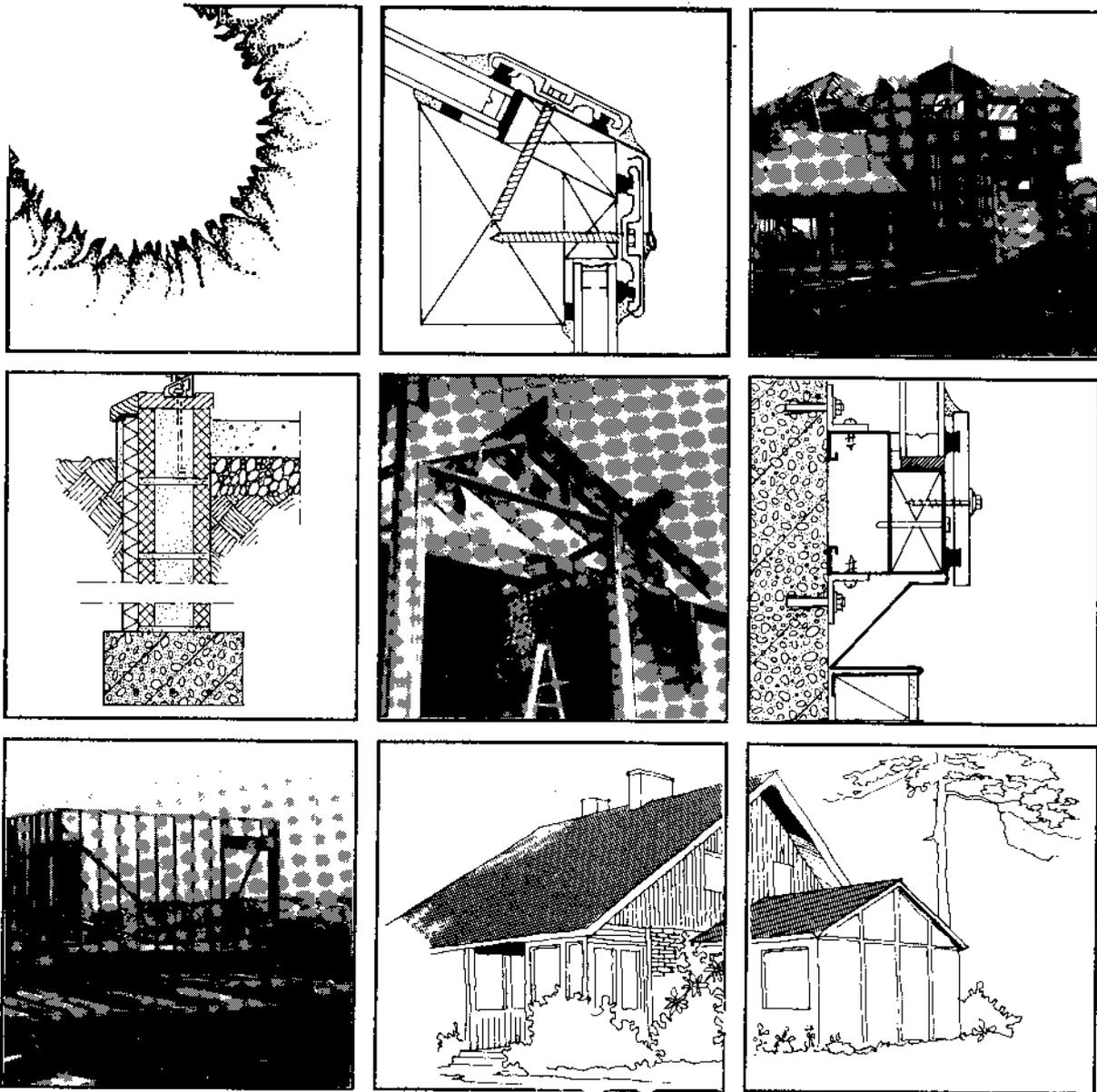


CONSTRUCTION ISSUES

5

DESIGN INFORMATION BOOKLET NUMBER FIVE

AUGUST 1989



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CONSTRUCTION ISSUES

5

DESIGN INFORMATION BOOKLET NUMBER FIVE

AUGUST 1989

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FOREWORD



The International Energy Agency (IEA), headquartered in Paris, France, was formed in November 1974 to establish cooperation among a number of industrialized countries in the vital area of energy policy. It is an autonomous body within the framework of the Organization for Economic Cooperation and Development. Twenty-one countries are presently members, with the Commission of the European Communities participating under a special arrangement.

One element of the IEA's program involves cooperation in the research and development of alternative energy resources in order to reduce excessive dependence on oil. A number of new and improved energy technologies that have the potential of making significant contributions to global energy needs were identified for collaborative efforts. Solar heating and cooling was one of the technologies selected for joint activities. Cooperative research is conducted under terms of a formal Implementing Agreement signed by the participating countries. One of the collaborative projects, Task VIII, concerns passive and hybrid solar, low energy buildings.

The goal of Task VIII is to accelerate the technical understanding and marketplace availability of energy efficient, passive solar homes. Fourteen countries have participated in the research - Austria, Belgium, Canada, Denmark, Federal Republic of Germany, Italy, Netherlands, New Zealand, Norway, Spain, Switzerland, Sweden, United Kingdom and United States.

The knowledge gained during this collaboration has been assembled in a series of eight booklets. The Design Information Booklets in the series are listed and described on the opposite page. Information on purchasing these booklets can be obtained by contacting the following organizations or by ordering directly from the U.S. Government Printing Office:

| | | | |
|---------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Austria Osterreichisches Forschungszentrum Seibersdorf und A - 2444 Seibersdorf | Germany Projektieitung Biologie, bkologie Energie KFA JUlrich Postfach 1913 D - 5170 JQlich | Norway A/S Miljoplan Kjorboveien 23 N - 1300 Sandvika | United Kingdom Renewable Energy Enquiries Bureau Energy Technology Support Unit Harwell Laboratory, Building 156 Oxfordshire OX 11 ORA |
| Belgium Science Policy Office Rue de la Science 8 B - 1040 Brussels | Italy Consiglio Nazionale Ricerche Progetto Finalizzato Energetica Via Nizza 128 I - 00198 Roma | Spain IER - CIEMAT Avda Complutense 22 28040 Madrid | United States Technical Inquiry Service Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401 |
| Canada Solar Energy Development Program Energy, Mines and Resources 460 O'Connor Street Ottawa, Ontario K1A OE4 | Netherlands Management Office for Energy Research (PEO) P.O. Box 8242 NL - 3503 - RE Utrecht | Sweden Svensk Byggtjanst, Litteratutjanst Box 7853, 103 99 Stockholm | Other Superintendent of Documents U.S. Government Printing Office Washington, D.C. 20402-9372 - |
| Denmark Thermal Insulation Laboratory Technical University of Denmark Building 118 DK - 2800 Lyngby | New Zealand School of Architecture Victoria University of Wellington Private Bag Wellington 1 | Switzerland Federal Office of Energy CH - 3003 Berne | |

The U.S. Department of Energy (DOE) is the Operating Agent of IEA Task VIII: Passive and Hybrid Solar Low Energy Buildings. Michael J. Holtz of Architectural Energy Corporation, Boulder, Colorado, serves as Task Chairman on DOE's behalf.

Booklet No. 1 Energy Design Principles in Buildings

This Booklet is essentially a primer of heat transfer in buildings. Fundamental heat transfer concepts and terminology are defined, followed by a discussion of heating and cooling strategies and principles for passive and hybrid solar buildings. It is written in non-technical language for the designer or builder not familiar with general heat transfer principles in buildings.

Booklet No. 2 Design Context

Booklet number 2 defines, in a checklist format, the issues that are unique to energy conserving, passive solar design that must be considered early in the design process. Issues discussed include site and climate analysis, building organization and design, building system options, space conditioning options, user influence and building codes and zoning ordinances.

Booklet No. 3 Design Guidelines: An International Summary

Passive solar and energy conservation design guidelines have been developed by each participating country. These guidelines are presented in national design guidelines booklets. Booklet number 3, Design Guidelines: An International Summary, summarizes the major findings and patterns of performance observed from the national passive solar and energy conservation guidelines.

Booklet No. 4 Design Tool Selection And Use

This Booklet addresses the characteristics desirable in a design tool and a means to select one or more for use. The selection process is organized around the design process; what design questions are being addressed, what information is available, what output or result from a design tool for which one is looking. A checklist is provided to assist in design tool selection. The use of benchmark test cases developed from detailed building energy analysis simulations is presented as a means to evaluate simplified design tools.

Booklet No. 5 Construction Issues

Construction problems unique to the use of passive and hybrid solar features are defined in this booklet as well as several proven solutions. Due to the unique construction technology in each country, representative construction details are provided. The intent is to define where construction detailing is crucial to the performance of low energy, passive solar homes and provide some ideas on how these detailing problems can be solved for a range of construction technology.

Booklet No. 6 Passive Solar Homes: Case Studies

This Booklet describes the passive and hybrid solar houses designed, constructed and monitored under the IEA Task VIII project, as a means of showing the architectural impact of energy conservation and passive/ hybrid solar features. This booklet reinforces the idea that good energy design is also good architecture and is cost effective. Each of the passive solar houses is presented as a case study on the design, construction and performance results.

Booklet No. 7 Design Language

Booklet number 7 is aimed at designers, architects and educators. It defines an approach to generating whole building solutions based on climate analysis and design context analysis. It also addresses architectural typologies based on climatic/energy principles. This booklet forms a general, universal companion to Booklet Number 3, Design Guidelines.

Booklet No. 8 Post Construction Activities

Post Construction Activities defines issues to be considered once the project is constructed and occupied. It addresses those elements of the passive solar building that are unique and may require special attention by the occupants. Performance evaluation of the home in terms of energy performance, comfort and occupant satisfaction is also addressed as a means of providing information back to the designer on how well the project is performing.

ACKNOWLEDGEMENTS



This report was made possible through the support of the Netherlands Agency for Energy and the Environment (formerly PEO/NEOM). The authors wish to acknowledge the Participants of IEA Task VIII who provided construction details and other technical information included in the report, and who also provided technical assistance and review of the various drafts.

The technical review, editing and production assistance of the Operating agent, Michael Holtz, and of Chris Mack, Linda Ross and Tracy Ashleigh, all of Architectural Energy Corporation, is gratefully acknowledged. Mr. Jan van 't Hof, Bouwcentrum Communicatie Adviseurs B.V., was responsible for camera ready preparation and graphic illustrations.

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Designers and builders in IEA member countries have over a decade of experience in building passive solar homes. During this period, we have learned what the most critical construction related issues are and how these issues can be addressed in a practical and cost-effective way.

From one country or climate to the next, passive solar home construction issues are generally the same. However, the specific construction details used to solve passive solar design problems will vary with climate, local construction practices and available building materials and products.

The purpose of this Booklet is to:

- identify construction issues and problems unique to passive solar home design and construction;
- show several different ways to solve these problems; and
- help builders and designers avoid repeating the mistakes of the past.

The construction details chosen for this Booklet illustrate examples for builders and architects to use during passive solar design and construction. These details - for both wood frame and masonry construction - are proven and established, not experimental. However, the details shown are just a few of many in use today. Furthermore, they were not necessarily selected because they are the very best ones available. They appear in these pages simply because they illustrate one practical way to solve a passive solar related construction problem.

Experience has shown that some passive solar design concepts involve more complicated and more costly details than others. To cite just one example, sloped glass is more expensive to install than vertical glass. Sloped glazing can provide excellent daylighting and may be aesthetically pleasing, but experience shows that sloped glazing can be the source of water leaks, if not properly designed, and uncomfortable indoor temperature swings. To keep building costs reasonable and occupants satisfied, designers are encouraged to rely on practical, simple solutions and avoid those passive solar details that can cause problems.

Construction issues examined in this Booklet deal with the three primary passive solar system types: direct gain, sunspace and thermal storage wall. Construction details are provided for the basic elements of a passive solar system: collection (aperture), heat storage, and controls (shading, movable insulation and fans).

The passive solar design concepts are also illustrated, not just construction details. However, the concepts are shown only to set the context for the discussion of the specific construction details that follow. For a complete discussion of passive solar design concepts, the reader is referred to Booklet 2, Design Context.

Construction details must satisfy a number of primary requirements. Those requirements range from such items as air and water tightness to durability and safety. They relate both to an occupant's use of a building and user requirements, as well as to the environmental factors that effect the building.

Consider the user requirement of airtightness. The degree of airtightness in a building plays an important role in determining the level of indoor comfort. At the same time, the level of vapour density of the construction may

1.1 GENERAL

- DIRECT GAIN
- SUNSPACE
- THERMAL STORAGE WALL

1.2 REQUIREMENTS

INTERNATIONAL BUILDING PERFORMANCE STANDARDS

USER REQUIREMENTS

- Stability
- Fire Safety
- Safety in Use
- Tightness
- Indoor Temperature and Humidity
- Visual Requirements
- Durability
- Economic Requirements

affect how durable a building is, since the movement of humid indoor air through holes in wood frame walls can lead to structurally damaging condensation.

The international standard ISO 6241-1084 (reference no. 1) describes performance standards in buildings. These standards relate to user requirements, uses of buildings and spaces, interaction between sub-systems within the building shell and environmental factors relevant to building performance. For the discussion of passive solar construction issues in this Booklet, we will limit ourselves to examining user requirements and environmental factors.

Figure 1.1, developed from information from the above-mentioned ISO standard, lists various categories of user requirements that the building should satisfy. They apply to spaces within or around buildings regardless of their location and design.

Figure 1.1 is a master list. It serves as a reminder, identifying the functions or requirements of various products within a building. Depending on the

| User requirements | Examples |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Stability | Mechanical resistance to static and dynamic forces, both individually and in combination. Resistance to impacts, intentional abuse, accident and cyclic (fatigue) effects. |
| 2. Fire safety | Risks of outbreak and spread of fire. |
| 3. Safety in Use | Protection against burning, sharp points and edges, and so on. |
| 4. Tightness | Watertightness (rain, ground water). Airtightness. Block entry of snow and dust. |
| 5. Indoor temperature and humidity | Control of air temperature, thermal radiation, air velocity and relative humidity (limitation of variation in time and space, response of controls). Control of condensation. |
| 6. Visual requirements | Aspects of spaces and surfaces (color, texture, regularity, flatness, vertical, horizontal, perpendicular, elements). |
| 7. Durability | Retention of performance over required service life, subject to regular maintenance. |
| 8. Economic requirements | Capital, operating and maintenance costs; budget; cost-effectiveness. |

Figure 1.1: User requirements

application, a product may satisfy one or more of these requirements. For specific situations, Figure 1.1 may be complemented by other categories relating to:

- User requirements which may not be expressed quantitatively, i.e. aesthetic, cultural or sociological factors.
- The requirements of other entities, such as builders (tolerances and ease of construction), component manufacturers (dimensional coordination), town planning boards, architects, building code officials, and so on.

| NATURE | ORIGIN | | |
|---------------------------------------------------|---------------------------------------------------------|---------------------------------|---------------------------------------------------|
| | External to building | | Internal to building |
| | Atmosphere | Ground | |
| 1. Mechanical factors | | | |
| 1.1 Gravity | Snow loads, rain, water loads | Ground pressure, water pressure | Dead loads |
| 1.2 Forces and imposed or restrained deformations | Ice formation pressure, thermal and moisture expansions | Seismic | Shrinkage, creep, forces and imposed deformations |
| 1.3 Violent weather forces (Kinetic energy) | Wind, hail, external impacts, sandstorm | | |
| 2. Thermal factors | | | |
| | Heat, frost, thermal shock | Ground heat, frost | Comfort |
| 3. Biological factors | | | |
| 3.1 Vegetable and microbial | Bacteria, seeds | Bacteria, molds, fungi, roots | Mold from condensation |
| 3.2 Animal | Insects, birds | Rodents, termites, worms | |

ENVIRONMENTAL FACTORS

Mechanical Factors

- Gravitational forces
- Forces and imposed or restrained deformations
- Violent weather

Thermal Factors

Biological Factors

- Vegetable and microbial
- Animal

Figure 1.2: Environmental factors relevant to building performance

FACTORS RELEVANT TO BUILDING PERFORMANCE

Figure 1.2 lists the environmental factors that affect the performance of buildings. These factors are categorized according to their nature (mechanical, thermal or biological) as well as their origin (indoors or outdoors).

Depending on the particular building configuration, the factors in Figure 1.2 can either be considered separately or in combination. Figure 1.2 serves as a reminder about the environmental factors to be taken into account when defining building performance and specifying design requirements.

The most important user requirements of the solar features to consider during the design of direct gain, sunspace and thermal storage wall are listed in Figure 1.3.

| User requirements | Direct gain | Sunspace | Thermal storage wall |
|------------------------|-------------|----------|----------------------|
| Stability | | 1 | 2 |
| Fire Safety | | 3 | |
| Safety in Use | | 4 | |
| Tightness | 5 | 5 | 5 |
| Temperature + Humidity | 6 | 6 | 6 |
| Visual | 7 | 7 | 7 |
| Durability | 8 | 8 | 8 |
| Economics | | 9 | 9 |

Figure 1.3.: User requirements for solar energy applications

The numbers in Figure 1.3 correspond to the points listed below:

1. Load-bearing frame, connection with outer wall and foundation.
2. Connection with foundation, wall and/or floor.
3. Materials of load-bearing frame.
4. Vertical and sloped glazing.
5. Watertight, airtight, vapour retarder.
6. Condensation.
7. Relationship of space, surface, finish color, vertical vs. sloped glazing.
8. Maintenance, frequency, accessibility.
9. Capital, operating and maintenance costs, cost-effectiveness.

The most important environmental factors which must be anticipated and protected against during the design of direct gain, sunspace and thermal storage wall elements are listed in Figure 1.4.

| Agents | Direct gain | Sunspace | Thermal storage wall |
|----------------------------------------|-------------|----------|----------------------|
| Mechanical: | | | |
| – gravitational forces and deformation | 2 | 1 + 2 | 2 |
| – kinetics | 3 | 3 | 3 |
| Thermal | 4 | 4 | 4 |
| Biological | | 5 | 5 |

Figure 1.4: Environmental factors affecting solar energy applications

1. Snow loads.
2. Thermal expansion of the glazing and frame (e.g. aluminium or plastic frame).
3. Wind, hail (large glazing areas).
4. Heat, frost, thermal shock for large glazing areas.
5. Fungi, roots at footings.

Thermal factors have a great influence on the choice of materials and detailing, since improper use of materials and improper detailing can lead to undesirable shifting and movement of the structure itself.

All designers must recognize these user requirements and environmental factors when developing construction details. This is especially true for passive solar designs where a conscious use of the environmental resource is made for heating, cooling and lighting purposes.

It is insufficient to just be aware of the environmental factors and user requirements which must be considered during the design process. After appropriate passive solar details have been selected, they must then be installed with great care during the building process.

Good thermal performance cannot be achieved without good workmanship. A well-designed passive solar home that is properly built will live up to client, designer and builder expectations. But the same home, if poorly built, may require nearly as much energy for heating as the conventional home.

Figure 1.5 illustrates a few of the potentially energy-conserving features that require the most attention to detail during the construction of any home – passive solar or conventional. Walls, ceilings and floors or foundations must have adequate insulation. This insulation must be installed in a way that eliminates gaps and minimizes losses through adjacent masonry or framing members.

The same emphasis on quality construction is essential during the sealing of air leaks, the selection and installation of windows, and the insulating of heating ducts. Detailed diagnosis and monitoring programs from IEA members have repeatedly confirmed the importance of quality workmanship.

WORKMANSHIP

ATTENTION TO
CONSERVATION DETAILS

QUALITY OF THE THERMAL

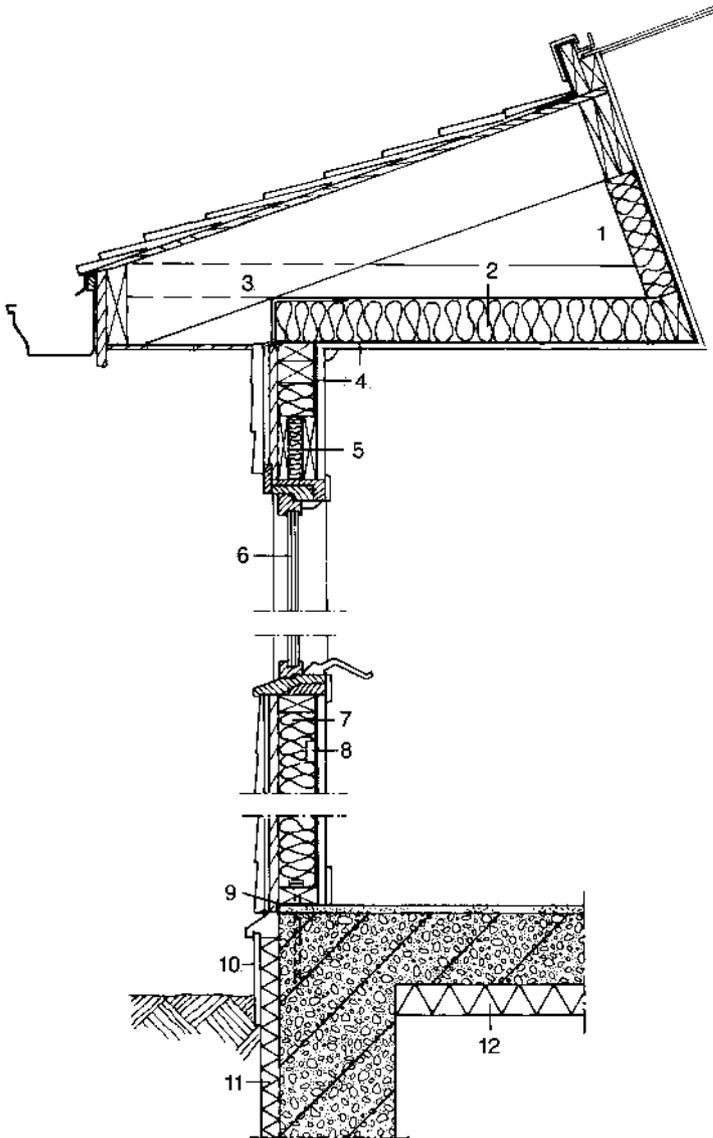


Figure 1.5A: Paying attention to energy conserving basics: platform construction

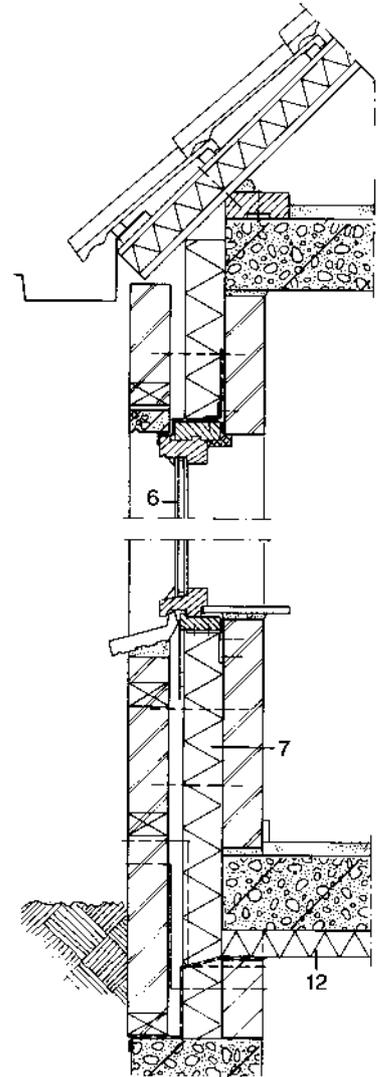


Figure 1.5B: Masonry wall

1. No gaps in insulation
2. Ceiling insulation
3. Raised heel truss allows for full insulation over outside wall
4. Adequate vapour retarder
5. Insulate window (box) headers
6. Energy conserving glazing (climate dependent)
7. Wall insulation
8. Sealing against air leakage at rough openings, electric outlets, etc.
9. Sealing between slab and wall with gasketing
10. Protecting rigid insulation above grade
11. Adequate foundation insulation (interior or exterior)
12. Installing subslab insulation if necessary (climate, water table, bedrock, etc.)

