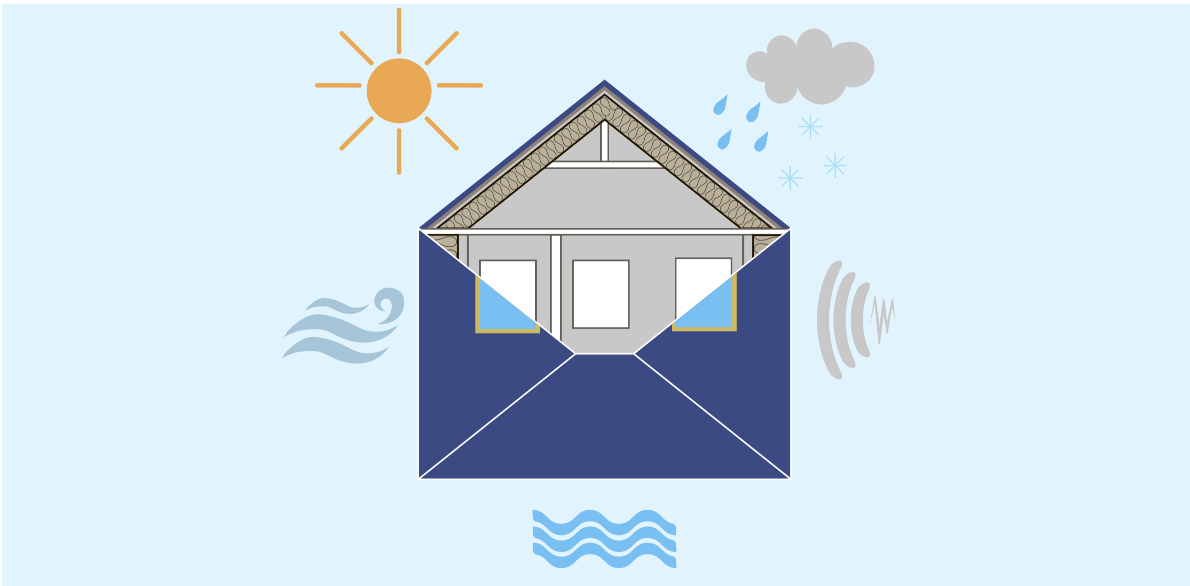
RESEARCH & TECHNOLOGY

MOISTURE PROBLEMS AND SOLUTIONS – KEEPING WATER AND MOISTURE OUT



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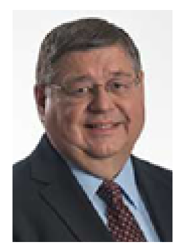

Moisture problems are relatively easy to identify – liquid water or damp, wet materials exists where it shouldn't. However, determining the best solution for a particular moisture problem is not straight forward because one solution does not fit all situations. The strategy to understand moisture problems is typically straight forward, but the details to address any one problem are more complicated.

There are four steps to undertake:

- First, identify all the sources of moisture affecting a building envelope or a building system.
- Second, determine if any of the moisture sources can be eliminated. Sometimes a source can be eliminated or at least minimized. However, many moisture sources cannot be eliminated and then must be addressed.
- Third, the building envelope must be constructed and maintained to protect from moisture exposure.
- Fourth, remove any accumulated moisture from the building system.

The first two steps of identification and elimination can be considered straight forward. The third step of exterior envelope protection is dependent upon the moisture source, location of a potential moisture problem and specific building system details. The complexity of protection dictates why one solution does not fit all situations. The removal of any excess or accumulated moisture via ventilation is not addressed in this article.

Moisture sources that need to be kept out of building system can be categorized into three main groups:

- Surface water impacting building foundation and exterior envelope,
- Subsurface water impacting building foundation and floor, and
- Indoor sources impacting exterior building envelope.

The primary surface water source is due to precipitation from rain or melting snow. Surface water will almost always exist so it can't be eliminated as a source; therefore, the building system must be protected from exposure to surface water.

