VI–8. Brick Masonry in Passive Solar Heating Systems

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ABSTRACT

Brick construction that incorporates passive solar energy heating can reduce notably the use of fossil fuels for the heating and cooling of buildings. The basic principles and devices necessary for planning construction using passive solar energy systems are discussed. These principles allow incorporation of passive solar heating in an architectural project according to the use and operation of the building. Also discussed are certain considerations for protecting against temperature fluctuations.

La costruzione in mattoni per l'utilizazione passiva dell'energia solare puo ridurre notevolmente l'uso di combustibili fossili per il riscaldamento o raffredamento degli'edifici. Gli elementi fondamentali e gli accorgimenti necessari per progettare costruzione basate sull sistema di utilizazione passiva dell'energia solare sono qui discussi. Questi elementi fondamentali comportano l'incorporamento dell sistema di riscaldamento solare passivo nella progetto architectonico a seconda dell'uso e dell'operazione dell'edificio. Vengano anche discusse certe considerazioni relative alla protezione dell'ambiente.

INTRODUCTION

The reduction of fuel consumption has become a major worldwide issue in recent years. Since it is often not possible to apply extreme energy conservation techniques because of required and desired system performance, alternate sources of energy other than non-renewable sources such as fossil fuels, i.e., natural gas, coal and oil, are being sought and developed. A source of energy which is readily available, but which has not been optimized in modern times is solar energy. The concept of using passive solar energy heating systems is not a new idea. The benefit of the sun's energy has been used since ancient times. For example, the early North American Indians built structures into sides of southern exposed cliffs and massive adobe structures to utilize the sun's energy. These structures stored the heat from the sun during the day, gradually releasing the stored heat during the night. By use of this passive solar heating method, comfortable living temperatures were maintained in the interior. Such concepts fell to the wayside when new sources of fuel were developed. Because of the availability of these new sources of energy, systems no longer had to be dependent on local resources. The abundance of these fossil fuels created a freedom of design of buildings. These new design concepts often did not address, and do not address, the energy performance of the building. Now, there is concern over exhausting the world's fuel supply. Since a large portion of the present energy consumption is used in heating buildings, today's technology should be applied to developing and improving heating systems which use the sun's energy. One of the most economical and efficient methods to accomplish this is by using passive solar heating systems.

Passive Solar Systems

Passive solar heating systems are those in which heat flows by natural means: radiation, conduction and convection. Passive solar systems are heating systems based on architectural design. The building components collect, store and radiate the solar energy as heat. No mechanical equipment is required in a passive solar system. Passive solar systems may be used in any climate to decrease the consumption of non-renewable energy sources. 100% passive solar heated structures may not be attainable in all climates, but any efficient reduction of fuel consumption is an advantage. The efficiency of passive solar systems may be increased by the use of fans and blowers which assist the natural flow of thermal energy. Such mechanically assisted passive solar systems are referred to as "hybrid solar systems." Thus, by incorporating passive and hybrid solar heating systems in the design of buildings, the world's fuel consumption may be greatly reduced. One of the benefits of passive solar systems is that they do not have the high initial cost or the longterm payback period common with many active mechanical solar heating systems. The passive solar systems consist of basic building components, floors, walls and glazing. South-facing glazing may be used as the collector. The glazing may be glass or other highly translucent materials. Such alternate materials may be plastics. The use of plastics should only be with manufacturer's recommendations because some plastics are subject to ultra-violet degradation and may also

discolor when exposed to sunlight for long periods of time. When a plastic discolors, its performance in a passive solar system may be greatly decreased. Massive floors and walls may be used as the thermal storage for the system. Good thermal storage may be achieved by using brick floors and walls.