The three keys to good energy efficient workmanship:

- 1) establish a good air barrier;
- 2) provide upgraded insulation for entire shell;
- 3) avoid gaps in insulation, or major thermal bridges.

In a direct gain system the collection, absorption, storage and release of solar energy occurs within the living space. Without proper design and planning, problems will occur. For example, an occupant's need for privacy or his desire for certain furniture arrangements might be adversely affected by the entry of too much daylight in one location or another. Certain fabrics exposed to too much direct sunlight can fade or deteriorate. Another potential problem that must be avoided is periodic overheating.

During the heating season, sunlight enters the living space through south-facing glass. This solar radiation is in turn absorbed by elements in the space such as the floor, walls, ceiling and furniture, and is then converted into heat. This heat either warms the air in the space or is stored within heavyweight elements for later use. These storage elements are typically floors or walls made of masonry materials (concrete, concrete block or brick), and specially designed thermal storage materials and containers.

Movable insulation, special glass coatings or films between double glazing can be used to prevent excessive heat losses in the heating season. During the cooling season the sun must be blocked from glazing areas in order to prevent excessive solar heat gains.

Figure 2.1 illustrates the main features of a direct gain passive solar system.

The principal function of a direct gain collector is to admit solar energy so that it can be absorbed and stored within the living space. Standard double glazing typically prevents one-quarter of the available solar energy from entering the building and provides very little resistance to heat loss on winter nights.

From the builder or designer's standpoint, two different types of solar collectors exist: pre-manufactured windows or skylights, and site-built glazing or skylights. The primary requirements for each type of collector are discussed below.

Manufactured windows used for solar gain can be installed along the south facade with standard detailing. When selecting windows and installing them for solar gain, builders and designers face a number of major issues: type of frame material, tightness of the frame, effectiveness of weather-stripping, type of glazing, number of glazings, durability of hardware and type of maintenance required.

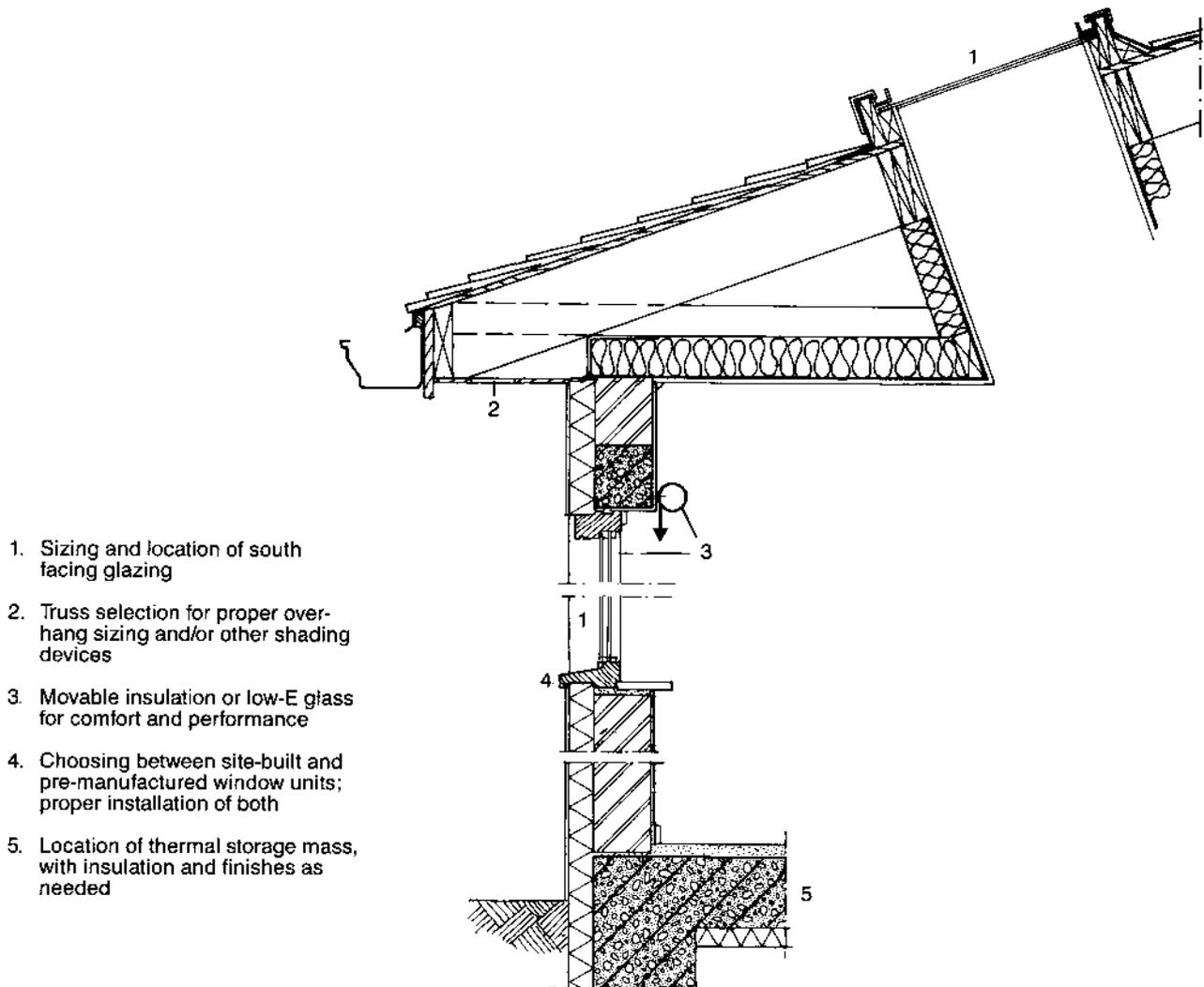
Window frames may be made of wood, metal or synthetic material. Regardless of the particular type of frame, it must be equipped with quality weather-stripping. Any metal-framed window should also have thermal breaks. Booklet 2 contains a frame classification with solutions for different applications. Charts explain the various properties – resistance to heat loss, durability, and so on – of different frame materials.

Once the frame and other features have been considered and a manufactured window has been selected and is ready for installation, the only major issue (user requirement) facing the builder is how well he seals the window to the rough opening. Good sealing is required to create an airtight, watertight barrier.

2.1 GENERAL

2.2 APERTURE (WINDOW)

PRE-MANUFACTURED WINDOWS FOR SOLAR GAIN



1. Sizing and location of south facing glazing
2. Truss selection for proper overhang sizing and/or other shading devices
3. Movable insulation or low-E glass for comfort and performance
4. Choosing between site-built and pre-manufactured window units; proper installation of both
5. Location of thermal storage mass, with insulation and finishes as needed

Figure 2.1: The main features of a direct gain system, and construction-related issues

Two simple steps are involved when installing a tightly fitting window in a home. First, the builder must select an appropriate sealant; typically either weather-stripping or foam caulk is used. Weather-stripping materials, like EPDM, neoprene or foam rope, must be able to stop all air movement. Fiberglass will not stop air flow. Builders who use expansive foams should be careful to avoid using foams which continue expanding after they are installed. Highly expansive foams can bend a window frame causing the window to bind during operation.

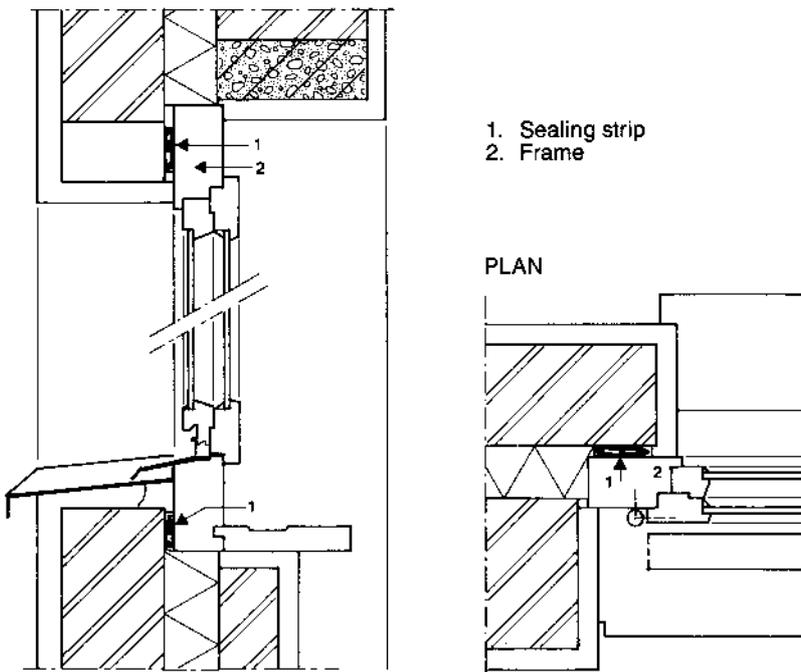
The second step is actual use and placement of the sealant material. Sealants should be applied continuously between window frame and rough opening. Whenever a builder is attempting to use a layer of polyethylene film for an air barrier, he should carefully seal the polyethylene around the opening where the window will be installed, before installing sealant between the window and frame. Builders not using polyethylene film must still seal whatever air barrier material they have selected ('airtight drywall', vapour permeable exterior air barrier film, etc.) to the window frame.

Figures 2.2 through 2.6 illustrate some examples of how manufactured windows can be sealed to the structure in both wood frame and masonry construction (reference no. 2).

In one example from Switzerland (Figure 2.2), the compressible weatherstripping is placed between the frame and the two courses of masonry. In the case of wood-frame walls, Swedish builders use wall-board to press the polyethylene against the window frame (Figure 2.3). A modification of that detail is the drywall return, a detail used by some energy-conscious builders in the United States (Figure 2.4). One of the most universal details is to simply fill the gap between the wood frame and window frame with foam or foam rope (Figure 2.5).

For a skylight on a pitched roof, a good air seal in the window frame itself is necessary (Figure 2.6). A good fit of the vapour retarder to the window is also required.

SECTION

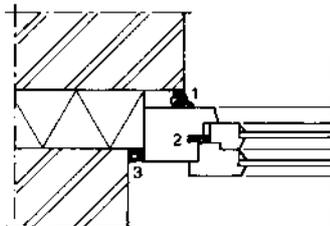


- 1. Sealing strip
- 2. Frame

PLAN

Improved construction
Additional casement seal and external frame seal.

PLAN



- 1 Rain seal (neoprene profile)
- 2 Wind seal (lip seal)
- 3 Wind and vapour seal (rubber profile)

Figure 2.2: Sealing premanufactured windows with gasketing

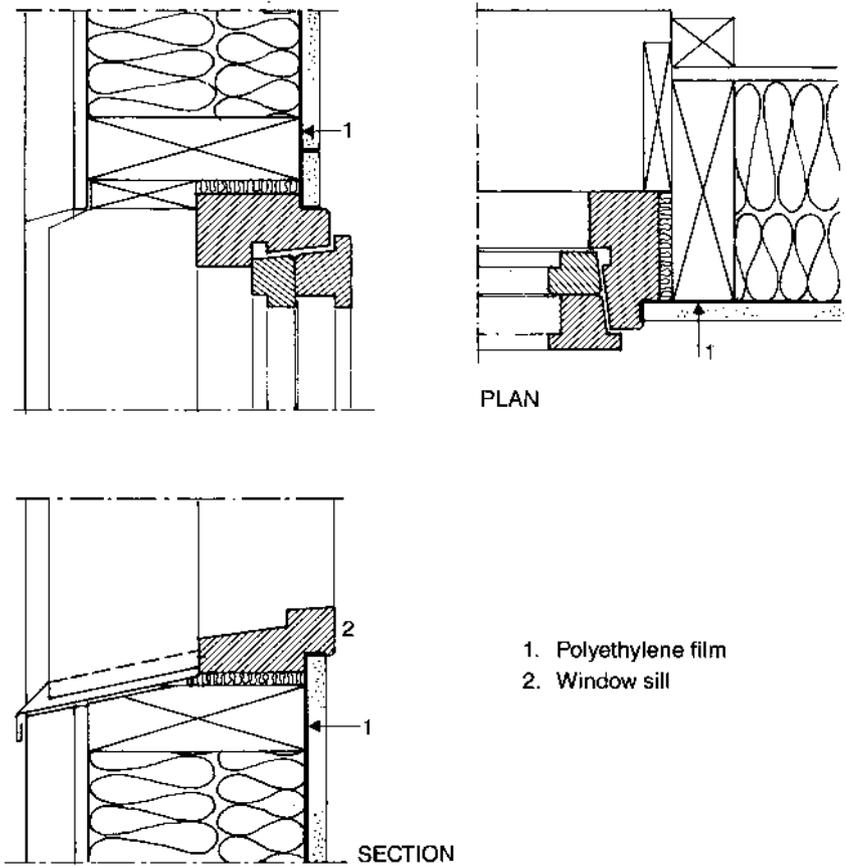


Figure 2.3: Sealing pre-manufactured windows to the polyethylene vapour barrier

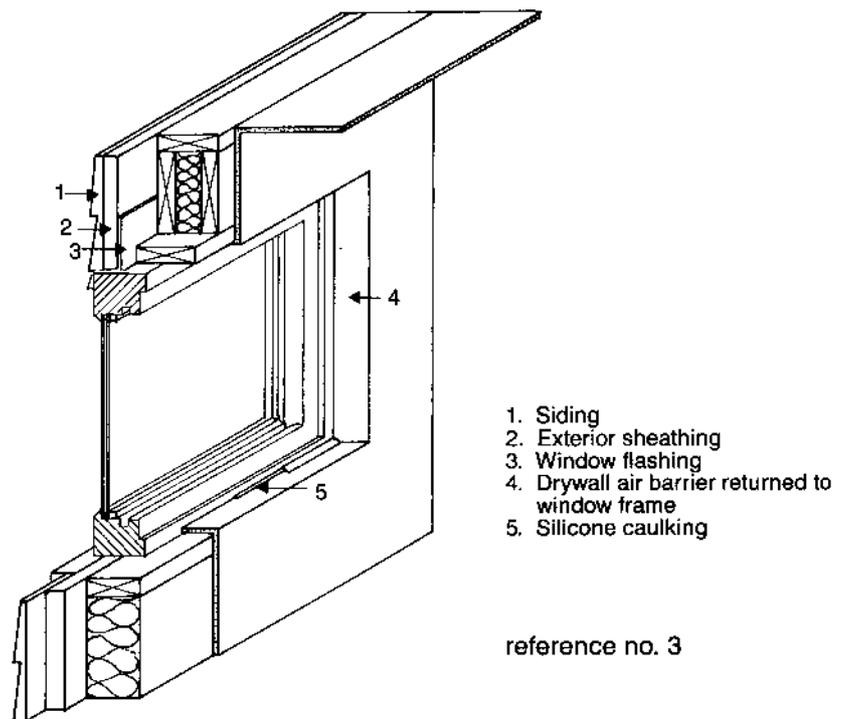
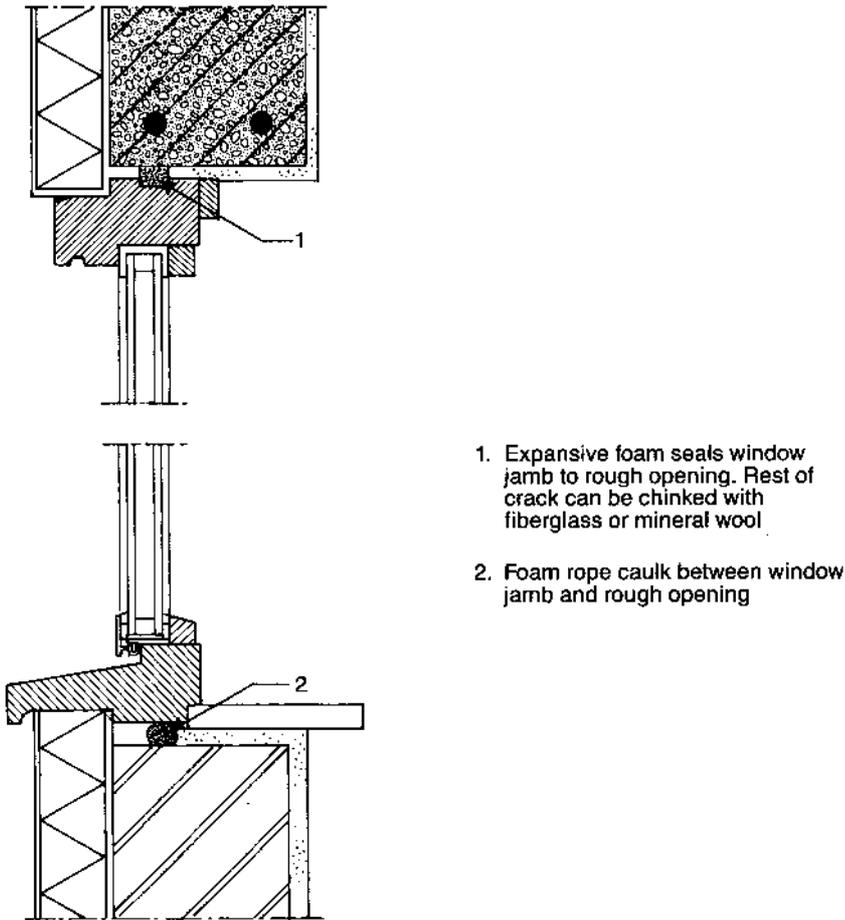


Figure 2.4: Installing a pre-manufactured window with drywall returns to achieve a tight seal



1. Expansive foam seals window jamb to rough opening. Rest of crack can be chinked with fiberglass or mineral wool
2. Foam rope caulk between window jamb and rough opening

Figure 2.5: Sealing around a pre-manufactured window with either expansive foam or foam rope

When builders use large pre-manufactured windows along the south wall, the frames must be able to accommodate a large amount of expansion and contraction. One method of reducing this movement is to decrease the size of each section of glazing by increasing the number of framing mullions and jambs. The disadvantage in doing this is that it also reduces the available area for solar heat energy to enter the system and increases costs. A better solution might be to consider a site-built glazing system.

Builders and designers can choose to build their own passive solar glazing systems rather than purchasing pre-manufactured windows. Two primary reasons exist for selecting site-built windows: to increase the size of collector area and to reduce costs.

SITE-BUILT GLAZING SYSTEMS

Builders who elect to site-build their direct gain passive solar windows should review the lists of user requirements and environmental factors. Several construction issues which are handled by window manufacturers must be reconsidered by builders who site-build their own windows. Several of the issues listed in the chart are discussed below. All the details and concerns raised here apply to vertical glazing only; issues relating to sloped glazing are discussed in the next chapter on Sunspaces.

- 1. Lip seal in window frame
- 2. Lip seal in casement
- 3. When placing roof window ensure that casing joints are sealed
- 4. Header
- 5. Casing
- 6. Vapour barrier
- 7. Rafter

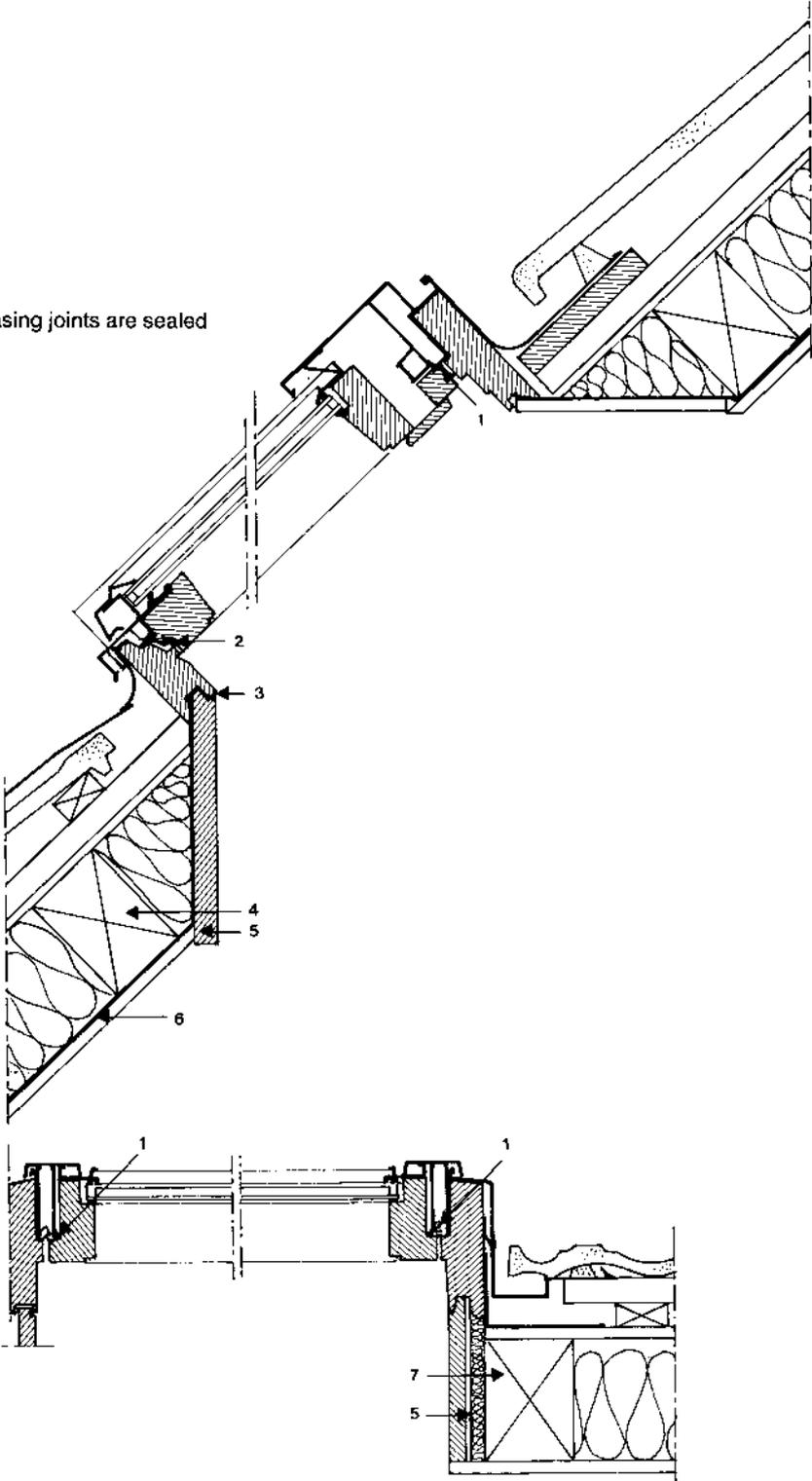


Figure 2.6: Center-hung roof window
Standard construction with built-in lip seal.

