Differing Moisture Content in Concrete and Mitigation Methods: Research of Sacramento

Taylor S. Tonda
California Polytechnic State University San Luis Obispo
San Luis Obispo, California

The city of Sacramento and its concrete foundations face one of the most challenging conditions in the flooring industry, high RH Moisture. RH Moisture or Relative Humidity Moisture is one of the main causes for flooring systems to fail. The source of High RH Moisture consists of surrounding geographic features like rivers, flood plains, and elevation, as well as improper or nonexistent use of a vapor barrier beneath the concrete foundation. Mapping and other data is used to support these claims. If a flooring system is not properly prepared for high RH Moisture levels, issues such as bubbling, delamination, and glue becoming unadhered can all lead to mass amounts of damage. The data used consists of hundreds of RH Moisture tests by Wagner Meters and will be used to prove the issue of high RH Moisture persists in the Sacramento area. The RH Moisture testing method has become an industry favorite compared to other methods due to the capability to read the middle of the concrete slab, where others only give surface readings. Once an RH reading is established it is up to the contractor to find the best solution to the Moisture problem using a topical moisture barrier.

Keywords: Relative Humidity, Moisture, Concrete, Wagner Meters

Introduction

Regulation on the amount of Volatile Organic Compounds (VOCs) for adhesives used in flooring impacted the adhesives' ability to withstand moisture content leaching from the concrete slab. To combat moisture from ruining a new flooring system many steps are necessary to tackle the problem. These steps consist of testing the slab for its RH moisture content, finding the best treatment option, and then installing the moisture treatment. There are many different methods of testing for RH content, as well as treatment options that will be touched on in the paper.

Moisture testing concrete slabs is one of the most important tasks in the flooring industry. The testing data set present in the research has covered nearly all of Sacramento California. Sacramento California is an area notorious for having high levels of moisture content in their concrete slabs due to a variety of factors. The goal of the research is to investigate each of these factors and attempt to draw conclusions as to why the slabs in specific areas have high levels of moisture. This is important information to know as the cost of replacing floors increases greatly if there is moisture to deal with in the subfloor. RH moisture testing information can then be applied to fields outside of construction; like real estate where building owners will have to front the cost of a flooring renovation to attract new tenants.

The Objectives of the Research are as Follows:

- Portray data collected from RH Moisture Tests in specified areas of Sacramento
- Break Down different categories that can affect moisture
- Show how categories effect the specified areas of Sacramento
- Determine the category that is the main cause of the High Moisture Readings
- Display cost impact of the high RH moisture readings

Moisture Testing

The three main concrete moisture testing methods used are the Plastic Sheet Test, Calcium Chloride Test, and Relative Humidity Test. All three of these tests are designed to have the ability to gather information about the moisture content of the slab, with differing degrees of accuracy. Below is a description of the testing method along with the corresponding ASTM standard.

The Plastic Sheet Test, under ASTM D4263-05, requires the use of an 18”x18” plastic sheet being placed over the top of the concrete slab. The sheet is then sealed to the concrete slab with tape to prevent any moisture from escaping. Then 24 hours later the sheet is removed and inspected for signs of moisture, like darkened concrete or visible water drops. The vapor can then be weighed and converted into a Moisture Vapor Emission Rate or MVER. The MVER will give you an idea of how much water will be emitted through the slab as well as which system to use to remedy the moisture. The Plastic Sheet Tests are not considered standard practice as the results only quantify the top layer of concrete moisture and do not provide any data on the conditions of the middle of the slab.

Calcium Chloride Tests, under ASTM F1869-11, places a calcium chloride disk under a sealed sheet of plastic like the test above. Calcium Chloride is known for its hygroscopic properties or its ability to absorb moisture from the air. After 24 hours of letting the calcium chloride sit, one will weigh the disk. The change in weight will be how much moisture has evaporated from the slab in 24 hours. Similar to the Plastic Sheet Test, Calcium Chloride can only test the upper portion of the slab. Not knowing the moisture content of the entire slab leaves very important data in the unknown.

Relative Humidity (RH) testing, under ASTM F2170-11, involves drilling a hole 20% or 40% of the concrete slab’s depth depending on the thickness and presence of a moisture barrier beneath the slab. Next one will vigorously cleaning the hole with a wire brush and vacuum all concrete dust. A Relative Humidity testing probe is then placed in the whole with an applicator rod. The test is then sealed with the provided cap for 24 hours, ideally 72 hours, and allowed to sit. The test is then read using a digital probe giving both the relative humidity and temperature of the room. These tests have become the industry standard due to their ability to test the middle of the slab. The moisture content of the middle of the slab is necessary to know due to the movement of moisture that will occur during the life of the slab.

