DESIGN and CONSTRUCTION vs. Weather

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Weather conditions affect the design, construction, and performance of buildings. The intent of this article, while presenting the cause and effect of weather, is to improve the understanding of how varying weather conditions can affect construction projects. Armed with this information, building professionals can take measures to eliminate (or at least reduce) the impact of weather.

Meteorology is one of my hobbies, and I have a special interest in how weather affects building design and construction. I have read many old weather sayings that have been repeated over the years. Some are based on scientific principles and are frequently dependable, but that is beyond the scope of this article. Some of these sayings include:

- Every wind has its weather!
- Rain before seven, gone by eleven.
- Dew in the night, next day will be bright.
- When in February you hear thunder, ten days later, you'll be snowed under.
- When wooly fleeces show the heavenly way, no rain will disturb the summer day.

The various geographic regions throughout the world have prevailing weather patterns that are typical for a specific region. Climate maps that include wind speed, rainfall, and snow accumulations are published in model code books. Climatic statistics for specific cities or states are available from the National Weather Service and from various private climatic agencies such as AccuWeather. This data can be incorporated into the building during design and can influence construction materials selected and the construction means and methods used.

THE CAUSE

Weather is simply a reaction to changes in atmospheric pressure. These changes alter air movement, temperature, and humidity. Some changes are dramatic and produce violent storms. Other changes are subtle and have little effect on weather. Meteorologists can predict these changes with reasonable short-term accuracy. What is done with these predictions directly affects comfort, project design, and construction procedures.

THE EFFECTS

Weather conditions can affect many aspects of the construction project from site work to worker comfort. For the purpose of this discussion, weather conditions are

divided into hot and dry, cold, wet, thunderstorms, and windy. The most common effects are briefly mentioned for each condition.

Hot and Dry Conditions:

It may be surprising to consider hot and dry weather as a problem. However, a lack of moisture can have dramatic effects on a project, especially on outside activities. Just what is affected during these conditions?

Site: Dust is associated with with hot and dry weather. One of the easiest ways to be tagged a bad neighbor is to allow large clouds of dust to settle on nearby property. Tanker trucks are often used to spread a water mist over designated areas to reduce dust. Dust also generates dirt that must be removed from interior surfaces on a regular basis during construction.

Concrete: Dry weather can cause the water in concrete and masonry to evaporate too fast. This rapid evaporation produces concrete with a lower compressive strength and a finished concrete that tends to curl upward and to spall.

Masonry Mortar: Dry weather causes rapid evaporation of moisture, which causes the mortar to begin setting prematurely. When mortar begins to set prematurely, there may not be sufficient moisture to ensure the brick absorbs the mortar paste properly. This reduces the bond strength between the mortar and the brick, which is a major cause of masonry leaks.

Brick: Unless properly wetted prior to laying, bricks become excessively dry and when laid, they absorb the water from the mortar so fast that the mortar paste that creates the bond between the brick units is not absorbed. When this occurs, a poor bond is formed, and can cause masonry leaks at the joints.

Paint: Weather can affect both application and performance of paint. During application, when ambient temperature or surface temperature of the substrate is too high or the relative humidity is low, reducers (solvents) in paint evaporate too fast. This rapid evaporation prevents the paint from curing properly, possibly causing delamination, wrinkles, blisters, peeling, and cracking. Most paint containers state the ambient and substrate temperature range. Some paint manufacturers include a recommended relative humidity range. Ultraviolet (UV) exposure is the worst enemy of paint performance. Eventually, all paint will succumb to UV, ultimately prompting fading, chalking, and embrittlement. However, some paints, such as high performance polyurethane and 100 percent acrylic, are formulated to be more resistant to UV exposure.

Seals and Sealants: All weather, especially freeze-thaw cycles and UV exposure, will reduce the resiliency of seals and sealants, resulting in a loss of elasticity. Loss of elasticity causes embrittlement. Replacing failed sealants can be an expensive endeavor because new product installed directly over an old sealant usually results in premature failure. To prevent premature failure, the failed material must be removed, the joint thoroughly cleaned, and new and proper sealant installed. Using high quality elastomeric sealants such as silicone and polyurethane usually prolongs the integrity of a sealed joint. Manufacturers often have details for joint design that provide for temporary protection from moisture intrusion if the sealant fails. However, these joint designs are not a substitute for a proper joint sealant.

Equipment: Filters on vehicles, machinery, and equipment, both inside and outside, are exposed to dusty conditions. These filters should be checked and changed regularly to prevent premature breakdowns. Dust can also find its way into working parts and

cause accelerated wear. Equipment should be cleaned and lubricated regularly.

Thermal Movement: Based on their respective thermal coefficients of expansion, some materials will move significantly more than others when exposed to temperature variations. For example, aluminum has a higher thermal coefficient of expansion than stainless steel and will experience more movement. However, contrary to common assumption, thickness does not affect the amount of movement. Thus, 0.032-inch thick aluminum sheet will not move any more than 0.125-inch thick extruded aluminum. However, when thick and thin pieces of aluminum are fastened to a substrate, the thick piece of aluminum, because of its mass, will exert more pressure on the fasteners than the thin piece of aluminum. When a design does not allow for thermal movement, joints or seams can open, fasteners can fail, and components can distort or break. Both expansion from heat and contraction from cooling should be considered during design and construction.