User Requirements:

1. Stability
2. Safety
3. Tightness
4. Indoor temp/humidity
5. Visual requirements
6. Durability
7. Economics

Environmental Requirements:

1. Mechanical factors
 - Deformation
 - Violent weather forces
2. Thermal factors

REQUIREMENTS

Examples of site-built window details for a vertical direct gain application are illustrated in Figure 2.7 (reference no. 4).

The framing for site-built window systems is usually made of wood. Two problems which must be avoided are warping and twisting of wood frame members. In order to avoid warping and twisting, builders should use laminated products rather than solid framing members. The least expensive approach is to nail and/or glue two framing studs together at the building site. An alternate approach is to purchase laminated framing products; these add to material costs but reduce the labor needed on site.

STABILITY

In passive solar applications, the use of exterior wood glazing caps to attach the glazing to framing members is not recommended. Wood is subjected to extremes of temperature, absorption of moisture and freezing and thawing cycles that age it rapidly and that can cause warping and leakage. In order to minimize maintenance problems, builders should use metal glazing caps on all site-built glazing systems. Metal glazing bars with built-in EPDM gaskets make the window air and watertight.

DURABILITY AND TIGHTNESS

Builders should install insulated glass units that are designed to withstand the stresses of large temperature swings. The key feature is the material used to seal the edges. Thanks to their ability to withstand high temperatures, sealants such as silicone, urethane and polysulfide are appropriate. Insulated glass units with butyl edge seals are not recommended. Figure 2.8 and the associated text provides more information about insulated glass units.

THERMAL FACTORS

Joint sealants should be selected carefully in order to assure that they are both durable as well as chemically compatible with adjacent materials (Figure 3.31).

A passive solar home with high indoor humidity, especially when located in very cold climates, can experience condensation problems. To provide a durable glazing system, efforts should be made to both isolate the glass seals from possible condensation and prevent damage to sills. The two most commonly used techniques are to choose durable sill material or to locate a condensate channel at the base of large glass areas.

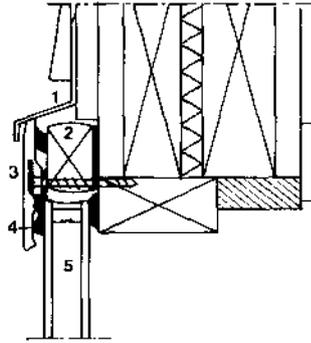
CONDENSATION DAMAGE

Building codes will typically require the use of safety glass if the glazing is located at or near floor level and beside or in a door.

SAFETY

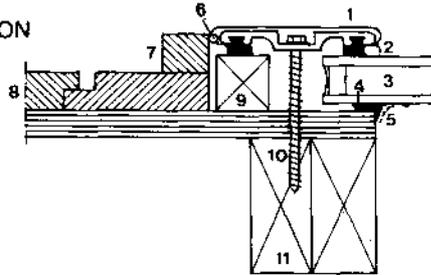
DIRECT GAIN

VERTICAL SECTION



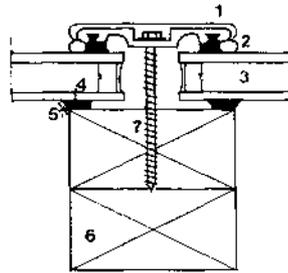
1. Flashing
2. Blocking
3. Glazing Bar
4. Gaskets
5. Insulated Glass Unit

HORIZONTAL SECTION



SIDE DETAIL:
VERTICAL GLAZING MEETS WOOD
SIDING

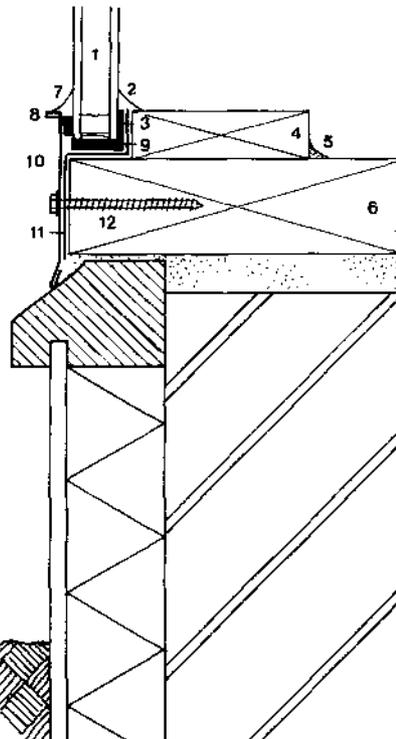
1. Snapcap bar and gasket
2. Silicone sealant
3. Insulated glass unit
4. Appropriate sealant
5. EPDM or neoprene tape
6. Appropriate sealant
7. Wood casting trim
8. Channel lap wood siding
9. Continuous blocking
10. Lag bolt
11. Structural framing



MULLION DETAIL

1. Snapcap bar and gasket
2. Silicone sealant
3. Insulated glass unit
4. Appropriate sealant
5. EPDM for neoprene tape
6. Structural framing (laminated)
7. Lag bolt

VERTICAL SECTION



SILL DETAIL: VERTICAL GLAZING

1. Insulated glass unit
2. Appropriate sealant
3. EPDM or neoprene tape
4. Sill stop
5. Appropriate sealant
6. Sill plate
7. Silicone sealant
8. Foam backing tape
9. Rubber blocking
10. Sill flashing
11. Sill sub-flashing
12. Lag bolt

Figure 2.7: Sample details for site-built vertical glazing

1. Secondary seal
2. Dessicant
3. Aluminium spacer channel
4. Primary seal
5. Glass

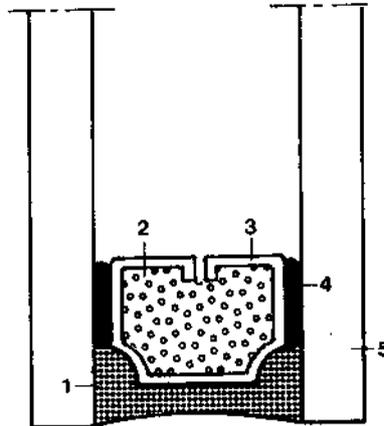


Figure 2.8: Double seal glass

Any heat collected by direct gain windows that is not needed to meet the building's daytime heating requirements can be stored in the floor, walls and ceiling if the heat capacity of these elements is sufficient.

The most frequently used storage materials are concrete, brick, quarry tile and concrete blocks. Concrete floors and masonry partition walls are two good examples. Water containers and special phase-change materials can also store heat effectively.

Gypsum board walls do not have a large thermal capacity. However, in a 'sun-tempered design' - one which has south-facing windows equivalent to 4-6 percent of the building's floor area - the heat storage capacity of the gypsum board and furnishings will be adequate.

Where a concrete slab floor is used for heat storage, any tile covering must be applied with solid grouting in order to ensure good thermal contact with the slab (Figure 2.9). Any finish applied to masonry walls should be highly conductive such as plaster; storage walls should not be covered with a layer of gypsum board.

Massive floors located in direct sunlight should be finished with a moderately dark color (0.6 absorption or better; Figure 4.9). All other wall and ceiling surface areas can be virtually any color.

If a heat storage slab is in direct contact with the ground, it may be necessary to place insulation beneath it. Insulation is most essential if the water table is high, the slab is laid on bedrock or the climate is particularly cold. The insulation beneath a slab should either be water-repellent or must be protected against moisture. A damp proof layer should be added beneath the insulation to prevent it from water penetration from the ground below. The sub-slab insulation must also be able to withstand the load being placed upon it by the slab.

Several types of floor mass systems are illustrated below (Figure 2.10/ 2.11) (reference no. 5). The most common type is a slab-on-grade. Concrete or brick mass coverings over wood subfloors are less common but can work well. The setting bed and the masonry paver jointly should form the minimum 5 cm thickness of mass necessary for adequate storage. Two layers of roofing felt should be laid down on the wood subfloor prior

2.3 STORAGE

LOCATION, MATERIALS

FINISHES

COLOR, MASS

SUB-SLAB INSULATION AND VAPOUR BARRIER

EXAMPLES OF MASS FLOORS

1. Provide a solid grout bed under any finish (tile) over a concrete slab. Color should be moderately dark.
2. Finish over masonry storage walls must be highly conductive. Can be of any color.
3. Insulation on exterior must be protected from the weather by stucco or other appropriate finish material. If block material is used, grout cavities solidly.
4. Insulate under storage slabs if the water table is high, the slab is on bedrock, or the climate is cold.
5. Put a damp proof layer under the slab. Locate it under the insulation unless crushed rock is also placed under the insulation.

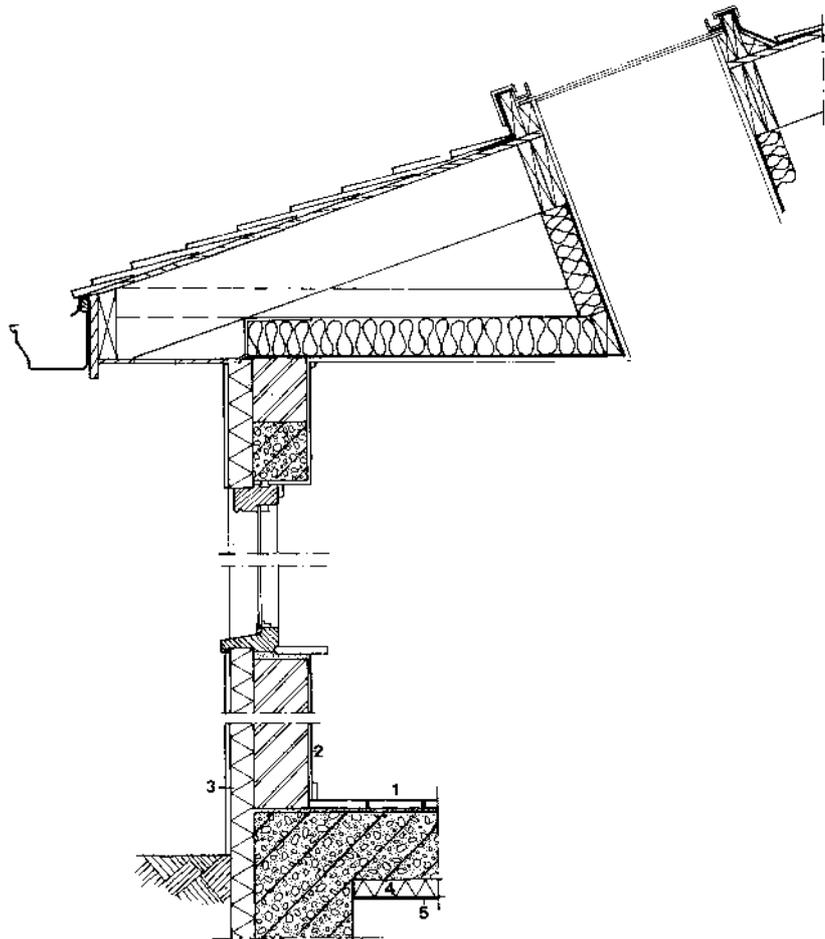


Figure 2.9: Examples of storage component issues in direct gain systems

to placing the lightweight concrete or masonry pavers. Check building code requirements regarding the joist spacing needed to reinforce this type of floor system.

THICKNESS

The recommended thickness of the floor mass can be achieved by adjusting the setting bed thickness to compensate for thicker or thinner floor tiles. For more information on thickness of thermal mass in floors and walls, refer to Booklet 3 on design guidelines.

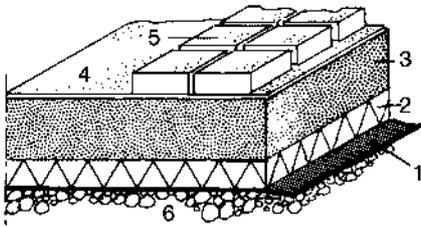
EXAMPLES OF MASS WALLS

The three types of wall mass most commonly used in direct gain systems include solid partition walls, frame partition walls covered with face brick, and exterior masonry walls insulated on the outside (Figure 2.12) (reference no. 5).

MASSIVE PARTITION WALLS

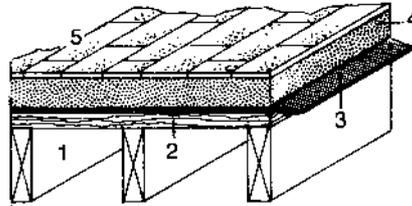
When placing mass in partition walls (Figure 2.11a), the first item of concern is assuring that the masonry will have adequate foundation support beneath it. Mass partition walls placed on slabs are easily supported by placing footings and reinforcing as required by local code. For a raised floor, above either a crawl space or basement, the masonry partition must be supported by a poured or block wall below (Figure 2.11b).

DIRECT GAIN



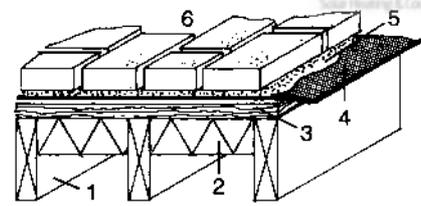
CONCRETE SLAB-ON-GRADE

- 1 Damp proof layer
- 2 Rigid insulation
- 3 Concrete slab
- 4 Setting bed
- 5 Masonry paver or floor tiles
- 6 Crushed rock



LIGHTWEIGHT CONCRETE ON WOOD FLOOR

- 1 Floor joist (insulate if over crawlspace or unheated basement)
- 2 Subfloor
- 3 Roofing felt
- 4 Concrete
- 5 Finished floor (tile)



MASONRY PAVER ON WOOD FLOOR

- 1 Floor joist
- 2 Insulation if over unheated space (check codes for joist-spacing requirement)
- 3 Subfloor
- 4 Roofing felt
- 5 Setting bed
- 6 Finished floor (masonry paver)

Figure 2.10: Storage elements in floors

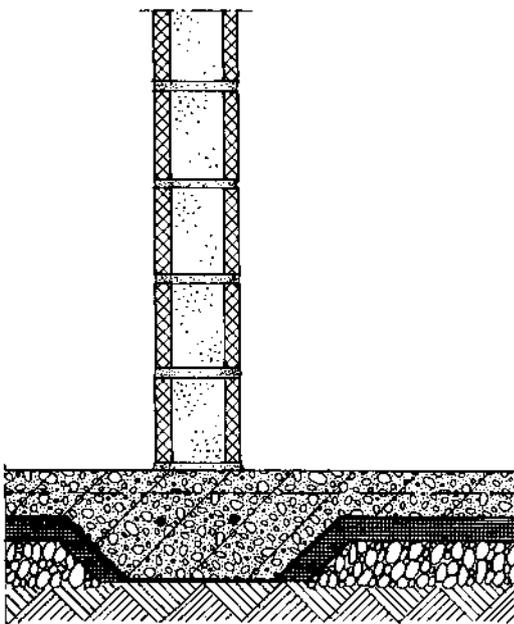


Figure 2.11a

Figure 2.11: Storage elements in walls

The storage elements in 2.11a are typically more cost-effective than the storage elements in 2.11b

- 1. Roofing Felt
- 2. Subfloor
- 3. Floor Joist
- 4. Insulation (if over unheated space)
- 5. Joist Hanger
- 6. Ledger

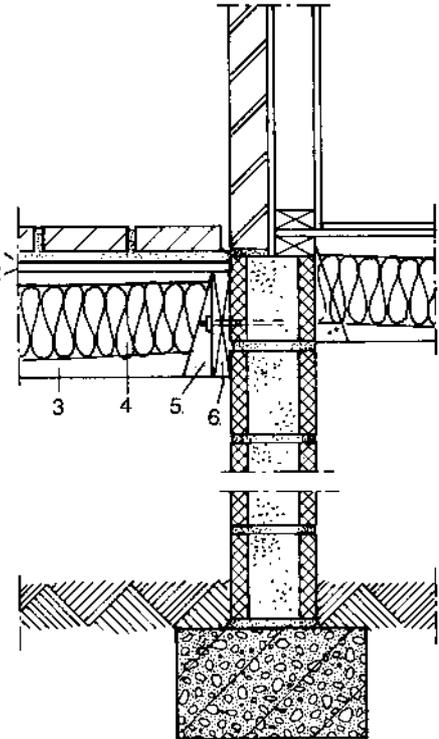
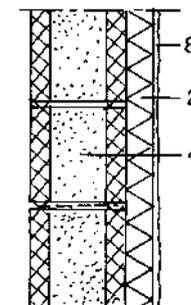
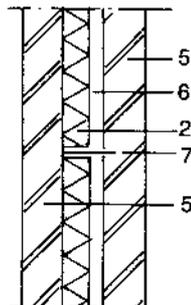
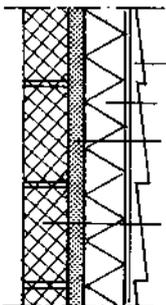


Figure 2.11b



- 1. Building paper and siding
- 2. Insulation
- 3. Plaster
- 4. Concrete masonry unit
- 5. Masonry wall (external)
- 6. Cavity
- 7. Joint reinforcement
- 8. Stucco

Figure 2.12: Examples of massive exterior walls

The least expensive massive material to use in a solid masonry partition wall is usually concrete or clay block. Webbing in the blocks must be filled solidly as the blocks are laid up. The blocks can then be painted virtually any color. If they have an additional finish surface applied, the finish material must be a highly conductive material such as plaster. Often, a less expensive way to achieve a finished appearance is to use one course of 15 cm bricks.

FACE BRICK WALL STORAGE OPTION

The face brick option is also fairly straightforward (Figure 2.11b). Typically, one side of a conventionally framed wall is covered with an inexpensive backer material such as unfinished gypsum board. A single course of brick or filled block – no more than 10 cm thick – is laid up against the backing material. Metal wall ties should be used to secure the brick to the frame partition wall. This approach to wall storage tends to be fairly expensive, since it includes a separate structural component (wood or metal framing) as well as the masonry material.

EXTERIOR MASSIVE WALLS

Wherever exterior masonry walls are used in conventional construction practice, converting them to thermal mass storage can be quite cost-effective. This conversion is achieved by simply placing insulation outside the masonry or between the two rows of masonry in double-wythe construction. Both approaches will perform about the same, so the most important consideration is using the approach that costs the least or most closely resembles conventional practice.

Using rigid foam is the most common way to insulate an exterior masonry wall (Figure 2.12). The foam must be applied with either a compatible adhesive (varies from one type of foam to the next) or a mechanical fastener. Typically, builders will apply a conventional wire mesh and stucco coating. A modification that requires less maintenance is the use of fiber-reinforced stucco-like material. This product, tinted during application, involves a three-coat process that adds somewhat to material and labor costs.

Adding a layer of foam between two wythes of masonry in an outside wall involves some tradeoffs. The two-wythe approach is more costly than using simply one course of core-filled block. However, no finish is required over the insulation (foam or batt) placed between the two layers of masonry. If two-wythe construction is standard practice, converting this double wall to storage is the least expensive way to add wall-mass in a passive solar home.

2.4 SHADING

To avoid excessive heat gain in the cooling season and to increase overall system performance, some method of shading the south-facing windows during the summer is essential. The most effective sunshade is one placed on the outside such as horizontal overhangs, fixed or movable horizontal slats, sliding panels, roller blinds, and pivoting or sliding shutters. Interior shading devices, while often not as thermally effective as exterior units, are generally easier to operate and maintain. Roller shades, blinds, drapes and movable panels are used as interior shading devices. For optimum year round use, the interior sunshades can also be used for insulation in the daytime during the cooling season, and at night during the heating season. For a more complete discussion of shading devices, see Booklets 2 and 3.

In many regions, the most common shading device is the fixed overhang. Based on the designer's specification, overhang design can be adjusted to a limited extent. One of the easier ways to adjust the depth of an overhang as well as its height above a window is to use a raised heel truss (Figure 2.13). This approach has a secondary energy benefit in that it allows for higher levels of ceiling insulation, compared to standard rafter or roof truss designs.

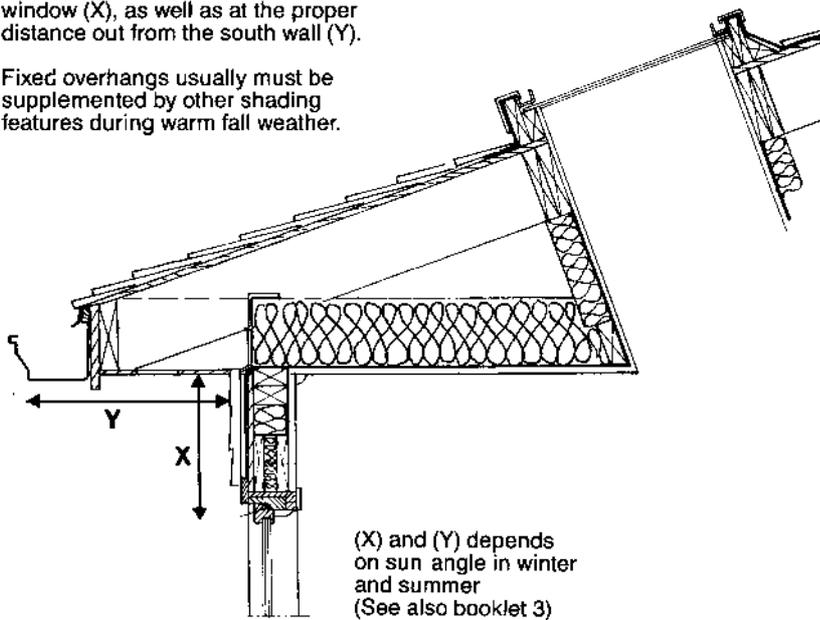
When an external shading device other than a fixed overhang is used, the principal user requirements and environmental factors to consider for the shading element are:

- Stability requirements: connection of shading features with window frame; mechanical resistance to static and dynamic actions; cyclic (fatigue) effects.
- Kinetic energy: wind, hail, external impacts.

USER REQUIREMENTS

Figure 2.13: A raised heel truss can be ordered that places the overhang at the proper height above the window (X), as well as at the proper distance out from the south wall (Y).

Fixed overhangs usually must be supplemented by other shading features during warm fall weather.



While south-facing windows are effective solar collectors during the day, nighttime losses out through any conventional glazing product can significantly reduce total solar savings. Two ways exist for reducing these losses: use of better insulating glazing materials, or installation of movable insulation products. Based on performance monitoring by the Solar Energy Research Institute in the U.S. (reference no. 6), the use of better insulating glazing products is the preferred option for improving performance because it eliminates the requirement of occupant intervention to optimally open and close the movable insulation.

2.5 MOVABLE INSULATION

The key difference between the two approaches is that better performance is generally assured with improved glazing products, while the effectiveness of movable insulation is completely dependent on conscientious operation by the occupant.

Builders should avoid installing movable insulation unless it is specifically requested by the client. Even in that situation builders should advise clients against ordering movable insulation for hard-to-reach locations such as skylights and clerestories. In those locations, builders who choose windows with low-emissivity glazing will spare themselves the headaches of having to site-build movable insulation products, since few are sold commercially to meet the special requirements of clerestories and skylights. Booklet 2 illustrates a variety of night insulation product configurations (folding shutters, roll-down shades, etc.) for conventional vertical windows.

