FUNGAL (Mold) ORIGIN AND CAUSE INVESTIGATIONS

Andrew D. Waggener, P.G.
Lewis W. Ernest, P.E.
Marshall Miller and Associates, Inc.
5825 Triangle Drive, Raleigh, NC 27617 ● (919) 786-1414

INTRODUCTION

Fungal conditions and resultant damages within structures have become a major source of concern and liability for both the private and public sectors. An increase in attention to these issues has been fueled by litigations, fungal-related property claims, health-related publicity campaigns and perceived or actual liability in real estate transactions.

Fungal investigators, which include engineers, scientists and building/mechanical specialists, have identified many common causal conditions that result in fungal growth within structures. The appropriate handling of fungal damages requires a detailed and systematic approach to evaluate these potential causal conditions and identify the origin and cause (O&C) of the fungal problem.

Determination of the O&C becomes a crucial step in the decision making process for property owners, insurance companies and attorneys in assigning liability. While not justified in all cases, the investment in a thorough O&C investigation can be money well spent in larger or complex situations that may result in large claims or litigation. Accurate O&C investigations accomplish two primary goals, which are 1) making remediation more effective by preventing the source conditions from reoccurring; and 2) assisting in limiting or assigning liability to the appropriate party(s).

This article will discuss the various procedures required of the engineers and scientists that are tasked with answering complex water/moisture source questions; identify the typical building components, causes, source areas and symptoms of fungal conditions; present an outline of the O&C investigative process; and present brief case study summaries that demonstrate the interaction of causal factors that affect building materials and the indoor environment.

FUNGAL OCCURRENCE

Fungus occurs as a result of natural conditions and is an important process in the breakdown and natural recycling of organic materials. The problems begin when these conditions occur within an enclosed, occupied environment where an affect on building materials and an increased risk to human health may occur. The three general components and conditions that are required for fungal growth in occupied structures are: the presence of fungal spores in nature, the presence of a food source (cellulose) within building materials, and moisture intrusion due to failed building systems. Temperature is also a factor, as most fungi can flourish in temperatures provided by conditioned (either properly or improperly) indoor environments, typically ranging from 60 to 90 degrees Fahrenheit. The presence of moisture is the catalyst for the development of fungal conditions and is the primary focus of O&C investigations. Relative humidity, generally greater than 70%, can provide the moisture necessary to trigger fungal growth. A moisture content of greater than 20% in common building materials can also be sufficient to support fungal growth.

Also important in the evaluation of fungal conditions within a structure is the method in which fungi can reproduce. Under certain conditions, fungi release microscopic spores into the air as part of their reproductive process. After they are airborne, the spores settle onto various surfaces and can rapidly colonize into new areas of fungal growth where a food and moisture source is present. Their small size also allows the spores to be distributed to non-affected areas of the structure by normal air flow and through the heating, ventilation and air conditioning (HVAC) system.

UNDERSTANDING BUILDING SYSTEMS

The key to investigating the O&C of fungus-producing moisture in buildings lies in the understanding of four primary building systems

that control moisture within a structure. These include the 1) HVAC, or mechanical, systems; 2) plumbing systems; 3) site drainage (surface and ground water); and 4) the building envelope. Having a broad knowledge of the construction, operation, functions, and typical failure points of these systems, combined with an understanding of their complex interaction is crucial to the unraveling of complex fungal O&C projects.

Mechanical Systems

A properly designed, installed and maintained mechanical system is very important in preventing the development of adverse moisture conditions that can result in fungal growth. These systems should condition and maintain the environment in the structure by controlling temperature and humidity and ensuring proper ventilation balance. The possibilities for moisture generation from mechanical systems are mostly related to condensation, which is generated within the system during normal operation or exterior of the system due to improper drainage, improper dehumidification of the ambient air, or by causing temperature differentials on exposed surfaces. Contributions from the other building systems, particularly the building envelope, can create many scenarios for moisture generation caused by the mechanical systems. As such, all O&C investigations gather pertinent information about the mechanical systems (e.g., size, filtration, duct system, operation, maintenance, etc.) for evaluation relative to the other conditions observed within the structure.

