MOISTURE MANAGEMENT DURING THE CONSTRUCTION PROCESS

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SUMMARY
Heightened concerns with respect to mold exposure have increased attention to the wetting of building materials during construction. The authors describe moisture issues associated with each phase of construction and provide examples of how they can be resolved. Significant water damage can occur from the introduction of wet materials, infiltration, condensation, plumbing releases and operations involving water. A pro-active mold prevention program is recommended to identify potential issues in the planning stage, which can be addressed by modifying construction sequence, materials selection, and/or work procedures. In the event of a water release, response actions are taken as soon as possible to facilitate drying. Any visible mold growth is eliminated prior to building occupancy. At completion, the new building is re-inspected to ensure that all surfaces are dry and free of water damage and that all potential sources of excess moisture are resolved.

IMPLICATIONS
The construction process is a significant source of mold growth and dampness in occupied buildings. Excessive moisture can be minimized by careful planning and management. Methods used to assess and remediate mold growth in occupied buildings are not transferrable to construction conditions and alternative approaches are suggested.

KEY WORDS
mold, damp buildings, remediation, bioaerosols

INTRODUCTION
Building materials are routinely exposed to moisture during the construction process. While new construction is generally expected to be free of obvious water damage at completion, owners, architect/engineers, and contractors increasingly recognize the liability associated with mold growth and damp conditions. Moisture issues and related health concerns after occupancy are costly to resolve and can compromise the responsible party's reputation. Damp conditions continuing after construction may trigger allergic reactions in occupants (IOM, 2004).

Underlying causes of mold growth during construction include:

- inadequate site drainage;
- introduction of materials with excessive moisture or improper materials storage;
- infiltration of rain, snow melt, surface runoff or ground water;
- condensation;
- plumbing releases; and
- wet processes.

Mold growth is initiated where surfaces do not dry out after water contact. Contractors have

historically considered moisture as a quality control issue. Although specifications for some construction projects address aspects of moisture control and mold prevention, attempts to minimize moisture contact and to repair water damage meet with varying degrees of success. While new construction is generally free of visible growth and obvious water problems, hidden mold growth and subtle or intermittent moisture sources may remain.

Porosity of building materials is a critical parameter with respect to mold growth. Products considered to be highly porous (i.e., standard gyp-board) absorb and retain moisture. Mold growth initiates on these materials when they remain wet for several days. Special attention is needed to protect porous materials from water contact and to resolve any wet conditions. Less porous materials, such as wood, are not as susceptible to mold surface growth and may occur on wood that remains wet for an extended period of time (Treschel, 2009). Although wet concrete does not directly support mold growth, it may still develop on surface dust or oil. Recently, some drywall and sheathing products have been modified to resist moisture absorption and microbial growth (Treschel, 2009). These can be quite effective and may be considered non-porous with respect to the construction process.

Methods commonly used by field practitioners to assess and remediate mold in occupied buildings may not be applicable to buildings under construction where no occupants are present, environmental conditions change continuously, and response actions take place concurrent with other activities in the area. The timeframe for resolution is also different. In occupied buildings, repair must be completed as soon as possible. In contrast, full resolution of a construction moisture problem may be deferred.

Elevated spore concentrations associated with construction dust mask any effects due to mold growth and identification of surface growth is best accomplished visually. Investigators often collect air and surface samples in conjunction with occupied building assessment and remediation clearance. These measurements are not informative with respect to construction sites. Stringent site controls prescribed for occupied building remediation (i.e., full containment) are generally not justified with respect to construction conditions.

METHODS

This paper describes moisture issues commonly encountered during construction and actions that have been found effective for their avoidance or resolution. General principles and examples presented are based on the authors' experience as environmental consultants, assisting the construction industry in their response to water damage events and providing pro-active moisture management. Moisture dynamics are evaluated based on plan review, interviews with site personnel, visual inspection, and materials testing with a moisture meter.