Workers: Physical activity associated with construction work will cause a considerable loss of body fluid. Since it is imperative that this body fluid loss be replenished, fresh water should be readily available to workers to prevent dehydration, especially to those outside. Drowsiness, disorientation, dizziness, and fatigue are common symptoms of dehydration and can result in lost-time accidents or sickness.

Cold Conditions:

Concrete and Masonry: Cold weather can cause ice crystals to form and retain moisture. Cool temperatures can also slow the curing, which may affect concrete strength, promote spalling, and can ruin the finish. Cold weather procedures recommended by the American Concrete Institute (ACI) for concrete work and Brick Institute of America (BIA) for masonry should be followed.

Site Freezes: When the site freezes, water is retained in the earth so that surface drying is slowed, resulting in prolonged muddy conditions.

Foundations: In cold climates, foundation bases must be set below the frost line to prevent heaving. The colder the climate, the deeper the frost line, and consequently, the deeper the foundation. If the foundation is above the frost line, freeze-thaw cycles can cause excessive structural movement.

Painting: Cold temperatures can cause the carriers (water in water-based paints and solvents in solvent-based paints) to freeze or thicken and retard the curing process. Condensation, which is moisture that forms on surfaces when air temperature falls below the dew point, usually leads to premature paint failure. Dew point is directly related to temperature and relative humidity and is often associated with cooling temperatures. When condensation forms with surface temperatures above freezing, the resulting moisture is called dew. Conversely, when condensation forms with surface temperatures below freezing, the resulting moisture is called frost.

Equipment: Water-cooled engines must be winterized and protected from cold temperatures. Like people, equipment can act a little sluggish when it is cold. Cold lubricants are not effective, and operating equipment with inadequate lubrication can cause accelerated wear of moving parts. Be patient; give equipment sufficient time to warm up before operating it.

Workers: Workers must wear extra clothing that is often heavy and bulky. When it is cold, everyone looks like the Michelin Man®. Bulky clothing can restrict movement and increase the risk of accidents. Also, muscles and joints are not as flexible and are more susceptible to injury when cold. Both dew and frost on smooth surfaces, such as single-ply roofs, metal roofs, smooth concrete, and structural steel, can cause falls. Drinking water must be protected from freezing.

Wet Conditions:

Yes, wet weather is the opposite of dry weather and unlike dry weather, it can cause more problems, big delays, and increased costs. Wet weather is frequently the reason contactors use to request increased contract time or money.

Site Work: Rains can turn a construction site into a gigantic mud hole that would make a "4-wheeler" drool with envy. Mud will hinder access to the site by all building trades and will prevent or slow general

earthwork (grading, trenching, and backfilling activities), paving, and foundation work. Both foot and vehicle traffic can be restricted, and compacted gravel or rock is often used in roadways to establish a firm base. The site should be properly graded to ensure positive drainage away from the structure and to prevent water collection points.

Groundwater: A high water table or excessive rain can increase groundwater. Regardless, dewatering provisions for excavation and trenching must be used to keep the site and excavations dry enough to allow steady progress. Furthermore, including permanent waterproofing for below-grade spaces in the building design will compensate for high water table and groundwater conditions.

Brick: Brick is a reservoir for moisture, and capillary action causes it to suck up moisture like a dry sponge. As damp brick heats up from the sun, the warmth causes the moisture to move toward the cooler interior. Unless the building is designed and constructed with an interior rain screen and through-wall flashing, the moisture will continue to migrate inward and condense on the cooler interior wall. In additions, poorly constructed or tooled masonry joints are openings for moisture intrusion. When brick emerges from the kiln, it is the smallest that it will ever be. But it expands as it absorbs moisture. The expanding brick can break adjacent brick and open mortar joints. Properly designed and constructed expansion joints will compensate for this movement.

Fibrous and Porous Products: Fibrous and porous materials that include wood, fibrous insulation, drywall, carpeting, and masonry are examples of materials that absorb and hold moisture. Moisture in or on these materials is a prescription for the dreaded "M" word – mold. To prevent distortion and damaged finishes, these items should be kept dry and protected before, during, and after construction.

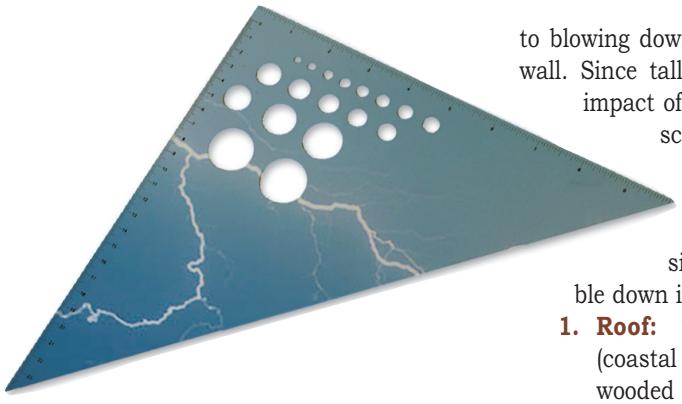
Paint: When relative humidity exceeds the manufacturer's recommended limits, or when fog or mist are present, paint will not cure in the normal time. This can cause poor adhesion, discoloration, and can give additional time for dirt to settle on the uncured and tacky surface.