Plumbing Systems

Plumbing systems provide for the supply and internal distribution of clean water to the structure and also provide for the collection and discharge of waste water to the sanitary sewer or septic system. As more appliances/equipment have been introduced into buildings, additional opportunities for plumbing water losses and resultant fungal problems have developed. The understanding of the location of these plumbing components is important in identifying the potential points of failure and subsequent moisture migration patterns.

Water losses from plumbing failures and/or leaks are usually noticeable, and if the resulting water damage to a structure is properly and quickly remediated, a significant fungal problem can be prevented. However, a slow plumbing leak in a concealed space (i.e. wall or floor cavity, attic, crawlspace, etc.) may go unnoticed for a considerable period of time, increasing the likelihood for a major fungal condition to develop. In any event, evaluating plumbing conditions within a structure is typically an important component in an overall fungal O&C investigation.

Site Drainage

Moisture conditions that are conducive to fungal growth can originate from within and/or outside the structure. The source of exterior water intrusion into a structure can result from improper roof or surface water drainage and/or ground water infiltration. Exterior water drainage problems can directly impact structures that are built on slabs near grade and in structures with sub-grade crawl spaces or basements. A long-term moisture laden environment within a crawl space or basement (especially in the absence of proper ventilation or moisture protections) promotes fungal growth. If pathways exist from these areas into the occupied area of a structure, fungal spores can easily be transported. As such, the assessment of exterior site drainage conditions and the potential for water/moisture intrusion into a structure is an important element of most fungal O&C investigations.

Building Envelope

The building envelope includes the materials and structural elements that are designed to protect and insulate the interior of the structure from the outdoor environment and maintain the conditioned environment within the structure. Breaches in the building envelope are a common source of water intrusions and/or moisture producing conditions. The building envelope consists of the roof, wall and floor systems, windows, doors, and insulation. Typically, fungus grows on organic materials in the building envelope (e.g. wood, paper, drywall,

dust, etc.) that are exposed to a moisture condition for a period of time, sometimes as short as 24 hours. Designers, builders and building owners now strive for more airtight construction and more efficient HVAC systems. However, in an age of fast-paced construction schedules, it is not uncommon for design deficiencies and construction shortcuts to compromise the integrity of the building envelope, resulting in isolated or widespread fungal growth.

Another common factor in the cause of breaches in the building envelope of commercial and residential structures is the lack of proper maintenance. This can result in a gradual, long term water intrusion that can cause an unrecognized fungal condition.

A complete fungal O&C investigation must consider the building envelope and it's compatibility with other building systems, with a keen eye for design, construction and maintenance deficiencies that could have resulted in the development of damaging moisture conditions.

TYPICAL COMPONENTS AND CAUSES OF FUNGAL PROBLEMS

During the investigation of fungal occurrence, investigators are faced with a myriad of potential issues involving design, construction and maintenance deficiencies. Typically, these may include one or more of the following:

- Inadequate ventilation/moisture protection in crawl spaces or attics;
- Improper floor/ceiling/wall insulation;
- Communication of moisture from the exterior of a structure via penetrations or porous materials in the building envelope;
- Improperly sized or improperly used HVAC systems;
- Leaking or improperly insulated HVAC ductwork;
- Wet materials during construction;
- Roof leakage;
- Window leaks and condensation;
- Failure of or improperly installed masonry flashing/weep systems;
- Exterior drainage pathways;
- Surface or concealed condensation within the building envelope; and
- Plumbing leaks.

SOURCE AREAS AND SYMPTOMS OF FUNGAL PROBLEMS

The source areas and symptoms for fungal conditions are obvious in some cases, and obscured and complex in others. Also, conditions that result in fungal growth may be long term in nature or can be sudden. In any event, some of the red flags that are common to the existence of potential fungal problems include:

- High humidity/moisture conditions within the structure;
- Improperly dried catastrophic water losses;
- Standing water or known water loss;
- Visible suspect fungal growth;
- Occupant complaints of discomfort or illness;
- Abnormal musty or offensive odors;
- HVAC system problems;
- Known design/construction deficiencies resulting in water/moisture conditions;
- Visible condensation;
- Warping/buckling of building materials.

