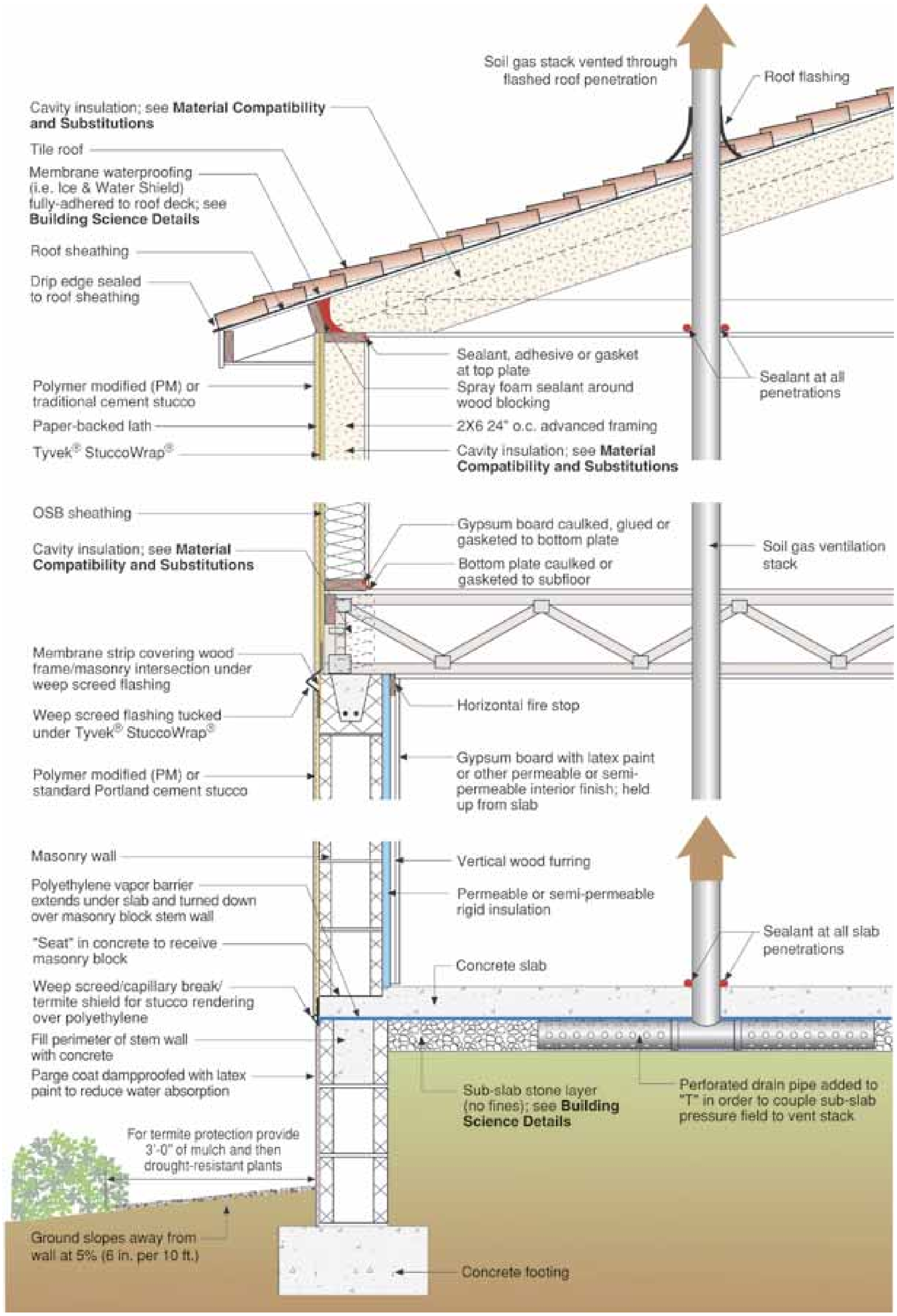
# Building Profile – The Maitland

## Cross Section




| | | |
|---|---|---|
| Foundation: Stem wall & slab | Cladding (1st floor): Stucco | Cladding (2nd floor): Stucco |
| Attic: Conditioned | Above Grade Wall (1st floor): Masonry | Above Grade Wall (2nd floor): Wood frame |
| Roof: Tile | | |

## Building Science Details

- **Air sealing details at transitions** – Air sealing can be particularly difficult, but no less important, at assembly transitions such as top-of-wall/roof assembly junctions, band joists, and between attached garages and living spaces. These three are discussed below because they have proven to be a consistent challenge for builders.

  Top-of-wall/roof assembly junction – The continuity of an exterior air barrier can be maintained at this junction if the air barrier material (foam insulation or stucco cladding, for example) is used continuously for the wall, soffit, and fascia. The continuity of an interior air barrier can be maintained through a combination of cut foam blocks and sealant/caulk, or spray foam. Note that neither cellulose nor fiberglass (batt or blown) can be used for the air barrier.

  Band joists – Continuity of an exterior air barrier can be maintained at the band joist with sealed or taped housewrap or rigid foam insulation. Continuity of an interior air barrier can be maintained through a combination of cut foam blocks and sealant/caulk, or spray foam. Note that neither cellulose nor fiberglass (batt or blown) can be used for the air barrier. The air barrier detail on second-story band joists is important because it is inaccessible (covered by structural/finish floor and ceiling finish) after construction. The air barrier/thermal envelope detail is important on ground floor band joists because of the thermal bridge that can occur at the top of crawlspace foundation walls (as the result of the air barrier and thermal envelope moving from the outside to the inside of the building enclosure and termite inspection zones located at the top of crawlspace foundation walls). Note that while fiberglass batts fulfill the requirement for protection from ignition in the open band joists, fiberglass batt material by itself cannot maintain the air barrier.