LOCATION OF MOVABLE INSULATION

As with shading devices, both exterior and interior movable insulating products are available. Interior insulation is more convenient to use as well as easier and cheaper to maintain because it is not subjected to wind and weather.

EXTERIOR MOVABLE INSULATION

Exterior products generally cost considerably more than interior products. However, exterior insulation offers some advantages over interior devices. Exterior insulation eliminates the possibility of condensation on windows. It is also more effective as sunshading in the summer since it blocks direct solar heat gain. When interior insulating materials are used to block the summer sun, excessive heat build-up between the glass and insulating material can cause enough thermal shock to break glass.

The wishes of the occupant must be considered when the choice is made between interior and exterior movable insulation. However, regardless of the approach taken, shutters or shades used to reduce summer gains also result in a loss of daylighting.

INTERIOR MOVABLE INSULATION

Interior movable insulation is typically made from either quilted fabrics, multiple layers of reflective material, or rigid insulating board sandwiched between some form of finish material. The principal advantage of fabrics is that they can be rolled neatly in place at the top of the window, whereas shutters must have enough room to be folded out of the way during the day.

Regardless of the type of material selected, designers and builders must make sure that the mounting system they select will not be obstructed by obstacles such as window crank handles or door knobs. The least obtrusive way to mount a shade is an 'inside mount' (Figure 2.14). However, an 'outside mount' is easier to install and is less likely to be obstructed by window crank handles.

USER REQUIREMENTS

Builders who elect to install interior movable insulating products must consider several environmental factors and user requirements:

- **Tightness:** an effective seal is required between the insulation and the window to prevent heat loss as well as condensation on the glazing (Figure 2.15).
- **Durability:** the edge seals as well as the shutter itself must be able to withstand daily use for decades with little more than replacement of edge seals if they wear out.

- Fire safety: some foam products used in movable insulation can release highly toxic gases during a fire. Fiberglass or reflective foil products are considered safer.
- Economics: the cost of movable insulation is relatively high, compared to the cost of better insulated glazing. However, that cost disadvantage can be partially offset if the occupant also wants drapes for privacy.

The major environment factor relating to interior movable insulation is the issue of moisture. In climates where the outdoor temperatures drop below 10 or -15°C , periodic problems with condensation on standard double glazing will occur. However, when night insulation is installed, condensation will be a problem at higher temperatures if there are any air leaks around the edge seals. It is very difficult to find a movable insulation product that is not susceptible to air leaks.

The primary differences between interior and exterior shutters are that the shutters must be built to withstand the effects of weather extremes and they must either be operated from the outside or provisions must be made to operate them from the inside. Rolldown shutters and rigid panels are the most frequently used products.

As with interior insulating products, the edges of the shutters or panels must fit well. However, the airtightness required of interior products is not necessary. Hinged shutters or panels allow for greater amounts of insulation than rolldown shutters. Hinged shutters may be somewhat difficult to operate during freezing wet weather. Careful attention must be paid to shutter attachment to the facade in order to prevent wind-forces from damaging shutters and possibly breaking windows. Builders should use heavier hinges and longer screws during attachment.

The rolldown insulating products are made of wooden, aluminum or PVC slats. Since they provide only a limited amount of insulation (Figure 2.16a), the U-values of most rolldown systems currently available are low; this is partly due to the kind of material used for the slats. Hollow aluminum slats, even when filled with urethane foam, have a high rate of conductance since the heat flows quickly through the aluminum around the edge of each slat. The insulation provided by PVC slats is superior to aluminum but their thermal performance is still disappointing. Tests of a hollow PVC slatted shutter yields a U-value of only 1.6. Over half of this additional U-value can be attributed to the air space created between the shutter and the window glass. When picking a rolldown shutter, builders should search for a product offering the thickest PVC slats available (reference no. 7).

The rolldown products have an advantage over panels or shutters in that they are stored in housing above windows. This reduces their exposure to the weather. However, roller blind housings are often leaky. The typical housing, with internal openings for maintenance access, has many joints which are very difficult to seal. Figure 2.16b shows a standard construction detail for a two-course masonry wall and a curtain wall. Next to them is an improved detail with external housing across the facade, with only one internal opening for a roller blind crank (reference no. 2). With certain designs, builders may be able to hide the shutter housing behind the soffit (Figure 2.16c).

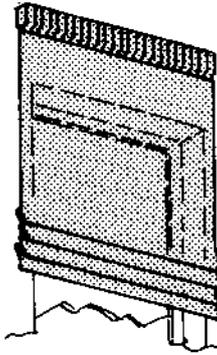
ENVIRONMENTAL FACTORS

EXTERIOR SHUTTERS

SHUTTERS, PANELS

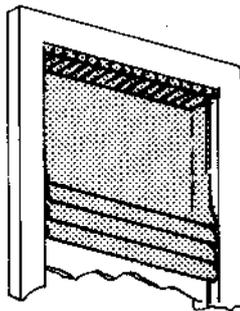
ROLLDOWN SHUTTERS

Figure 2.14: Indoor movable insulation

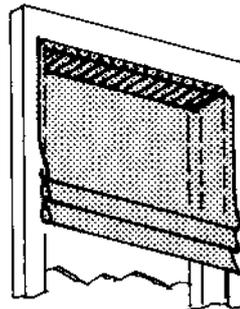


Designer/Builder selects a mounting method from three options:

1. *Outside Mount.* The mounting bar and shade shall be mounted on the wall above the window with shade overlapping window frame on both sides by no less than 25 mm. This method allows all folds to be stored above the window so light and view will not be obstructed.



2. *Hybrid mount.* The mounting bar shall fit inside the window frame. More accuracy is required to fit the shade, and additional moulding may be necessary for mounting the magnetic tape.



3. *Inside Mount.* The mounting bar and shade shall both be mounted inside the window frame, and the shade shall overlap the window frame a minimum of 25 mm on each side to cover the magnetic tape.

REQUIREMENTS

The principal user requirements and environmental factors to consider when selecting and installing exterior insulation are:

- Stability requirements: mechanical resistance to static and dynamic actions, resistance to impacts, cyclic (fatigue effects).
- Durability: resistance to extreme heat and cold, UV radiation.
- Economic requirements: capital, operating and maintenance costs.
- Kinetic energy: wind, hail and external impacts.

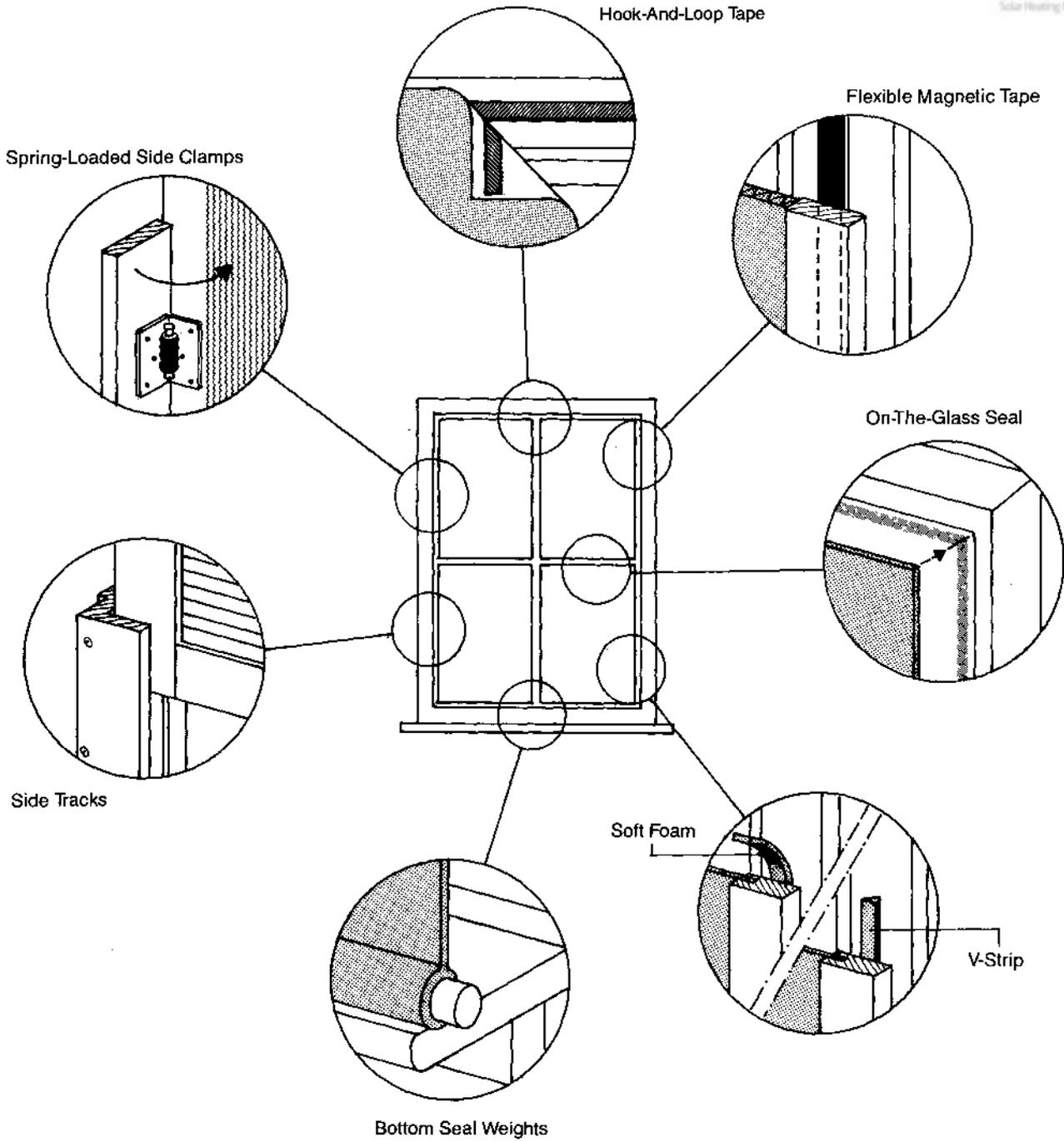


Figure 2.15: A variety of edge seals for indoor movable insulation (reference no. 8)

DIRECT GAIN

Figure 2.16a: Exterior movable insulation

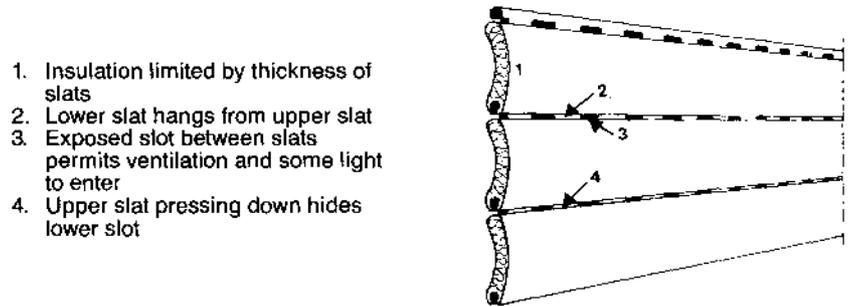


Figure 2.16b: Rollerblind housing

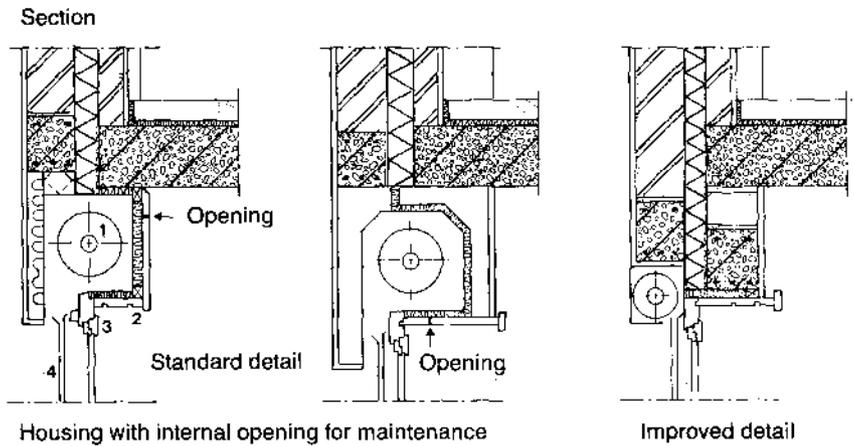
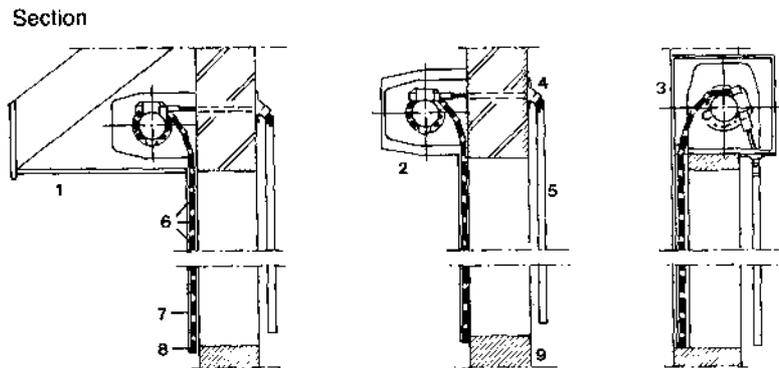


Figure 2.16c: Roller shutters

Rolling shutters are ideal for both new construction and retrofit applications. Installers can mount the housing:

- in an existing soffit
- on the surface of the wall
- directly within the wall (new construction)



- | | |
|--------------------|--------------|
| 1. Soffit | 6. Slats |
| 2. Cover | 7. Side Rail |
| 3. Housing Box | 8. Base Slat |
| 4. Universal Joint | 9. Sill |
| 5. Crank Handle | |

3.1 GENERAL

A sunspace is a sun facing room adjacent to, yet physically separate from, a home's main living area. The sunspace temperature is allowed to fluctuate. The solar energy collected and absorbed by an attached sunspace is generally used to heat both the sunspace and the adjacent living areas. During the heating season sunlight enters the sunspace through south-facing glazing, is absorbed by thermal storage elements (floor and walls) of the sunspace for controlling overheating, and is converted into heat that is stored and reradiated.

Excess warm air flows through door or window openings in the common wall into the home during the daytime. The sunspace is isolated from the home on cold winter nights and warm summer days.

Because of higher ambient temperature and solar radiation conditions during the summer months, special provisions must be made for keeping the sunspace cool during this period. Clearly, the easiest way to keep a sunspace cool is to build it with vertical glazing that is easily shaded. For this and other reasons listed below, a growing number of builders favor vertically glazed sunspaces. Their preference for vertical glazing tends to increase with their level of experience at building sunspaces and the occupant reaction they have received from overheated sunspaces caused by sloped glazing. But since occupants are more familiar with sunspaces that have glazed roofs, and since overhead glass appeals to many designers and occupants, builders should be familiar with construction details that apply to both sunspace design concepts. In fact, the majority of pre-manufactured sunspace kits available to builders and occupants today tend to emphasize the sloped glazing look. However, the problems of watertightness and overheating associated with sloped glazing must be recognized and fully presented to the client.

Sunspaces must be designed for ventilation to the outdoors during the summer. The sunspace is often used for preheating ventilation air, which is another reason for ensuring good ventilation.

The use of two fans with very simple thermostat controls can often enhance the performance and livability of sunspaces. When occupants are away from home, fans can automatically move excess heat from the sunspace into the home during winter days or draw in cooler outside air during summer days.

Both the spatial design and the glazing configuration of the sunspace are primarily determined by its use as either living space, plant growing space or energy producing space. One other factor that influences design is integration of the sunspace form with the rest of the building. Optimizing a sunspace design so that it achieves the desired design objectives can be somewhat difficult. Often major tradeoffs must be made. For a more lengthy discussion of design issues and guidelines, the reader is referred to Booklets 2 and 3. The majority of this section will deal with construction issues associated with sunspace design.

Figures 3.1, 3.2 and 3.3 illustrate three different approaches to glazing sunspaces: using vertical glass only; using vertical glass and skylights, and using vertical and sloped glass together.

VERTICAL VS. SLOPED GLAZING

As mentioned previously, sunspaces with vertical glazing have some advantages to sunspaces with vertical glazing and sloped glazing. Among its comparative advantages, vertical sunspace glass is:

1. less likely to develop air and water leaks;
2. less expensive to install;
3. less likely to become fogged (often the result of improperly supported double glazing, in which the seals break);
4. easier to keep cool in summer; vertical glass does not have to be covered with shading material, which means the amenities of views and natural lighting are available year-round;
5. does not lose heat as rapidly as sloped glass in winter;
6. performs better on sunny winter days than glass at shallow angles (especially at northern latitudes);
7. requires less maintenance, is easier for the occupant to clean;
8. will not collect snow during winter weather, and is also immune from ice damage from any part of the home located above the sunspace; and
9. is much easier to equip with movable insulation (though movable insulation is not usually a cost-effective performance feature in vertically glazed designs).

Sloped glazing does offer a few positive features. A skylight can bring light deeper into a sunspace or the adjacent living space. When the wall between the sunspace and living space is massive, sloped glazing can allow direct solar gains on more of the mass wall for a larger portion of the year. Additionally, sloped glazing allows for balanced plant growth throughout the sunspace. But these advantages are often outweighed by the comparative advantages of vertical glazing listed above. In the balance, vertical glazing generally offers easier construction, better energy performance and improved livability.

3.2 USER REQUIREMENTS AND ENVIRONMENTAL FACTORS,

Figure 3.4 presents the user requirements and environmental factors for the major sunspace components: the frame, the glazing, solar controls and thermal storage elements. A few issues relating to these requirements are mentioned below and subsequently covered in greater detail.

The stability of the frame is provided by rigid connections and/or wind bracing. Durability is determined by the choice of framing material (wood or metal) and its exterior finish.

The effect of wind on the glazing areas, excessive expansion and contraction of metal framing, and warping of any wood members are principal environmental factors to consider when designing and building the frame. Any condensation from the windows that pools on the framing can also cause damage. The loads from wind and snow (sloped glazing only) determine the thickness of the glass.

SUNSPACE

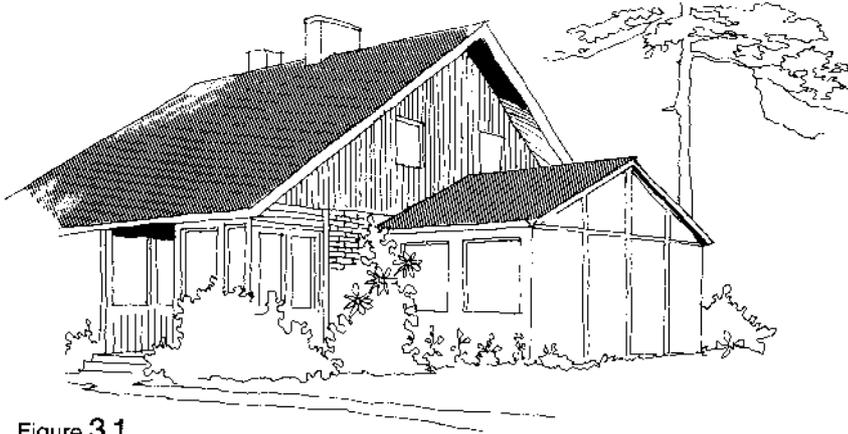
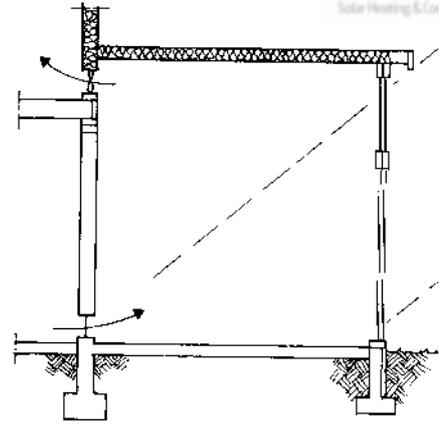


Figure 3.1

Vertically glazed sunspace with trapezoid windows to bring sunlight deep into the space.



Fully insulated roof, thermostatically controlled fan and dampered return air vent will improve performance.

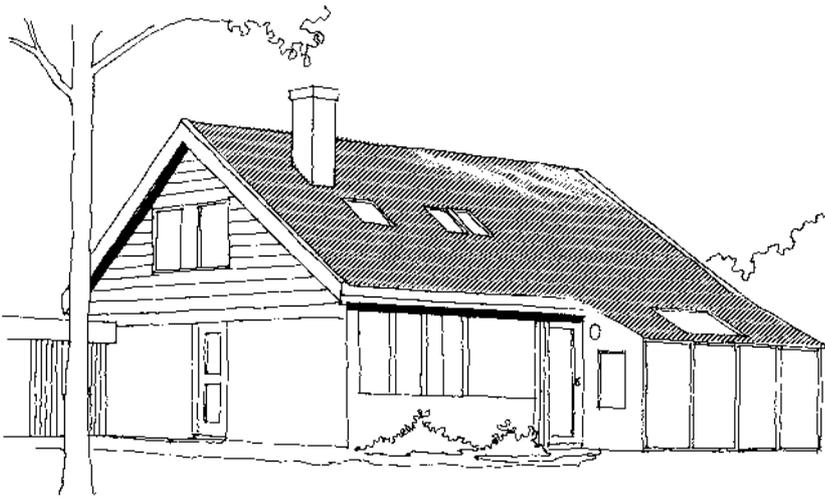
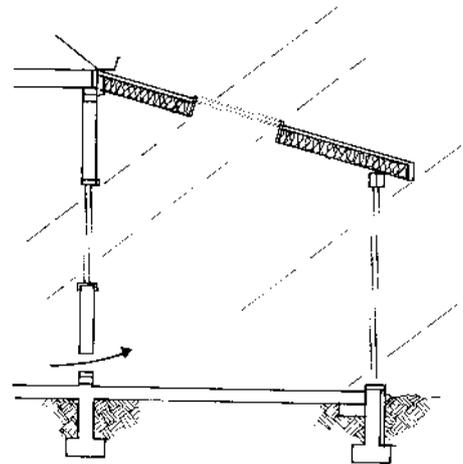


Figure 3.2

Vertically glazed sunspace with skylights, exhaust fan.



Skylights can bring light deep into sunspace or even the adjacent living space.

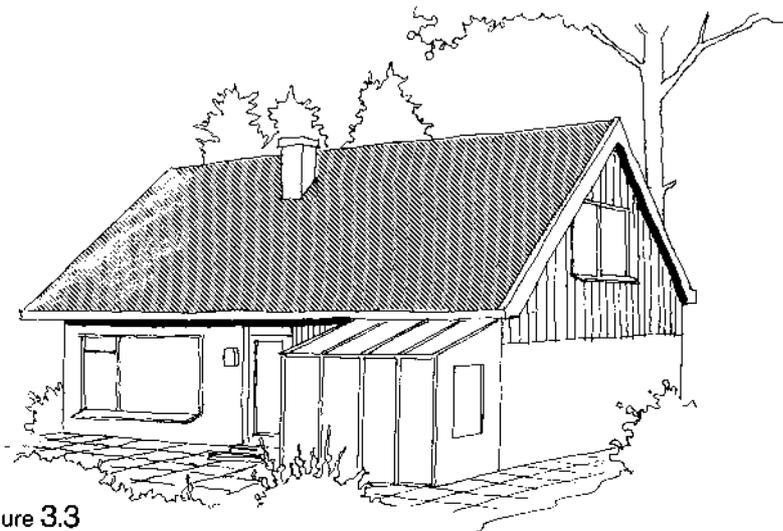
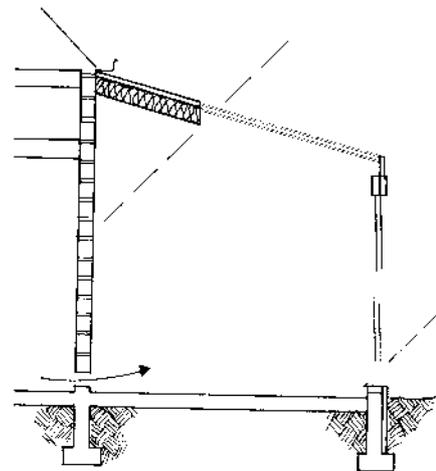


Figure 3.3

Vertical and sloped glazing.