FUNGAL O&C INVESTIGATIVE ACTIVITIES

Investigators can use a variety of information, resources and tools to help identify the O&C of fungal conditions. Isolating the moisture sources present, combined with sampling and fungal identification, can often associate a condition with a potential moisture source. This information can then be used to define primary versus secondary causes of the existing condition. The review of construction drawing details and/or mechanical equipment specifications can also provide valuable clues to causal conditions. Developing an understanding of the history of a structure and the probable pathways of moisture migration is vital in determining the cause of a fungal problem.

Investigators use various tools to measure or document conditions that can assist in fungal O&C determinations. All field investigations

start by using the eyes and nose to identify the symptoms, apparent causes and locations of the fungal problem. Moisture meters and technologies such as infrared imaging can be used to map moisture patterns in building materials to pinpoint and verify the source location and a causal condition. Other common investigative equipment such as boroscopes and remote cameras are used to minimize destructive investigations. The investigator combines this information with a working knowledge of the building systems to ensure that a thorough investigation has been completed, considering all aspects of the problem and cause. In complex cases, an investigator may need to develop a list of potential causes for a fungal problem and then systematically eliminate the possibilities by a thorough inspection until the source or cause is isolated.

Once all investigative activities have been completed, the information gathered during the investigative process is fully evaluated, often times by professionals with a particular expertise such as in mechanical or structural engineering. Typically, this will result in the lead investigator being able to develop a sound and substantiated opinion as to the O&C(s) of the fungal condition. A report of findings is prepared to detail the investigative methods and provide a thorough discussion of the findings to support the conclusions made.

CASE STUDIES

Most fungal investigations have yielded O&C findings that are attributed to common conditions. However, in some instances fungal O&C determinations involve an interaction of multiple water sources. The three case studies presented below involve cases with multiple potential factors contributing to the fungal condition.

Case Study One

Problem and Symptoms

Prevalent fungal conditions developed in a newly constructed, and yet to be occupied, multi-unit apartment complex, as evidenced by fungal growth on the sheetrock of the interior perimeter walls and a strong musty odor. The condition continued to reoccur in spite of efforts by the contractor to repair construction deficiencies and abate the mold. Due to the prevalence of the condition in several similarly designed and constructed units, and the high liability exposure due to multiple occupants, a thorough O&C investigation was warranted.

Investigation Findings

Indoor air sampling verified the presence of high levels of airborne fungal spores within various apartment units. Airborne concentrations were higher on the first level but were also significantly amplified on the second level. Systematic investigation of typical moisture/water sources revealed isolated occurrences of water intrusion due to poor drainage, caulking failures, plumbing failures and window/roof leaks; however, these isolated occurrences were eliminated as the primary cause for the widespread problem. Moisture mapping and infrared moisture imaging identified isolated moisture locations within the lower rear perimeter wall cavities on the first level, particularly in the vicinity of the attached exterior storage units. Wall cavity sampling eliminated the second level as a potential source area and confirmed substantial fungal growth in the rear first level wall cavities. Removal of sheetrock in representative units allowed for direct moisture measurements, revealing high moisture readings (>20%) in the wooden base plate along the lower, rear wall and also exposed hidden and active fungal growth.

Inspection of the HVAC systems revealed that the systems were adequately sized and were operating properly. Due to non-occupancy of the unit, it was noted that the HVAC systems had been set to maintain a high summer temperature (80 degrees) with a resultant high humidity environment. This was determined to have contributed to an amplification of the fungal condition but was eliminated as the root cause.

The attached exterior storage buildings were not ventilated, had a strong musty odor and had some visible fungal growth. Based on the inspection and discussions with the architect, it was determined that the storage buildings were add-on features that were not incorporated into

the original design. Investigation of the exterior brick cladding above the rooflines of the storage units revealed the absence of a specified flashing and brick weep system in those areas, a lack of weep holes at the base of the wall in this area, as originally designed, as well as at other exterior brick veneer locations.