  Attached garages – the building enclosure surfaces shared between conditioned space and an unconditioned garage must have a continuous air barrier. See **Figure 7** for details in terms of using sealants and rigid insulation to create a continuous air barrier between the attached garage and living space. Refer to http://www.buildingscience.com/housesthatwork/airsealing/default.htm for air sealing details.

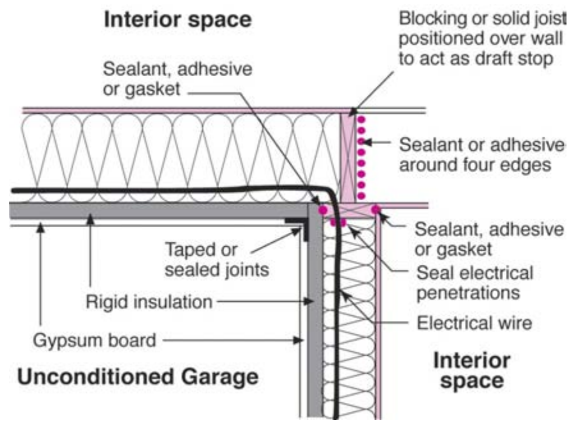



**Figure 7**

- **Drying mechanisms** – In any climate, vapor control is based on the relationships among the following: the permeability of wall components, the type of cladding (reservoir or non-reservoir), the presence/lack/nature of an air space, and the magnitude/duration of the vapor drive (based on the relationship between the exterior and interior moisture content and temperature differences). The type of sheathing and housewrap used in any wall assembly must be based on an understanding of these inter-relationships. See “Insulations, Sheathings, and Vapor Diffusion Retarders” for more information (http://www.buildingscience.com/resources).

  In both the first and second story wall assemblies, drying can occur to the exterior and the interior as long as permeable latex paints are used. The use of semi-permeable rigid insulation on the interior of the first story masonry wall assembly allows drying to the interior at a controlled rate. Either expanded polystyrene (EPS) or extruded polystyrene (XPS) can be used in this location. We recommend that less than one inch of XPS be used. A thicker layer retards inward drying due to its lower vapor permeability.

- **Drainage "step" in slab perimeter** - The block "seat" is readily accomplished by securing dimensional lumber of the desired size to the inside top edge of the concrete form.

- **Drainage plane, air barrier, and vapor control** – The drainage plane on the first story exterior wall is the face of the stucco. The drainage plane on the second story exterior wall is the StuccoWrap®. Flashing details at penetrations on each story must reflect this difference.

The building paper behind the weep screed flashing at the transition from first to second story is an important “back-up” protection against liquid water penetration into the wall assembly. The first floor air barrier is the concrete block (with continuity at the top of the wall provided by the cap block). On the second floor, the air barrier is both the exterior stucco rendering and the interior gypsum board installed using the Airtight Drywall Approach. Control of moisture drive from the outside in is accomplished by the relative impermeability of the OSB on the second story. On the first story, the storage capacity and insensitivity of the concrete block mitigates the impact of moisture penetration in the wall assembly, and the entire assembly permits drying in both directions.

- **Window flashing** – Window flashing details are wall assembly or cladding specific. See **Figures 8a-c** and refer to the *EEBA Water Management Guide* http://www.eeba.org/bookstore.

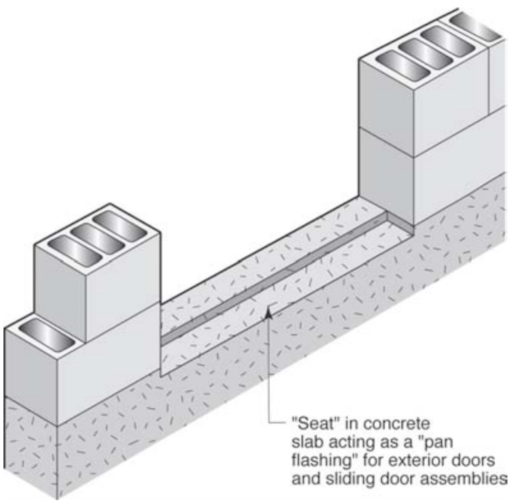



Figure 8a: Exterior door pan flashing “seat”