Thermal mass wall between house and sunspace.

Budgetary constraints are very often a major factor that forces design tradeoffs. For example, if the occupant wants to use a sunspace as extra living space, movable insulation will make the space more comfortable at night. But since movable insulation for sloped glazing is somewhat expensive, it may never be installed. Such budgetary constraints may result in construction modifications.

A large number of sunspaces are built at the site. Many others are pre-fabricated by sunroom manufacturers and assembled at the site. The factory-built units are often added as well-lit, sunny rooms which face in virtually any direction and which may not be added with any energy-saving feature in mind. Only those sunspaces added for passive solar collection are considered here.

Wood framing is usually the material of choice when a sunspace is built on site. By contrast, most pre-fabricated units are made from aluminum extrusions. Both systems have advantages and drawbacks. Several are listed in Figure 3.5.

Pre-fabricated systems are usually easy to assemble. Most frames come with an extrusion system that collects and drains away condensation on the glazing. When properly installed, kits tend to be waterproof and wind-tight and they require relatively little maintenance. Manufacturers usually offer optional features that are pre-designed to fit, such as track-mounted interior shading and movable insulation products. Drawbacks to pre-fabricated systems are: the kits may be expensive, and the number of pre-determined sizes offer limited design flexibility. The extruded aluminum kits tend to favor glazing on all sides as well as overhead. In fact, most

3.3 PRE-FABRICATED SITE-BUILT

PRE-FABRICATED SYSTEMS

| | advantages | disadvantages |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| prefab | <ul style="list-style-type: none"> - simply assembled - waterproof, airtight joints - little maintenance - optional features pre-designed to fit (e.g. movable insulation; shading; circulation and exhaust fans) | <ul style="list-style-type: none"> - expensive - limited dimensions - difficult to insulate |
| site-built | <ul style="list-style-type: none"> - adapted to desires, requirements - fine tuning: insulation, sunshading and ventilation | <ul style="list-style-type: none"> - maintaining tight seals - special attention required with caulking and sealing |

Figure 3.5: Comparing pre-fab and site-built sunspaces

manufacturers do not supply materials for those portions of the sunspace which are not glazed. Builders shopping for a sunspace kit should look for a product that has thermal breaks within the frame. This is especially true if the sunspace forms part of the living area and is heated.

SITE-BUILT SYSTEMS

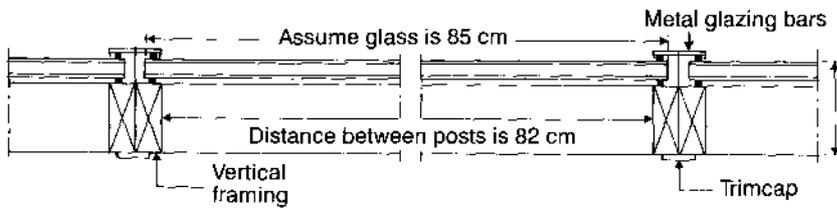
Site-built systems can be designed for the specific desires of the client. Experienced sunspace builders may create a price advantage with site-built systems compared to pre-fabricated kits, especially if builders use only vertical glazing. However, unless they are carefully detailed, such systems may fail to maintain a tight seal against the weather. Special attention must be given to caulking and sealing. If wood is used on the outside (for example as glazing caps), periodic inspection and maintenance are required to protect the structure. Builders should use kiln-dried timber. Laminated wood products – either purchased pre-glued or glued and nailed on site – are recommended for their excellent stability and resistance to warping. Wood sills or horizontal wood members that are likely to be exposed to frequent interior condensation should be sealed to resist moisture damage.

3.4 FRAMING AND VERTICAL GLAZING

Since wood framing systems for vertically glazed sunspaces are less expensive than metal, the following discussion addresses site-built wood framed applications. In addition, the glazing material for the following details assumes that insulated double-glass units are installed. Most designers and builders choose glass in vertical applications because it offers them the best optical properties for views.

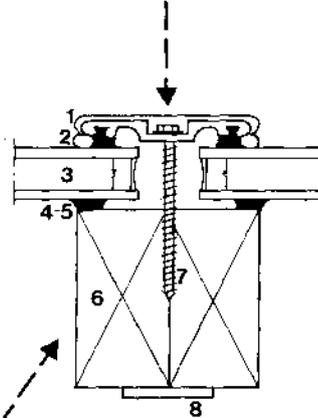
Three common ways exist to frame a vertically glazed wall for a site-built sunspace. These details also apply to direct gain and thermal storage wall glazing systems, when wood framing is used.

1. Framing members can be placed on a sill plate such that they are slightly closer together than the width of the glass (Figure 3.6a). For example, an 85 cm wide double-glazed patio glass replacement unit could be placed against two vertical members spaced approximately 82 cm apart. The glass bears 1.5 cm on each side as well as across the top. Furthermore, the vertical framing is held back the width of the insulated glass (often 2 cm) from the edge of the oversized plate, so that the glass can fully bear on the plate (Figure 3.6b).
2. A variation of this approach relies on the same spacing, but the framing is milled out the depth of the glass (Figure 3.7). Once installed, the glass is flush with the front of the framing. This particular approach requires more precise measurements and carefully squared framing. The glass must not touch either side or the top or bottom.
3. With the third approach, openings are framed slightly larger than the glass units, with a margin of roughly 1 cm on all four sides (Figure 3.8). Glazing stops are placed inside the frame all around the perimeter of the glass so that the glass rests against the stops on all sides. Metal glazing bars press the glass against the stops. As with the previous technique, precise measurement and square framing are essential.



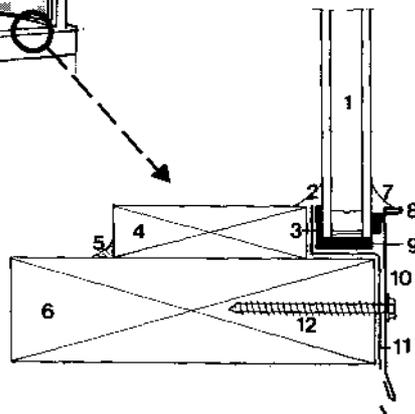
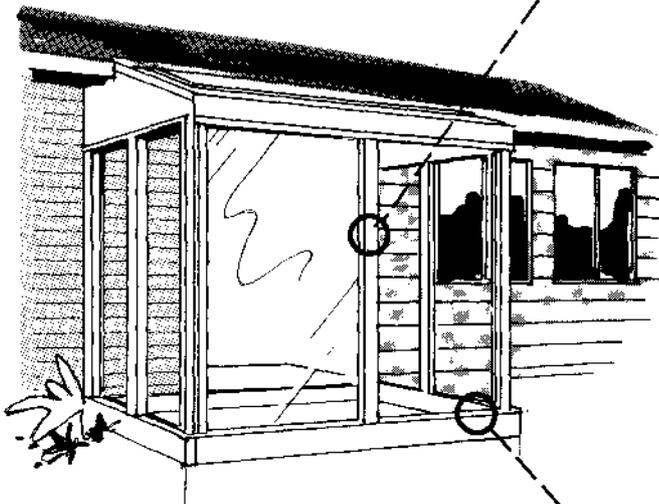
Width of plate, which is ripped down to hold the posts and glass

Figure 3.6a: Plan view



MULLION DETAIL

1. Snapcap, bar and gasket
2. Silicone sealant
3. Insulated glass unit
4. Appropriate sealant
5. EPDM or neoprene tape
6. Structural framing
7. Lag bolt
8. Trim



SILL DETAIL: VERTICAL GLAZING

1. Insulated glass unit
2. Appropriate sealant
3. EPDM or neoprene tape
4. Sill stop
5. Appropriate sealant
6. Sill plate
7. Silicone sealant
8. Foam backing tape
9. Rubber blocking
10. Sill flashing
11. Sill sub-flashing
12. Lag bolt

Figure 3.6b

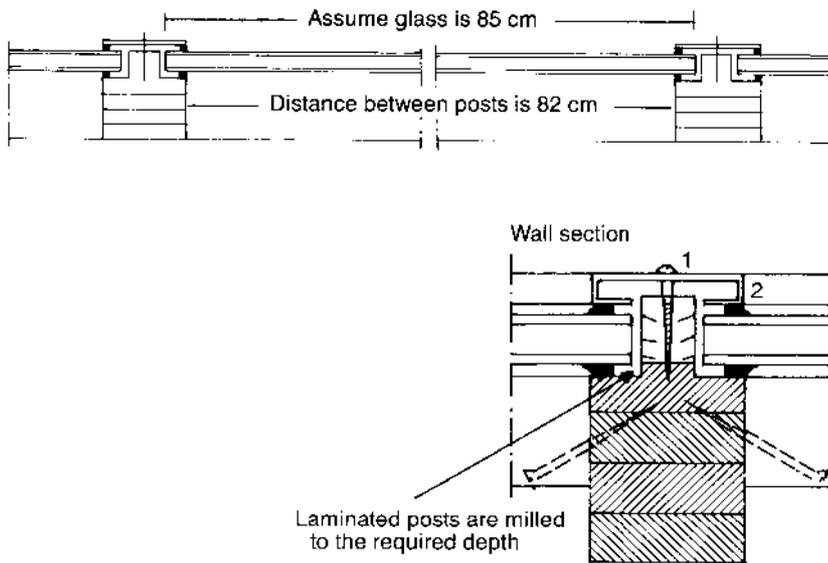
Figure 3.6: Wood framing option 1 for vertical glass

Regardless of which approach is used, a number of other details are available which should be included when the frame is being assembled and the glazing attached (Reference no. 4):

- Set all nails and other hardware that is near the glass 0.5 cm deep into the framing.
- Doublecheck the spacing dimensions of the openings for the glazing prior to final placement.
- Place 0.5 cm neoprene blocks on the sill, 15 cm in from each corner of the glass. This prevents the glass from coming into direct contact with the wood sill plate.
- To maintain a good seal, place some type of sticky-backed glazing tape (such as neoprene or EPDM) against framing or glazing stops where the glass will rest. Avoid using a product that is sticky on both sides; if you must slightly reposition the glazing, or replace a broken unit, products such as butyl glazing tape can be messy.
- Using gasketed lag bolts, press the glass against the framing with gasketed aluminum glazing bars. This provides a durable, low-maintenance cladding. Wood, used in the past as a glazing cap, has not proven to be very durable; it warps, which eventually leads to leaks.
- To prevent seepage at the base of the window, install a sill flashing and finish it with a bead of silicone caulk. Secure the flashing with gasketed lag bolts.

If the south-facing wall ends in a gable above a standard vertical installation described above, some custom-cut trapezoidal windows can be added to increase solar gains and bring light deep into the sunspace. If the trapezoidal glass is to be fit inside the frame (as described in # 2 or # 3 above), the glass units should not be ordered until the gable endwall is framed. This assures the glass will fit. Order the glass 1.5 cm shorter than the actual measurements of the prepared openings.

These details apply to the vertical wall even if a particular site-built design calls for some sloped glazing. The construction methods described above are among the least expensive ways to build a large glazing wall for a sunspace. If homeowners insist on some sloped glass in a roof, they should be made aware of the associated costs and other disadvantages.



1. Gasketed lag bolt
2. Gasketed aluminum glazing bar

Figure 3.7: Wood framing option 2 for vertical glass

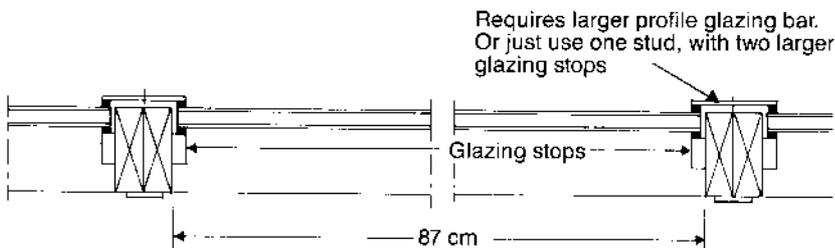


Figure 3.8: Wood framing option 3 for vertical glass

If the client desires some overhead glass, the first recommendation is to limit the sloped glass to a few pre-manufactured skylights (Figure 3.2). While their costs are considerable, skylights avoid some of the more significant problems which tend to be present with large glazed roof designs.

For designs requiring larger areas of overhead glass, it is strongly recommended that it extend up no more than the length of one patio glass door unit (Figure 3.3). This simplifies the building process. It also minimizes cost increases and allows builders to install a system that, compared to a multi-pane system, is less likely to develop leaks. Finally, it will improve performance (unless the roof is inclined very steeply, at 45-60 degrees), since the unglazed portion of the roof can be insulated to reduce night heat loss.

A roof with sloped glazing must be airtight and watertight. It should also be designed and built to require the least possible maintenance. It is not always easy to fulfill these objectives. Even properly applied sealants and gasket material will degrade when subjected to constant ultraviolet radiation, rain and ice. But experience shows that leaks and maintenance can be minimized.

3.5 SITE-BUILT FRAMING AND GLAZING OF A SLOPED ROOF

STRUCTURAL DETAILS

PRIMARY LOAD BEARING SYSTEM: GLASS IN SHED ROOF

SECONDARY LOAD BEARING SYSTEM PART OF GLASS ROOF

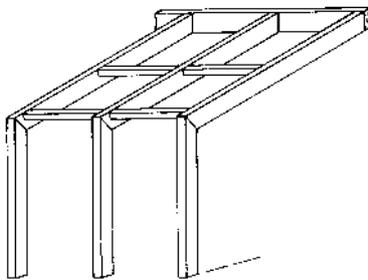


Figure 3.9: Sunspace framing option

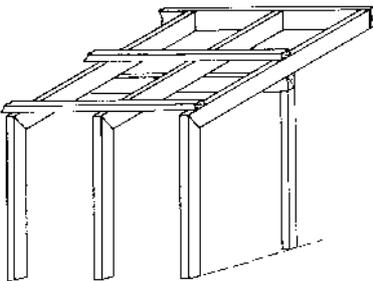


Figure 3.10: Sunspace framing option

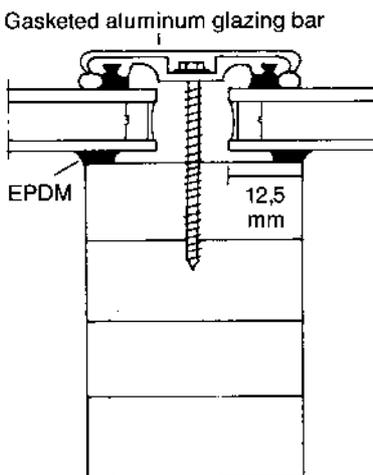


Figure 3.11: Laminated rafter detail for sloped glazing.

If the roof of the sunspace involves a large span, the load bearing structure for a partially glazed roof can be provided in two ways.

The main roof rafters, spanning from the front wall to a ledger against the home, can be designed to support the loads imposed by the glazing as well as the insulated roof section (Figure 3.9). These rafters must either bear directly on posts in the front wall, or a headering system will be needed to distribute the load from the rafters.

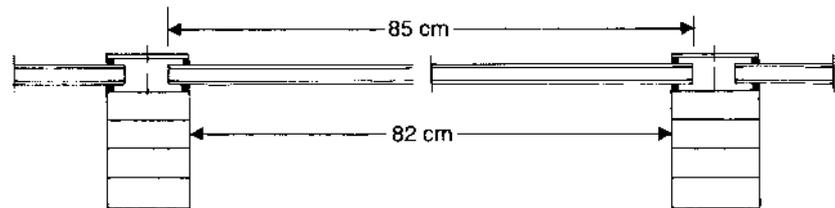
A more slender framework can be used if it bears on an intermediate steel or laminated wood beam (Figure 3.10). Separate rafters can be laid out to carry the glass on the lower side and the insulated roof on the other.

Regardless of how the loadbearing structure is designed, site-built overhead glass is installed using some of the same details presented above for vertical glass, with some additional attention to the eave line.

1. The rafters are spaced such that at least 1.25 cm of glass rests on each rafter (Figure 3.11). The same amount of glass must also bear on blocking or beams at the top and bottom of each glass unit.
2. EPDM or sticky-backed neoprene tape is placed around the entire perimeter of the framing before the glass is laid in place.
3. The top and sides of the glass are fastened to the framing with gasketed aluminum glazing bars. To prevent water leakage, use gasketed screws.
4. The eave can be finished in several different ways. One technique is to attach a piece of blocking along the base of the glass and place 0.5 cm rubber blocking against the blocking (Figure 3.12). A horizontal glazing bar seals the glass/blocking gap, with a beveled bead of silicone to prevent water from sitting on the glass side of the glazing bar.

Another way to detail the bottom edge of the glass is to simply extend it out over the edge of the front wall, cap the end with a U-shaped piece of flashing (with weep holes), and again seal the flashing and glass with silicone (Figure 3.13). With this approach, the glazing bars on three sides will hold the glass in place.

It is especially important that any sloped glazing be double-sealed to prevent the seal from breaking.



Size of rafter varies with span and snow load.

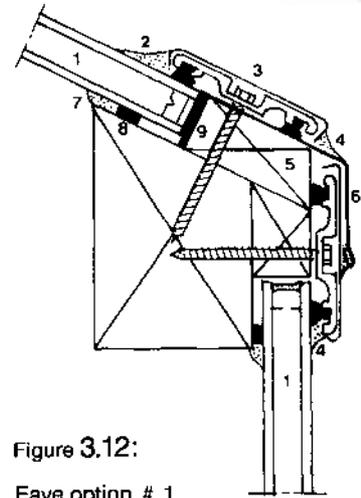
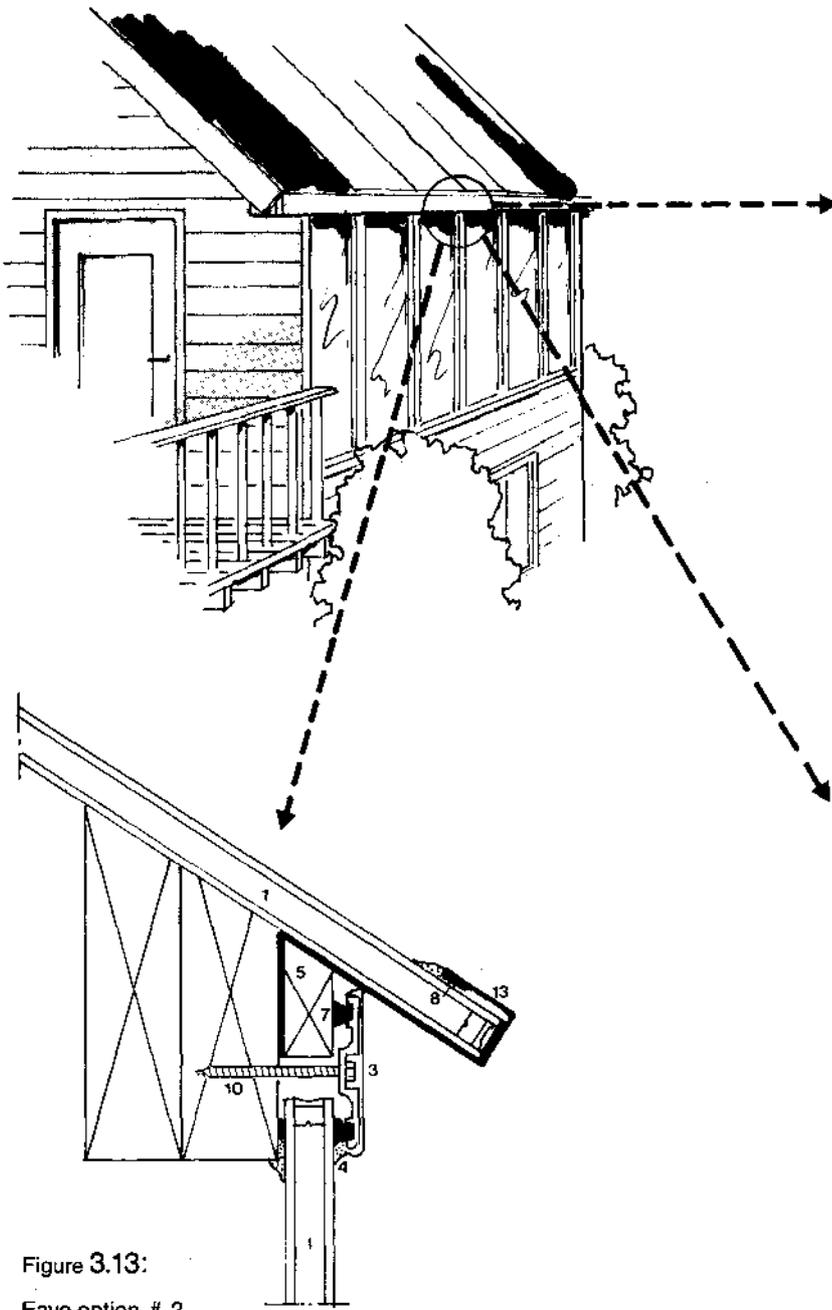


Figure 3.12:

Eave option # 1

SLOPED GLAZING TO VERTICAL GLAZING

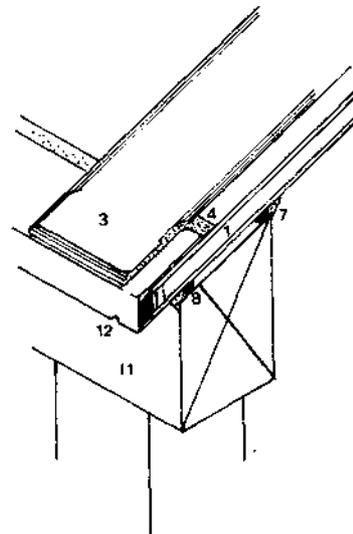


Figure 3.13:

Eave option # 2

GLASS EAVE:
SLOPED GLAZING TO VERTICAL GLAZING

GLASS EAVE:
LOWER EDGE SLOPED GLAZING

1. Insulated glass unit
2. Extra wide silicone sealant
3. Snapcap, bar and gasket
4. Silicone sealant
5. Continuous blocking
6. Flashing
7. Appropriate sealant
8. EPDM or neoprene tape
9. Rubber blocking
10. Lag bolt
11. Structural framing
12. Weep hole
13. End cap flashing

3.6 PRE-FABRICATED FRAMING SYSTEMS

Where pre-fabricated frames are the most useful is when a sunspace design calls for curved or complex profiles. Extruded aluminum frames are available in a wide range of shapes. Manufacturers have even managed to develop curved structural supports from wood. Builders and designers should contact sunspace kit manufacturers to learn about the various advantages and disadvantages among available sunspace kits.

