MASTER

Energy-Conserving and Passive-Solar Construction Details

Robert D. Taylor

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

In cooperation with

Western
SUN

This handbook was funded by
the U.S. Department of Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:

Microfiche \$3.00
Printed Copy \$ 4.50

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

ENERGY-CONSERVING AND PASSIVE-SOLAR CONSTRUCTION DETAILS

Market demand is the driving force behind product development in any industry. The building industry is facing a major shift in the demand for its products as the costs of conventional heating fuels escalate. Prospective home buyers are asking more questions like: "What are the R values of the walls and roof? Are these windows single or double glazed? What is the heating system? Are you implementing any passive solar heating?"

Recently in Denver, the Solar Energy Research Institute sponsored a one-day seminar on passive solar building. Since advertising of the seminar was not extensive, the program coordinators expected about one hundred builders to register; they had to limit the registration to four hundred fifty. When asked, the attending builders said they were responding to a changing market—one that was becoming more educated about housing thermal design and thus demanding more energy efficient dwellings.

Using passive solar heating techniques with sound energy conserving design and construction has emerged as the optimum approach to reducing the amount of conventional fuels required for space heating in residential and light commercial buildings.

Experience and economic analysis have shown that given a sum of money to upgrade the thermal design of a structure to be highly energy efficient (reduce heat losses), one half to two thirds of that money should be spent on energy conserving measures such as added insulation, and the remaining one third to one half should be used on passive solar applications.

The research and development of a product in any industry is a costly process. The evolution of good energy efficient passive solar buildings has been no different. As the end of the era of cheap energy came into view in the early 1970s, several groups of solar pioneers coalesced across the country and began learning and relearning the practical applications of renewable solar energy. The immediate results of these efforts were custom single family dwellings as builders and researchers experimented with different solar designs.

Only recently have the initial experimentation and evaluation yielded cost-effective solutions to the major passive solar concept problems. This report presents many of those solutions that can be applied to a whole range of residential and light commercial buildings.* The emphasis is on using commercially available building materials in new applications to minimize costs and maximize thermal design. Also presented are some passive solar components that up until now have been site built but which lend themselves to being manufactured and installed by building tradesmen.

The costs given are typical of what builders have incurred in different parts of the country. They are included only to give the reader a basis for comparison of the different building systems. The thermal performance figures and comments are included to give the reader a feel for what these components can do for the thermal design of a building.

---

*Architectural Drafting by Neil Carter, Graphic Supports, Santa Fe, N. Mex.

SERIO

LIST OF FIGURES

	<u>Page</u>
Energy Conserving Construction Details	
1 Insulated Turned-Down Slab	2
2 Comparison of Frame Insulating Walls.....	3
3 Framing Details for Energy Conservation.....	4
4 Insulating Foundation Walls.....	5
5 Alternative Ways to Deal with Exterior Transitions Between Foundation Walls and Frame Walls.....	6
6 Multiple-Layered Foil Insulation in Unvented Vaulted Roof.....	7
7 Cantilevered Truss Roof System Allows Full Depth of Insulation to Outside Stud Wall	8
8 Insulating Exposed Beam and Decking Flat Roofs	9
9 Insulating Joists over Crawl Space	10
Glazing Systems	
10 Wood Frame/Standard Size Insulated Glass-Glazing System	11
11 Sloping Glass/Wood Frame Glazing System, Greenhouse Application.....	12
12 Venting Commercial Window/Insulated Plate-Glass Glazing System—Direct Gain Application.....	13
13 Exolite with PVC/Aluminum Glazing System—Sloped Application	14
Installing Thermal Mass	
14 Thermal Mass.....	15
15 Brick Veneer Inside Frame Insulating Wall	16
16 8-in. CMU Mass Wall with Expanded Polystyrene Insulation	17
Trombe Walls	
17 16-in. Concrete Stagnated Trombe Wall	18
18 Brick/High Density CMU Stagnated Trombe Wall	19
19 Vented Adobe Trombe Wall	20

LIST OF FIGURES (Concluded)

	<u>Page</u>
20 "Heat Wall" Water-Loaded Trombe Wall	21
21 Water-Loaded Drum Wall.....	22
Rock Beds	
22 Horizontal Rockbed	23
23 Vertical Rockbed.....	24
Passive Hot Air Collector	
24 Thermosiphoning Hot Air Collector	25

Energy Conserving Construction

- Incremental Cost of Construction
  - Place 1" Extruded Polystyrene \$0.55/ft²
- Thermal Performance
  - Reduction of Slab Perimeter Losses
  - Warmer Floor Slab

Figure 1. Insulated Turned-Down Slab

2x6 Well Insulated Wall

- Cost of Construction
\$4.20/ft² Wall, Total
(Includes \$2.00/ft² Framing Costs)
- Thermal Performance
Total R Value = 24
Cost per "R" = \$0.17