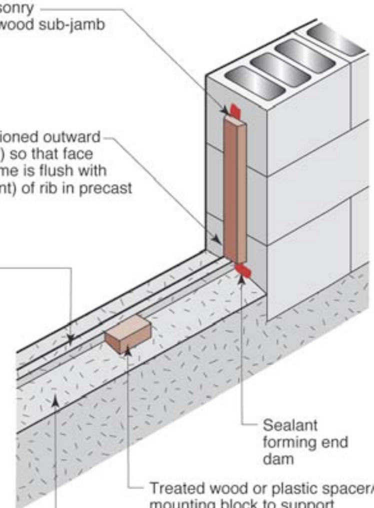



Figure 8b: Window sill drainage detail

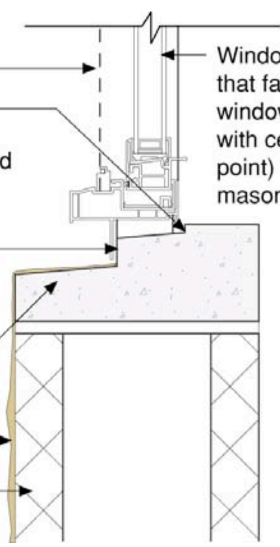



Figure 8c: Window sill drainage section

- **Advanced framing** – An important element of high performance wood-frame construction is an advanced framing package. For more detailed information on advanced framing techniques, see http://www.buildingscience.com/housesthatwork/advanced framing/default.htm.
- **Framing on slabs** – Installing a capillary break between the sill plate and a concrete slab on **all** walls—exterior, interior, partition—is good practice. A closed cell foam sill sealer or gasket works well. Alternatively, a strip of sheet polyethylene can be used. This isolates the framing from any source of moisture that may be either in or on the concrete slab (and using sill sealer on all walls maintains wall height exactly the same).
- **Soil gas ventilation** – The sub-slab to roof vent system handles conditions that are difficult if not impossible to assess prior to completion of the structure— confined concentrations of air-borne radon, soil treatments (termiticides, pesticides) methane, etc. The cost of this "ounce" of prevention is well balanced against the cost of the "pound" of cure. Note that this system is a passive system that can easily be converted to an active ventilation system by installing an in-line fan into the stack in the attic.
- **Thermal barrier** – In this climate, moisture control does not require specific levels of insulation. Inside/outside temperature differences do not require cavity-warming exterior rigid insulation to control wintertime condensing surface temperatures. Having said this, insulating sheathing in general is a good idea. We recommend full cavity fill in the walls, but the 2X6 framing is more about advanced framing than the depth of cavity insulation that can be achieved. The R-22 cellulose or R-30 batts in the conditioned attic have proven to be adequate to provide interior conditions for enhanced HVAC equipment durability and duct performance when they are located in the attic. Note that the cellulose netting or fiberglass batt supports create the insulation “belly” and accommodate cavity fill depth that exceeds the depth of the truss top chord.
- **Sub-slab stone bed** - The four-inch deep 3/4" stone bed functions as a granular capillary break, a drainage pad, and a sub-slab air pressure field extender for the soil gas ventilation system. The sub-slab stone bed is a practical method for venting soil gas should be necessary.

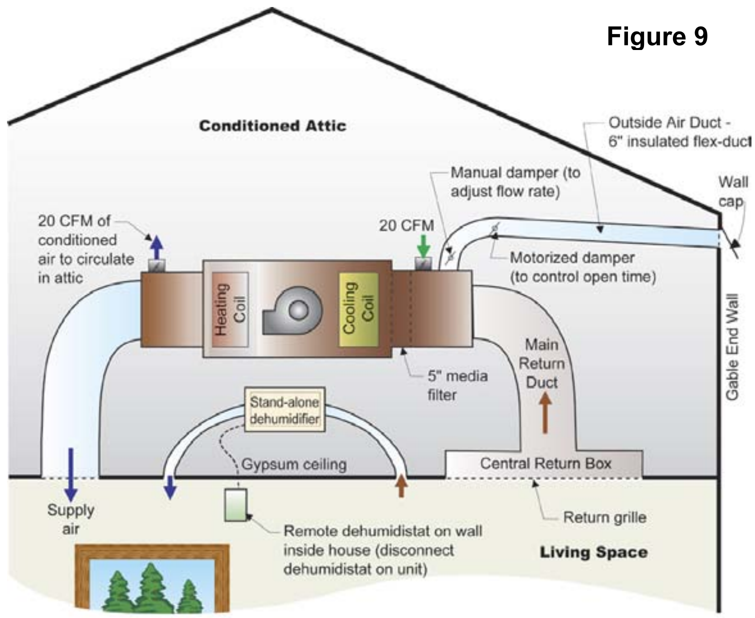
## Climate Specific Details

- **Termite management** - In hot-humid climates, termites are best managed with a three-pronged approach that deals with the three things termites need - cover from sunlight, moisture, and food (wood or paper):
  1. Reduced cover - Keep plantings 3 feet away from the building perimeter, thin the ground cover (wood mulch or pea stone) to no more than two inches depth for the first 18 inches around the building, and maintain the termite inspection zone on the exterior of the foundation above grade.
  2. Control moisture - Maintain slope away from building as shown, carry roof load of water at least three feet away from building, and make sure that irrigation is directed away from the building.
  3. Treatment - Use an environmentally-appropriate soil treatment (such as Termidor®) and a building materials treatment (such as Bora-Care®) for termite-prone near-grade wood materials.
  4. Inter-relationship of first three points – Since a builder and a homeowner’s ability to employ or stick to each of the three strategies above will vary, make sure that an inability to fully employ one strategy is compensated for by complete rigor by the others. For example, if for some reason, chemical treatment of soil or building materials is not an option, then complete rigor in controlling moisture and ground cover must be maintained.
- **Conditioned attics** – This assembly may require discussion with local building code official. See **Appendix II** for assistance.

- **Mechanical systems** - The key elements of a system for this climate are:
  1. **Sealed combustion gas furnace** - for energy efficiency and health/safety with the unit inside conditioned space.
  2. **Minimum 12 SEER AC unit** - for energy efficient management of sensible load.
  3. **Central-fan-integrated supply ventilation** - this system is simple, effective, and economical. It provides fresh, filtered, outside air in a controlled amount using the existing HVAC delivery system for even distribution and mixing. Set-up intermittent central-fan-integrated supply, designed to ASHRAE 62.2P rate, with fan cycling control set to operate the central air handler as much as 33% of the time, but not less than 25% of the time, occurring within at least every three hours to provide ventilation air distribution and whole-house averaging of air quality and comfort conditions ($125 to $150). Include a normally closed motorized damper in the outside air duct with the AirCycler™ FRV control (+$50 to $60). See http://www.buildingscience.com/resources/mechanical/air_distribution.pdf for more detailed information.
  4. **Supplemental dehumidification** - all homes in this climate call for supplemental dehumidification; the reduced sensible load of high performance homes reduces the dehumidification the AC unit provides, extends shoulder seasons, and raises the impact of occupant-generated moisture.

     There are a number of different ways to accomplish supplemental dehumidification with varying costs and performance advantages (For a detailed discussion of supplemental dehumidification see http://www.buildingscience.com/resources/mechanical/conditioning_air.pdf). Described below is one low-cost yet effective approach and one more costly but higher performance/systems-engineered approach:

     **Figure 9**

     1. Ducted stand-alone dehumidifier: This system is a "site-constructed" and consists of an off-the-shelf standard dehumidifier ducted in the attic and controlled by a dehumidistat located in the living space. This arrangement of individual components has proven to be an effective and economical system for the production home building setting. The installed cost ranges from approximately $350 to $550. The system is comprised of any Energy Star dehumidifier that uses a blower wheel instead of a paddle fan to move air past the coil (dehumidifier located in attic in an insulated enclosure and ducted to living space), Honeywell dehumidistat model H8808C located in living space and Honeywell switching relay (with transformer) model RA89A 1074. See **Figure 9**.