A few sample details of extruded aluminum structural support and attachment details are shown in Figures 3.14 and 3.15.

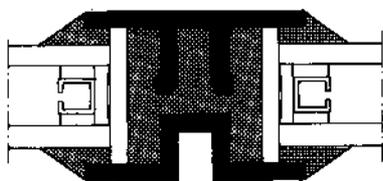


Figure 3.15: Aluminum Support Detail

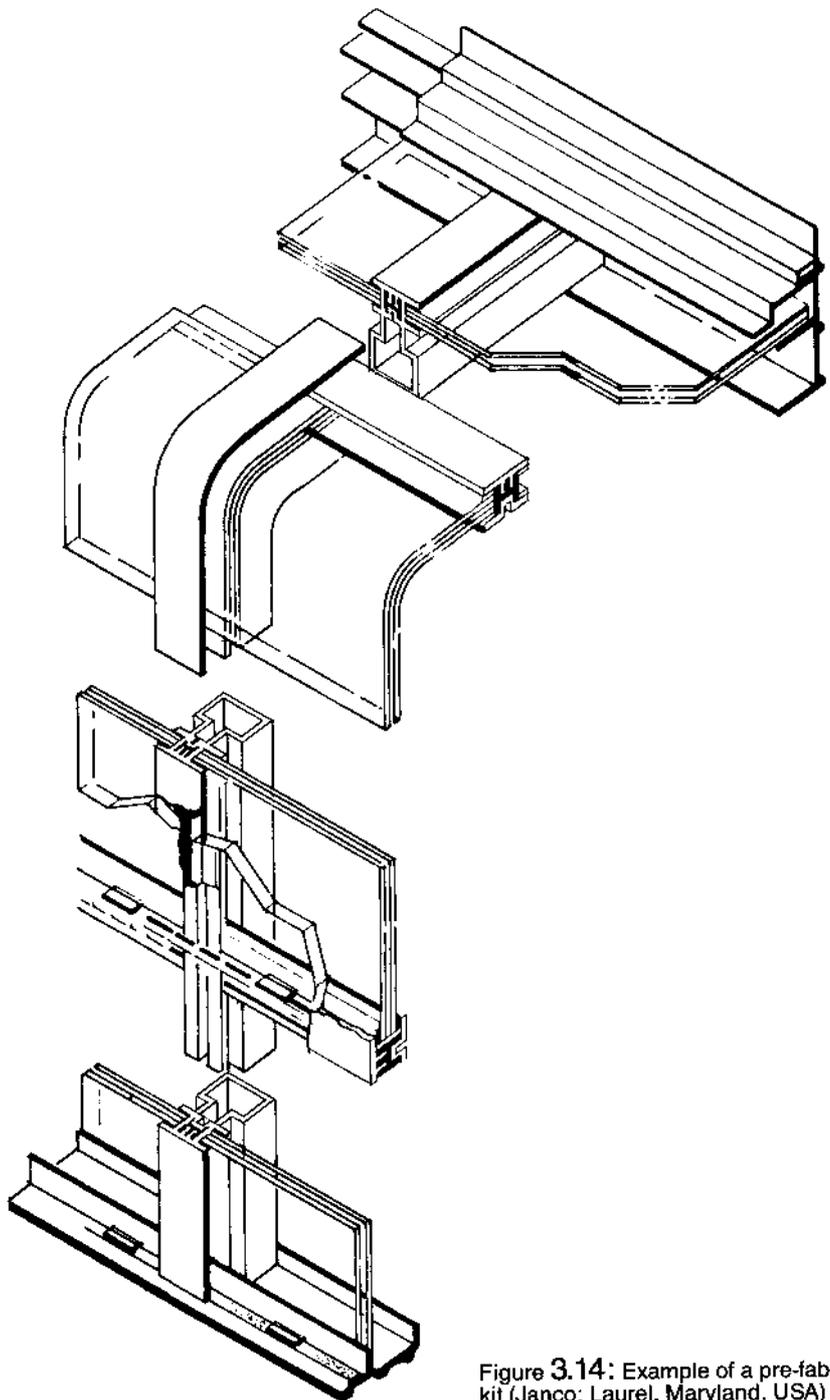


Figure 3.14: Example of a pre-fab kit (Janco; Laurel, Maryland, USA)

Some specific features to look for when selecting a pre-fabricated framing and glazing system are the following (reference no. 9):

1. It should have thermal breaks within the frame in order to reduce heat loss and minimize condensation or frost formation on the frame during the winter.
2. The frame should be designed to withstand the snow and wind loads present in the region where the home is built.
3. The frame should have condensation gutters on the interior of the frame, on both horizontal and vertical framing members. Ideally, the frame will allow any condensate that collects to drain down and then out by gravity, while still preventing air leaks through the drainage system. Water in the drainage channels should not be allowed to rest against the seals of double glazed units. Many manufacturers have managed to isolate their sill from the glass to protect the glass seals from moisture deterioration.
4. Built-in tracks should be present to guide interior shading or insulation systems (discussed later in this chapter).
5. To provide a clean interior or exterior appearance, several manufacturers supply cap bars that snap-on to hide all screws, bolts and fasteners. One has introduced a butt-glazed system that eliminates any need for horizontal glazing bars.

For clients who insist on including some overhead glazing, it is strongly recommended – especially with site-built designs – that the glazing be limited to the length of a single patio glass door or less (Figure 3.3). With this approach, rainwater will drain harmlessly off the glazing. Beyond that height, however, the attachment system normally includes horizontal glazing caps. Most pre-fabricated units will include some type of horizontal glazing gaps, even if the overhead glazing section is relatively short.

Where the roof is subdivided by horizontal glazing bars, each one forms a potential barrier to water. Without special attention to this detail, water will pond at points around the bottom of the glass and will in time cause leaks (Figure 3.16). Horizontal glazing bars in the roof must be designed so that water on the outside will not collect at the top of the bar but will drain away. Several possible solutions are:

- Select a glazing bar with an angled shape that minimizes the bar's tendency to form pools of water above it (Figure 3.17). This may cause minor problems at the junction of horizontal and vertical glazing caps. (Glass roofs normally have contiguous vertical members with the horizontal members inserted between them. The opposite is also possible but may give rise to a lot of difficulties in detailing the junctions.)
- Make sure the roof angle is no less than about 30°. The steeper the slope of the roof, the less likely the horizontal members will be to collect water.
- Apply silicone sealant above the glazing bar so that it bridges the junction between the glass and square members (Figure 3.18).

3.7 HORIZONTAL MEMBERS (reference no. 9)

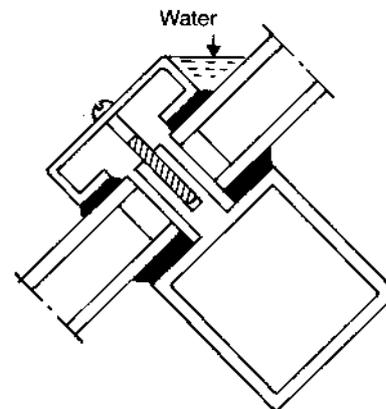


Figure 3.16: Horizontal framing

Water can build up at horizontal framing members.

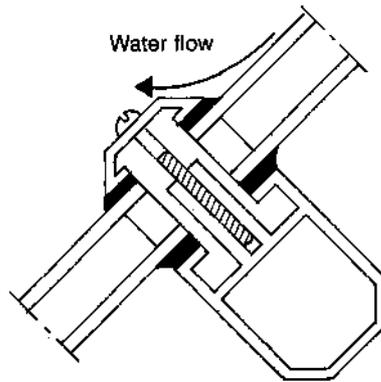


Figure 3.17: Horizontal framing

Correct shape of cover strip.

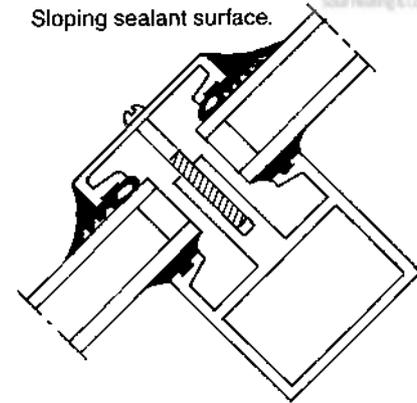


Figure 3.18: Horizontal framing

Beveled silicone bead can help prevent water damming.

3.8 INTERIOR DRAINAGE SYSTEMS (reference no. 9)

In sunspaces where humidity is high, there is always a risk that condensation will appear on both the glass and any metal frame during cold winter days. An assessment of the humidity level to be expected should be made at the design stage. In order to prevent condensation from dripping down into the sunspace, condensate should be collected in specially designed gutters or channels. The best way of removing the condensate is to lead the water from the collection channels into a vertical hollow framing member (Figure 3.19). Most manufacturers have a system which drains water from all the horizontal members into the vertical extrusions, which then carry the condensate down to the sill plate. Pre-fabricated sills should be sloped to force condensation out weep holes by gravity.

With pre-fabricated metal framed systems, be sure the system drains the interior of the horizontal glazing supports in order to prevent condensate from resting against the bottom of glass at this junction. If not drained away, this water might weaken the seals and cause leaks or fogged glass (Figure 3.20).

The dimensions of a drainage channel should be such that water will easily flow out the sides as the depth of water rises. The minimum width and depth are both 6 mm. If there is any deflection in the horizontal profile, the depth of the channel should be increased to 10 mm (Figure 3.21).

If drainage holes do not come pre-drilled in a manufactured sunspace, they should be drilled prior to assembly so that drilling during construction may be avoided. Any drilling during assembly runs the risk of detracting from the interior appearance or structural strength. Also the danger exists that metal shavings left inside the channels might block drainage holes.

CONDENSATION IN WOOD-FRAMED SUNSPACES

Where wood framing is used, occupants will tend to experience less overall condensation, since the frame itself loses heat much slower than a metal frame. However, in cold climates, the glazing is just as likely to develop condensation problems as the glazing in a metal-framed sunspace. If an occupant intends to furnish the sunspace and use it as a seasonal living area, 'indoor rain' from condensation in a wood-framed sunspace can cause a major problem.

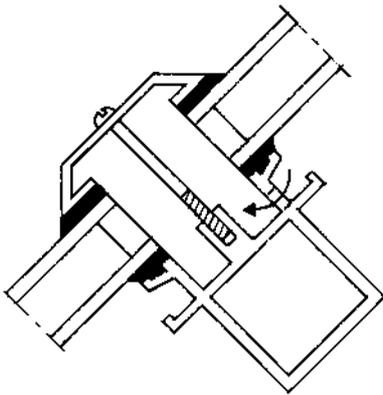
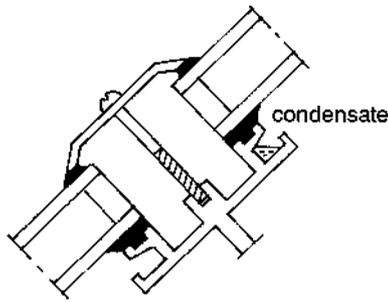


Figure 3.19a
Condensate drained into main drainage system.



Channels must be provided to collect the condensate.

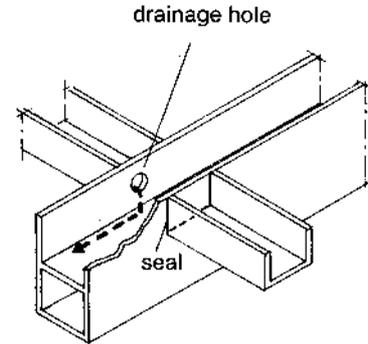


Figure 3.19b
Water should drain from the horizontal to the vertical members via drainage holes.

Four ways to reduce the problem are:

Provide condensate channels at the base of all glazing units-both sloped and vertical (Figure 3.22). These channels will collect condensate but will not drain it away. They must be sealed on the ends where they abut the vertical framing members. Furthermore, they must be large enough to collect condensate and store it until it can evaporate when the sun warms up the space.

Some manufacturers make wood-framed structural support systems that have a non-structural glazing attachment system both above and below the glazing itself. As with the all-metal systems, the glazing support beneath the glass offers the advantage of interior drainage channels. While this is a relatively expensive solution, it should significantly reduce the problem of dripping condensation.

Another reliable way to reduce problems associated with 'raining condensation' is to use a low-emissivity glazing product. Since it keeps the inner glass surface warmer, low-E glass stops condensation at the source. It takes a considerably lower outdoor temperature for condensation to form on low-E glass than on standard double glazing. Low-E glass will add to material costs.

- The last and least expensive solution is to either reduce or eliminate sloped glazing. If the glazing area eliminated would have been at a shallow slope (under a 40-50° angle), overall energy savings will be relatively comparable.

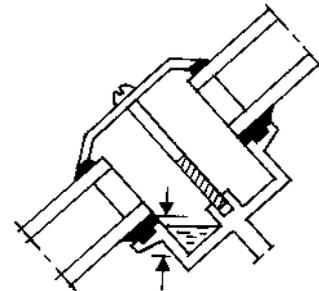


Figure 3.20
Water in the drainage channel must not come into contact with the seals on the inside.

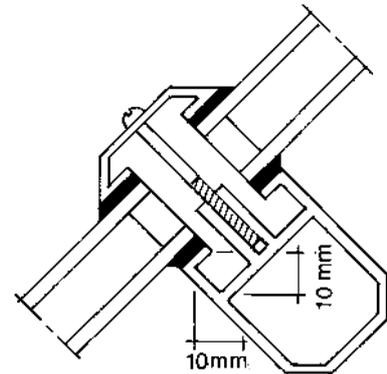


Figure 3.21
It is essential that the drainage channel has adequate depth.

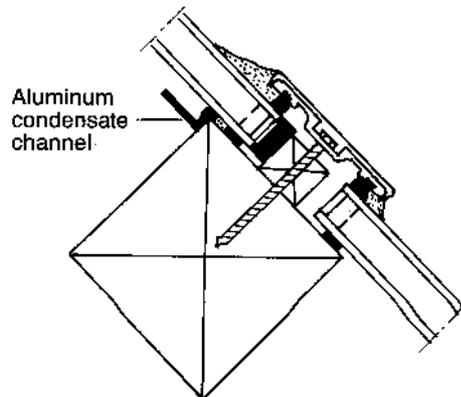


Figure 3.22
When using horizontal wood framing members, put in aluminum angle as a condensate channel; seal the two ends with silicone, and place a bead between the silicone and the glass.

3.9 COMBINING GLASS AND INSULATED ROOF SECTIONS

When a roof is partially glazed in a snowy climate, it is recommended that the sloping glazed portion of the roof be located below the insulated portion rather than above it. If the reverse is true, serious problems can develop. Typically, meltwater from the glass roof will freeze as soon as it reaches the insulated roof (Figure 3.23). The ice can grow into large ice ridges that prevent water from draining off the roof. In turn, this can give rise to high stresses in all external seals around the panes of glass and in the load bearing structure.

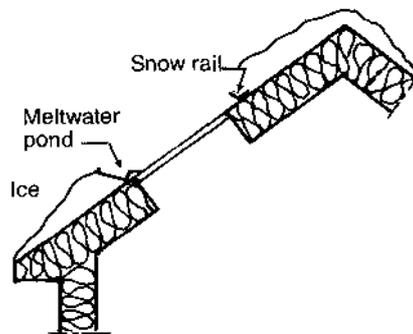


Figure 3.23

The combination of a glass roof and an insulated roof beneath it can easily give rise to problems.

Heating cables installed in the roof are an expensive solution. A better approach is to avoid the design problem in the first place. Where a design requires that light or heat be brought into the back of a sunspace, using curved skylights instead of flush-mounted glazing will reduce the problems related to ice damming.

Sunspaces built in mild climates are not hampered by this particular constraint. However, sloped glazing should be minimized in milder climates, since it exacerbates summer cooling problems.

3.10 NIGHT INSULATION

Installing night insulation in a site-built sunspace can be a difficult task. Movable insulation is relatively easy to install in a pre-fabricated metal framed sunspace that is equipped with built-in tracks. However, night insulation is expensive in either pre-fabricated or site-built applications. The resulting energy savings and improvement in solar performance are less significant than they are for direct gain systems within the heated dwelling. The only reason to justify installing movable insulation in a sunspace is if interior comfort at night is important.

The type of movable insulation most suitable for use in a sunspace with sloped glazing is roll-down shades. Unfortunately, the most frequently used material - quilted fabrics - can cause problems. Fabrics can absorb moisture from condensation, yet they have no way to dry out, since they are stored in rolls during the daytime. There have been well-documented cases of mold and mildew ruining quilted fabric shades. The most moisture-resistant roll-down material in a sunspace consists of multiple layers of reflective foil.

To improve overall performance and interior comfort, a better strategy than using movable insulation is minimizing heat losses. Builders should use a good quality frame and low-emissivity glazing. As mentioned previously, low-E glass will also reduce condensation problems. Another step to consider is the use of low-E windows filled with an insulating gas. Argon gas between glazings will reduce heat loss as effectively as triple glazing.

LOW-E GLAZING

A sunspace requires thermal mass to store sufficient heat to keep it from getting too warm on sunny winter days or too cold on freezing nights. The rest of the solar gains collected during the winter can be used to heat the adjacent living areas.

3.11 STORING AND DELIVERING HEAT TO THE HOME

The easiest place to store heat in winter is in a mass floor. The options include a bare concrete slab, a tile or brick finish over a concrete floor, or bricks laid on dry sand. A very costly option used in the past – a block-bed or rock-bed under the primary slab floor – proved ineffective and should be avoided.

FLOOR STORAGE

The important energy issue facing the builder is how to insulate the heat-storing floor. Two techniques are possible. Perimeter foam insulation can be used either inside or outside the sunspace foundation (Figure 3.24). It should extend down to the frost line. Alternatively, insulation can be placed under the floor, along with a short piece of insulation between the foundation and the slab (Figure 3.25). Insulating under the floor makes the most sense if the water table is high, the slab rests on bedrock, or the climate is very cold. The performance difference between the two is likely to be relatively small, which means the option chosen may be more a matter of builder cost and convenience.

FLOOR INSULATION

One way to both deliver heat to the home and store more heat for use within the sunspace is to use thermal mass in the connecting wall. The most common type of storage wall is made of solid masonry, usually 15 to 25 cm in thickness (Figure 3.26). For more detailed consideration of sizing, see Booklets 2 and 3.

COMMON WALL STORAGE

Construction issues relating to a masonry common wall are similar to those describing masonry partition walls for a direct gain system (Section 2.3.):

- The masonry wall will require a more substantial footing than a light frame wall.
- The masonry must be solid. If concrete blocks are used, the cavities should be filled with grout. When walls are built with two wythes of brick, the finger space between them must be grouted.
- Any finish material added to either side should be highly conductive, such as plaster.
- The wall surface facing indoors can be any color. More heat will be stored in the wall and delivered to the adjacent living space if the sunspace side of the wall is a moderately dark color. This is particularly true if the connecting mass wall is directly struck by the sun's rays.

To prevent the home from getting too cool on winter nights and too warm on summer days, sunspaces are separated from the adjacent living

DELIVERING WARM AIR IN WINTER

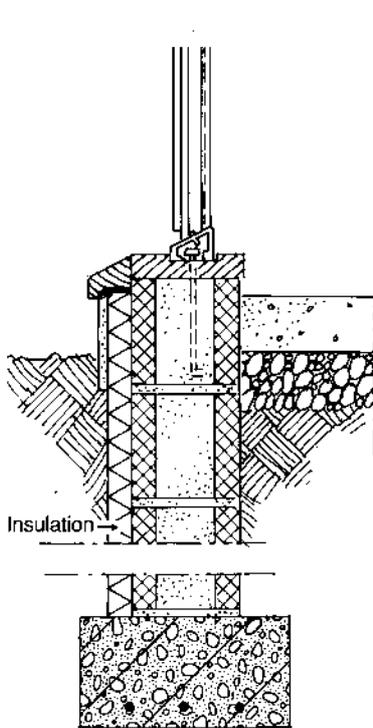


Figure 3.24
Foundation Insulation can be put either inside or outside the foundation wall.

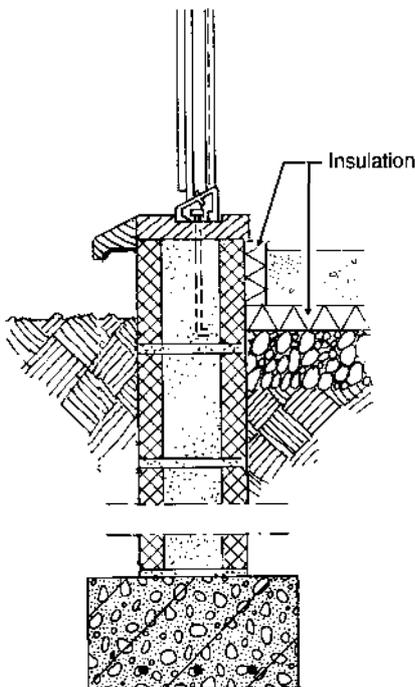


Figure 3.25
Insulation beneath the floor and at the slab edge is another option.

Mass wall between sunspace and house should be grouted solid.

Any finish applied to the wall must be highly conductive.

Interior surface can be any color.

Exterior color should be moderately dark, as should floor color.

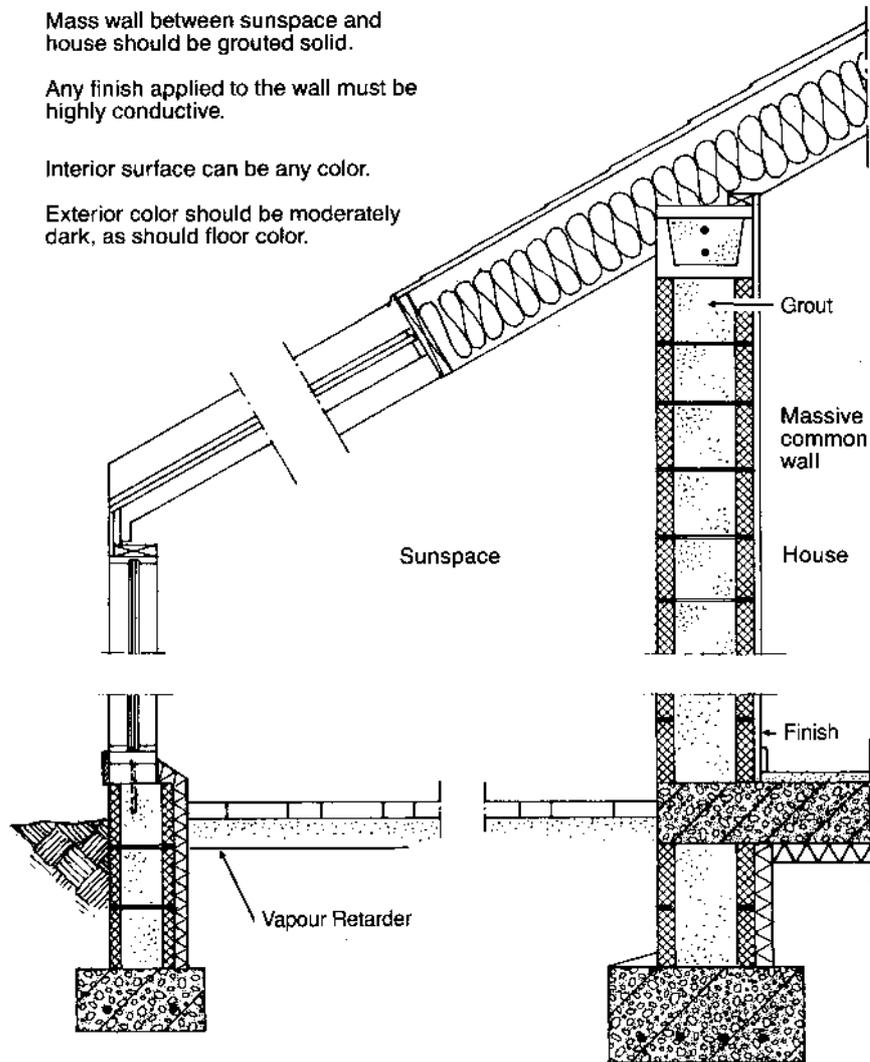


Figure 3.26

spaces. Yet since the sunspace will usually collect more solar energy than it can use, some provision must be made to move the excess warm air – often between 25 and 35°C – into the home.