APPLICATIONS OF BRICK

Brick masonry is an excellent thermal storage media for passive solar systems. Brick masonry is available in a variety of dark shades which have high absorptivities. It is practically maintenance-free. It has a high thermal storage capacity because of its mass. It has sufficient conductance to provide adequate thermal storage. Brick masonry may perform as a structural component of the building. It may be left exposed on the interior which allows a great deal of architectural freedom for esthetics. The capability of being exposed on the interior also does not inhibit the performance of the storage media because coatings or other coverings are not required.

PASSIVE SOLAR HEATING SYSTEMS

There are many types of passive solar heating systems. The basic types in which brick masonry is used are: Direct gain systems and Thermal storage wall systems.

These basic systems are simple architectural considerations in the building design.

1. The building should have a rectangular floor plan, elongated on the east-west axis. This provides the maximum exposure of the south wall to the sun's rays, which is usually the solar collector in the passive solar system. The collector wall should not deviate more than 22.5° East or West of true South. Where maximum performance is desired the collector wall should usually face true south.
2. The south-facing wall is glazed. The south-facing glazing collects the solar energy and transmits it to the interior of the building.
3. There must be a thermal storage media, brick exposed to the solar radiation which is transmitted through the south glazing.
4. There should be sufficient overhangs or other shading devices to shade the south-facing glazing from the summer sun. This is done to avoid overheating in the summer months.
5. There should be few windows on the east and west walls and preferably none on the north walls. This reduces heat losses.

An ideal site location for a passive solar heated building is to be bermed into a south-facing slope. Thus, the north wall is protected from changing environmental conditions from the earth berm. Berming the north side of the building should be done with caution to avoid problems caused by groundwater.

These architectural concepts are the basic requirements for passive solar heating systems. In addition to these concepts, there are many environmental and building use considerations. Many of these considerations may usually be neglected from the design of passive solar systems because their effect on performance is small. Examples of factors which may often be neglected are wind velocity, re-radiation into the night sky, the effect of moisture content, etc. Neglecting factors which usually have a small effect on the system performance is substantiated by the fact that the number of days or hours of clear day solar radiation is highly unpredictable and the heating of the building is usually determined by steady-state methodologies which do not accurately represent building thermal performance. Additional factors which should be considered are:

1. Temperature—Exterior design temperature is necessary to determine the size of the passive solar system required. Related to exterior temperature is the number of degree days which is necessary to determine the total thermal load of the building. The daily, monthly and annual exterior temperature fluctuations may greatly affect the performance of the overall passive solar structure. Interior temperature fluctuations usually occur in passive solar systems but these fluctuations occur at the most opportune times. During the heating season the structure is warmest during the day. The effect is similar to nighttime thermostat setbacks. The required interior temperature is also very important. In some instances such as heated warehouses, average interior temperatures of only about 55°F (13°C) to 65°F (18°C) are required, whereas in residential structures 70°F (21°C) to 72°F (22°C) average interior temperatures are desired, with a maximum temperature fluctuation of about 4–7°F (2–4°C). In some commercial buildings larger temperature fluctuations may be allowed.
2. Latitude—Latitude is important to determine the appropriate shading. It also affects the amount of solar radiation received on the collector wall. The higher the latitude, the shorter the period of time that the sun is above the horizon and also the solar radiation must penetrate more atmosphere. The result is that there is less solar radiation received at higher latitudes.
3. Glazing and Light Quality—The amount of natural lighting required will affect the determination of the type of passive solar heating system used. Fabrics often suffer from ultra-violet degradation when exposed to direct sunlight.
4. System Operation—Passive solar heating systems may be shaded from the sun by fixed, adjustable, or removable shading devices. Adjustable or removable overhangs or shading devices require operation. These operable devices allow the optimal benefit of winter sunlight and can completely eliminate any solar exposure on the south-facing glass in the summer. In many situations, shading provided by operable devices is not preferred. Often owners and occupants of buildings do not want to manually operate the shading devices. In such cases, automatically operated or fixed shading devices should be used. Fixed shading devices are usually projected overhangs, with calculated projections which allow

the winter sun, which is low over the horizon, to shine on the south-facing glazing and shade the summer sun, which is higher over the horizon. See Fig. 1. Fixed overhangs are most practical at high latitudes because the difference between the altitude of the winter sun and summer sun is the greatest.

