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Study on the passive solar house with water filled cavity[1]

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Abstract. In order to eliminate the shortcomings of the existing solar house, a kind of passive housing structure was put forward. The principle, construction and control of this kind of housing were studied. A large number of cavities filled with water were arranged of construction. Cavities in the wall and floorslab were connected with solar collectors hanged on building exterior wall. Water could flow in circulation between solar collectors and cavities in the wall and floorslab. Thermal storage capacity and fluidity of water was used to realize a comfortable temperature of the winter room through rise temperature of walls and floorslabs uniformly. The use of this structure in summer could be further explored on the basis of the winter heating application achieved. This kind of housing was the same as the common house in terms of the internal structure, and the room temperature was more uniform because of the large amount of water used. Compared with the traditional structure, the thermal efficiency of this structure has greatly improved.

Key words. Passive solar housing, thermal storage capacity, water, structure.

1. Introduction

Energy crisis is a common problem in the world today, and how to make better use of solar energy, wind energy, geothermal energy and other clean energy has become a scientific research focus. Solar energy is inexhaustible, no pollution and cheap. With a tide of more and more attention to energy conservation and environmental protection worldwide, the development of energy-efficient buildings has become a major trend of building development in many countries. In this situation, the solar housing as a kind of energy-efficient buildings which fully exploit the potential of solar energy should receive adequate attention.

The ways of using solar energy in buildings is divided into active way and passive way. Active use of solar energy systems need to use other power sources, such as electricity, to achieve the purpose of heating or cooling. Passive mode is totally rely

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the power generated by solar to complete heat extraction, transportation, storage and distribution in winter, and to cool rooms by shading solar radiation, natural ventilation in the summer, through the rational arrangement and cleverly constructed of the building.

2. State of the art

The earliest patent technology of passive solar house was "black tiles" invented by an American Professor named Morse in 1881. But the research of solar house was accelerated after 1983. The first experimental solar house named MIT-1 was built by Massachusetts Institute in United State. The first article about solar heating was written by Dr. Holter in 1942. The first academic meeting about the use of solar heating was held at the Massachusetts Institute of Technology in 1950. Trombe walls obtained French patent later which had a significant contribution in the development of solar house were successfully researched by Dr. Felix Trombe director of the Institute of France odero solar who proposed first and Michel as an architect who was an collaborator. Especially after the energy crisis in 1973, it set off a climax to the study of solar house. The first research conference which theme is passive solar house was held in New Mexico May 1976. PASOLE, the passive solar house simulation program, was successfully prepared by Dr. J. D. Balcomb in United States Alamos Los National Laboratory in the same year. In the spring of 1977, Balcomb analyzed the influence of different weather conditions and structural parameters on the thermal performance of solar house used the validated program simulation. By 1980s, passive solar houses enter the practical stage from the testing phase in the world. In 1980, the Los Alamos National Laboratory published passive solar housing design manual in New Mexico, the United States. In 1982, the passive solar house magazine began publishing. In the last 20 years, the research trend of solar building has been gradually changed from theory and experiment to numerical analysis and computational simulation based on computer [1–10]. The work of practical quantitative simulation about the application technology of passive solar energy was Rapid progressed, and many of them have become commercial software, such as ENERGY, SOLA, TARP, ASEAM, DOE, BLAS, EnergyPlus, etc.

3. Methodology

Water's specific heat capacity is maximum in common substances, so water has a strong heat storage capacity. Water has good flowability at same time. If the floors and walls can be made with water, a "Water House" will be constructed in which thermal stability and temperature uniformity will be greatly improved. An ideal approach is walls and panels are made of two sheets sandwiching a layer of water. The outer sheet of exterior wall and roof is made by good insulation properties, the inner sheet of exterior wall and roof is made by good thermal conductivity. Tow sheets of interior walls and floors is made by good thermal conductivity. The water in the wall and the floor is heated by a solar collector, and the flowability and heat