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Any building with a portion of the building volume below the outside finished grade soil surface may be exposed to subsurface water and soil moisture. Any building with a basement, partial basement, or walkout basement needs to be protected from potential subsurface water and soil moisture exposure.

A building that uses a slab-on-grade construction or has a concrete floor can have moisture challenges due to subsurface soil moisture with certain soil conditions. Regardless of building design, the building foundation and floor system must be able to cope with any soil moisture or subsurface water issues.

To solve moisture problems, the moisture source must first be identified. Then based on the moisture source and location of the problem, a solution can be developed.

Protecting from surface water

Undesired surface water impacts on buildings are commonly caused by rainwater, surface water runoff and snow/ice melt. These precipitation-based sources cannot be eliminated so they must be controlled to not cause adverse impacts on a building system.

Several phases need to be followed to control surface water from impacting on a building system. These phases include the following:

1. **Site Selection** – where the building will be located determines much of what needs to be done to control surface water.

2. **Site Preparation** – proper site preparation has a significant impact on effectiveness of surface water control.

3. **Site Drainage** – details need to be addressed so surface water drains off and way from building on finished site.

4. **Exterior wall and roof system selection** – the selected roof and wall system along with flashing transitions must be selected to ensure precipitation does not penetrate exterior of building.

5. **Construction process** – attention to detail during the construction process must be done to ensure a well-designed wall and roof system is effective.

The proposed site of a new building needs to be evaluated to determine not only how surface water will drain away from the site but also how much water potentially will drain onto the site. For example, a site may have excellent drainage away from the site but is located where a lot of surface water from up the hill will drain to the proposed site. In this example, the proposed building site is probably located in a drainage path for a large watershed area. If so, can the proposed building site be moved some so that it is no longer located in the significant drainage path? A second example of potentially poor site selection is a proposed building site located in 'hole' or depressed area where surface water collects rather than drain away. Surface water should be able to drain away from the site at a sufficient rate so that surface water does not flood a building during design rainfall events for the specific location.

Site preparation is the phase to address any problems identified during the proposed building site selection phase. Sometimes, a new building site needs to be elevated to increase a surface water diversion capacity or to get the finished building elevation high enough so surface water can drain away from the building. During site preparation is the time to ensure surface water will adequately drain away for the new finished building.

A building site located near the bottom of a hill will require the construction of a surface water diversion with sufficient capacity so that surface water flowing to the site will flow around the new building site. Sometimes the building site elevation needs to be increased to ensure enough diversion capacity can be constructed. A site with naturally slow or poorly draining soils needs to use a similar clay type soil fill to increase the elevation under the building so that surface water does not infiltrate into the fill and collect under the building. A granular material like gravel or sand can be used to elevate the building base to a higher finished elevation. Figure 1 graphically shows how low permeability fill should be placed to ensure infiltrated surface water does not collect under the new building base.

If the building fill base was all granular material, surface water in the diversion will infiltrate the fill base under the building which can result in significant subsurface water problems. However, the source of the water is infiltrated surface water rather than a subsurface water source.

If the building example shown in Figure 1 had a basement with the floor below the elevation of the bottom of the surface water diversion and all the fill material was all granular, a good chance exists that the basement could have moisture problems during wet weather periods.

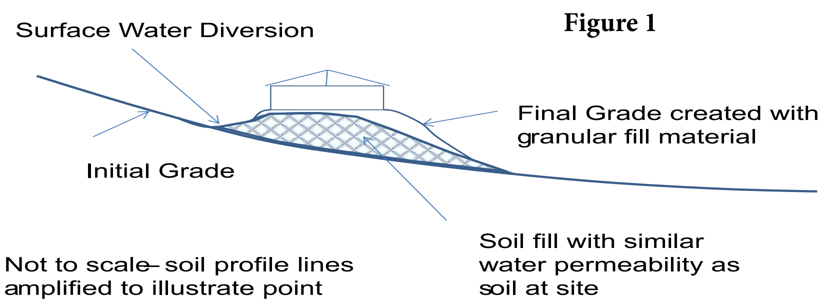

Figure 1. This illustrates how low permeability fill should be placed to ensure that infiltrated surface water does not collect under the new building base.