        **Note:** The following manufacturers make Energy Star-qualified blower wheel stand-alone dehumidifiers:

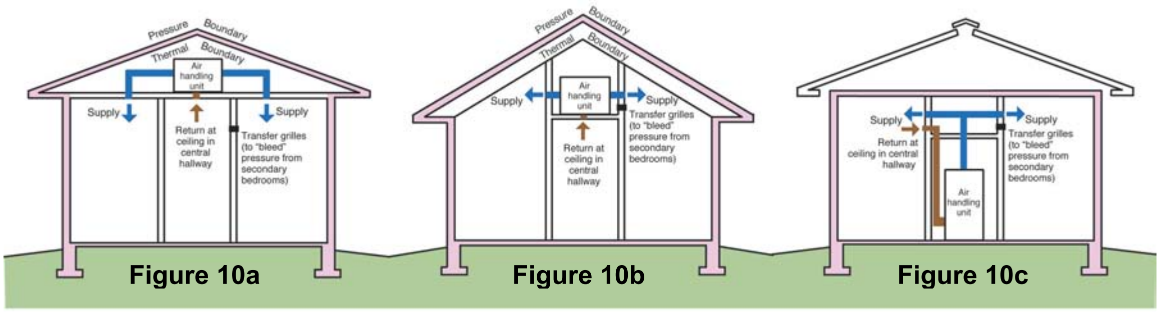
        - LG Electronics (all models): http://www.lge.com/catalog/prodlist?categoryId=CTG100515&modelCategoryId=CTG1000521&parentId=CTG1000440
        - Haier America (all models): http://www.haieramerica.com/categories.php?cat_id=2

    - Heat Controller (all BHD models use a turbo-impeller with turned blades): http://www.heatcontroller.com/
    - Or you can check the EPA Energy Star website for dehumidifiers from these manufacturers: http://www.energystar.gov/index.cfm?c=dehumid.pr_dehumidifiers

  2. Aprilaire 1700: This is a truly engineered, coherently manufactured, supplemental dehumidification system with built-in air filtration, ducted design, and a controls package that integrates central blower cycling for distribution, dehumidification and intermittent introduction of outside air ventilation. The system is also designed for flexibility—it can be connected to the conditioned space directly or to the central air distribution system in a number of configurations. It's also compact and lightweight enough to be set on or hung from most framing. The installed cost for this system is currently about $950 to $1,050. For more information, see: http://www.aprilaire.com/category.asp?id=F63D255EB0054BBF811DBB024BF068FA.

     For more information on other high performance supplemental dehumidification systems, see: http://www.thermastor.com/DesktopDefault.aspx..

5. **Ducts in conditioned space** - The preferred method for keeping HVAC ducts and mechanical equipment inside conditioned space is moving them down from the attic. Moving the conditioned boundary up (to the underside of the roof sheathing) so that the attic is conditioned also works as shown below. In this building profile, a conditioned attic can be used for HVAC ducts and equipment. In no case should HVAC ducts be placed within exterior wall assemblies-this is not part of what is meant by ducts in conditioned space. A vented attic assembly may be used in this climate as long as the ceiling plane is air tight and no ductwork or air handling equipment is located in the attic. See **Figures 10a-c**.
6. **Transfer grilles and jump ducts** – Single air returns require transfer grilles to provide return pathways that prevent pressurization of bedrooms. Appropriate sizing for ducts, including these pressure relief methods, can be found at http://www.buildingscience.com/resources/mechanical/509a3_cooling_system_sizing_pro.pdf. See **Figures 11a-d**.
7. **Water heater** - any type of gas water heater (in terms of venting) works if the water heater is located in the garage. If the water heater is located inside conditioned space, then it must be a gas power vented or power-direct vented unit, or an electric water heater.




Note: Colored shading depicts the building's thermal barrier and pressure boundary.
The thermal barrier and pressure boundary enclose the conditioned space.

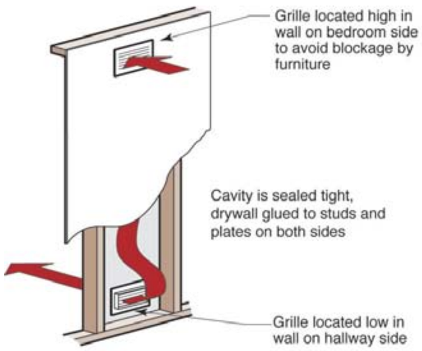



**Figure 11a**

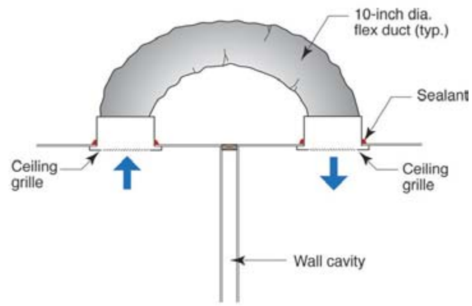



**Figure 11b**

**Figure 11c**

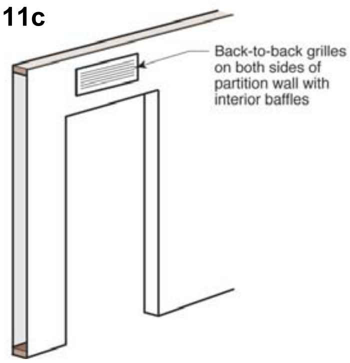
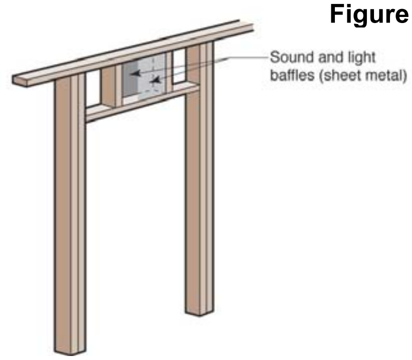