The performance of the passive solar system may be greatly enhanced by the use of night insulation. The insulation may be applied on the interior in the form of drapes or panels, or on the exterior as reflector panels. Reflector insulating panels may be hinged at the base of the south-facing glazing so that when open during the day, they reflect additional radiation through the glazing and when closed, provide night insulation. Night insulation may be operated manually or automatically.

5. Special Requirements—Special requirements may dictate the type of system used. The depth of penetration of the solar radiation into the structure may affect the system type selected. Buildings should be elongated on an east-west orientation to maximize the solar exposure of the south-facing glazing and to minimize the distance from the south wall to the north wall. Building energy performance is increased if the north wall is heated by solar radiation entering through south-facing glazing. The north wall may be exposed to direct sunlight in wide buildings by the use of clerestories. See Fig. 3.
6. Human Comfort Factors—Another aspect which affects the requirements of the building's use is human comfort. Passive solar systems provide beneficial conditions for human comfort. The brick storage areas of the system are warm. When surrounded by warm surfaces, the human body receives radiation from the warm surfaces. This permits the occupant to feel comfortable at lower interior air temperatures because heat is radiated to the body rather than from the body.

Direct Gain System

A direct gain system is a very simple system which is often used. The system consists of south-facing glazing which allows winter sunlight to enter the habitable spaces of the building. The thermal energy is stored in brick floors and walls. A schematic of a direct gain system is shown in Fig. 2. The south-facing glazing may be windows, operated or not, or glass doors. The brick masonry exposed to solar radiation should be a dark color and at least four (4) in. (100 mm) thick. All walls and other components not exposed to solar radiation should have light-colored surfaces to provide continuous reflection of the heat radiated from the dark brick masonry to the air and surroundings in the habitable space. Direct gain systems provide rapid temperature increases in the habitable space and they have relatively large temperature fluctuations. This is because such systems often must be designed to prevent overheating.

In some situations, especially at the lower latitudes, it may be difficult to obtain large areas of the brick thermal storage walls and floors which are exposed to sunlight. This is because of the high altitude of the sun. By using clerestories, as shown in Fig. 3, the area of exposed brick masonry may be increased. The use of clerestories also provides an opportunity to use the north wall as a thermal storage medium. Having the north wall heated by solar energy greatly increases the thermal performance of the structure.

Ultra-violet degradation is of great concern in direct gain systems. Materials affected by ultra-violet degradation should not be exposed to direct sunlight. This may become an inconvenience in living areas heated by direct gain. The walls and floors exposed to sunlight in use for thermal storage should not be covered. Wall hangings and carpets may greatly decrease the performance of the system.

Thermal Storage Wall Systems

A thermal storage wall system, often referred to as a "Trombe wall system," is schematically represented in Fig. 4. The thermal storage wall is constructed with exterior south-facing glazing and a 10 to 18 in. (250–460 mm) thick brick masonry wall, 2 to 4 in. (50–100 mm) from the interior face of the glazing material. The massive brick wall may be loadbearing or non-loadbearing. The winter sunlight penetrating the south-facing glazing heats the dark brick. The heat slowly penetrates the brick wall and warms the interior. Thermal storage walls may have sufficient storage capacity to maintain comfortable temperatures in buildings for periods up to three completely overcast days. The thermal storage wall systems have considerably less temperature fluctuations than do direct gain systems, but usually do not achieve the same high initial temperature. An example of the performance of a thermal storage wall system is illustrated in Fig. 7. This shows a typical thermal storage wall performance in New Mexico. The exterior temperature ranged from 15°F (−9°C) to 35°F (2°C). The temperature on the interior surface of the thermal storage wall ranged from 67°F (19°C) to 82°F (28°C), with the peak occuring 6–8 hrs. after the highest exterior temperature was reached. The massive brick thermal storage wall prevents ultra-violet degradation of materials contained in the living space. The performance may be substantially increased by providing vents at the top and bottom of the brick wall to provide convection in addition to heat radiated from the interior surface of the wall. This will decrease the temperature fluctuations and increase the maximum temperature in the living space. Fig. 5 shows a schematic of a vented thermal storage wall. When venting the storage wall systems, vents with automatic or manual closers should be used so that the system does not reverse at night, creating a heat loss. If controlled vents are not installed on the vented thermal storage wall system, night insulation is essential to prevent heat loss at night. Night insulation is also recommended on unvented thermal storage walls and those with controlled vents to increase the efficiency of the system.