The roof and exterior wall materials protect a building from precipitation of all kinds and types. Proper selection of materials and design of transitions between different

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roof and exterior wall surface components are critical to ensure the building is protected from liquid water throughout all temperatures the building is likely to experience. The owner, the builder's customer, may be most concerned about esthetics and maintenance. However, the reliability of the chosen system over time also needs to be considered. A capillary break, which minimizes the movement of moisture from outside into the building structure, must also be incorporated into building system. A "Pen Test" can help determine if the chosen design will protect the building from rainwater moisture penetration. An example this pen test is shown in Figure 2 from "Moisture Control Guidance for Building Design, Construction and Maintenance" which can be found at https://www.epa.gov/sites/production/files/2014-08/documents/moisture-control.pdf on the web from USEPA. This document is an excellent resource to understand and address moisture problems in buildings.

The construction process for a new building is the implementation of the material selection and transition design phase. Attention to detail is critical. The success from selecting best materials and developing sound transition designs will occur only if the building is built according to the design.

Figure 2

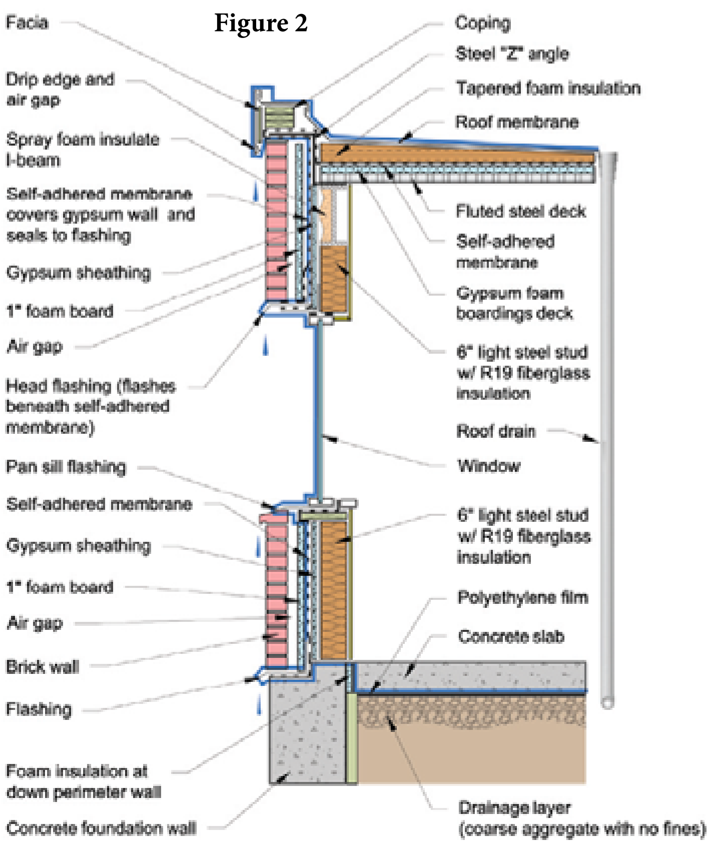

Figure 2: A "Pen Test" can help determine if the chosen design will protect the building from rainwater moisture penetration. This example is taken from "Moisture Control Guidance for Building Design, Construction and Maintenance" found at https://www.epa.gov/sites/production/files/2014-08/documents/moisture-control.pdf

Protecting from subsurface water and soil moisture

Any building has the potential to have challenges from subsurface water and soil moisture simply because the building has direct contact with the soil. However, the building practices to protect a given building depend upon the site soil characteristics and seasonal and permanent water table depths along with building foundation type. Types of building foundations to be addressed include concrete wall and foundations for shallow crawl spaces, deep basements, partial or walkout basements as well as slab-on-grade and post-frame construction foundations.