RESULTS

Phase One: Planning

Many buildings are designed without full understanding of moisture sources and their impacts. Effort spent anticipating these issues at the outset and integrating appropriate controls into the process generally provide a net savings in terms of avoiding project disruption and costly repairs and also reduce liability. Moisture considerations at the planning stage include:

1. Sequencing (i.e., installation of porous materials should be delayed, wherever possible until the area has been fully enclosed)
2. Materials Selection (i.e., where moisture contact cannot be avoided, non-porous materials should be specified)

3. Procedures (i.e., protecting porous materials, responding to incidents)
4. Mock-Up Evaluation (i.e., a pilot hose-test of window assemblies)

Phase Two: Initial Construction
Moisture concerns during site excavation and erection of the structure are relatively minor. Materials arriving wet should be rejected or restored. Stockpiles of porous materials should be elevated above the ground and loosely covered to allow air circulation. With the structure open and drainage incomplete, building surfaces will get wet and standing water should be removed periodically. Where porous materials must be installed before full enclosure, temporary protection (i.e., plastic sheeting) is a necessity.

Phase Three: Interior Finishing
Some porous materials inevitably become wet even if they are installed after the building is considered enclosed.

Common issues encountered during the later stages of construction are listed below, along with preventative measures (in italics):

1. **Infiltration (i.e., leakage of rain or snow melt occurs where construction is incomplete or flawed, doors and windows are left open, drainage structures fail).**
   Delay installation or use moisture-resistant materials where wet conditions may occur; close windows at end of shift.

2. **Installation of drywall on wood framing.**
   First, confirm that wood is dry with a moisture meter.

3. **Planned releases associated with plumbing (i.e., pressure testing).**
   Minimize and keep away from porous materials.

4. **Accidental plumbing releases and HVAC leaks (i.e., line breaks)**
   Maintain quality control and conduct frequent building inspections.

5. **Condensation from cold surfaces (i.e., pipes, ducts, concrete).**
   This can be prevented by: sealing openings to humid outside air; properly installing mechanical insulation as soon as possible, taking care to cover all surfaces and seal joint; dehumidification; or delaying HVAC startup.

6. **Moisture released from equipment operation (i.e., cooling, drilling, unvented propane heaters).**
   Minimize and keep away from porous materials.

7. **Elevated relative humidity prior to HVAC startup.**
   Consider portable dehumidification to prevent mold growth for prolonged periods of very high humidity (relative humidity restrictions for installing many finishing materials are often more stringent than required to prevent mold growth).

8. **Wet product application (i.e.,sound proofing, leveling compound)**
   Maintain gap between floor and drywall to prevent wicking; delay baseboard installation until dry.

9. **Curing concrete (i.e., significant moisture emissions for several months)**
Raise contents above floor; take precautions to protect insulation under mechanical equipment.

10. **HVAC contamination (i.e., dust, moisture)**
Seal equipment not in use; avoid drawing in dusty or humid air; maintain filters.

Phase Four: Completion
When construction is complete, all surfaces should be dry and free of mold growth or other signs of water damage. Additionally, all potential sources of excess moisture should be resolved. This should be determined by a comprehensive inspection and maintaining a "punch list" of deficiencies until all are completed.

Pro-Active Management
Anticipation and management of construction moisture can minimize moisture contact, resolve moisture damage, and deliver a dry, clean building at project's end. A pro-active moisture control program is best integrated into the overall construction process. Responsibilities should be clearly delineated between the owner, design team, general contractor, and sub-contractors. Potential moisture issues that may arise after occupancy due to inadequate maintenance should also be identified. A chain-of-command should be established to ensure timely and coordinated decision making. All actions should be documented.

Consideration should be given to designating a site moisture control coordinator to facilitate the process. Specific functions of an onsite moisture control coordinator may include identifying potential sources, specifying control measures, training workers, inspecting the site, and verifying corrective actions.