Combined Systems

The best thermal performance in living conditions may result by combining the thermal storage wall system and

the direct gain system. This combination permits some direct sunlight into the living space which achieves higher interior temperature than produced with the thermal storage wall. The thermal storage wall system provides less temperature fluctuation than the direct gain system. The direct gain portion also provides natural lighting. The combination essentially utilizes the best of the two systems.

Sun Spaces

Sun spaces often used as greenhouses are a combination of the components of a direct gain system and a thermal storage wall system, and are illustrated in Fig. 6. The sun space is a room or space which has a glass roof and a south-facing glass wall. The east and west walls may also be glass. The floor is similar to that of a direct gain system. It consists of at least 4 in. (100 mm) thick dark brick masonry. The north wall is a 10–18 in. (250–460 mm) thick dark brick thermal storage wall. The room is vented or ducted to other areas of the structure and with the assistance of blowers and fans, the structure is heated by utilizing the extreme temperatures achieved in the sun space. The sun space usually has extreme temperature fluctuations and may be unbearably hot during daylight hours. They do require removable shading devices to prevent solar gains in the summer. They will also require night insulation if they are to become useable living spaces in the evening hours.

SUMMARY

These passive solar heating systems are not complex, and may be utilized in any heated building to reduce fuel consumption. The design and sizing of these passive solar heating systems is also fairly simple. The size may be estimated by empirical requirements on past performance. Accurate size and design may be calculated by using steady-state methodologies to determine the required heating load and then subtracting the solar heat gain collected and stored in the system from the required heating load. This provides the ability to size the auxiliary heating system required to maintain the interior design temperatures in the building.

REFERENCES

1. *Technical Notes* 43, Brick Institute of America, McLean, Virginia, 1979
2. *Technical Notes* 43A, Brick Institute of America, McLean, Virginia, 1979