Three different strategies are typically implemented to control subsurface water and soil moisture. These strategies include the following:

1. **Control or Minimize Subsurface Water** – Use foundation or footing drainage to remove subsurface water from contacting building foundation and footings.
2. **Minimize Surface Water Infiltration** – Implement building foundation construction practices and surface water drainage practices so minimize surface water infiltrating close to building.
3. **Protect from Soil Moisture** – Install vapor barriers and capillary breaks to protect building from soil moisture penetration.

Foundation and footing drainage provide the base control of subsurface water by removing the water from the soil next to the building. Keeping water away from a building foundation protects the building from frost heave problems and minimizes any water leakage problems into a building basement. Two publications provide detailed discussions about foundation drain systems for slab-on-grade construction, crawl space foundation construction and basement wall foundation construction. The first one is "Moisture Control Guidance for Building Design, Construction and Maintenance" from USEPA. The second one is "Build a Better Home: Foundations" which is available from APA – The Engineered Wood Association (http://www.apawood.org/). This APA publication focuses on home construction, but the foundation information is applicable for any building that uses wood frame construction on top of a concrete foundation system.

Either a seasonal or permanent high-water table can adversely impact a building foundation. A properly

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designed and installed foundation drainage system can lower the elevation of a water table. The water table can be lowered because the foundation drains allow subsurface water to drain out of the soil around the building foundation. The resulting subsurface water free zone provides a place for a building foundation to exist without being impacted by subsurface water in contact with building foundation. The ability of a foundation drainage system to lower a water table is discussed in more detail in the APA "Build a Better Home: Foundations" publication.

A post-frame building foundation can be protected from subsurface water using a foundation drainage system if a high-water table is found on a post-frame building site. The drainage system must be placed outside (typically 2' or more) of the post foundations and at a lower elevation than the bottom of the post foundation pads. The installation of a foundation drainage system must not impact the post foundations. The post foundations of a post-frame building need to be kept subsurface water free to minimize frost heave issues.

Surface water that infiltrates into the soil becomes subsurface water. The key is to minimize surface water infiltration near a building. As discussed in part two of this series, good site drainage must be established so surface water drains away from building. However, foundation drain systems need to be protected from surface water infiltration flooding. Many foundation resources will show the need for granular backfill or gravel to be placed against a basement foundation wall, especially on building sites with clay and/or highly expansive soils. The granular or gravel backfill helps protect the foundation wall from high soil pressures when soils expand during wet periods. A low permeability soil needs to be placed at least 6 to 8 inches think to minimize surface water infiltration directly into the granular or gravel backfill. If the granular backfill is installed from the drainage system to the top of the finish grade around a building, rainwater is likely to drain directly into the gravel backfill especially during heavy and extended rainfall events. When rainfall directly enters a foundation drainage system, the drainage system typically becomes flooded because the typical 4" perforated drainage pipe is not nearly large enough to serve as a storm water drainage system. If a building basement with a basement foundation often becomes wet during heavy or extended rainfall periods, check to see if rainwater can easily enter the foundation drainage system.

Soil moisture exists in soil even when all subsurface water has been drained out of the soil. Capillary water in the soil can often cause moisture problems inside building spaces that are in contact with the soil when building foundation components are not protected from soil moisture. The specific details for protecting a building foundation from soil moisture varies depending upon building foundation construction system. The two publications mentioned earlier provide detailed discussions and diagrams on how to protect different foundations from soil moisture. In general, gravel (often 3/4" diameter) or damp proofing methods provide a capillary break protecting the foundation from capillary moisture movement. A vapor barrier, often polyethylene film, minimizes moisture vapor movement from the soil into the building space.

Protecting the exterior building envelope from moisture

Indoor moisture sources can be the cause of many types of building moisture problems. Two solution aspects need to be addressed with respect to indoor moisture – protecting the exterior building envelope and removing excess moisture with ventilation. This fourth part focuses on protecting the building exterior envelope.