Conclusion

After elimination of numerous existing and potential water causes, the O&C of the widespread interior fungal condition was deemed to be related to water/moisture accumulation at the base of the brick veneer perimeter walls, particularly at the rear of the structure in the vicinity of the unventilated storage units. The absence of a proper flashing/weep system in some areas prevented proper drainage of water from the wall cavity. Also, the abnormal environment within the storage units was believed to have exacerbated the problem by increasing the vapor pressure on the exterior of the brick and driving the moisture condition toward the interior wall cavity.

This moisture retention problem could be attributed to both the design and construction of the structure. The lack of consideration for the affect that the addition of the storage building would have on the masonry drainage system and the omission of proposed flashing dams and weeps combined to create the problem. To abate the problem, a masonry contractor was contracted to perform the necessary drainage modifications, a fungal remediation contractor was retained to perform remediation activities and ventilation was added to the exterior storage buildings. This generally eliminated the moisture intrusion, focused the destructive remediation efforts toward elimination of the specific fungal source areas and reduced the potential for future liabilities.

Case Study Two

Problem and Symptoms

Visible fungal growth was observed to be developing behind the vinyl wall paper of a 30,000 square foot commercial office building with a brick veneer. A musty odor was present and the property manager had received multiple health-related complaints from the occupants. The building was approximately five years old and was comprised of three above grade levels and a basement. The fungal condition was predominantly occurring in the perimeter (exterior) walls, particularly on the first floor level of the structure. Some isolated areas of fungal growth were also identified on the interior walls of the building.

Active fungal remediation was being performed in the building to address the problem, but the fungal growth was noted to have reoccurred at some locations. Given the multiple potential factors for the condition and the complexities involved, and the desire to find the source(s) of the problem, an extensive O&C investigation was commissioned.

Investigation Findings

The building was reported to have been unoccupied for one year after completion of construction. At that time, four major tenants moved in to occupy the first and second levels of the building. The building had been upfitted to provide numerous offices and specialty service suites. Modifications had been made to parts of the mechanical systems(s) and the layout of the building during tenant upfitting. One large lower level suite required special environmental conditions and the tenant reportedly installed additional HVAC and exhaust equipment for that area.

The building was observed to be serviced by various roof top HVAC units (including the added units). Although the HVAC system for the building was centrally automated, each tenant maintained override controls.

There had been various minor water intrusions within the building since it was occupied (i.e. plumbing leaks, roof leaks, etc.). Systematic investigation of the overall building allowed for the identification of the pattern(s) of the fungal problem. Generally, the fungal pattern(s) were observed to be in the perimeter walls (more prevalent on the first level), isolated areas of interior walls (particularly in central stairwell from basement to the second level) and in the basement area. The basement was observed to

have previous and current water intrusion problems.

The wall cavities were opened at various locations to further observe the pattern of fungal growth within the walls. While the fungal growth was noted to be more pronounced in the wall cavities behind the vinyl wall papered areas, fungal growth also existed within the wall cavities behind painted walls. This inspection eliminated direct water intrusion from the exterior brick veneer cladding as a source issue. The perimeter walls were noted to contain numerous glass windows and window panels. Although there was no indication of direct window/glass panel leakage, there was evidence of minor condensation on and around various windows.

Given this information, the O&C investigation was directed toward a detailed evaluation of the mechanical system of the building. The design of the original mechanical (HVAC) system of the building was reviewed, as well as the additional equipment installed by the tenant(s). A monitoring system was placed within the building to measure temperature, humidity and pressure at various locations within the building over a period of ten days, under various HVAC operational conditions. Evaluations of this data revealed that some areas of the building experienced extreme temperature and humidity differentials. More notable was the fact that the building, especially the first floor level, was documented to typically be under significant and abnormal negative pressure.

