

Mean Radiant Cooling In A Hot-Humid Climate

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ABSTRACT

Shaded interior mass walls in a hot-humid climate can be thermally grounded to an earth heat sink under an insulated structure. The mean radiant temperature (MRT) of the shaded and thermally grounded interior mass walls will be cooler in summer than normal light weight frame wall construction and significantly below human body temperature. Because the interior walls are cool, the human body will lose heat by radiation to the cooler interior mass walls. The result is an improvement in the bio-climatic sensation of comfort and an increase in energy conservation.

THERMAL GROUNDING

Thermal grounding is a term used to describe

in direct conductive contact with the cool earth temperature directly under the structure. When using perimeter insulation of a subsurface 3'-6" deep concrete grade beam that supports the interior mass wall, the heat gradient from the wall through the soil lags behind the average ambient air temperature on a seasonal time lag. In a properly designed structure, the interior mass walls are typically as much as 15 degrees F cooler than exterior light weight frame walls during peak summer cooling hours.

In a properly designed structure thermal grounding may be achieved through the careful combination of several energy conservation and building techniques including:

1.) Extruded styrene slab edge insulation of the perimeter exterior of a deep concrete foundation beam used to support the interior mass walls. The foundation is in conductive contact with the interior mass walls and is used to discharge

excess heat gain at very slow rates to the cooler earth under the slab of the insulated structure.

2.) Solid concrete mass walls shaded in summer from exterior sunlight in order to reduce direct radiant gain to the interior mass walls. Porches, overhangs, armadas, and shading arbors are all building examples of effective architectural shading techniques.

3.) Effective insulation, caulking, reflective exterior surface colors, tinted window glazing, and other proven conservation features that combine to reduce summer cooling loads.

4.) Air cooling wall cavities and attic spaces using solar-induced ventilation in combination with radiant heat barriers to reduce both radiant and conductive heat gain in summer. Roof cupolas, ridge vents, and vented sun breaks are examples of techniques used to reduce heat build-up in air cavity spaces.

5.) Raising the interior air design temperature in summer to 82 degrees F. by using ceiling fans that recirculate dry interior air at speeds up to 250

6.) Using high ceilings in occupied spaces will allow the heat to naturally stratify and let warm air collect near the ceiling and above the zone of direct human occupation. This excess heat can be ventilated using high transom windows without introducing a hot-humid air stream to the zone of human occupation near the floor. Outside ventilation is used primarily in spring months.

In hot-humid climates the possible increase in humidity could cause discomfort unless the interior air is kept dry or the moisture is re-evaporated. Ceiling fans help evaporate condensation from the interior mass walls when high dew point temperatures are present. If the interior air is kept within an acceptable range of temperature (60 - 88 degrees F) and relative humidity (20 - 60 % RH), tests by Victor Olgyay have shown, "that for every 1 degree F the mean radiant temperature of surrounding interior wall surfaces is lowered, air temperature may be

increased 1.4 degrees F and thermal comfort will still be maintained." ¹ For example at the same relative humidity an interior room with the MRT of the surrounding surfaces at 80 degrees F and the air temperature at 80 degrees F would have a similar comfort level if the MRT of the surrounding surfaces were at 90 degrees F and the air temperature was at 66 degrees F. Thus, warm interior air temperatures can in fact be comfortable even at moderately high humidity levels (60 % relative humidity) provided the MRT of the surrounding surfaces remains below 82 degrees F and air is circulated using ceiling fans at speeds up to 250 feet per minute.

The sub-surface grade beam insulation reduces lateral slab edge heat exchange in summer to the warm upper levels of soil and forces the heat gradient to drop below the level of the concrete grade beam. This process increases the depth of the effective earth mass and essentially raises the thermal grounding line up and into the interior mass walls. The higher summer interior air design temperature (82 degree F) in combination with the cooling ventilation of ceiling fans and the relative cool interior wall's MRT combine to reduce conductive heat gain to the interior of the insulated structure.