Incident Response
When water damage occurs, quick response actions prevent mold growth. These include identifying the source and extent of moisture, characterizing moisture pathways, removing standing water, accessing wet enclosures, and drying. Affected surfaces must be identified and wet enclosures opened to prevent mold growth.

The extent of moisture spread can be estimated based on understanding the water source and potential water pathways and visual inspection. Additional damp areas are often overlooked, however, unless adjacent surfaces are evaluated (i.e., moisture meter, infra-red thermography). For controlling mold growth, it is critical to identify covered surfaces that will remain wet unless opened to air circulation (i.e., behind baseboards and attached furniture).

In many situations, the amount of drywall and insulation requiring removal due to mold growth is much less than the area needed to facilitate drying and removal of defective materials for quality control. Material that has contacted water but does not support mold growth does not have to be removed if it is acceptable structurally. Moldy materials must be either removed or effectively treated. Where drying cannot be accomplished immediately, a sanitizer may be applied to prevent or control mold growth on a temporary basis.

Mold remediation procedures are limited by site-specific circumstances. Full containment (i.e., negative pressure) is not needed for occupant protection, but partial isolation (i.e., dust barriers and

mechanical air scrubbers) may help expedite cleanup. Remediation may be deferred to a later time where no power is available, time is required to seal leaks within the construction sequence, or concurrent site activities will interfere with remedial work. Observation after rainfall or applying water from a hose may be needed to verify that the water source has been eliminated. Repair effectiveness should be confirmed (i.e., re-inspect after rainfall or spray water from a hose and observe for leakage). Remediation effectiveness is best determined by verification of work practices and visual inspection. The remediation process can often be accomplished by construction personnel following a specified procedure, rather than employing a specialized restoration contractor. Investigation of water damage events should also consider the issue of responsibility (architect's design? sub-contractor mistake? etc.).

Case Studies

Major Plumbing Flood. Water from a pipe break after drywall installation migrated down several floors. Within one day, wet areas were identified by moisture meter, and adjacent drywall and insulation was removed to facilitate drying with dehumidifiers and portable fans. Follow-up inspection found all areas free of mold growth except in small areas where moisture remained trapped behind attached cabinetry. Remediation was limited to these latter areas.

Sweating Compressed Gas Line. Condensation was observed dripping from uninsulated compressed gas piping. Investigation revealed that the design condition had been exceeded due to infiltration of moist outdoor air. This was resolved by sealing an exterior opening with plastic. No remediation was necessary because condensate dripped onto concrete only.

Window Failure. After drywall installation, suspect spotting began to appear around windows. Investigation revealed that all windows were leaking (manufacturing defect) and that adjacent materials were wet throughout the project. Water-damaged drywall and insulation were removed and surfaces dried by operation of the HVAC system protected by special filters. Exposed sheathing and wood framing was wiped with 10% bleach solution.

DISCUSSION

Costs associated with the implementation of moisture control measures can be minimized by integrating these into the overall design and project management process. Initial costs should be balanced against expenses and disruptions associated with water damage.

CONCLUSIONS

1. Water damage during construction may be caused by infiltration, condensation, leaks, and introduction of wet materials.
2. Where moisture issues are not resolved during the construction process, occupants may be exposed to mold growth and other damp building conditions.
3. Ongoing moisture problems can be prevented by attention during project planning and by effective response actions in the event of a moisture release.
4. Mold testing is not relevant to the assessment of construction site hygiene. This can best be accomplished by visual inspection and moisture measurement.
5. Hazardous material procedures are not needed to remediate mold during construction. This can generally be accomplished without full containment or specialized contractors.

RECOMMENDATIONS

1. Project planning should anticipate potential moisture sources and integrate appropriate

phasing, materials selection, and work procedures into the construction process.

2. Site management should include frequent checks on the effectiveness of specified moisture controls and visual monitoring for indicators of excess moisture.
3. Contingency plans should be in place allowing for prompt and effective response to moisture episodes.
4. At completion, the structure should be verified to be dry and free of mold growth, with all potential moisture sources resolved.

REFERENCES

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