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INTRODUCTION TO PASSIVE SOLAR CONCEPTS

Anchumol V.P
Department of civil Engineering
Immanuel Arasar JJ College of Engineering, Nattalam, Marthandam, K K District.
e- mail-dj.anchuvincent@gmail.com

Abstract*- The United States Air Force is committed to energy efficiencyand the use of renewable forms of energy in allof its facilitieswhen shown to be reliable and cost effective. In its response tothe Military Construction Codification Act of 10 USC 2801,Executive Order 12003 and Office of the Secretary of Defensedirectives, the Air Force has implemented numerouspoliciesandprocedures to significantly reduce the usage of fossilfuelderivedenergy. Since the oil embargo of the early 1970's, the Air Forcehas encouraged and demonstrated the integration of a variety ofenergy conserving features, including solar applications, in itsfacilities. Passive solar systems represent one type ofsolarapplication that can be used in almost all facilities to improvetheir energy efficiency and to lower their energy costs.

1.Introduction

Passive solar systems use the energy from the sun to heat, cool, and illuminate buildings. The Air Force has used passive solarconcepts in buildings since it was established in 1947 and willcontinue to do so whenever possible. Figure 1-1 illustrates apassive solar strategy used by the Air Force in 1947. Althoughthis form of passive heating system is no longer in use, itillustrates the Air Force's early commitment to the use of passivesolar systems in commercial-type buildings.

Solar concepts described in this handbook fall into two broadcategories: (1) those that use the energy from the sun to directlyor indirectly impact the thermal needs (heating and coolingenergy use) of the building, and (2) those that use the energyfrom the sun to directly impact the lighting needs of the building.Solar systems that heat or cool the building will be called *solarthermal systems;* ones that light the building will be called*daylighting systems.*

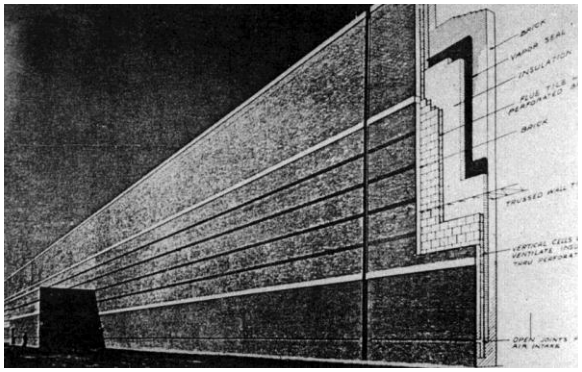

Figure 1-1: Breathing Wall. Tinker AFB, Oklahoma

The breathing wall, built in 1947, is a double layer mass wallacting as an indirect gain solar heating system.

It is not anticipated that a properly designed passive solarcommercial-type building will completely eliminate the need forthe auxiliary energy systems used to heat, cool, or light thebuilding. Because of the size of the buildings, large internalloads, and their diverse use patterns, it is anticipated thatpassive solar systems will supplement the energy systems of the building. However, it is possible for a combination of passivesolar concepts to reduce total energy costs by as much as 40%and have savings-to-investment ratios (SIR) that should makethem cost effective.Technical and solar terms used throughout all of the volumes ofthe handbook are defined in Chapter 5 of this volume.

Passive Solar Concepts

A total of eleven different passive concepts will be considered inthis handbook. Many other possible solar concepts wereevaluated. The ones listed below are appropriate in a widerange of climates and building types.
(H) Direct gain with storage
(H) Indirect gain

(H) Direct gain (without storage)
(H) Sunspaces
(C) Night Mechanical Ventilation
(C) Natural Ventilation
(L) Windows
(L) Skylights
(L) Sawtooth Apertures
(L) Monitor Apertures
(L) Atria

The letters (H), (C), and (L) stand for heating, cooling, andlighting, respectively, and are used to remind you of the purposefor each passive solar system concept.Solar thermal concepts use the energy from the sun to heat orcool the building and usually consist of four separatecomponents:
(1) collection
(2) storage
(3) distribution
(4) control

Passive Heating

Passive heating concepts use heat from the sun to offset winterheating needs. The collection subsystem may include windows,skylights, or some other type of solar aperture. The purpose ofthe collection subsystem is to allow sunlight into the building toheat the space and, if appropriate, to heat the storage mass. Thestorage subsystem usually includes parts of the floor or interiorwalls of the building.