The actual diurnal heat gain to the interior mass walls should be quite small (only a few Btu/ft-day). The surface area of the foundation beam must be adequate to transfer the small excess heat gain in the interior mass walls to the soil with a relative low thermal conductivity (ranging from .1 Btu/hr-ft-F, for a dry clay soil up to 1.78 Btu/hr-ft-F for a wet soil).

Although seasonal temperature fluctuations in soil reach a depth of several feet, the penetration of short term temperature fluctuations is almost negligible. The soil under the insulated structure will be stabilized after slab construction to a temperature between that under the slab and the undisturbed soil. During summer the inside air temperature of the building will be allowed to reach as high as 82 degrees F. The heat flux into the soil (due to the temperature gradient between the interior mass walls and the surrounding soil) helps keep the building cool while discharging only a small amount of heat into the cool earth heat sink. The interior mass walls provide a cool mean radiant source and raise the upper limit of the

summer design air temperature in a thermal comfort zone.

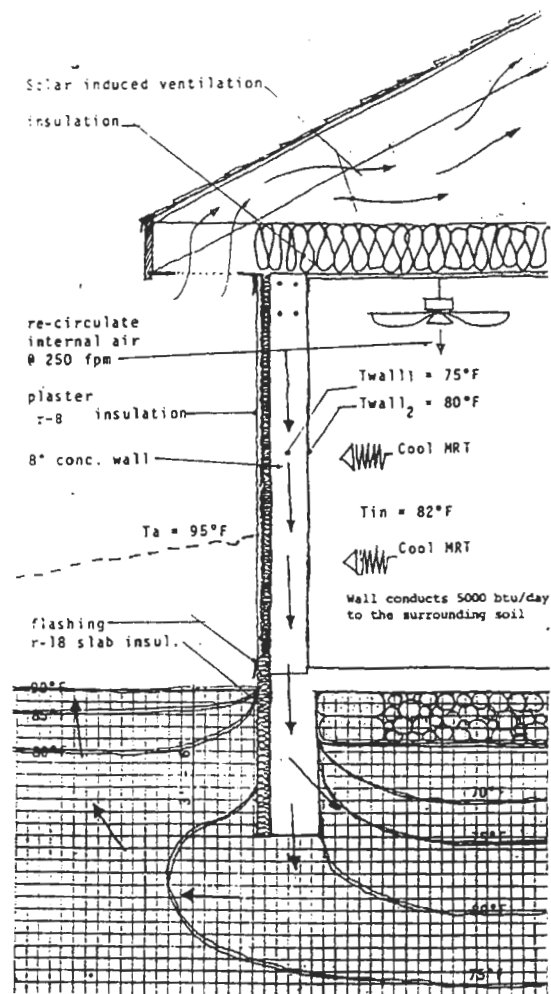


fig. 1. Thermal Grounding with a deep foundation beam

Hot-humid climates usually have early morning high humidity conditions. Thermally grounded walls may be at a temperature close to or below summer dew point temperatures ranging as high as 78 degrees F. Therefore earth grounded interior walls may also act as dehumidifiers. In hot-humid climates a mechanical or chemical dehumidification system may be required to condition this latent load. Using a ceiling fan to evaporate any moisture on the interior mass walls will be effective to control mildew and odors provided the air flow to the wall is not severely restricted.

¹ Olgyay, Victor., Design With Climate, Princeton Univ. Press, Princeton, N.J.