**Figure 11d**




## Field Experience Notes

- **Air sealing** – Unvented assemblies—walls or roofs—are robust when the air sealing is robust. The hardest spots are not the "fields" but the "margins" of assemblies. Spray foam may seem like an expensive element of the assembly, but the labor savings and air sealing quality in comparison to the alternatives are clear.
- **Roofing** - Roofing tiles in general, and light-colored ones in particular, have proven a wise choice to reduce cooling loads in this climate. For more information, see http://www.buildingscience.com/resources/roofs/performance_of_unvented_attics.pdf or see the Energy Star Reflective Roof Product List at http://www.energystar.gov/ia/products/prod_lists/roof_prods_prod_list.xls.
- **Elastomeric paints and stucco** - We have found that acrylic latex paints generally outperform elastomeric paints on stucco. While elastomeric paints have excellent crack-spanning capability, they can be much less vapor permeable than acrylic latex paints. Elastomeric paints have been known to blister when moisture gets into the assembly. In hot-humid climates, the higher vapor permeability of latex paints is overall more important than the higher crack-spanning capability of elastomeric paints unless a high permeability (greater than 20 perms) elastomeric paint coating is used.
- **Advanced framing** – For a technical resource that may help with resistance to advanced framing methods from local code officials, see the *Building Safety Journal* article written by Nathan Yost of BSC at

**Figure 12**

http:www/buildingscience.com/resources/articles/16-19_Yost&Edminster_for_au.pdf.

- **Energy trusses** –There are a number of different truss configurations that yield greater depth at the heel, but they vary quite a bit in cost. The truss shown in **Figure 12** (sometimes called a “slider” truss) has proven to be among the most cost-competitive. And of course, the pitch of the roof affects just how much insulation you can get at this location, regardless of the type of truss.
- **HVAC commissioning** – The most efficient equipment means little if the system is not set up and started up properly. Follow high performance start-up procedures such as the following: http://www.buildingscience.com/resources/mechanical/air_conditioning_equipment_efficiency.pdf.

## Material compatibility and substitutions

- **Exterior sheathing/building "paper"** - We do not recommend any substitutions behind stucco and a wood-framed wall. The paper-backed lath is an excellent bond break for the stucco and the unique corrugated profile of the StuccoWrap® is an excellent drainage plane material. In addition, structural sheathing is required for its resistance to wind loads in this hurricane prone region. Note that a cladding/sheathing combination capable of passing the hurricane impact test is a critical component of any wall assembly within many areas of this climate zone.
- **Cavity insulation materials** – Acceptable cavity insulation includes any that have a relatively high vapor permeability—cellulose, fiberglass, foam (as long as air sealing is accomplished by a separate component or system when cellulose or fiberglass is used). Since this wall assembly is designed to dry exclusively to the interior, do not use any layers in the assembly interior to the exterior sheathing that have low vapor permeability. Note that when foam insulation is left exposed in an assembly, a "thermal barrier" or "protection against ignition" may be required. Code implementation/interpretation have proven to be particularly troublesome for "gray" areas, such as spaces that are conditioned but not occupied (conditioned attics and crawlspaces).
- **Eave blocking and spray foam** – Since stucco is used as the exterior cladding, it can be used continuously on the soffit and fascia (replacing the spray foam and blocking) to move the air barrier from the top of the wall to the roof overhang (see Hot-Dry/Mixed-Dry Climate building profiles).
- **Flooring** – Many finished flooring materials — either because of their impermeability (sheet vinyl, for example) or sensitivity to moisture (wood strip flooring, for example) — should only be installed over a slab with a low w/c ratio (≅0.45 or less) or a slab allowed to dry (<0.3 grams/24hrs/ft$^2$) prior to installation of flooring. In general, sheet vinyl flooring should be avoided.
- **Sub-slab sand layers** - A sand layer under the slab (to prevent differential drying and cracking) should never be placed between a vapor barrier and a concrete slab. Cast the concrete directly on top of the vapor barrier. This problem is better handled with a low w/c ratio (≈0.45 or less) and wetted burlap covering during initial curing (see **Appendix III**).
- **Latex paint** - The substitution of low permeability finishes (vinyl wall paper, oil-based paints) for latex paint is strongly discouraged because of reduced drying potential. (Note that there are latex paints with very low vapor permeabilities, but they are generally clearly labeled as such.)
- **Gypsum wallboard** –Areas of potentially high moisture, such as bathrooms, laundry rooms, and kitchens are excellent candidates for non-paper faced wallboard systems (e.g. James Hardie’s Hardibacker®, GP’s DensArmor®, USG’s Fiberock®). In addition, paper-faced gypsum board should **never** be used as interior sheathing or backer for tub or shower surrounds where ceramic tile or marble (any material with joints or grout lines) is used as the finish.