The purpose of the storage subsystem is to store the collected solarheat until it is needed by the occupants in the building. In mostcases, heat is collected during the daytime and used at night.Stored energy is released from the storage mass and distributedthroughout the building to offset heating energy use

Distribution**:-**Distribution is accomplished by arranging the functional spacesof the building such that those that need heat are closest to thestoragesubsystem.The size and shape of the solar apertures (collection subsystem)affects the quantity of heating energy available to offset auxiliaryheating energy needs. The size of the storage subsystem affectsthe quantity of heat stored and the time delay between initialcollection and final use of energy. The size, shape, and location ofrooms in the building impact the optimum distribution of theheat throughout the building.Heat distribution is accomplished by a combination of radiationand convection. Heat is radiated from the storage subsysteminto the rooms being heated after the collected solar energy haspassed through the storage system. Heat is*convected*throughthe air, warming it, and thereby warming the people in the room.

Control **:-***Control* of the passive heating system might be quite differentfrom control of an HVorHVAC system. In many passivebuildings, controlis achieved through the use of shading devices,or some other means to regulate the sunlight entering thebuilding. More complex passive buildings may also havethermostats to control fans and motors thatregulate the air flowor control vents. In many passive buildings, the controlmechanisms are manual; that is, people control the building.A balance between the size, shape, and location of each subsystemmust be achieved to ensure optimal system performance andefficiency.If the collection subsystem is too large or too small,then either too much energy is collected and the building isoverheated or not enough energy is collected to be effective.Similarly, if the storage subsystem is improperly sized, then iteither holds the energy in storage too long (oversized) or not longenough (undersized) to provide heat to the building when it isneeded. Finally, if the spaces of the building are not correctlyorganized, the heat cannot be distributed in a manner thatensures optimal auxiliary heating energy savings and comfort. Indeveloping this handbook, extensive analysis was done todetermine the -optimal size of different subsystems for variousclimate zones and building types.

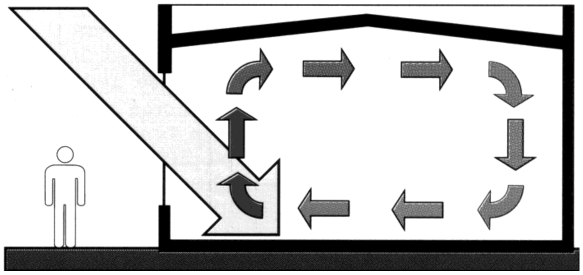

Figure 1-4: Direct Gain (DG) Schematic Figure

Figure 1-5: Direct Gain. Walker Field Terminal,

Indirect Gain (IND)

Indirect gain (IND) concepts place the collection and storage components of the solar thermal system very close to each other as part of the same wall. Heat is collected and stored in an exterior wall or on the roof of a building, and distributed to the building by passing all the way through the storage mass. For some applications, air that passes between the aperture and the storage mass (which are only 4 to 6 in. apart) is heated andcirculated to rooms to offset immediate heating energy needs. Indirect gain systems are often used when extended storagecapacity is needed in a building because it is possible to make the storage component very thick (12+ inches). In commercial-typebuildings, there were no cases where walls in excess of 8 inchesthick were needed or useful. See Figure 1-8 and 1-9

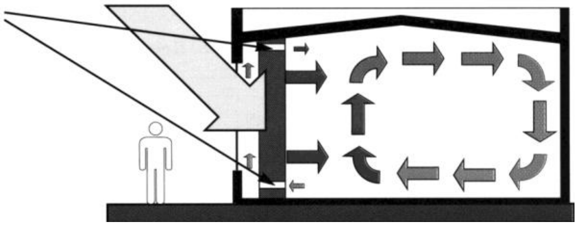

Figure 1-8: Indirect Gain (IND) Schematic Figure

Figure 1-9: Indirect Gain. Shelly Ridge Girl Scout Center,
Philadelphia Area Council.

Sunspaces (SUN)

Isolated gain passive solar heating systems isolate the collection and storage subsystems from the building. One special categoryof an isolated gain system is a sunspace. A *sunspace (SUN)*combines some features of direct gain systems with features ofindirect gain systems. A sunspace is a room attached to or integrated with the exterior of a building in which the room temperature is allowed to rise and fall outside the thermal comfort zone. The space can be inhabited, thus acting like a direct gain system. However, the walls and floor of a sunspace are used as storage. The back walls of the sunspace allow the heat to pass through them, much like an indirect gain system, to heat the room adjacent to the sunspace. See Figure 1-10 and 1- 11.

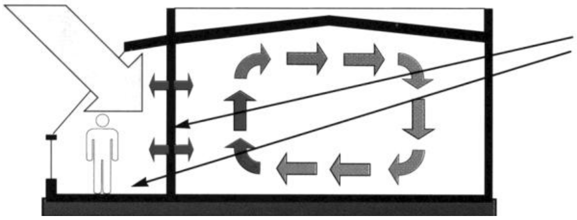

Figure 1-10: Sunspace (SUN) Schematic

Figure 1-11: Sunspace. Commissary, McGuire AFB,New Jersey

Different types of passive heating systems have been considered to allow for design variation and to recognize the fact that some concepts work better in some building types. In general, passive heating systems work best in buildings: (1) with low levels ofcontinuous internal load (less than 1.5 w/sf), (2) that areoccupied for extended periods (more than 8 hours), and (3) arelocated in climates with heating seasons in excess of 1,000 HDD. The severity and length of the heating season are not as critical as the internal load and occupancy schedule of the building.