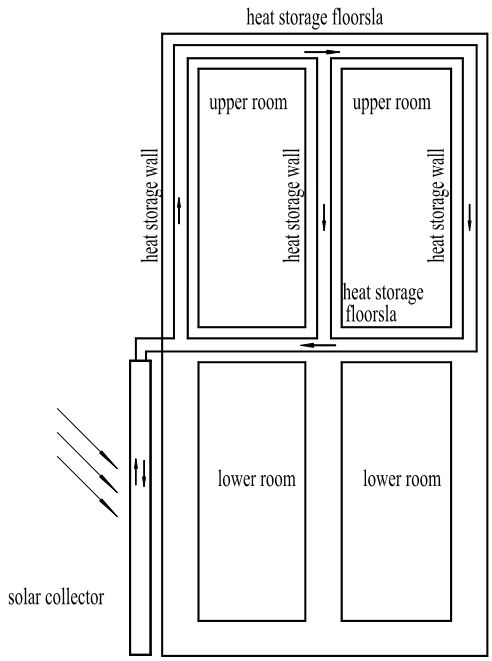

Fig. 1. The heat storage walls (floorslabs) and solar collector installed in the lower layer

storage capacity of water storage can make a suitable temperature in the room. Unfortunately, this configuration is not easy to realize and is not practical.

In fact, we can set up variety shape of cavity in the walls and floors, for example, buried pipe to form cavities. Filling with water in cavities, the wall and floor's heat storage capabilities are enhanced. They were called heat storage wall and heat storage floorslab. Being heated in the solar collector, water flows in the walls and floorslabs. In addition to improving the heat storage capacity of the wall and the floor, the water has the function of the heat medium. Heat storage walls and heat storage floorslab increase indoor temperature in winter by convection and radiation. Water is heated in solar collector, and flows into the heat storage wall (or heat storage floorslab), when heat release, cooling water flows back to solar collector. Heat storage walls (or heat storage floorslabs) are connected with the connecting pipe into the loop.

4. Installation method of solar collector

Used the installation method of Fig. 1, water flow into the heat storage wall and heat storage floorslab. Water rise to the heat storage walls and heat storage floorslab heated by solar collector, and drop back to solar collector when heat released. It has certain advantages that in the non-one-story building solar collectors are installed

next level. When there is no sunlight at night, the solar collector does not heat water, then high temperature water stays in the heat storage wall and heat storage floorslab, and the slow release of heat maintain proper thermal environment indoor. Low temperature water stays in the solar collectors. Indoor and outdoor water is no longer circulating, avoid the heat loss of hot water in the outdoor fittings. Because the solar collectors cannot install in the next layer, this method of installation will not use at first floor.

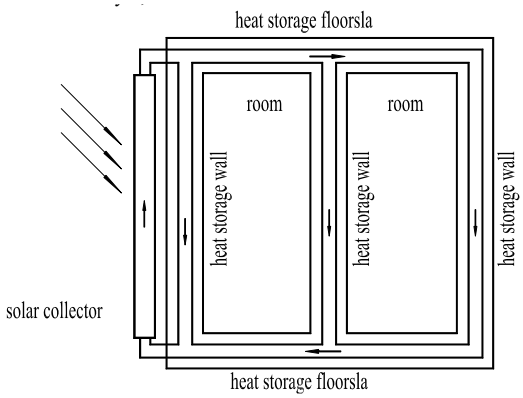

Fig. 2. The heat storage walls (floorslabs) and Solar collector installed in the same layer

Another installation of solar collectors is installed in the same layer, as shown in Fig. 2. When the outdoor temperature is low at night, water will reverse flow. As the water is still circulating in the indoor and outdoor, the corresponding portion of the heat collector should be prepared insulation to reduce heat loss. Solar collector can be set in the exterior wall having long sunshine time, which can be set at east wall and west wall, not limited to the south wall. When two or more differently oriented wall are installed solar collectors, there is a benefit using the lower installed manner, that is different orientations of solar collectors can be connected with heat storage walls and heat storage floorslabs, because the water in the heat collector is not recycled when the sun shine is not on the wall where the heat collector installed on, and heat storage walls and heat storage floorslabs could avoid being cooled for water cycle. Solar collector which the sun does not shine on will play a role of radiator if installation in the same layer is used (Of course, we can install an automatic valve, in order to close it to stop water cycle when the solar collector cannot play a role of heating).

4.1. Basic type

The basic type is depicted in Fig. 3.