## Appendix I – Building Materials Property Table (Template)

### Building Material Properties Table (Template)

| Material | Relevant dimensions | Vapor Perm (A)/(B) | Air Perm | Absorbtion | R-value | Fire code status (flame spread/ smoke dev | Products |
|---|---|---|---|---|---|---|---|
| Primer | | | | | | | |
| Latex paint | | | | | | | |
| Oil paint | | | | | | | |
| Std. Wallbd | | | | | | | |
| X-ppr face bd | | | | | | | |
| Wood (s-p-f) | | | | | | | |
| Fbrglass batt | | | | | | | |
| Hi-density f.b. | | | | | | | |
| Loose fill f.gls | | | | | | | |
| Cellulose ins. | | | | | | | |
| Spray foam | | | | | | | |
| EPS | | | | | | | |
| XPS | | | | | | | |
| Foil-fcd polyiso | | | | | | | |
| Hi-density fg bd | | | | | | | |
| OSB | | | | | | | |
| Plywood | | | | | | | |
| Thermo-ply® | | | | | | | |
| Variegated "stucco wrap" | | | | | | | |
| Synthetic housewraps | | | | | | | |
| Polyehtylene sheeting | | | | | | | |
| Silicone-treated gypsum | | | | | | | |
| Brick veneer | | | | | | | |
| Stucco | | | | | | | |
| PM stucco | | | | | | | |
| Cedar/redwood clapboard | | | | | | | |
| Pine clapbd | | | | | | | |
| Fibercement lap siding | | | | | | | |
| Vinyl siding | | | | | | | |
| Al. Siding | | | | | | | |
| T-111 | | | | | | | |
| Hollow-core concrete block | | | | | | | |
| Concrete | | | | | | | |
| Asphalt shingles | | | | | | | |
| Wood shakes | | | | | | | |
| Low-slope membranes | | | | | | | |
| Standing seam metal | | | | | | | |
| Clay tiles | | | | | | | |
| Cement tiles | | | | | | | |
| #15 asph felt | | | | | | | |
| #30 asph felt | | | | | | | |
| 60-minute Type D | | | | | | | |
| Bituminous membrane | | | | | | | |
| Others? | | | | | | | |
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## Appendix II – Unvented Roof Summary Article

Kohta Ueno, Building Science Corporation, 2003

This article was written to tie together and summarize the various papers on unvented conditioned cathedralized attics found on our website. We realize that there is a wealth of information, and much of it too detailed to understand or digest in a single sitting. Furthermore, building officials might not have the time available to carefully examine the many documents on the page; this is meant to summarize the main arguments, and provide pointers to where detailed information and measured data can be found.

The articles dealing with unvented roofs are as follows (in chronological order):

From http://www.buildingscience.com/resources/resources.htm#Roofs

"Measurement of Attic Temperatures and Cooling Energy Use In Vented and Sealed Attics in Las Vegas, Nevada" Armin F. Rudd, Joseph W. Lstiburek and Neil A. Moyer; Presented at the '96 Excellence in Building Conference, 14-17 November, and published in EEBA Excellence, The Journal Of The Energy Efficient Building Association, Spring 1997. Energy Efficient Building Association, Minneapolis, MN

"Vented and Sealed Attics In Hot Climates", A. F. Rudd and Joseph W. Lstiburek, Presented at the ASHRAE Symposium on Attics and Cathedral Ceilings, Toronto, June 1997. ASHRAE Transactions TO-98-20-3. American Society of Heating Refrigeration and Air-Conditioning Engineers, Atlanta, GA.

BSC Figures 1 and 2 (Unvented Roof Insulation and Framing Details, Air Barrier at Unvented Roof)

"Questions posed regarding unvented roofs," A. F. Rudd. 2000.

"Unvented-cathedralized attics: Where we've been and where we're going," A. F. Rudd, Joseph W. Lstiburek, and Kohta Ueno. 2000.

"Unvented Roof Systems, " Joseph W. Lstiburek, 2001.

"Unvented Roofs, Hot-Humid Climates, and Asphalt Shingles," January 2003, Joseph Lstiburek.

"Unvented Attic Discussion", Revised January 2003, Joseph Lstiburek.

## Unvented Roof (Conditioned Attics): Theory and Practice

Building codes typically require attic ventilation; the origin of this requirement comes from cold climate demands to avoid ice damming and vent internally generated moisture. In hot (cooling-dominated) climates, the purpose of attic ventilation is to remove solar gain from the roof, thereby reducing the contribution of roof cooling load. In typical houses, the contribution of the roof cooling load to the total load is on the order of 10%.

However, our modeling and research has shown that the requirement for venting attics in hot-dry and hot-humid climates is of questionable validity. Our studies on houses in various locations (including Las Vegas, Tucson, and the southeastern United States) have shown that by moving the ceiling air barrier and thermal barrier to the roof plane, better building airtightness can be achieved, and that the elimination of heat gain to the attic ductwork (due to conduction and leakage) more than offsets the additional heat gain caused by not venting the attic.

Placement of the air handler and ductwork system in this conditioned attic space negates the effect of duct leakage, which is commonly 10-20% of the rated air handler flow in typical construction. For houses with tile roofs, operating temperature for this 'conditioned attic' or 'attic utility area,' has been measured at typically within 5-7° F of indoor temperatures, without any direct space conditioning (i.e., conditioned by duct leakage and conduction); this provides less harsh operating conditions for the ductwork and air handler than typical unconditioned attics.

An excellent (and entertaining) discussion of the basics is found in the article: "Unvented Attic Discussion," 1999, Joseph Lstiburek.

Detailed studies are also on the same web page: the paper that addresses both computer models and test houses is "Measurement of Attic Temperatures and Cooling Energy Use In Vented and Sealed Attics in Las Vegas, Nevada." The paper ""Questions posed regarding unvented roofs" provides a summary of typical questions on the performance and applicability of unvented roof systems.

## Unvented Roof Assembly Details (Air and Thermal Barriers)

Moving the thermal and air barrier from the flat ceiling plane to the roof deck requires special detailing; since the attic is now conditioned space, it must be air sealed and insulated. Typical areas requiring draftstopping are the intersection between the 'conditioned attic' and the 'unconditioned attic' typically found over the garage or the porch. Details addressing these air barrier questions have been drawn and are enclosed here (see BSC Figures 1-4); they show the requirement for thermal barrier (i.e., insulation) and air barrier continuity around all of the conditioned space.

BSC Figure 1 details the intersection between a conditioned attic and a perpendicular ridge overframed garage attic that is not conditioned; the detailing for an unconditioned porch roof would be similar. Figure 2 shows an intersection in-line with the trusses; it requires the construction of a 'kneewall' with a rigid air barrier (such as plywood, OSB, rigid foam sheathing, or Thermo-ply®).