Conventional 2x4 Wall

- Cost of Construction
\$3.92/ft² Wall (Includes
\$2.00/ft² Framing Costs)
- Thermal Performance
Total R Value = 14
Cost per "R" = \$0.28

Figure 2. Comparison of Frame Insulating Walls (Plan Views)

Figure 3. Framing Details for Energy Conservation

- Cost of Construction
  - Nail on Bentonite Moisture Barrier \$0.75/ft²
  - Nail on 1" Extruded Polystyrene \$0.55/ft²
  - Trowel on Vinyl-Acrylic Latex Coating \$2.00/ft²
- Thermal Effectiveness
  - Reduction of Conductive Losses
  - Increase Interior Thermal Mass

Figure 4. Insulating Foundation Walls

Figure 5. Alternate Ways to Deal with Exterior Transitions Between Foundation Walls and Frame Walls

Figure 6. Multiple Layered Foil Insulation in Unvented Vaulted Roof

Standard Truss Roof System

Figure 7. Cantilevered Truss Roof System Allows Full Depth of Insulation to Outside of Stud Wall

- Cost of Construction
Second Insulating Roof \$2.25/ft²
- Thermal Performance
Total R Value = 38

Figure 8. Insulating Exposed Beam and Decking Flat Roofs

- Construction Costs
  - 6" Batt Insulation \$.26/ft² Installed
  - 16" High Carbon Rods \$.07 Each or \$.05/ft²
- Thermal Performance
  - R Value of Floor = 27

Figure 9. Insulating Joists over Crawl Space

Glazing Systems

Figure 10. Wood Frame/Standard Size Insulated Glass Glazing System

- Cost of Construction
\$8.50/ft² Installed
(Source: Communico, Inc., Santa Fe, New Mexico)

Figure 11. Sloping Glass/Wood Frame Glazing System, Greenhouse Application

- Cost of Construction; Average for System (including wood framework)
\$10.50/ft² Installed

(Source: Environmental Ventures, Santa Fe, New Mexico)

Figure 12. Venting Commercial Window/Insulated Plate Glass Glazing System. Direct Gain Application.

- Cost of Construction
\$7.50/ft² Installed
- Thermal Performance
Solar Transmittance = 83%
Maximum Operating Temperature = 160° F

Figure 13. Exolite with PVC/Aluminum Glazing System — Sloped Application

Installing Thermal Mass

Figure 14. Thermal Mass

Figure 15. Brick Veneer Inside of Frame Insulating Wall

Figure 16. 8" CMU Mass Wall with Expanded Polystyrene Insulation

Trombe Walls

- Cost of Construction

Concrete or Block Wall	\$8.50/ft ²
Glazing System	7.75/ft ²
Total	\$16.25/ft²
- Thermal Performance
  - Affords High Solar Heating Fraction
  - Typically Adjacent Rooms Experience Maximum 10°F Temperature Fluctuation

(Source: Communico, Inc., Santa Fe, New Mexico)

Figure 17. 16" Concrete Stagnated Trombe Wall

- Cost of Construction

Masonry Wall	\$7.58/ft ²
Glazing System	<u>7.75/ft²</u>
Total	\$15.33/ft ²
- Thermal Performance
  - Brick with Magnesium Has High Conductivity. More Heat Is Conducted to Interior of Wall Which Raises Interior Wall Surface Temperature.

Figure 18. Brick/High Density CMU Stagnated Trombe Wall

Figure 19. Vented Adobe Trombe Wall

(Source: Crimsco, Inc., Kansas City, MO)

Figure 20. "Heat Wall" Water-Loaded Trombe Wall

- Cost of Construction
\$10.50/ft² of Glazing
- Thermal Performance
Thermal Storage for
Nighttime Convective
Heating

(Source: Al Von Bachmayr, Architect,
Boulder, CO.)

Figure 21. Water Loaded Drum Wall

Rock Beds

- Cost of Construction
\$2.25/ft² Rock (not Including Foundation or Slab)
- Thermal Performance
  - Redistributes Heat from South Side of Building to Wherever Needed
  - Raises Floor Temperature 5 - 10°F Resulting in Lower Thermostat Settings

(Source: Communico, Inc., Santa Fe, N. Mex.)

Figure 22. Horizontal Rockbed

- Cost of Construction
 $7' \times 12' \times 1.5'$ Cages = \$600 Each
 Total \$7.30/ft² Wall Area
 or \$9.75/ft³ Rock
- Thermal Performance
 - Capability of servicing
 Two Living Areas
 Simultaneously

(Source: Mark Jones Corporation, Santa Fe, N. Mex.)

Figure 23. Vertical Rockbed

Passive Hot Air Collector

- Cost of Construction
\$12.05/ft² Glazing
- Thermal Performance
Heats up Air 80° F to Service Rockbeds, etc.
Fans Not Required with Proper Placement

(Source: Mark Jones Corporation, Santa Fe, N. Mex.)

Figure 24. Thermosiphoning Hot Air Collector