The ideal circulation system between the sunspace and house works naturally. Windows and doors between the sunspace and home allow warm air high in the space to move into the home. Cooler air is drawn in at floor level. This approach requires a very conscientious and ever-present occupant to work effectively. If doors and windows are opened too soon in the morning or not at all during the day, or closed too late in the evening, valuable heat is wasted.

The mass common wall described above will help solve this performance problem. A less expensive solution involves the installation of a moderately sized fan or blower. When wired to a thermostat, the fan can be set to automatically move air from the sunspace into the home whenever the sunspace is warm enough (Figure 3.27a).

Several features which a builder should install with such a warm air circulation system are listed below (Figure 3.27a):

- A quiet fan with adequate air movement capacity. As a rough rule of thumb, the fan should have a 1.5 to 3 L/s rate of air flow. Sunspaces with large amounts of mass can use the smaller sizing ratio. The fan can be put in one of three different locations:
 - * in the wall between the house and sunspace;
 - * in a duct in the basement or crawl space that is pulling air from the cool side of the house and that pressurizes the sunspace;
 - * in a framed duct high in the sunspace that takes warm air and dumps it on the cooler north side of the home.

- An automatic cooling thermostat. The thermostat should have an operating range between roughly 15 and 30°C, and should have a differential of 2°C.

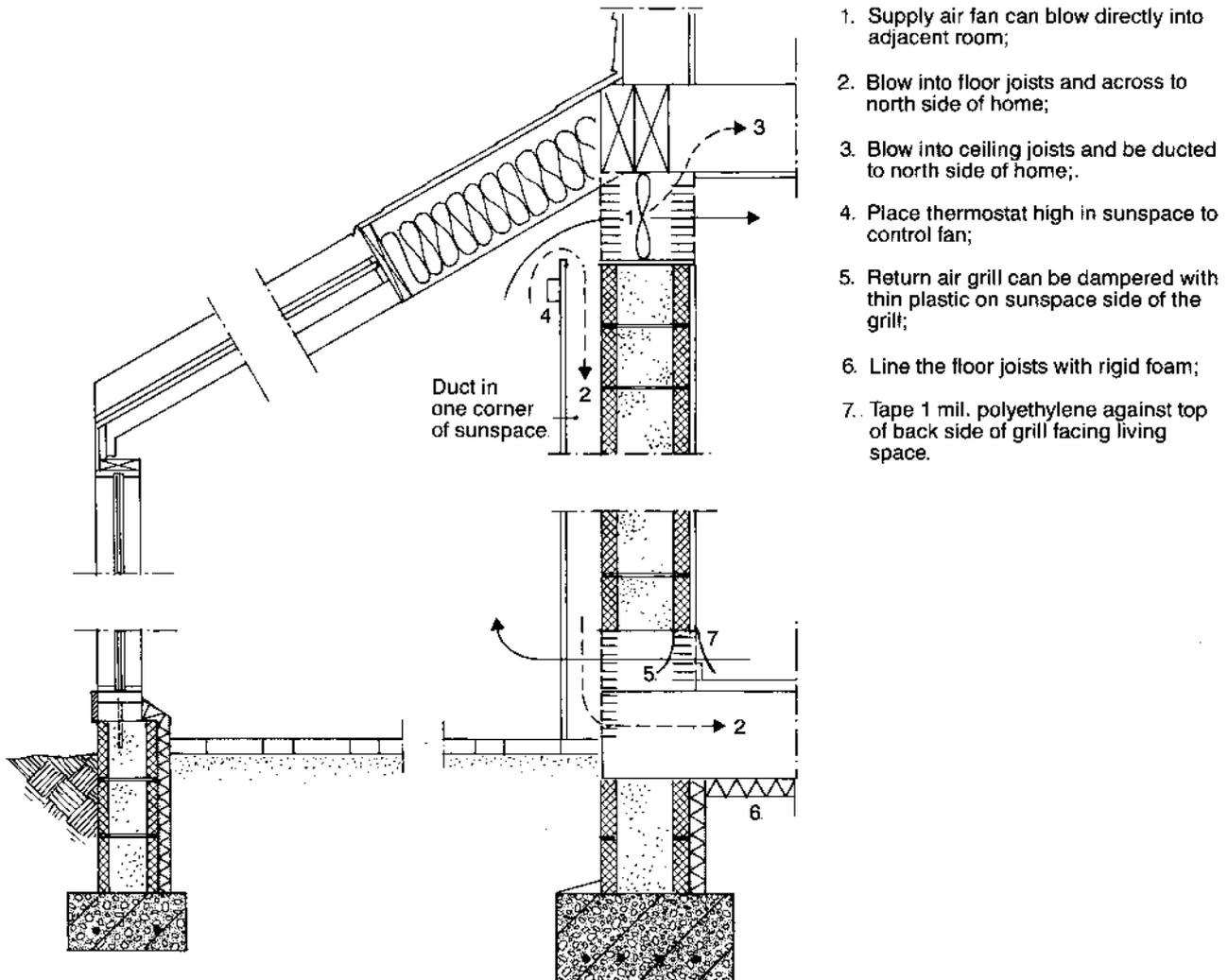


Figure 3.27a: Fan-forced warm air circulation from sunspace into the home.

- An on-off switch that allows the system to be shut down either daily or seasonally.
- A return-air opening in the wall (or duct from the north side of the home). This opening, too often overlooked in the past, is an essential item. Without it, colder outdoor air will be pulled in through cracks in the sunspace walls, and the fan is likely to fail much sooner. To prevent reverse air flows at night, the return air grill can be automatically dampered by taping a very thin plastic film across the sunspace side of the grill.

A number of sunspace kit manufacturers offer a warm air circulation package specifically designed to fit their framing system. Builders should compare its price and features to assure it provides them with adequate circulation capacity and options.

3.1 2 VENTILATION FOR COOLING

All sunspaces require ventilation during the summer. Openings are needed to exhaust air once the sunspace temperature exceeds either the indoor comfort level or the ambient air temperature.

An operable window is the most important ventilation feature in a sunspace. When patio glass door units are used as vertical solar collectors along the south wall of a site-built sunspace, the most convenient location for operable windows is usually on the east and west end-walls. For south facing sunspaces with vertical glazing, this is often all the ventilation that is required.

In a sunspace with sloped glazing, solar radiation can generate extremely high temperatures during much of the spring, summer and fall. Added ventilation capacity will be needed; natural ventilation by itself will rarely be adequate. To boost ventilation, the two primary options to consider are roof openings or exhaust fans.

ROOF VENTILATION

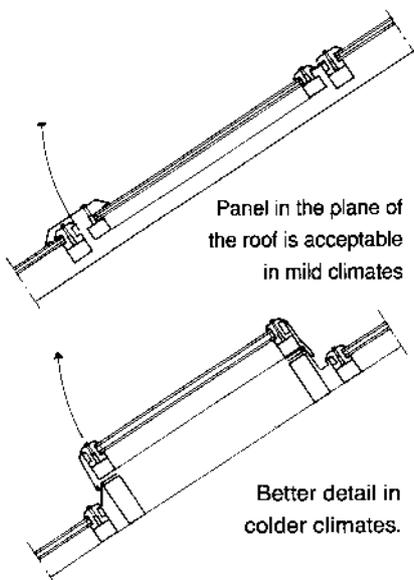


Figure 3.27b: Openings in glazed roof

Openings in the roof may be either smaller operable skylights distributed over the surface of the roof or large operable sections of the glazed roof itself. Both approaches tend to be expensive. However, the advantage they offer over windows at ground level is that they induce a draft by creating a stack effect.

In mild climates, operable roof panels which are mounted flush with the rest of the glazing may be acceptable. But in cold climates, the operable skylights or roof panels should generally project above the surface of the roof in order to provide watertight and reliable junction details (Figure 3.27b). These joints must be protected so that water will neither leak into the building nor rest against the seal around the doubleglazing.

Where smoke vents must be provided, these and ventilation openings are usually combined. In the event of fire, control is automatic, while for ventilation it is manual. In larger buildings motorized operation using a worm drive is the most common.

When occupants are away from the home for an extended period of time they may be reluctant to leave sunspace windows open. Their concerns may range from worries about security against thieves to protection against rain damage. Exhaust fans offer an automated solution. An automated exhaust fan will also take over the ventilation function if an occupant at work one summer day suddenly realizes he simply forgot to reopen his sunspace windows after a storm the night before.

EXHAUST FANS

Features a builder should include when adding an automatic exhaust fan are as follows:

- An adequately sized fan, preferably with operable louvers and mounted in aside wall. Where there is a considerable amount of sloped glazing, the fan should be sized to provide 10 to 15 air changes per hour of ventilation.
- An exhaust thermostat with a differential of at least 2-3°C plus an operating range between 25 and 50°C.
- Screened and louvered vents low on the opposite wall from the fan. The vents must be able to be insulated and sealed tightly during the heating season.

A number of sunspace kit manufacturers offer optional power exhaust systems. Their main advantage is that the fan often comes pre-installed in a side-wall panel.

Shading devices are usually unnecessary for the vertical part of sunspaces. By contrast, shading devices are essential in sunspace designs which include a large amount of overhead glass. A summary of the various products available – along with a listing of features, advantages and disadvantages – is provided in Figure 3.28.

3.13 SHADING

Shading devices fall into four general categories: exterior devices, products between layers of glass, coatings directly on glass, and materials mounted on the interior. The most effective shading devices are those on the outside of the glazing.

Unfortunately, many exterior devices are made of fabrics which are susceptible to UV degradation and hail damage. Fabrics manufactured for durability can be as expensive as glazing materials, exclusive of any mounting hardware. An airspace is needed between the glass and exterior shading device in order to operate as designed and prevent thermal shock to the glazing below.

EXTERIOR SHADING DEVICES

Exterior devices that can be operated on a daily rather than a seasonal basis allow the occupant the opportunity to enjoy the open feeling provided by overhead glass. Yet, operable exterior shading devices tend to be expensive and must be securely attached in order to avoid wind damage and to continue operating as designed.

A few pre-fabricated kits offer operable venetian blinds between panes of double glass. To avoid causing thermal shock to the glazing, builders should make sure that one side of the blind is highly reflective.

SHADING BETWEEN DOUBLE GLASS

| | Mobile | | | | |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | outside | | | | inside |
| | | | | | |
| designation | sloping - vertical awning | telescopic stay awning | slats (roller blinds) | slats (revolving) | infrared reflection sliding panels (or raising devices) |
| material | synthetic fabric | synthetic | wood | aluminum | coated synthetic foil |
| sunshading effect | moderate - good | moderate - good | moderate - good | moderate - good | moderate - good |
| operational effort | manual: high electr: slight | high slight | high — | moderate slight | high slight |
| max. dimensions | width of awning max. 350 cm | telescopic stay length 350 cm | standard width 90, 100, 140, 160, 180, 200 cm | width of slats 150-170 cm | width of sliding panel raising device |
| cost (manual) | high | low | moderate | high | moderate |
| min. slope | 30° | 5° | 10° | 0° | 15° |
| advantages | - combination of sloping and vertical awning with mechanism | | - 'natural' solution | - very good distribution of light in sloping position - setting of the slats for more sun radiation | - not subject to weather influences - reduces glare |
| disadvantages | - danger for damage in the case of absence; can only be automated at high control technology expenses (storm/snow damage) winds are a problem; all are expensive | | - only manual operation | - strip shadow pattern in open position | - strong reflection (outside) - expensive - can cause thermal shock if the airspace is not properly vented (can break the glass) - blocks view/light source. |

Figure 3.28: Shading for sunspaces (reference no. 10)

INTERIOR SHADING DEVICES Mounting shading devices on the inside is the most common but least effective approach. It is essential to ensure that the shading device is quite reflective and that adequate air circulation between glass and shade is provided. This will ensure that the glass does not become too hot. Numerous instances have been reported of damaged glazing where heat was allowed to build up between the glass and interior shading device.

A last sunspace shading system relies on coated or tinted glass. The major tradeoff here is that coated glass blocks out desirable wintertime sun as well as the unwanted summer sun. However, it is the least troublesome and most reliable approach.

To summarize the obvious, the most effective way to shade overhead glass in a sunspace is to minimize its use and rely on vertical glazing, which is more easily shaded, for solar gains.

At present the most common sunspace collector material is glass. However, materials other than glass – such as acrylics and polycarbonates may also be used.

3.14 GLAZING

The advantages and disadvantages of various glazing products are presented in Figure 3.29. Each can be used in combination with any of the other materials to maximize their respective best qualities. For example, the roof of the sunspace might be glazed with double-wall acrylic because of its ease of handling during construction, while the vertical portion might be standard glass to provide a excellent durability and the best view to the outside.

ADVANTAGES,
DISADVANTAGES

| | advantages | disadvantages |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GLASS | <ul style="list-style-type: none"> ○ excellent selective transmission ○ transparant ○ good weatherability ○ heat, air-pollution and UV-resistant ○ low thermal expansion ○ inexpensive in standard sizes (e.g. patio glass units) | <ul style="list-style-type: none"> ○ expensive in custom sizes ○ breaks easily ○ heavy ○ often difficult to install in large sheets |
| ACRYLIC | <ul style="list-style-type: none"> ○ high optical clarity, strength and weatherability ○ light weight and easy to handle ○ impact resistant ○ insulation and transmission similar to glass | <ul style="list-style-type: none"> ○ expensive ○ prone to surface abrasion ○ buckles and cracks if not properly installed ○ significant expansion and contraction characteristics ○ will sag at high temperatures |
| POLY-CARBONATE | <ul style="list-style-type: none"> ○ very high impact strength ○ similar solar transmission | <ul style="list-style-type: none"> ○ scratches easily ○ not rigid ○ becomes brittle and changes color after prolonged exposure to the sun (especially at high altitude) |
| FIBER-GLASS | <ul style="list-style-type: none"> ○ low cost, easy to handle ○ high strength and durability with coatings such as Tedlar ○ available flat or with corrugations | <ul style="list-style-type: none"> ○ solar transmittance reduced when UV coatings are added ○ will yellow and 'blossom' without coatings (esp. at high altitude) ○ short lifespan |
| POLYESTER FILM | <ul style="list-style-type: none"> ○ low cost ○ high surface hardness | <ul style="list-style-type: none"> ○ medium lifespan ○ UV degradation if not coated ○ relatively high longwave transmittance |
| POLY-ETHYLENE FILM | <ul style="list-style-type: none"> ○ very inexpensive ○ light, flexible, easy to install ○ good inner glazing properties | <ul style="list-style-type: none"> ○ short lifespan (less than one year) ○ poor resistance to longwave radiation ○ wind and temperature can cause sag |
| POLYVINYL FLUORIDE FILM | <ul style="list-style-type: none"> ○ excellent weatherability and strength ○ high solar transmittance ○ can be bonded to fiberglass as a UV resistance screen | <ul style="list-style-type: none"> ○ expensive ○ available only in thin films ○ relatively high longwave transmittance |

Figure 3.29: Glazing advantages and disadvantages (reference no. 5)

PHYSICAL PROPERTIES

The physical properties of different glazing products are summarized in Figure 3.30. To cite one energy-related example, the U-value of acrylic, polycarbonate and fiberglass do not differ that much from that of glass. As for the stability requirement, builders should be aware that the thermal expansion properties of both acrylic and polycarbonate are about 10 times as large as that of glass; in the case of fiberglass it may be 5 times the value of glass. With a temperature variation of 50°C (such as from -10°C to +40°C) and for every meter of length, the maximum thermal length change would be:

| | |
|---------------|---------------|
| glass | 0.4-0.45 mm/m |
| acrylic | 4-6.5 mm/m |
| polycarbonate | 5-7.5 mm/m |

Builders should carefully consider the maximum operating temperature of the glazings that are purchased. For example, acrylic is limited to 85-95°C and polycarbonate can operate between 100-150°C. The expected life span of synthetic materials is also considerably shorter than that of glass.

| | Conductance or U-value (W/m ² K) | Thermal expansion temperature m/mK (x10 ⁻⁶) | Maximum operating temperature (°C) | Estimated lifetime (years) | Solar transmission (percent) |
|----------------------------------------|---------------------------------------------|---------------------------------------------------------|------------------------------------|----------------------------|------------------------------|
| GLASS | | 8-9 | 200 | | |
| Single Glazed Float Glass | 6.4 | | | 25+ | .91 |
| Double Glazed Float Glass | 3.0-3.7 | | | 15+ | .77-.85 |
| ACRYLIC | | 80-130 | 85-95 | 10-20 | |
| Plexiglass (Rohm & Haas) | 6.0 | | | less at high altitude | .90 |
| Lucite (Du Pont) | 6.0 | | | | .92 |
| Exolite (CY/RO) | 3.3 | | | | .83 |
| POLYCARBONATE | | 60-70 | 100-150 | 15 | |
| Lexan (G.E.) | 6.0 | | | 11 | .81-.89 |
| Tuffack Twinwall (Rohm & Haas) | 3.5 | | | | .77 |
| Cycrolon SDP (CY/RO) | 3.3 | | | | .74 |
| FIBERGLASS REINFORCED POLYESTER | | 25-40 | 110-170 | 10-20 | .86 |
| Lascolite (Lasco Industries) | 4.2 | | | 11 | |
| Filon w/Tedlar (Vistron Corp.) | 5.4 | | | | |
| Sulite Premium (Kalwall) | 3.1 | | | | |

Conductance (U) - The reciprocal of resistance, $1/R=U$ (W/m²K). It represents the thermal transmission per square meter of a particular material or assembly per degrees K of temperature difference between its inside and outside surfaces.

Solar Transmittance - The ratio of the total transmitted flux to the total incident flux.

Figure 3.30: Glazing: physical properties (reference no. 5)

One established feature where glass has a clear-cut advantage is in energy control coatings. Different low-emission coatings can be selectively used for different orientations in a way that can dramatically reduce undesirable heat losses and heat gains. For example, builders can significantly reduce the cooling problem inside a sunspace by using low-transmission glass in overhead applications, moderate-transmission glass facing east and west, and high-transmission glass facing south. All three can come with U-values as low as 1.2 to 1.3. Architects and builders are encouraged to obtain the insulating and solar transmission properties of low-E products of the various manufacturers.

LOW-E COATED GLASS

The space between double-glazing can be filled with an inert gas. Adding a gas like Argon between the glazing will reduce heat loss by conduction and reduce the chance of condensation on the glass surface.

GAS-FILLED GLASS

A gas filling can improve the U-value of a good low-E window to 1.6. Using gas in an airspace does not affect solar transmission.

All collector installations need to be carefully caulked and sealed. To aid in the selection of appropriate products, the major construction sealants used in collector construction and their performance characteristics are listed in Figure 3.31. The materials that are good to excellent as to their elongation, life (20+ yrs.) and resistance to UV are urethane, silicone and polysulfide; all others have shorter life spans.

3.15 SEALANT AND CAULKING

Silicone caulk has been frequently recommended in this Booklet as an appropriate sealant. However, builders should be aware that not all silicone caulks are the same. Check each one for its compatibility with other materials.

Materials used during assembly must be able to stand up to the climatic stresses to which they are subjected during construction. This applies to rain and snow in particular. Adhesives and other sealants which may be used must offer satisfactory adhesion even to a moist base. It is unrealistic to assume that construction will take place only during good weather.

3.16 ASSEMBLY

Caulking

| Name*) | Cost** | Adhesion | Elongation (%) | Life (yrs.) | Cont. Service Temp. (°C) | Resistance to UV |
|----------------------|---------|---------------------------|----------------|-------------|--------------------------|------------------|
| Urethane | 100-150 | Excellent | 300-450 | 20 + | -50 to 135 | Good |
| Silicone | 150-200 | Good (excellent w/primer) | 100-200 | 20 + | -60 to 205 | Excellent |
| Acrylic Terpolymere | 150-200 | Excellent | | 20 + | 85 max. | very good |
| Hypalon (1 part) | 100 | Very good | 15-50 | 15-20 | -20 to 110 | Good |
| Polysulfide (1 part) | 100-200 | Excellent | 200-350 | 20 + | -50 to 120 | Very good |
| Butyl Rubber | 50-100 | Very good | 75-125 | 7-10 | -40 to 135 | Fair |
| Acrylic Latex | 50-100 | Excellent except w/metal | 75-125 | 2-14 | -30 to 100 | Fair |
| Oil | 50 | Fair - Good | 5 | 1-7 | -25 to 85 | Poor |

** All costs stated relative to the cost of Urethane =100.

| Name*) | Shrinkage Free | Cure time (days) | Paint | Thinner | Use Primer On |
|---------------------|----------------|------------------|-----------------------|-------------------------------|---------------------------------|
| Urethane (1 part) | Excellent | 14 | If desired | MEK, acetone, lacquer thinner | Not required |
| Silicone | Excellent | 5 | Possible Difficulties | Paint thinner naphtha, toluol | Not required |
| Acrylic Terpolymere | | | | | Not required |
| Hypalon (1 part) | Good | 60-180 | If desired | Toluene, xylene, xylo | Not required |
| Polysulfide | Excellent | 4-7 | If desired | TCE, Toluene, MEK | Special primer on all but metal |
| Butyl Rubber | Fair | 7 | Recommend | Paint thinner, naphtha | Not required |
| Acrylic Latex | Fair | 3 | Recommend | Water | Porous surfaces |
| Oil | Fair | 120-360 | Necessary | Paint thinner | Porous surfaces |

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*) Specific product material properties may vary from those listed in this table. Consult manufacturers literature for specific information.

Figure 3.31: Characteristics of caulking (reference no. 3)

The collector component in a thermal storage wall is usually south-facing glass placed directly in front of a solid masonry wall that serves as the storage component. Other materials occasionally used for heat storage include water containers and phase-change materials. In this discussion, we will focus primarily on configurations which use solid masonry for heat storage.

4.1 GENERAL

In a thermal storage wall, the collection, absorption, storage and control of solar energy occur adjacent to rather than directly within the living space. The heat stored in the wall is conducted through to the living space several hours later. If a thermal storage wall has been designed properly, it will supply heat to the living space at night when the dwelling's heat loss is highest and its heating need is the greatest.