The solar water heater and several heat storage wall (heat storage floorslab) are connected to form a basic system. The vent valve or the air collector is set at the highest point of the whole system to discharge air when gas gather to a certain degree

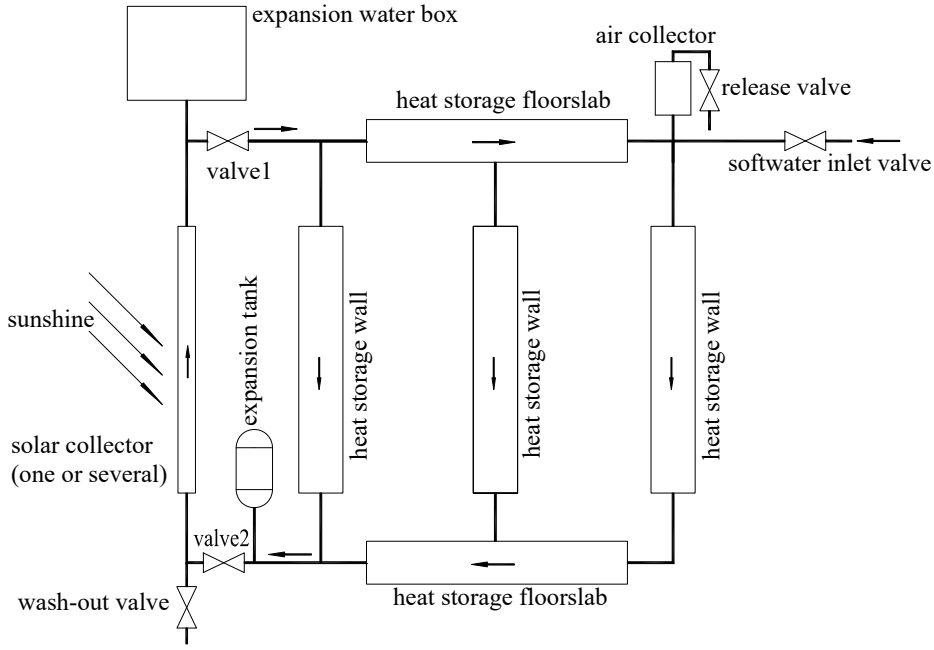

Fig. 3. Basic type- using solar energy for heating

in order to prevent the formation of air blocking effecting on water circulation. A wash-out valve is set at the lowest point of the whole system to vent water of pipe at maintenance time. Soft water is needed in order to prevent fouling. Water inlet valve can be used when the system need be filled with water, and we can also fill water into the expansion tank directly.

The basic type is only used for winter heating. The expansion water box for containing water expansion and contraction (the expansion tank can be used to discharge gas in water, so air collector is not necessary.) When weather gets warmer and it become overheating indoor, valve 1 and valve 2 which are installed between solar collector and heat storage walls (heat storage floorslabs) should be closed. So the solar heat collector is no longer supplying heat to the heat storage walls (and heat storage floorslabs). The tank contains water volume expansion and contraction in the heat storage walls and floorslabs. The basic type is only working in winter, and it is idle in summer.

4.2. Selection of heat storage wall (floorslabs)

Solar collectors installation location should be choose appropriately not to interfere with the function of the window and balcony, tough the shape of house is varies. House walls and floorslabs (floors and ceiling) can be made heat storage in whole or in part. Of course, part of a wall or a floorslab can be made also. If the heat storage walls (floorslabs) cannot be connect to a loop, some pipes can be added to

form a loop which can be laid in the walls and floorslabs. Interior walls and walls of important room have priority if partly setting heat storage. When this structure is set in building, each system is connected to only one heat storage floorslab (ceiling or floor), another heat storage floorslab is connected to the adjacent layers of the system. Figure 4 shows the heat storage system of four sides of heat storage wall and a side of heat storage floorslab (ceiling), and three solar collectors are installed on three exterior walls.

4.3. The cavity in heat storage wall (floorslab)

One side of has tow or more joints which will be connected the adjacent heat storage walls (floorslabs) or solar collector. The connecting pipe is embedded in the wall or in the floorslab. Heat pipes in the heat storage wall (floorslab) designed into a grid shape, curved shape, etc. The pipeline in heat storage floorslab can be set in the structure layer, leveling layer or other layer. The pipeline in the heat storage wall can be set combined with the construction technology of the wall in an appropriate layer in the wall. The pipeline can be produced previously in construction module and be poured (or masoned) in walls (or floorslabs) and can also be worked at the construction site. The pipeline can be poured in precast concrete parts as well.