Building: Building performance can be significantly improved by draining everything from the roof to the foundation. Moisture is an intruder that will penetrate the building shell of the best defended structure. However, once moisture breaches the building shell, drainage provisions can be used to capture it and direct it to the exterior.

THUNDERSTORMS

Thunderstorms are simply rain with an attitude, plus light and sound for special effects. Usually, the darkening sky and towering dark clouds give warning of an approaching thunderstorm. Other times, they occur suddenly. They are particularly dangerous to workers and to tall structures, especially those in the open. Workers should seek inside protection on the ground floor or basement away from steel, windows, and doors. Straight-line winds (sometimes approaching hurricane velocity) that usually accompany thunderstorms can wreak havoc on construction sites. Construction crews should ensure that materials are properly secured and protected, construction in process is properly braced, trash and debris are in containers that are properly secured, and personal protection measures are taken. Also, buildings in areas with frequent thunderstorms should be designed with lightning protection.

Thunderstorms often include hail and wind. The National Weather Service considers severe hail to be 3/4-inch diameter (dime size). However, smaller size hail can



break windows and severely damage exposed materials such as sheet metal and roofs – especially shingles and single-ply roofs. It will dent and deform sheet metal and strip thin paint from substrates. Where severe thunderstorms are common, consider roof systems that are resistant to hail.

Occasionally, a thunderstorm produces the T-Rex of storms – the tornado. Usually short-lived, these guys suck up anything not properly anchored and spit out debris all over the place. Metal buildings seem to be their preferred diet. Sometimes it seems that tornadoes will hop over masonry or concrete structures to get to a metal building. Since tornado shelters are underground, what does that suggest about designing and constructing in areas that have frequent tornadoes?

Hurricanes are storms with a really, really bad attitude, and they usually spawn thunderstorms that can produce tornadoes. However, hurricanes typically occur in southern Atlantic and gulf coast regions of the United States. During design and construction, special consideration and attention must be given to the model building code requirements for these areas.

WIND

In most instances, wind can dramatically multiply the effects of the previously discussed elements. Wind increases drying by accelerating the removal of moisture (notice how your lips chap in the wind). It reduces cooling time by accelerating the removal of heat (we blow on hot soup to cool it quicker). Wind drives moisture into the structure by increasing the pressure on the film of moisture on the surface of the structure (we squirt openings with a high pressure hose to test for leaks). It makes cold feel colder by accelerating the evaporation of perspiration (a jacket feels good on a windy day).

Wind damage can vary from removal of a hard hat to rearranging staged materials to blowing down an unsupported masonry wall. Since tall, flat walls receive the full impact of wind, it can move tall skyscrapers several feet off true vertical. Walls that are not structurally braced and do not have provisions for movement can tumble down in a pile of rubble.

1. **Roof:** The geographic location (coastal or inland area, open or wooded area, urban or rural area, etc.) of a structure, or the building shape and building height can influence the wind uplift pressure on a roof. High winds can produce sufficient wind uplift forces to cause severe damage or a complete blow off. This puts a different meaning on the expression, "raise the roof." Building design should consider building location, shape, and height, and the projected wind speed. For example, a flat roof with loose stone in a southern coastal location is not a good idea.
2. **Doors and Windows:** Air and moisture infiltration are directly proportional to pressures produced by the wind speed. The anticipated wind speed and the height of doors and windows must be calculated into their design and installation. In arid climates, fine dirt can easily filter through unnoticeable cracks in doors and windows and leave a small furrow of dirt along the crack.

SUMMARY

Weather is always here. It is always around us. As the old saying goes, "Everyone talks about the weather, but no one does anything about it." True, weather cannot be controlled. But, building professionals can prepare for it and adjust to resulting conditions. Proper preparation, adjustment, and reaction to local weather will influence the success of a construction project and the completed building.

Weather extremes can test building performance. Building performance can be improved with insulation, corrosive-resistant metals, decay-resistant wood, UV-resistant paint and sealant, selective roof systems, drainage planes, permanent flashing, positive drainage everywhere, and high performance windows and doors with high performance glass.

Even landscaping can affect building performance. Deciduous trees (trees that shed leaves in fall) can provide cooling during summer when the leaves block the sun. In the winter, when the leaves are gone, the sun shines through the bare trees to provide warmth.

Roofs are usually the highest part of a building, and they stick out like a sore thumb. Consequently, roofs probably get more abuse from UV, moisture in both solid and liquid states, and the wind than any other part of the building. Building professionals must provide the best roof system for each application and then protect it during construction. Additionally, roofing crews, because of their work environment, are most vulnerable to weather conditions and should be provided with proper training and protection relative to weather.

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