Source: TNEMEC “3 Ways to Test Concrete for Moisture”

Moisture Remedies

Once a concrete slab has been tested and high levels of RH Moisture are detected, one must use a topical moisture remedy to prevent failures in the flooring systems that will be installed. Many products like Luxury Vinyl Tile, Vinyl Composition Tile, Sheet Vinyl, Rubber, and some Carpet Tiles lack the ability to allow moisture to escape as moisture evaporates from the concrete slab. The excess moisture that is not able to evaporate will cause damage to the flooring over time. To prevent moisture from damaging the flooring system a topical moisture treatment is necessary. The two systems that have gained popularity are low permeable vapor barriers and epoxy dampening agents.

Low permeable vapor barrier, like Traxx Vapor Barrier, typically come in rolls and are layed out similar to rolls of carpet. The seams are held together with a specialized tape that creates a vapor emission proof layer keeping moisture from reaching the flooring system. The rolled vapor barriers are heavily used due to the ability to install flooring on the same day as the vapor barrier installation. The epoxy method require multiple days of work before the flooring can be installed. If the schedule is heavily condensed a rolled vapor barrier would be the ideal system to use.

The epoxy vapor barriers create a seamless vapor emission proof layer for the flooring to be installed on top of. Lacking the seams, a rolled vapor barrier has created less points of failure for the vapor barrier. This is crucial in flooring systems that are intended to have a long lifespan. The downside to the epoxy vapor barriers is the duration of install. Epoxy vapor barriers require 1 day of grinding or bead blasting and floor preparation for the epoxy to adhere to the concrete. There will also be 1 day needed for the epoxy vapor barrier to be rolled onto the concrete with tools like paint rollers and allowed to set. The Epoxy vapor barrier method will take an additional 2 days of labor to complete compared to that of a rolled vapor barrier system. Another issue with epoxy-based moisture barriers is silica dust being released during the grinding or bead blasting phase. The article "The Benefits of Rolled Moisture Barrier" written by Jerry Palys covers the difficulties in preparing the concrete for an epoxy-based moisture barrier in the quote "Now that OSHA has passed new regulations setting limits on airborne silica dust, there is a growing need for other moisture mitigation options." (Palys, J. 2018) Making sure the employees installing the moisture barrier are safe should be the top priority of any company. By using a rolled moisture barrier, the changes of silica dust inhalation are diminished.

Moisture Testing in Sacramento

On nearly all commercial construction projects in the Sacramento California concrete moisture testing is a requirement. The cost implications high moisture reading brings are typically high with the Article "Moisture Testing Concrete" with the quote "In fact, widespread instances of concrete slab moisture-related floor covering failures have emphasized the importance of accurate and complete moisture testing prior to the floor being installed. It is reported that over $1 billion dollars is spent every year to replace, repair and correct floor covering problems related to excessive moisture and elevated PH levels of concrete floor slabs." (Craig & Donnelly 2006 p.5) Sacramento has multiple feature that cause high moisture reading in concrete slab long after they have been cured. The characteristics of concrete slabs that will be investigated are elevation, location, flooding susceptibility, and nearby geographic features. Moisture content in slabs also differ between areas of Sacramento. Areas like West Sacramento's Riverside Parkway are built on flood plains which can greatly impact the moisture content of Concrete slabs. Riverside Parkway is one of the focus points to this research.

Lessons Learned Placing Tests

Wagner Meter's Rapid RH moisture tests have exact methods for proper installation and what to be careful of when installing. The biggest concern when working with moisture tests that must be drilled in concrete slabs is the potential hidden dangers. Post Tension Cables, Wiring, and Plumbing are all hazards that must be accounted for before one drills a test. Failure to do so can cause massive amounts of damage to the building and cause injury to the installer.

Interior air conditions can greatly impact the health of a building. In Between tenants, many owners choose to turn off the HVAC system as no one will be present in the building. The changing of air temperature and humidity greatly impact the moisture content of a porous concrete slab. Regarding the importance of HVAC and moisture testing Wagner Meter, the maker of the RH Moisture Test, states "Accurate moisture measurement is also foundational for providing proof of warranty, limiting liability, and meeting industry standards that provide best practices for moisture management. Standards like ASTM F2170 specify that both a concrete slab and the air space above the slab be at service conditions (HVAC systems operating) for at least 48 hours before beginning relative humidity (RH) testing." (Spangler, 2017 p.1) The reasoning for the HVAC to be on prior to the moisture test is the concrete will change moisture content as temperature and humidity change from the HVAC system. Making sure the tests are completed in a standard occupied condition is very important, as mistakes in the readings lead to very expensive issues.