5. Result analysis and discussion

5.1. The advantages of the passive solar housing construction

The biggest advantage of this type of construction is exactly the same as an ordinary house from the inside view is not to add additional structure or to change the space division. Water can flow to any one location house and people are free to choose any part of wall (floorslabs) as the heat storage plate. The exist of water, the heat storage capacity of wall (floorslabs) is greatly enhance, and the volatility of room temperature is reduced. It can be automatically controlled addition of a simple element.

5.2. The difference with solar floor heating

When floor heating is working, the floor is heat radiating surface, and water is heat medium. The source of solar floor heating is sunlight, and water still plays a major role of heat medium.

The structure described in this article in the form of being set a large number of cavities in the walls and floorslabs are accumulated a lot of water much more than that of the floor heating. The more use of water in this structure is its storage capacity in addition to using water as a heat medium.

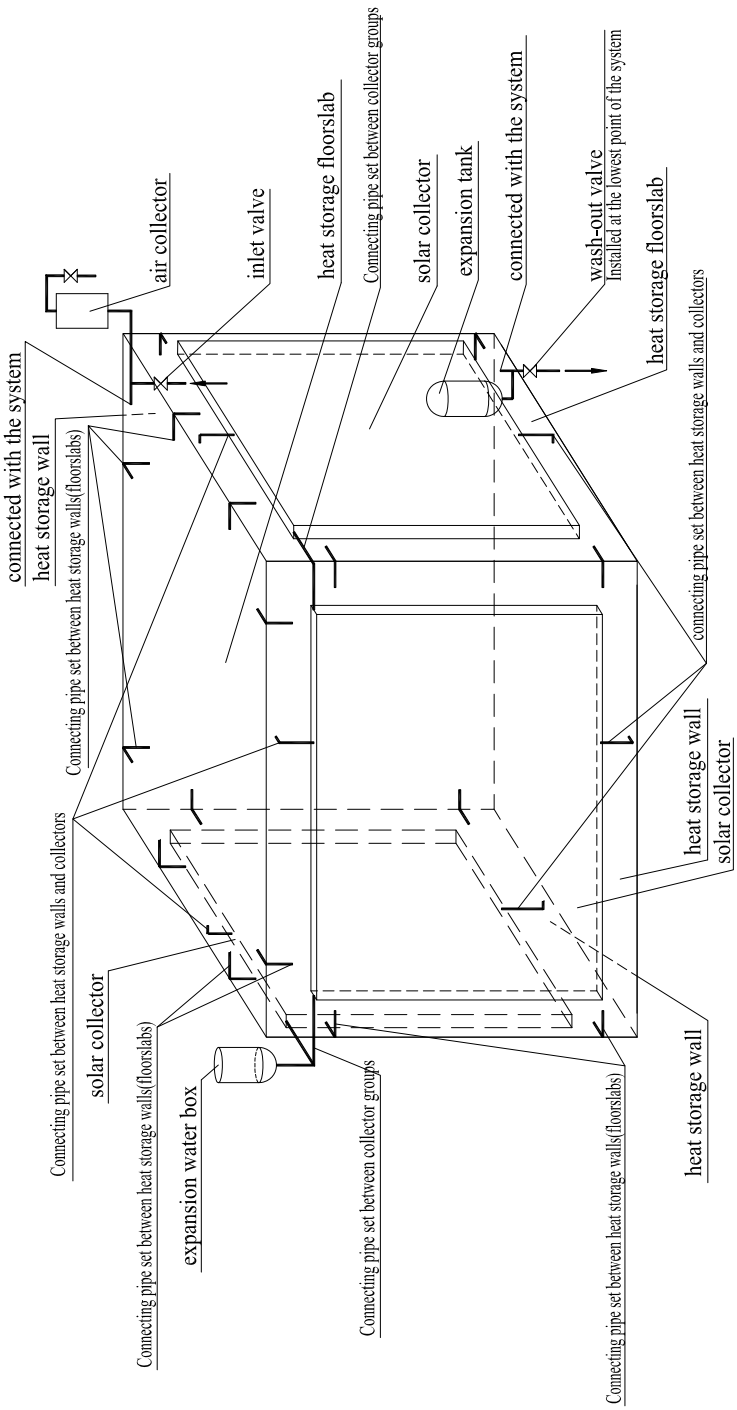

Fig. 4. Installation of solar collector and heat storage wall (floorslab)