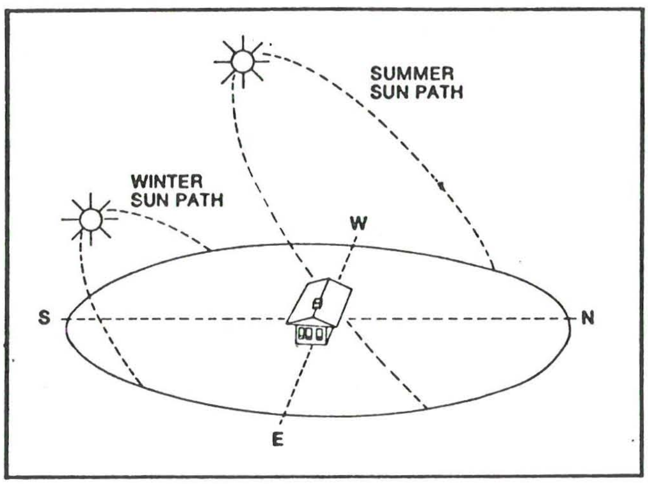

Figure 1. Sun Altitude—Winter and Summer

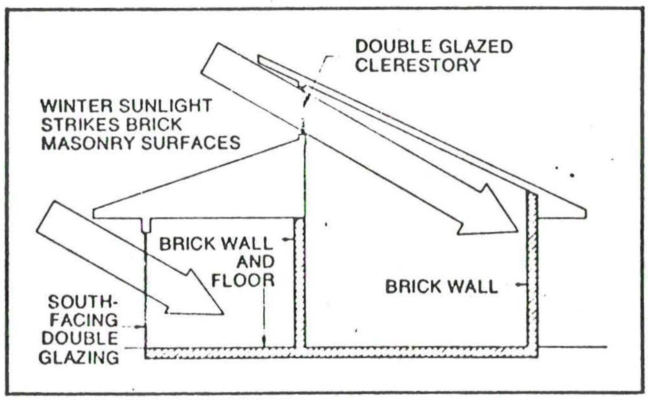

Figure 2. Direct Gain System

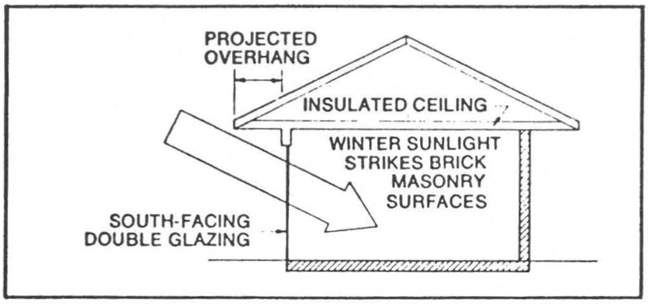

Figure 3. Increased Building Depth Using Direct Gain System with Clerestory

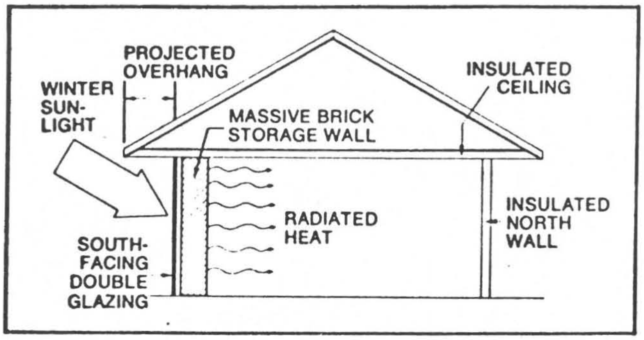

Figure 4. Thermal Storage Wall System

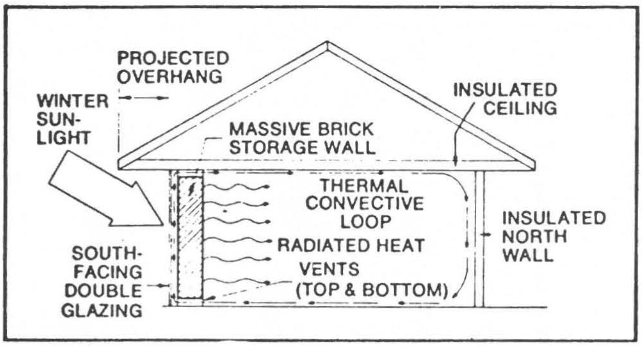

Figure 5. Vented Thermal Storage Wall System

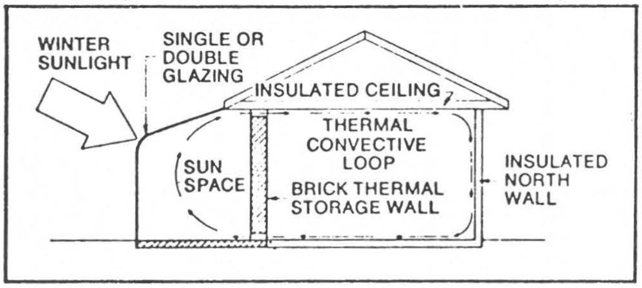

Figure 6. Attached Sunspace

Figure 7. Typical Temperature Range Through a Thermal Storage Wall for Instrumented Days* in the Month of January 1976