Flooring contractors were contacted during the research as to why the Calcium Chloride test have lost popularity in recent years, other than the fact they do not test the middle of the slab. Calcium Chloride attract water from the surface of the slab giving one an idea as to how much moisture is present in the slab. The contractor spoken to about Calcium Chloride testing stated the biggest issue is leaving the tests on the floor and having someone accidently damage the test. The calcium chloride puck is not protected and any damage to it will cause results to be inaccurate. With the newer in-slab tests there is little to no worry with damage after installation.

Contractual Obligation and Ethics

Due to the monetary increase a high moisture concrete slab can cause it is of the utmost importance that the tests are set correctly, and the data is recorded accurately. Following ASTM F2170-11 exactly will ensure the results of an RH moisture test are as accurate as possible. The use of Wagner Meters RH Moisture reading application connects the reading device to a mobile device and sends the collected data directly between one another. By using the application there is less of a chance for data manipulation and mistakes.

Methodology

The data set collect consists of six years of RH Moisture readings, all placed throughout the different neighborhoods of Sacramento. The tests were set following ASTM F2170-11 and were allowed to sit from 24 – 72 hours before results were read. The collected data consists of the number of tests set, location of the tests, RH moisture readings, cost impact, date, elevation, and notable. The data is further broken down to show the average cost impact of high RH moisture readings as seen in the results section of the paper.

The area of Riverside Parkway was found to have abnormally high levels of RH moisture throughout the area. Due to consistently high RH Moisture readings the area of Riverside Parkway will be a focus area and compared to areas of low RH moisture Sacramento to determine potential causes of high moisture content. A determination of the cause of high moisture can then be found through analysis of the maps provided. The maps display the area of interest and the locations of the buildings tested. The location of the building was used to find an elevation of the building and proximity to features known to cause high RH moisture readings. The maps will be used to support claims of high moisture content being caused by a certain condition(s). The information gained can then be used to direct builders and those in real estate as to where high moisture areas of Sacramento are and how to plan for it.

Potential Causes of High Moisture Readings

High Moisture in concrete slabs can be caused by a variety of factors with the city of Sacramento experiencing many of these. The potential causes of high moisture that are studied are elevation, location, Flood Plane proximity, and nearby geographic features that can cause high moisture readings like rivers. Elevations of the buildings were found using. The building locations are broken into two separate categories based upon if the RH moisture tests were higher than 85% or not. Those higher than 85% are considered failed and required a topical moisture barrier to prevent moisture related damages. Flood planes are found by the mapping data the city of Sacramento provides on the city website. Geographic feature will be seen on the maps provided in the section below.

Slab on grade concrete must be protected from ground moisture with the use of a moisture barrier. Failure to do so can cause moisture to rise through the slab, causing damage to your flooring system. In the paper "Moisture Testing of Concrete Slabs, the author states "Without effective, low-permeance moisture protection directly beneath the slab, moisture migrating from sources below the floor can, over time, lead to an increase in the moisture content of the slab after the flooring material is installed." (Craig & Donnelly 2006 p. 4) A beneath slab moisture barrier is the first step in preventing moisture related issues.

Results and Discussion

The City of Sacramento and its surrounding areas experience a variety of moisture conditions making RH moisture testing a necessity when installing new flooring. The many different geographic features the area contains leads to these differing moisture levels. Once moisture content of concrete is known the data can be used in multiple ways. Contractors can apply the RH Moisture data to the schedule and cost of construction. While other sectors such as real estate can use the RH Moisture data as a factor of the cost of owning a building.

The data range gather consisted of 514 RH moisture tests total. Below there are detailed steps on how each test was set per the manufacture's specifications. A document for the Wagner Meters recommended steps can be found in the resources section of this document:

- Verify the testing location has not experienced temperatures above 95 for a duration of 48 hours prior to testing
- The number of tests needed for an area is based upon 3 tests for the 1st 1000 square feet and 1 additional test for the next 1000 square feet
- Depth of hole for test placement is 40% of slab depth for slabs with a moisture barrier beneath and 20% of slab depth for slabs with no moisture barrier beneath
- Drill holes, scrub with metal brush, and vacuum concrete dust to meet ASTM F2170-11 standards and note locations on floor plan
- Insert tests using the provided insertion tool making sure to place the test at the set depth, then seal with cap
- Wait 24 hour minimum before reading the test results with the RH Moisture reader with most accurate results available after 72 hours
- Record results, for best practice use Wagner Meters RH Moisture reading application as it connects directly to a mobile device

Figure 1 below details the results of moisture test results in Sacramento along with the cost implication of high moisture readings.