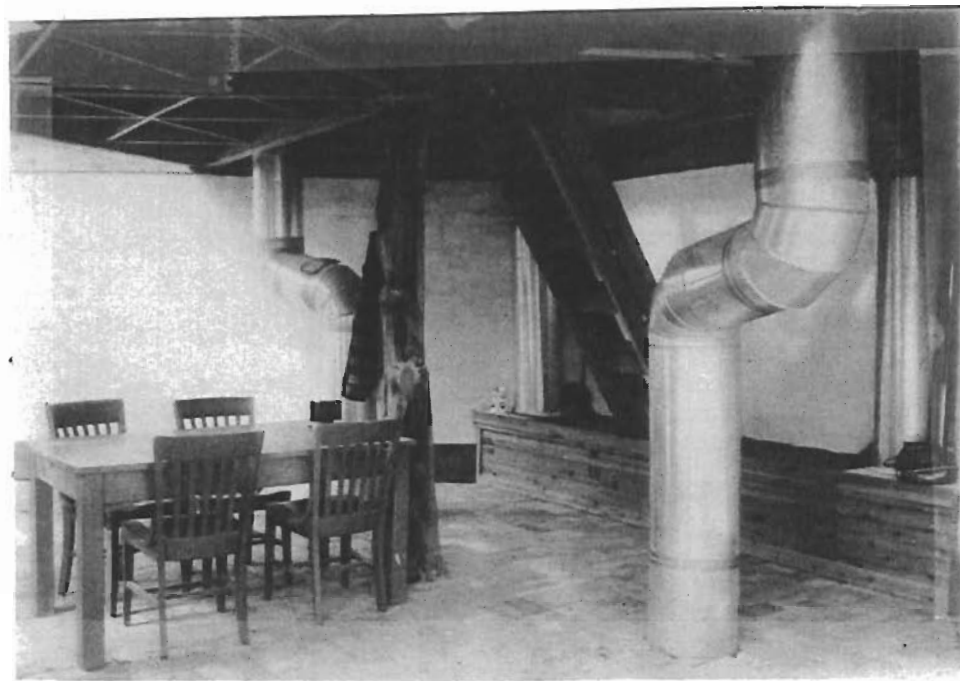


fig. 2 Interior Mass Walls of the Passive Test Structure, Balcones Research Center.

TEST STRUCTURE

A test structure with thermally grounded mass walls using a deep foundation beam with slab edge insulation was constructed by a team from the School of Architecture, The University of Texas at Austin and monitored by The Texas Energy and Natural Resources Advisory Council (TENRAC) between 1980 and 1982. The 10,000 cubic feet test structure was located at the University of Texas, Balcones Research Center, in Austin, Texas. The test structure demonstrated the feasibility of using thermal grounding of interior mass walls for MRT cooling in the sub-humid region of central Texas.²

In the test structure 23 tons of shaded 8 inch thick concrete walls are thermally grounded by conductive contact to a 3'-6" deep grade beam insulated with R-8 slab edge insulation. The walls and grade beam are further buffered by an earth berm one half of the way up to the level of the roof.

² Garrison, Michael., Passive Solar Test Project. The Texas Energy and Natural Resources Advisory Council, Energy Development Fund, State of Texas, 1982.

Monitored results showed that early summer mean radiant temperatures of the mass walls were very mild (70 degrees F) having cooled in late winter and spring. Little direct sunlight reached the interior mass walls due to a combination of effective shading techniques. Interior air temperatures recorded during summer remained below 82 degree F without the use of mechanical air conditioning even though outside air temperatures reached 100 degrees F. The lower inside air temperatures were due to the combination of R-19 insulation, caulking, shading glazing with greenhouse shade cloth, and solar induced ventilation of attic and wall cavity spaces at close to one air change per minute using a roof cupola mounted 30 feet above the floor of the structure. During the summer months the MRT of the interior mass walls gradually began to rise peaking at 82 degrees F at 5:00 pm in October. The MRT of the interior mass wall was 22 degrees F cooler than the interior surface temperature of a south facing light weight wood frame wall at 5:00 pm on a typical hot partly cloudy day in August. Because of the lower MRT of the interior mass walls during the hot summer months the sensation of interior conditioning was thermally comfortable even at interior air temperatures as high 84 degrees F.

Peak Summer interior air temperature reached a high of 84 degrees F in late afternoon when the outside air temperature reached 100 degrees F, and the interior air temperature did not drop below 80 degrees F until after midnight. During late summer the mean radiant temperature of the interior mass walls typically experienced a 5 degree F diurnal temperature swing at the wall surface (75 degrees F just after sun up and up to 80 degrees F just after dark). Windows and doors remained closed during the day to prevent convective heat gain from the hot ambient outside air, and interior air was recirculated inside the space using ceiling fans at speeds of 250 per minute. Early experience had shown that air temperatures were higher inside when windows and doors were opened during the day to allow for ventilation. The attic cavity was ventilated using air drawn from an air plenum in the earth berm and from under the slab. The humidity levels monitored within the structure were climatic dependent, with periods of high interior humidity levels consistent with high exterior humidity levels.