Where a building is located impacts how to properly protect exterior walls and insulated ceiling assemblies from moisture problems. Different climate zones have been established for the US as shown in Figure 3. The specific design and construction details vary depending upon where your building is located. The climate map shown in Figure 3

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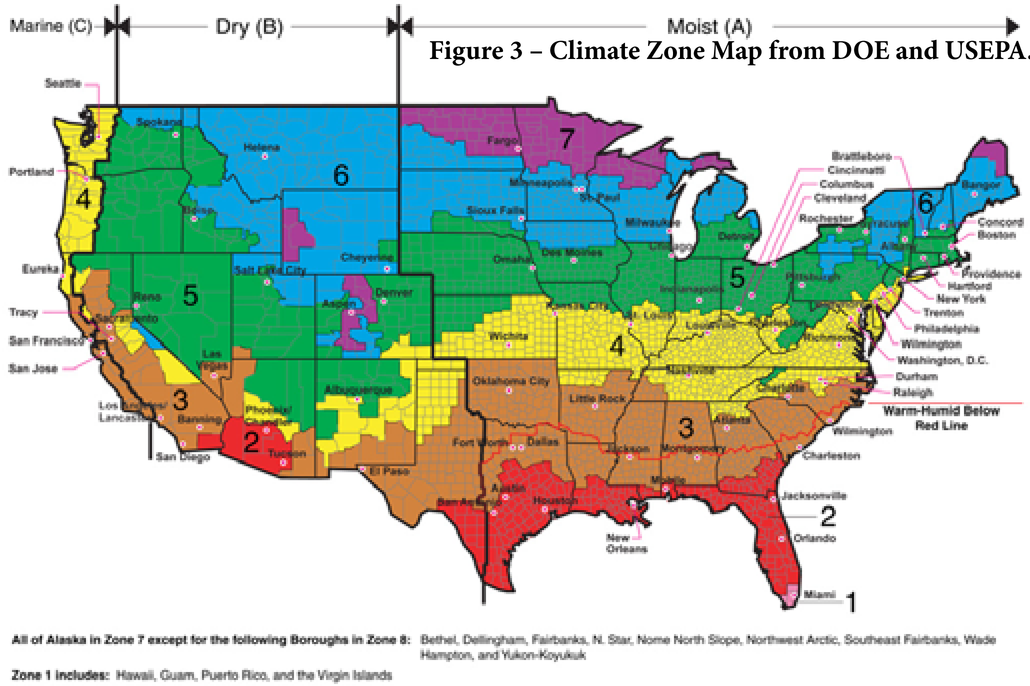

Figure 3 – Climate Zone Map from DOE and USEPA.

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is found in "Moisture Control Guidance for Building Design, Construction and Maintenance" from USEPA.

The appropriate design and construction details depend upon where the building is located and the following three strategies to protect the building components:

1. Vapor migration – installing a vapor retarder in proper location.
2. Indoor air infiltration – preventing inside air leaking into exterior walls and/or insulated ceilings.
3. Outside air penetration – preventing outside air leaking into exterior building components.

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Vapor Migration

Moisture that is permitted to migrate at a sufficiently high rate through an insulated building component will often condense inside the insulated building assembly. This condensed moisture inside the insulated assembly will result in a variety of moisture problems. A vapor retarder minimizes the moisture migration rate through an insulated wall or ceiling. Moisture will migrate through an insulated building component from a high vapor pressure to a low vapor pressure. However the climate where the building is located will dictate whether the inside air has a higher vapor pressure or a lower vapor pressure. Climates where the inside is usually warmer than outside, the inside vapor pressure is normally higher than outside. Conversely, climates where the inside is usually cooler than outside, the outside vapor pressure is normally higher than inside. Buildings located in Climate Zones 5, 6 and 7 should have a vapor barrier, with a perm rating less than two, located near the inside of an insulated assembly and no more than one third of the total insulation value of the assembly should be located on the "warm side" of the vapor retarder. Buildings located in warmer climates should use a vapor retarder, with a perm rating of greater than two, and can be located on either the inside or outside of the insulation. A more detailed discussion on vapor retarders is located throughout "Moisture Control Guidance for Building Design, Construction and Maintenance" from USEPA.

