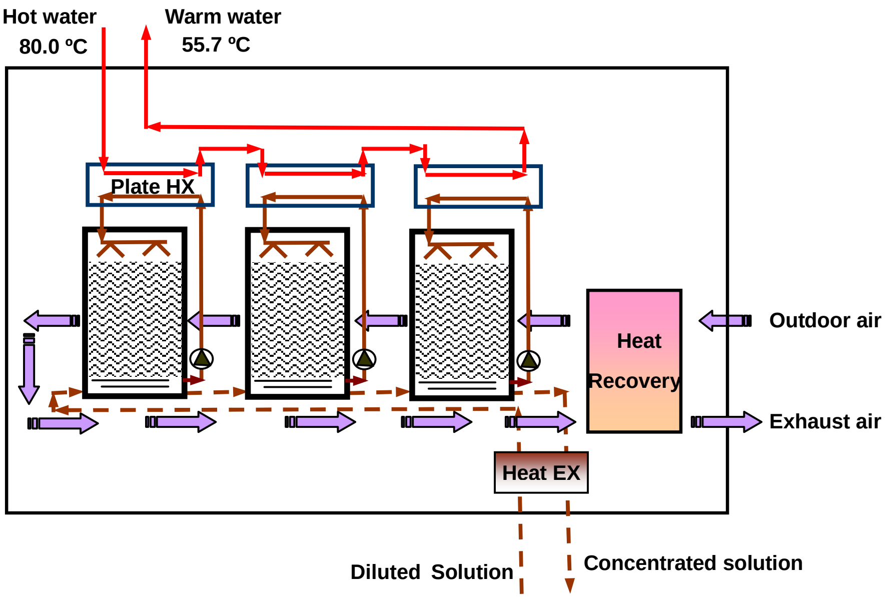


Fig.14 *Brine regenerator* [6]

Due to the special feature of energy demand of this system, an energy plant system with high efficiency was developed as shown in Fig.15. Natural gas BCHP (Building Combined Heat and Power) system is adopted. Gas engine and fuel cell are used as the energy conversion kernel. The output electricity is all consumed by LED building, and together with the heat from the solar heat collector on the roof, the rejected heat from BCHP system is provided to the brine regenerator as its input energy. The energy efficiency of the BCHP system is higher than 85%, while the efficiency of power generation is about 43%.

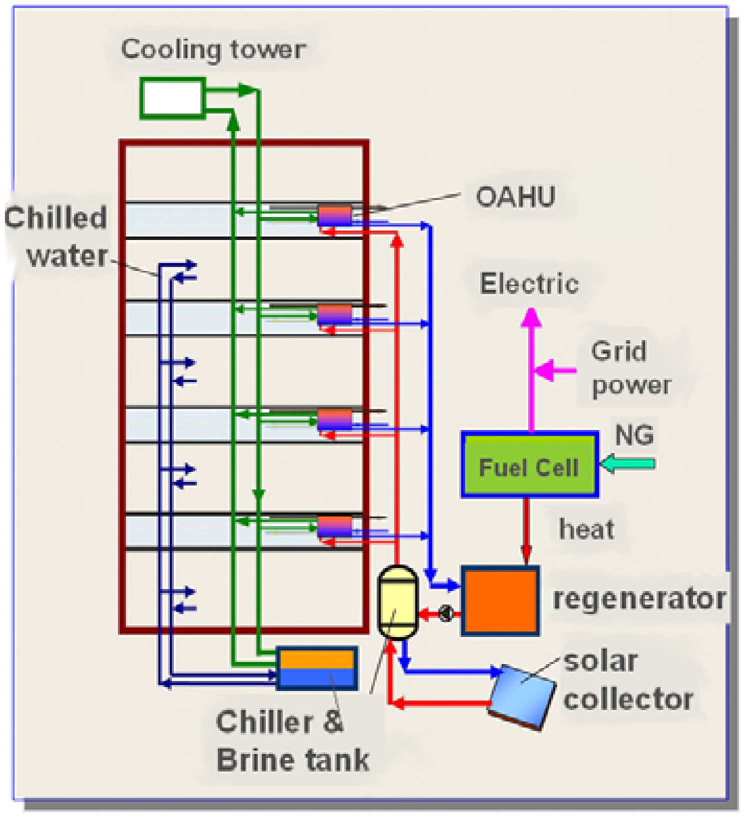


Fig.15 *Schematics of energy plant system*

The chillers here are mainly used to provide chilled water at 18°C to the cool ceiling and the outdoor air handling unit for the end cooling. A well being able to provide water at 15°C and 70m^3/h water volume is also an alternative. The COP of the electric chillers when outlet chilled water at 18°C is about 9. Therefore, the energy efficiencies of both plans are very high.

Up to now, LED building's structure and fabrics have just been completed. The HVAC system and energy plant system are going to be installed. After all of the designed items are finished, further measurement, test and analysis will be conducted according to the different purpose of different research tasks.

Acknowledgement

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