Some of the heat generated in the air space between the glazing and storage wall is lost back out through the glazing. The hotter the air in the cavity, the greater the loss. The warm massive material next to the glazing will also radiate heat to the glass at night.

Three ways to minimize these losses and improve performance are (1) warm air can be vented into the adjacent room during the daytime; (2) movable insulation can be used between the mass and glass at night; or (3) a special coating can be added to the surface of the thermal storage material. Experience shows that use of the selective surface coating – one that absorbs a large percentage of solar radiation and has very little radiation – when properly applied, is the most cost-effective way to improve thermal storage wall performance.

In a vented system, heated air enters the living space at roughly 30 to 45°C. The removal of this heat from the airspace reduces the amount of heat stored within the wall itself (Fig. 4.1a).

VENTED VS. STAGNATING WALLS

The delay between the time when sunlight first strikes the unvented or stagnating storage wall and the time when the heat has finally traveled through the wall and reached the living space is called a time lag. Depending on the thickness and thermal properties of the various wall materials, this lag period can be from eight to twelve hours. In a vented thermal storage wall, also known as a Trombe wall, this time lag still occurs, but some of the heat is short-circuited by vents that provide heat to the living space throughout the day.

Builders are encouraged to build unvented thermal storage walls (Figure 4.1.b). Venting does not significantly improve winter performance. Also, dust and insects can collect between the wall and collector, creating an eyesore which usually cannot be cleaned without removing the glazing. Venting also requires the installation of dampering devices that the occupant must adjust at least seasonally and possibly even daily.

If the climate is cold enough to require daytime heating, the best way to supply it is by combining some direct gain windows with the thermal storage wall system (Figure 4.1c). This eliminates a number of problems for both the builder and the occupant. In moderate climates, where daytime heating may not be as important as nighttime heating, an unvented system – with or without direct gain windows – is preferable. However, daylighting potential is reduced. Therefore, a combination of direct gain windows and a thermal storage wall is preferred.

COMBINING DIRECT GAIN AND STORAGE WALL

THERMAL STORAGE WALL

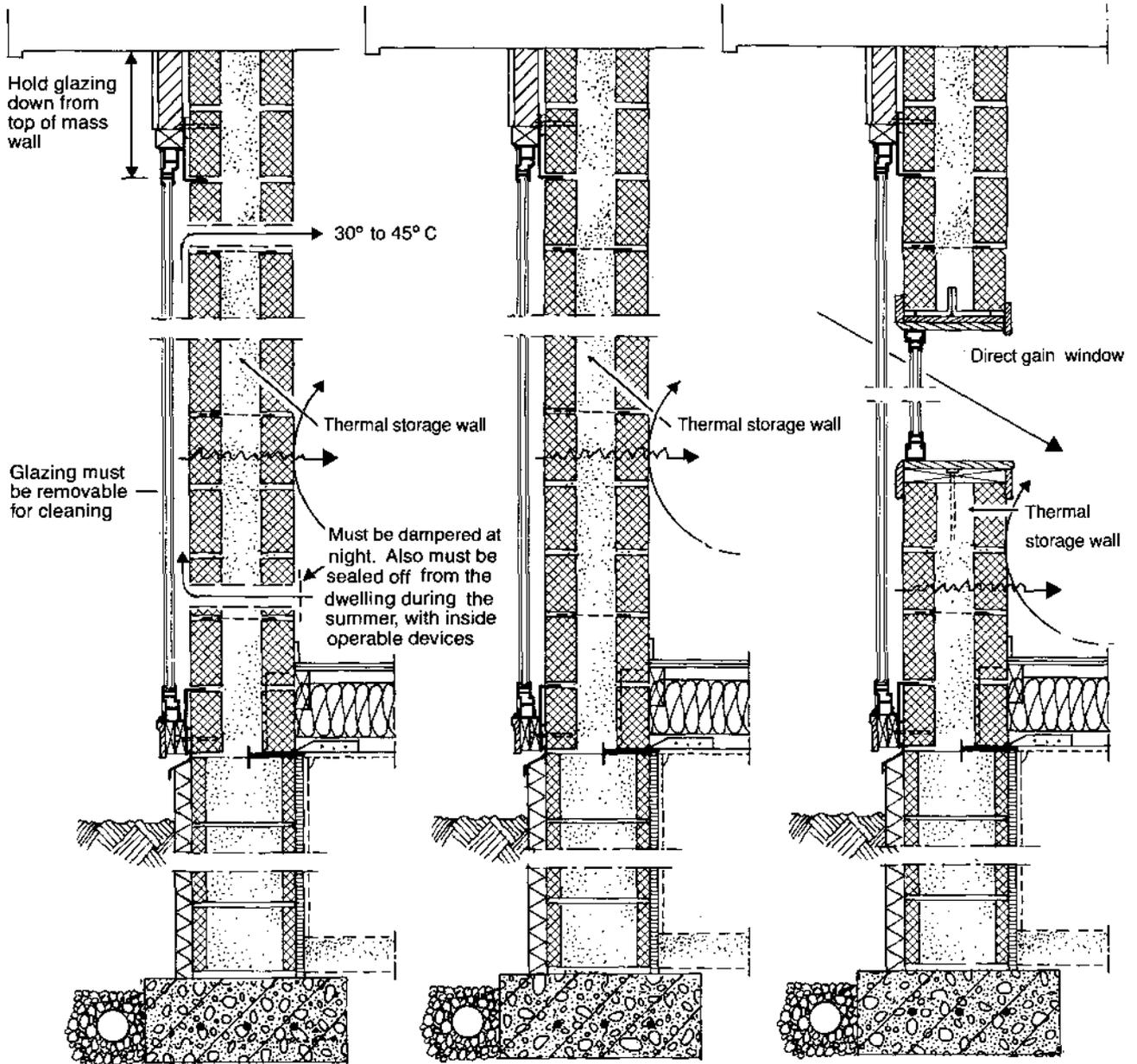


Figure 4.1a
Vented thermal storage wall causes visual/maintenance problems

Figure 4.1b
Unvented thermal storage wall is a better option

Figure 4.1c
Best option is to add some direct gain windows in the thermal storage wall

4.4 FRAMING MATERIALS

Wood and metal are the two types of material used to build frames for storage wall glazing. While neither material is ideal, metal frames are the recommended choice.

WOOD FRAMING

Wood framing has been used successfully in thermal storage walls for a number of years in the hot and dry climates of the southwestern United States. It is easier and less expensive to work with than metal frame material. The mullion details are similar to sunspace site-built glazing details described in the previous chapter (Figures 3.6, 3.7, 3.8).

However, wood framing in thermal storage walls can dry out and become so dry and so hot that within a 10-30 year time frame, it may become a fire hazard. On a sunny winter day, air temperatures inside a thermal storage wall can reach 70°C, while the temperature inside framing members can actually be higher. There have been several documented cases of fires which have been started in storage wall frames. Builders who choose to use wood in their frames should use kiln-dried lumber. Green wood can release material that may cloud up to the collector surface. Green wood is also more susceptible to warping.

METAL FRAMING

The two significant advantages with metal framing are durability and safety. Its major disadvantages are that it expands and contracts more than wood framing, it is a higher source of heat loss at night, and it is generally harder to work with and more expensive than wood. Yet the durability and safety issues tend to outweigh these disadvantages.

Metal frames can be either built and assembled on site or purchased as a pre-fabricated kit. However, not many manufacturers advertise and sell pre-fabricated kits for thermal storage walls. Builders are likely to have to design their own metal frames (Figure 4.4 and 4.5) and then either make it themselves or contract with a local metal fabricating shop.

Whenever possible, metal frames should be insulated or have a thermal break. This is especially important around the perimeter of the frame. High-temperature fiberglass can be used as a liner around the inside. The ideal situation is when a home's exterior walls are all masonry and the home has outside insulation covering everything but windows and the glazed thermal storage area. In this case, exterior insulation can be wrapped around the frame, then flashed along the top and either covered with trim or matching finish materials along the sides and bottom.

When metal frames are used, builders must be aware of the expansion characteristics of the metal they select. Typical materials used include steel 'L' brackets as the base, side and top pieces, plus metal studs for backing supports. Great care must be taken to ensure that the glazing does not directly touch the metal. Rubber blocking should be placed beneath the glass, and neoprene or EPDM tape or gasketing should be placed around all edges of the glazing.

Regardless of whether wood or metal framing is used to support the collector material, two guidelines should be followed by builders. First, they should minimize the amount of framing used in order to expose more of the storage wall to solar radiation. Second, the material used to attach the glass to the frame should be metal. While gasketed aluminum glazing bars cost more than wood, they require virtually no maintenance and are more likely to prevent problems with air or water leakage.

The framing which holds the collectors can be either directly attached to the storage wall (Figure 4.6) or placed on a portion of the foundation wall (Figure 4.7). When the latter approach is planned, the shelf on the foundation wall will have to protrude roughly 10 cm, in order to accommodate the glazing and necessary framing materials. Both approaches will work.

ATTACHED VS. DETACHED
FRAMING

Any paint, caulking or sealants used in the frame should be resistant to high temperatures. When selecting caulking materials, builders should select products that can also maintain their seal despite the expansion and contraction within or around the collector. This requires that a builder carefully review available sealants and probably select the more expensive products such as silicone caulk rather than acrylic latex caulk.

SEALING

The storage wall component can be made of any material that has a high heat capacity and high conductivity. The most commonly used materials are all masonry: core-filled concrete or clay block, a concrete block and brick combination, poured concrete or multicourse brick. In a properly sized wall, these materials all gradually release collected and stored heat during the evening hours. When a layered storage wall is used, continuous thermal contact must be maintained between the layers to ensure proper heat transfer through the wall.

4.5 STORAGE
WALL

Figure 4.8 illustrates a number of storage wall examples. Wall thickness generally varies from 20 cm to 30 cm. For a discussion of wall sizing issues, consult Booklet 3.

LAYERED CONTINUOUS
THERMAL CONTACT

These massive storage wall materials will generally require larger foundations and footings to accommodate the extra weight of the wall. Foundations supporting a thermal storage wall must be insulated on the exterior. It is also important to carefully insulate any portion of the storage wall itself that is not glazed.

FOUNDATION

Unless the outside surface is made of dark colored bricks, the outside of the walls should be stained or painted a dark color to maximize absorption of solar energy. The surface can be painted with high temperature paint such as that used on outdoor cooking grills. Since paints and other materials within a collector may outgas, the wall should be cured by covering it with polyethylene for at least one week after painting. This should "bake-out" any products that might otherwise build up on the back side of the collector surface.

COLOR

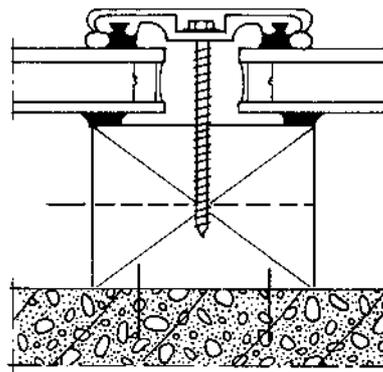


Figure 4.3

Depending on the desired depth, the glazing can actually be attached to a single framing member attached flat against the wall.

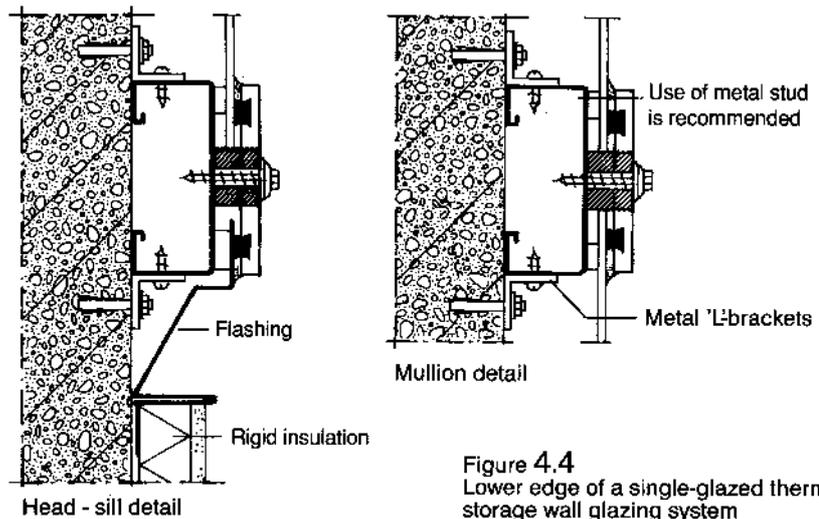


Figure 4.4
Lower edge of a single-glazed thermal storage wall glazing system

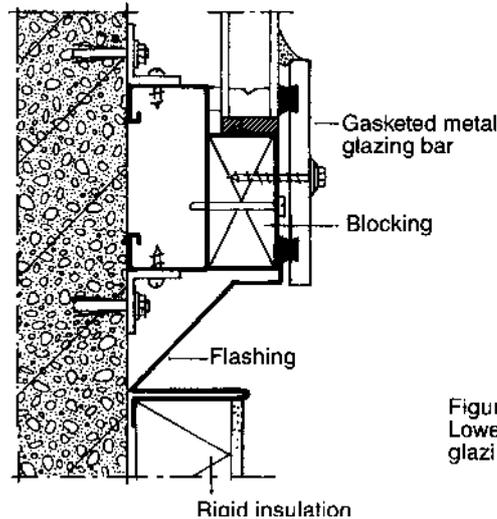


Figure 4.5
Lower edge of a double-glazed thermal glazing system storage wall

SELECTIVE SURFACE COATING

Application of a selective surface material can improve performance of a thermal storage wall by as much as 30 percent. Most selective surface materials are manufactured in thin sheets that are adhered directly to the storage wall surface. They absorb almost all incoming solar radiation but emit only a very small portion as heat. They thus reduce heat loss back out through the collector glazing and can increase efficiency to the point where movable night insulation is no longer necessary.

Since selective surface materials are exposed to much higher temperatures than most building materials, manufacturers specifications must be carefully followed during application. Some products come as a thin sticky-backed foil that must be carefully pressed against a silicone resin that is spread over the masonry surface. This final masonry surface must be very smooth, usually requiring at least two coats of cement/sand plaster. Even when a builder carefully follows directions, it is difficult to prevent a few wrinkles or bubbles during application. One way to minimize this problem is to use a translucent glazing product that hides any minor defects.

THERMAL STORAGE WALL

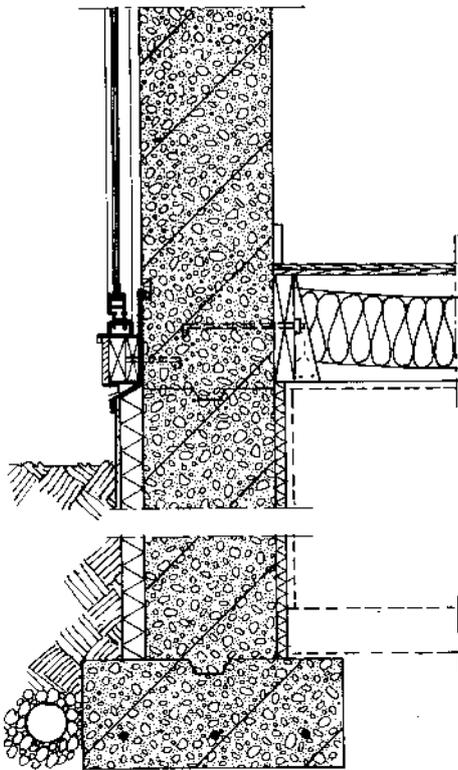
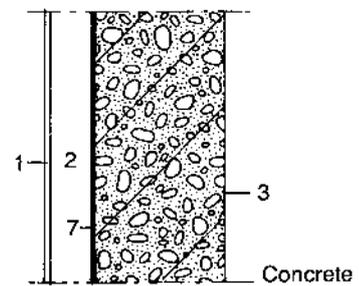
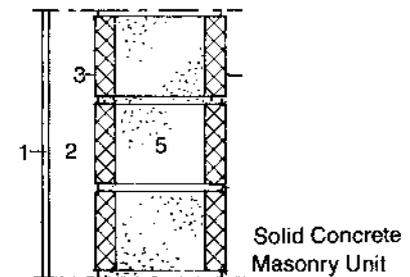
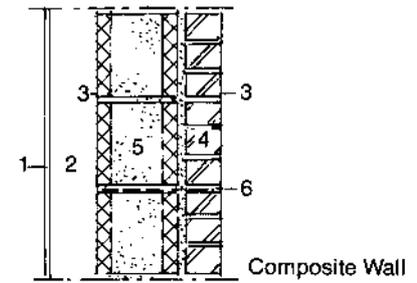
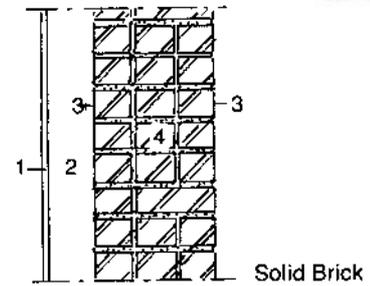


Figure 4.6: Frame is directly attached to the wall



1. Collector
2. Airspace
3. Finish
4. Brick
5. Concrete Masonry Unit
6. Joint Reinforcement
7. Selective Surface Coating

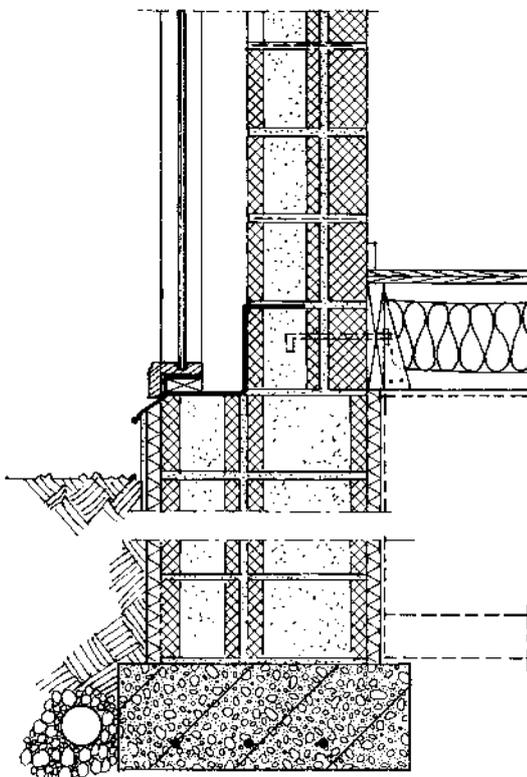


Figure 4.7 Frame is placed on a portion of the foundation wall

Figure 4.8: Thermal storage wall elements.

INTERIOR WALL SURFACE The room side of the wall can either be painted or left untreated. Finishes such as plaster or wallpaper will have a minimal effect on performance. The use of gypsum board as an interior finish can seriously impair thermal performance. In order to get the most out of a wall backed with gypsum board, the board surface must be in full contact with the masonry wall surface.

SOLAR ABSORPTANCE In Table 4.9, the solar absorptance is listed for different materials. Black typically absorbs over 90 percent of the incoming solar radiation. Dark brown or blue absorbs over 80 percent. This Table is meant to serve as a guide only. Differences in texture, tone, overcoats, pigments and binder can modify these values.

4.6 SHADING To avoid excessive overheating during the cooling season, some method of shading the thermal storage wall must be provided. The range of possible methods is roughly the same as that for direct gain shading. Exterior devices include overhangs, trellises, awnings, louvers (horizontal or vertical, fixed or operable) and wing walls. Any fixed device must be carefully designed and installed such that it does not shade the wall during the heating season.

INTERIOR DEVICES Interior shades are typically curtains, blinds or roller shades located in the space between the collector and the storage wall. Thermostatically controlled motor driven interior shades are rather expensive; manually operated interior shades typically have fewer maintenance problems. In both cases, it is important for them to require minimal maintenance and offer operation control from indoors.

4.7 MOVABLE INSULATION As a general rule, builders should avoid installing movable insulation on thermal storage walls. Insulating products are expensive, can be very difficult to maintain, and the savings they achieve are entirely dependent on conscientious use by the occupant. Admittedly, movable insulation does increase performance by reducing nighttime heat loss during the heating season. However, selective surface products offer the same performance advantage at much lower cost and with no reliance on occupant participation.

Where clients specifically request movable insulation, two basic types are available to choose from: interior and exterior products. With few exceptions, the interior products are limited to shades that roll down between the wall and the glazing. Placing the insulation in the airspace generally reduces the problems of storage and maintenance. However, access must be provided to ensure that the movable insulation can be repaired if it becomes inoperable. Furthermore, it can be difficult to prevent warm moist indoor air from leaking through movable insulation pulley operators and then condensing on the collector surface.

Exterior products are the same as those used in direct gain systems (Section 2.5). They tend to be slightly more effective at reducing unwanted heat gain during the cooling season, since they block sunlight before it passes through the glazing.

THERMAL STORAGE WALL



| | Solar Absorptance |
|--------------------------------------|-------------------|
| Optical flat black paint | .98 |
| Flat black paint | .95 |
| Black lacquer | .92 |
| Dark gray paint | .91 |
| Black concrete | .91 |
| Dark blue | .91 |
| Black oil paint | .90 |
| Stafford blue bricks | .89 |
| Dark olive drab paint | .89 |
| Dark brown paint | .88 |
| Dark blue-grey paint | .88 |
| Azure blue or dark green lacquer | .88 |
| Brown concrete | .85 |
| Medium brown paint | .84 |
| Medium light brown paint | .80 |
| Brown or green lacquer | .79 |
| Medium rust paint | .78 |
| Light gray oil paint | .75 |
| Red oil paint | .74 |
| Red bricks | .70 |
| Uncolored concrete | .65 |
| Moderate light buff bricks | .60 |
| Medium dull green paint | .59 |
| Medium orange paint | .58 |
| Medium yellow paint | .57 |
| Medium blue paint | .51 |
| Medium Kelly green paint | .51 |
| Light green paint | .47 |
| White semi-gloss paint | .30 |
| White gloss paint | .25 |
| Silver paint | .21 |
| Polished aluminum reflector sheet | .12 |
| Aluminized Mylar film | .10 |
| Laboratory vapour deposited coatings | .02 |

Solar Absorptance - The ratio of absorbed flux to the total incident flux.

Figure 4.9: Solar absorptance of various materials (reference no. 11)

The architectural details presented in this booklet should be seen as examples of solutions developed and applied in the countries participating in the study. Because of the differences in climate, local construction practices, regulations and the available materials and products, they are extremely varied.

The solutions, however, have one thing in common: they are based on user requirements and environmental factors that occur when using direct gain, sunspace and thermal storage wall passive solar heating systems. Due to the thermal behavior of materials and products at high temperature, considerable attention to architectural details is required in passive solar homes.

Only by working from these user requirements and environmental factors, will it be possible to develop good details. Moreover, great care should be taken to ensure that the work to be carried out at the construction site is relatively simple, so that errors can be avoided.

The selection of the appropriate passive and hybrid solar heating system is based on cost-effectiveness and amenity. During design, the costs and benefits of pre-fabricated construction versus site-built construction should be carefully evaluated. Regardless of the method of construction chosen, research and experience has shown the importance of quality workmanship on performance. Therefore, great care must be exercised during both the design phase and the construction phase for passive solar homes.

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