Indoor air infiltration

The exterior building envelope needs to be protected from indoor air infiltrating into exterior insulated walls and insulated ceiling assemblies. Buildings located in Climate Zones 4, 5, 6 and 7 are ones which definitely need to minimize inside air infiltration. The air inside is typically relatively warm compared to outside air, especially during cold weather periods. The dew point temperature is often defined as the temperature at which moisture will condense from air onto a surface exposed to the air. During cold weather, the inside dew point temperature is normally higher than the outside air temperature even though inside relative humidity level is acceptable. The inside dew point temperature being higher than the outside air temperature is the foundation for indoor air infiltration-based moisture problems.

When warm, moist inside air infiltrates into an insulated exterior wall, the infiltrated air will usually come in contact with a surface or location inside the cavity that is cooler than the dew point temperature of the inside air. When warm, moist air comes in contact with building materials that are at or below the inside air dew point temperature, moisture will condense out of the infiltrated air and causes a variety of moisture problems. Exterior insulated walls can be protected from indoor air infiltration-based moisture problems by addressing the following construction details:

- Seal all electrical boxes located on exterior walls. Air can easily infiltrate through unsealed electrical boxes into many types of insulation resulting in moisture problems inside exterior wall cavities.
- Seal all holes in the top plate of exterior walls. Sealing the top plate of exterior walls reduces any inside air that can leak into an exterior wall cavity because air will not enter into a wall cavity if it cannot escape from the cavity.
- Seal the inside exterior wall surface to the top and bottom plates or use spray foam insulation to create an air barrier at the inside insulation surface. Convection currents can develop when inside air can enter into an exterior wall cavity, cools and then can exit from the bottom of the same exterior wall cavity. When warm inside air cools inside an exterior wall cavity, moisture problems will typically result.

Insulated ceiling assemblies can be a source of moisture problems in attic spaces. Warm air will naturally infiltrate up through any hole or crack in the ceiling surface system into the attic space. When inside air enters the cold air in the attic, moisture carried by the inside air will typically condense out the infiltrated inside air and cause moisture problems in the attic space. Adequate attic ventilation is generally not capable of removing the amount of moisture moved into the attic by leaking warm air from the inside of the building. Air infiltration into an attic can be minimized by addressing the following construction details:

- Seal all attic accesses to minimize any air leakage from the inside into the attic.
- Seal all holes in the top plate of all interior walls. If air cannot escape from an interior wall cavity, air will not leak from the inside into the attic via interior walls.
- Seal all electrical fixtures and any recessed light fixtures located in the ceiling. Unsealed recessed ceiling light

fixtures will result in a significant amount of air to leak from inside a building into the attic space.

Outside Air penetration

Outside air penetration needs to be minimized for buildings located in all Climate Zones. For buildings located in cold climates, cold air that can penetrate into an exterior building assembly can cause a cold surface to develop on the inside surface. Moisture problems will occur on the cooled inside surfaces when these surfaces are at or below the dew point temperature inside the building.

For buildings located in warm climates and are air conditioned, moisture problems can develop inside insulated assemblies when warm, moist outside air penetrates the assembly. A convection current will carry moisture in the warm outside air and the moisture will condense on the outside surface of the cooled inside building assembly surface. Any air-conditioned building that has moisture condense on the outside of a window during hot, humid weather will most likely have moisture problems in insulated exterior building assemblies if outside air penetrates the cavity. This air infiltration can be minimized by addressing the following details:

- Seal between windows/exterior doors and rough structural frame prior to installation of exterior flashing.
- Ensure an exterior air barrier is installed and is continuous.
- Install attic baffles or air chutes to minimize air that enters attic space from penetrating under ceiling insulation.

This article was subjected to a peer review process conducted by the NFBA Editorial Committee, which consists of at least 10 members from engineering and academic organizations throughout the United States who are each knowledgeable about Post-Frame construction.