Conclusion

A series of investigative activities and the evaluation of the data gathered revealed that the primary cause of the fungal growth on and in the perimeter wall system of the building was related to concealed condensation within the wall cavities. Evaluation of the documented operational environment inside the building as compared to exterior conditions, in concert with a vapor pressure analysis of the wall systems, indicated that a significant negative and stack pressure condition within the building resulted in moisture laden air being pulled through isolated areas of the wall system of the building. As a result, the alteration of the thermal gradient within the wall system allowed for the development of prolonged moisture condensation, which was exacerbated in some areas by the interior vinyl wallpaper, which acted as an impermeable vapor barrier. The improper operation of the HVAC systems and the incompatibility of the mechanical systems previously installed in the building were cited as primary factors in the fungal development. Various water intrusion incidents/conditions and humidity conditions at various locations within the building were also cited as contributing factors.

The report of findings recommended modifications to the mechanical systems within the building to properly condition the air and provide for positive pressure. This will minimize future migration of humid exterior air through the building envelope and into the wall cavities of the building, thereby eliminating the moisture source and reducing the potential for future fungal growth.

Case Study Three

Problem and Symptoms

Abnormal musty odors and isolated areas of visible fungal growth developed at various locations within a 20-year old residential structure. The claim was that the conditions associated with two recent plumbing repairs had caused the fungal condition. Therefore, an O&C investigation was requested to determine if these occurrences had caused or contributed to the reported fungal conditions in the structure.

Investigation Findings

The single-story residential structure was found to be in generally good condition. It was located on relatively flat property and was constructed over a crawl space. A musty odor was reported within the structure, particularly when the HVAC unit was in operation. Two bathroom areas had experienced recent plumbing problems, which had required the removal/replacement of some subfloor material. Inspection of the crawl space revealed a current and long-term moisture condition as indicated by

existing wet soil and efflorescence on the foundation walls although there was no report of flooding of the property. The soil floor was noted to be only partially covered with a vapor protector and the crawl space area was observed to have minimal ventilation. The HVAC air handler unit, located within the crawl space, revealed evidence of a condensation line blockage, corrosion, and fungal growth within the unit. There were various breaches in the HVAC duct system located in the crawl space that corresponded with observed condensation and areas of heavier fungal growth. Widespread fungal growth was observed on the floor joists and sub floor throughout the crawl space with pronounced patterns of water stains/fungal growth present under the problematic bathroom areas. Numerous floor penetrations were identified that provided pathways for communication from the crawl space into the residence. Fungal testing revealed an elevated airborne fungal spore concentration within the residence, with fungal types similar to those identified in the crawl space.

Conclusion

The origination of the fungal condition was determined to be primarily within the crawl space of the residence. The musty odors and fungal spores were being transported into the residence via the HVAC system and penetrations in the sub floor. The root cause of the moisture and fungal condition in the crawl space could be attributed to long term surface/groundwater infiltration into the crawl space combined with an inadequate vapor barrier and lack of proper ventilation in the crawl space. The condition was exacerbated by condensation associated with the breached HVAC duct work, malfunction of the HVAC system and the long term, unabated plumbing leaks. The moisture resulting from the recent plumbing leaks was deemed to be only a minor contributor to the overall fungal condition within the residence. The report of findings made recommendations for eliminating the various moisture sources to be followed by fungal remediation activities.

SUMMARY

This paper has highlighted the factors involved with and the benefits of successful fungal O&C investigations. Also, it has emphasized the importance of determining the source and cause of a fungal problem within structures, for without the identification and legitimate elimination of a source/cause of a problem, a problem cannot be completely solved.

While fungal conditions are known to be an age old problem that has adversely affected structures throughout history, serious concerns about present day building designs, construction materials and techniques, coupled with energy efficient HVAC systems have, in some cases, been found to compound moisture/fungal related conditions within modern structures.

The engineering community has been called upon to investigate and identify the common cause(s) of fungal problems within structures. Builders, building owners, designers, as well as code officials will hopefully use fungal origination and causation information in the future to minimize fungal development problems within both old and new buildings.