Finally, in addition to this prescriptive detailing, the houses should be subjected to a blower door test protocol, with the attic hatch open, which tests the airtightness of the entire building shell, including the unvented roof. This test truly determines whether the air barrier details, taken in aggregate, are effective. We recommend the airtightness goal used in the Building America program; see the web page->Building America -> Performance Targets. The airtightness goal is based on the surface area of the building, and is tighter than the majority of typical residential construction.

Of course, controlled mechanical ventilation is a recommended addition to all houses.

## Unvented Roof Assembly Material Performance

One of the first questions brought up when unvented roof systems are proposed is whether it will be detrimental to the life of the building materials in the assembly. In addition to measuring the energy performance of test houses in various locations, Building Science Corporation also measured temperatures of attic air, roof sheathing (plywood/OSB), and roof tiles or shingles. The resulting data showed that when a vented tile roof in Las Vegas was compared with an unvented cathedralized roof, the maximum roof sheathing temperature difference was 17° F (see "Questions posed regarding unvented roofs"). The maximum measured roof sheathing temperature of 154° F for the unvented attic was well within acceptable temperature limits (less than 180° F) (see "Unvented-cathedralized attics: Where we've been and where we're going").

Furthermore, Las Vegas would be among the 'worst case' locations for elevated temperatures of building materials (108° F ASHRAE 0.4% design temperature); few locations (e.g. Phoenix) have design conditions worse than that location.

The air handler and HVAC system (ductwork) are operating at much less stressful temperatures (within 3-5° F of indoor setpoint, instead of typical attic temperatures), and no ultraviolet light enters via roof vents. These factors will tend to increase lifespan of this mechanical equipment and ductwork systems in unvented roofs.

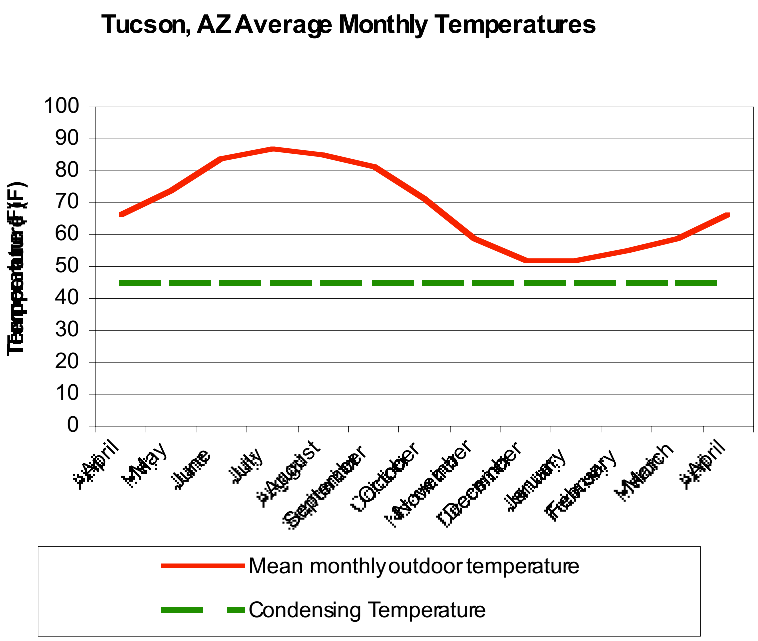
Climate Data

As mentioned in “Questions posed regarding unvented roofs,” unvented attics with cathedralized insulation can be recommended in the continental US wherever the monthly average outdoor dry bulb temperature does not fall below 45° F; this coincides with the definition of a hot-dry or hot-humid climate.

This temperature limitation is a function of potential condensation problems within the roof assembly. The logic behind this decision is detailed in the web page “Unvented Roof Systems.” As mentioned in that article, unvented assemblies can be built in mixed or cold climates, but further detailing is necessary.

At www.weather.com (The Weather Channel Web Site), monthly average temperature information is available, in order to determine climate location (cold, mixed, or hot zone). Data for Tucson, AZ is shown below; it shows a lowest monthly temperature averaging above 45° F:

| **Tucson, AZ** | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean outdoor temp (F) | 66 | 74 | 84 | 87 | 85 | 81 | 71 | 59 | 52 | 52 | 55 | 59 | 66 |




In addition, this data includes average precipitation records, which will allow the differentiation between humid and dry climate zones (i.e., over 20 inches/year or under). Tucson’s historical data shows an average precipitation per year of ~13 inches (hot dry zone).

## Appendix III – Sand Layers Should Not Be Placed Between Polyethylene Vapor Barriers and Concrete Floor Slabs

by Joseph Lstiburek, Ph.D., P. Eng.

Excess slab moisture intrusion problems resulting in flooring failures, mold growth and other microbial contamination problems are typically due to sand layers located between polyethylene vapor barriers and concrete floor slabs.

The sand layers become reservoirs for water in the liquid state (bulk water) that enters the sand layers by gravity flow from the top, sides and bottom of the sand layers (**Figure 1**). The liquid water is both held in the sand layers and redistributed within the sand layers by capillarity (**Figure 2**). Additionally, due to these capillary forces, the liquid water is incapable of draining out of the sand layers. The only mechanism of drying of the sand layers is upwards through the concrete slabs by vapor diffusion and capillary draw (**Figure 3**).