PASSIVE SOLAR HOMES

Market examples of homes were developed using cool MRT interior mass walls similar to the design of the Balcones Research Test Structure.³ The example homes are similar in cost and appearance to houses in the surrounding neighborhoods of Austin, Texas, but space conditioning loads are substantially lower.

McDADE HOUSE

The 2,000 square-foot Carson House in McDate, Texas situated in the somewhat incongruous "Lost Pines" belt just east of Austin, is designed to combine several energy conservation measures including: architectural shading devices, solar induced ventilation using a roof cupola, thermal grounding of interior high mass walls and recirculation of the interior air using ceiling fans. The high mass interior concrete walls are shaded by light weight wood framed sleeping rooms and porches. Four ten foot high interior concrete walls surround a central 30 foot by 30 foot Living Room. The concrete walls are grounded to the cool earth by a 3'-6" deep concrete grade beam with continuous slab-edge insulation around the perimeter. A roof-top cupola, 30 feet

³ Garrison., Michael., Passive Solar Homes for Texas, Texas Energy and Natural Resources Advisory Council, Energy Development Fund, State of Texas, 1983.

above the central room ventilates a continuous wall cavity between the ceiling and the roof. The thermal performance of the Carson House was similar to the Balcones Research Center Test Structure. The Cool MRT of the interior concrete walls was 68 degrees F in May and 79 degrees F in September.



fig. 3. Mcdade, Texas

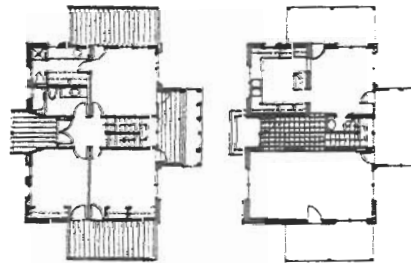


fig. 4 Driftwood House

DRIFTWOOD HOUSE

The 1,500 square foot Pollard House located in the subdivision of Driftwood, Texas, just south of Austin, is a two-story house designed to combine the conservation package of insulation, caulking, roof cupola, and cross ventilation with interior high mass walls of stone. The entire kitchen, dining room, living room, entry, and central stairs are built of interior rock walls. The upper bedrooms are clustered around a central dog-run ventilation porch. Each of the bedrooms is attached to a covered sleeping porch. A cupola is located above the central stairway and ventilates both the attic and a two-story high sunroom on the south side of the house. The house was constructed for just under \$75,000 dollars in 1986 and has operated comfortably for almost ten years. The utility bills are 50% of those of similar sized houses in the same subdivision.

CONCLUSION

The structures built in the sub-humid region of Central Texas each showed similar characteristics in documenting the effectiveness of Mean Radiant Cooling. Each of the structures was comfortable in summer and used less mechanical conditioning than light weight wood frame houses typical of the area.

Each of the structures was designed using the following assumptions;

1. Reducing the rate of space heat gain to less than 8 Btu/day-sf floor-F
2. Reducing the exterior glazing to less than 12% of the wall area and the south facing glazing to a ratio of less than 10% of floor area.
3. Reducing sunroom south facing glazing to a ratio of 23% of house floor area. and adding 1 cu. ft. of mass per sq. ft. of sunroom glazing. The exposed surface area of the mass is equal to the surface area of the glazing.
4. Adding a roof cupola that will ventilate the attic at a rate of at least 15 air changes per hour.
5. Adding ceiling fans that run at speeds up to 250 ft. per minute.
6. Adding shaded high mass interior walls thermally grounded to the earth under the slab with a continuous slab edge insulation.

The results of the Mean Radiant Cooling demonstration projects are particularly encouraging to home builders for two reasons; First, since the systems are low enough in initial cost, middle income buyers can afford to install

enough systems to make a significant reduction in residential energy consumption, and second, because MRT systems operate at low temperatures they are easy for most consumers to understand, operate and maintain. The final conclusion is that enhanced cooling comfort at reduced operating costs is possible using the ancient process of Mean Radiant Cooling.

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