Passive Cooling

Passive cooling systems have the same basic components as passive heating systems, but work in a different manner. Whereas the purpose of passive heating systems is to draw heatinto the building, the purpose of a passive cooling strategy is toremove or reject heat from the building, and thereby cool it. Because the mechanisms that drive passive cooling strategies are not fully understood, many cooling concepts are difficult to fully evaluate during the comprehensive planning process. Therefore, the number of cooling concepts advocated in this volume of the handbook is limited. A more detailed discussion of passive cooling concepts can be found in Volume IV: Passive Solar Design.

Peak Coolin

Passive cooling benefits are achieved by avoidance of the cooling load in the building. In many commercial-type buildings, the peak cooling requirement is directly associated with solar gains. By avoiding solar gains, a portion of the cooling load is avoided. This can be accomplished by shading the apertures of the building.

Shadin

Shading can be achieved using the shape and form of the facade, using low transmission glazing, or using devices inside of the building. From a passive solar viewpoint, the most effective method of shading is on the outside of the building using overhangs, fins, or louvers, as illustrated in Figures 1-12 and 1-13. A less effective method is to use glazing with a low shadingcoefficient.

Shading devices must be carefully designed. For passive heating systems, shading devices should block the sun during the summer months hut allow sunlight to enter the building during winter. For daylighting systems, the sun is usually blocked during the swing seasons (spring and autumn) as well as the summer. In either case, there will be variations depending upon the building type and internal loads.

Figure 1-13: Shading. Military Personnel Support Center,Grissom AFB, Indiana

Natural Ventilation (NVN)

Natural ventilation (NVN) relies on the natural airflow and breezes to reduce the need for mechanical cooling when thebuilding is occupied. See Figure 1-14 on the following page. Inmost cases, natural ventilation occurs simply by openingwindows when the outside air temperature is lower than theinside air temperature. This strategy is effective primarily during the spring and autumn (the swing seasons), thus avoiding the intermittent use of mechanical heating and cooling equipment. The Air Force recommends that commercial-typebuildings have operable windows when climatic conditions offerthe potential for significant energy savings. This strategy is a nocostchange in building design and operation. It should be noted that inappropriately opening windows as a heating control strategy during the heating season may offset any gains achieved by using them for natural ventilation.

Daylighting

Daylighting is the use of natural light from the sky as a supplement for electric lighting in buildings. Traditional daylighting systems differ in one major respect from passive heating systems: they use the sky as a source of light and avoid letting direct sunlight into a building. Since light from the sky isused in lieu of direct sunlight, daylighting systems function quite well on overcast, partly cloudy, or clear days. Daylighting is an instantaneous use of the light from the sky. Therefore, daylighting systems consist of collection and distribution components and do not include a storage component like passive heating systems. However, much like solar thermalstrategies, daylighting systems are categorized according to the type of collection system used. Thus, there are three basic typesof daylighting systems:
(1) sidelighting
(2) toplighting
(3) coredaylighting
Daylighting is the most effective passive solar strategy in almostall commercial building types because it reduces two majorenergy uses in these buildings: electric lighting and cooling.

Conclusion

A properly designed passive solar building is one that saves both energy use and energy costs. However, a primary purpose of thishandbook is to save energy costs. The possibility of savingenergy costs without reducing energy use or by increasing energy use will also be considered. Saving energy costs without reducing energy use can occur if the peak demand for a buildingcan be reduced. For example, in the previous example, suppose the demand were reduced from 500 kW to 250 kW. Then theenergy costs would be reduced from $7,000 to $4,500 even if thereis no reduction in energy usage (it is still 20,000 kWh).Saving energy costs by increasing energy use can occur in twoways. First, by decreasing the peak demand but simultaneouslyincreasing the consumption of electricity, it is possible to reducethe overall cost of energy in a building. For example, suppose the500 kW building could have the peak demand reduced to 100 kWif it “costs” an additional 10,000 kWh. Thus, the total electricitycosts would be based upon 30,000 kWh and 100 kW. Totalelectricity costs would be $4,000, down from $7,000.The second way to reduce energy costs by increasing energy useis to switch fuel, that is, change from a more costly fuel to a lessexpensive fuel. A good example of this is to use natural gasinstead of electricity to heat a building. Even though natural gasheating is less efficient than electric heating, the cost differentialassociated with the two fuels usually makes it cheaper to usenatural gas rather than electricity. Although specialcircumstances may make it difficult or impossible to trade off onefuel for another, it is a viable alternative that should beconsidered during the comprehensive planning process.

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