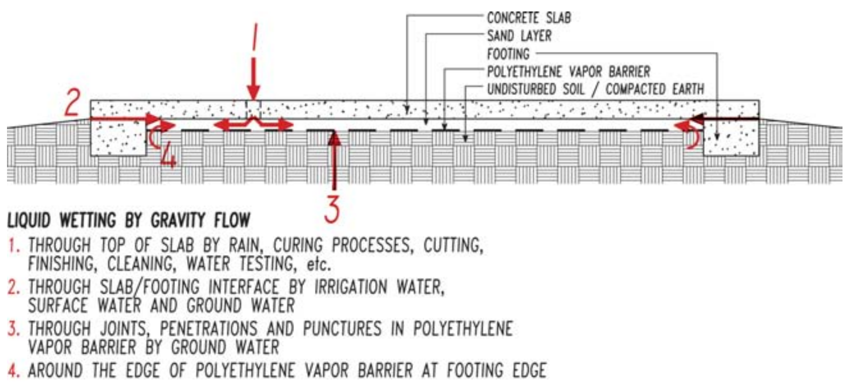



FIG. 1 WETTING MECHANISMS

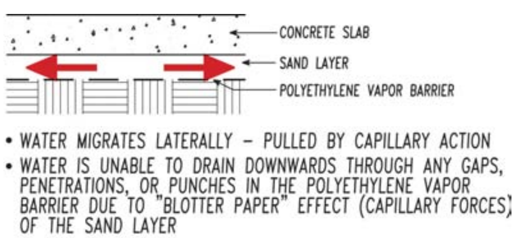



FIG. 2 WATER DISTRIBUTION IN SAND LAYER

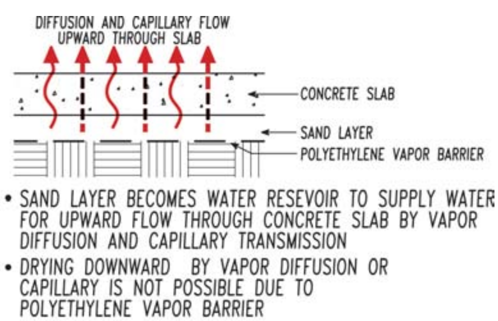



FIG. 3 UPWARD DRYING THROUGH SLAB

There is no barrier or protection for the upward moisture flow through the concrete slabs from the wetted sand layers. The intended protection for upward moisture flow from below grade are the polyethylene vapor barriers, but this intended moisture protection has been rendered ineffective by the gravity flow wetting mechanism that has saturated the sand layers that are located above the polyethylene vapor barriers.

The moisture flow upwards through the concrete slabs by vapor diffusion and capillary transmission passes through the top surface of the concrete slabs as well as through floor surface treatments and leads to mold and other microbial contamination problems.

The rate of wetting of the sand layers by the gravity flow wetting mechanism is several orders of magnitude greater then the rate of drying of the sand layers by the vapor diffusion and capillary transmission drying mechanism. The sand layers become water reservoirs that continually supply water for the upward flow through the concrete slabs by vapor diffusion and capillary transmission.

Picture the sand layers as "blotter paper" that once wetted do not let water drain out of them. The only method of drying available to the "blotter paper" is evaporation. In the case of the sand layers the only method of "evaporation" is upwards through the concrete slabs due to the presence of the polyethylene vapor barrier under the sand layers.

Concrete slabs should be placed in direct contact with polyethylene vapor barriers. A sand layer should not be installed between concrete slabs and polyethylene vapor barriers.

Where concrete slabs are in direct contact with polyethylene vapor barriers a reservoir is not created if rainfall occurs during the construction process and penetrates the slab, or if wet curing is used. Additionally, wet concrete cutting operations, cracks in slabs, gaps and penetrations in the polyethylene vapor barrier coupled with cleaning, water testing, ground water migration or irrigation do not affect slab moisture transmission if a reservoir is absent or cannot be created between the polyethylene and the concrete slab.

When concrete slabs are cast directly over polyethylene vapor barriers the concrete water-to-cement (w/c) ratio must be correctly specified in order to control bleed water and plastic shrinkage cracking. Bleed water will not be present if the w/c ratio is below 0.5 and plastic shrinkage cracking becomes negligible when the w/c ratio is below the range of 0.48 to 0.45. Differential drying and slab curl are controlled with either a curing compound or a temporary covering of plastic sheeting.

Concrete slabs with a w/c ratio of 0.45 or less should be placed directly on a polyethylene vapor barrier coupled with a curing compound or a temporary plastic sheeting slab covering in order to avoid problems.

The following 4 reasons are generally cited for using a sand layer over polyethylene vapor barriers is as follows:

1. The sand layer controls bleed water with high w/c ratio concrete slabs
2. The sand layer reduces curl with high w/c ratio concrete slabs when top-side curing is not controlled
3. The sand layer reduces plastic shrinkage cracking with high w/c ratio concrete slabs
4. The sand layer protects the polyethylene vapor barrier from punctures

The first three reasons are based on sound technical arguments. However, each of the first three are based on the condition that the sand layer be prevented from getting wet during the construction process and beyond and are typically associated with floor slabs that are placed "after the building is enclosed and the roof is watertight." Additionally, the first three are based on the condition that wet curing such as ponding or continuous sprinkling will not occur or that joint sawing using wet methods or power washing will not occur. The first three are also conditional on slab and foundation designs that will not be sensitive to ground water wetting from local water tables and local irrigation.

In the case of exposed slab construction, the first three reasons are rendered moot since the conditions for their use are not met ? nor can they be met. Accordingly, a sand layer should not be specified.

The fourth reason, "puncture protection", is based on incorrect physics. A sand layer is not necessary to protect polyethylene vapor barriers. Vapor diffusion is a direct function of surface area. Rips, holes, tears and punctures in sheet polyethylene vapor barriers constitute a very small surface area of vapor transmission compared to the total floor slab area. If 95 percent of the surface area of the slab is protected by a vapor barrier, then that vapor barrier is 95 percent effective. This holds true only if air flow or air leakage is not occurring through the vapor barrier. Where concrete is in direct contact with the polyethylene vapor barrier this is the case. Air flow is not occurring. The concrete slab is an "air-barrier" and the polyethylene is the "vapor barrier" ? and an effective vapor barrier even if the polyethylene has numerous punctures.

In the case of exposed slab construction there is no justification for the use of a sand layer between the polyethylene vapor barrier and the concrete slabs.

The specification of a sand layer over a polyethylene vapor barrier is typically directly responsible for flooring failures, mold and microbial contamination problems.