5.3. Shortcomings and problems to be studied

This structure is not perfect, it has some drawbacks. Extensive use of water will increase the load of the building. The presence of cavity in wall or floorslab causes the increase in thickness of the wall or floorslab. The complexity of the construction increases the cost of construction. In addition, there are also some problems need to be study more deeply, and find good solutions; otherwise it is difficult to promote the construction.

Most of the water system is in the interior of walls and floodslabs, so the easy implement way is to use tubular made by some material to form seal cavity, then to fill them with water. Metal and plastic is common choose to form cavity. The material is requiremented to be able to maintain a long water-filled state without leakage. If there is leakage, maintenance will be more difficult or even not to repair. If the cavity is set in the non bearing layer, the wall or the plate can be broken open to repair, and if the cavity is set in the load bearing layer, it can not be repaired, the system will be abandon. Steel and plastics are common building materials, however, long-term contact with water the steel will rust occurs, and the plastic will appear the problem of aging.Joints of material and junctions of fitting is the weak link, where is prone to leakage. But the use of other materials with good durability which price is much higher will increase the construction costs substantially.

Fouling causes cavities thinning, pipes clogging, and because it is difficult to repair, fouling affects the using effect of this structure and service life. Even the use of soft water, prolonged use will consume part of the water, and because the remaining water ion content has increased, there is still fouling problems. To neglect leakage, fouling and other issue, to dispose pipeline in structure layer is a good idea. The pipe has been protected by concrete from the external damage. But in the structure layer, a large number of tubes will produce harmful effect to the mechanical properties of the structural layer. It is a question whether it can be achieved from mechanics' point of view to lay a lot of tubes in the structure layer, and even if it can achieve, whether it is economically reasonable is worth to explore. If the idea is rejected by the research on this issue, the cavity has to be set in other layers.

The components should be standardized in order to simplify the construction site and to improve the quality of components. The pipes can be made into standard components according to a certain modulus which can be poured or masoned directly in walls or floorslabs and can be poured into the preforms also.

In order to obtain a better temperature distribution, the water should be able to uniformly flow smoothly. The shape of the cavity should be chosen according to the hydraulic calculation.

The temperature of the water in the solar structure is suitable for the propagation of microorganisms. A large number of microbial breeding will produce a blockage in the pipeline and the problem of corrosion pipeline has become serious at same time.

In different structural forms, such as concrete structure, masonry structure, steel structure, there should be a different construction process. In cold regions, if such a structure is used, the problem of freeze in pipe may appear encountered continuous cloudy. Some work needs to be done, such as building a model room to test and

compare with traditional solar house heating effect.

6. Conclusion

Disadvantages of the traditional solar houses hinder the promotion of the passive solar house. The passive solar house with water filled cavity make well used of the fluidity and the heat storage capacity of the water, and it has the effect which the traditional solar houses are difficult to achieve. Heat storage walls (floorslabs) are built by made cavity which filled with water in walls (floorslabs). The heat storage capacity of walls and floorslabs are greatly improved for the cavities with water. Because of the mobility of the water, the heat flow between the various heat storage plates, so the uniformity of the temperature distribution of the room is greatly improved. Due to the special arrangement of the solar house which function is not dependent on the architectural space and good combination of its functional components and walls (floorslabs), the building can be constructed in the same way as an ordinary house, without increasing the structure or changing the space. Because water can be well control by valve and automatic control can be easy achieved, the indoor temperature can be adjust well. The study adds a new form of solar house. However, due to the need for further research on anti scaling, leakage prevention, standardization and other aspects, there is still a certain distance from practical application. In addition, some of the more complex automatic control can be achieved to heat in winter and to cool in summer in order to use solar energy fully.

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