#of Tests	Avg. Cost per Test	Cost Impact	High Moisture	Low Moisture	Total # of Testing Locations
514	$153.77	$4,048.97	74	20	94

Figure 1: Moisture Testing Data

As seen by the graph above approximately 79% of the jobs performed in Sacramento have high RH reading in their concrete slab of above 85% RH. From this data the further research will focus on Riverside Parkway in Sacramento due to all buildings in the area having high RH moisture readings. These buildings will then be compared to other location throughout Sacramento to establish a reasoning for the high RH moisture readings.

Areas of Sacramento and Features

Figures 2 and 3 below show the areas of interest found in Riverside Parkway and the greater area of Sacramento. These two areas will be discussed below.

Figure 2: Riverside Parkway

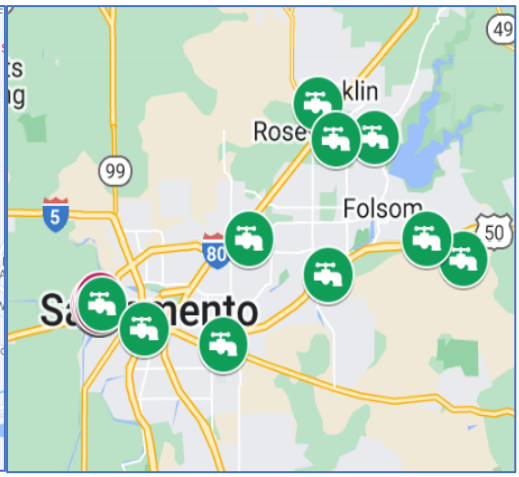

Figure 3: Sacramento

Low elevation and nearby rivers were found to be causes of concern for the area of Riverside Parkway. All buildings tested in the area failed with RH moisture readings up to 99 RH. As seen in the data sheet provided in the appendix, the buildings were not all built at the same time, meaning different methods of construction could have been used. Riverside Parkway is also a part of the Sacramento flood plane, which will have high levels of ground water near the concrete foundations. High ground water levels allow more moisture to penetrate the concrete after the curing process is over. A Quote found within the Foundational Handbook supports this claim when the author states "In general, moisture management schemes must control water in two states...Second, liquid water must be kept from accumulating around and under the foundation. Liquid water comes from sources such as Uncontrolled flows of surface water (and) High water table." (DOE 2013) Both a high volumes of flowing surface water and a high-water table are found within the area of Riverside Parkway.

The passing RH Moisture testing sites all had high elevations and were away from flood plains. High elevation buildings will be less likely to contain high RH moisture readings due to gravity pulling water away from the building's foundation. The natural draining of water gravity provides are essential in keeping the passing RH moisture sites dry. The dry locations were also not located near flood plains or other sources of water known to flood. Proximity to water is likely to cause higher RH moisture levels in the concrete slab.

Applicability to Construction and Real Estate

High RH Moisture levels in concrete slabs lead to higher cost of construction when a flooring system is needed to be installed. The data set used in this paper shows an average increase in cost of over $4,000 to the project if high moisture is found. By using RH moisture tests the flooring contractor will be able to plan for the use of a moisture remedy and the increase in cost can be known by all parties involved in construction. High Moisture readings can also be factored into the value of a building. If the buyer knows the concrete slab of a building contains high levels of moisture, a life cycle cost analysis can be done to find how much replacing the flooring will cost in the future.

Conclusion and Future Research

A moisture barrier placed beneath the concrete slab is one of the most effective ways to prevent moisture from damaging flooring systems. Keeping this in mind, all future construction project should use a moisture barrier as the first defense against moisture. By utilizing a moisture barrier beneath the slab large amounts of money can be saved when flooring is needed to be replaced.

Elevation of the buildings seemed to be one of the most common factors in having high RH moisture readings. The buildings that were in riverside parkway all contained high levels of RH moisture and shared a very low elevation compared to those of low RH moisture. The buildings located in Riverside Parkway also stand within the middle of flood plain. Although the area does not frequently flood, when heavy rains are experienced in Sacramento the ground water table will rise. The rising water table can move up through the concrete causing flooring system to fail.

Gaining data on the health of a building is crucial in making smart construction decisions and real estate investments. Having easy access to health characteristics of the foundation like RH moisture content and proof of a moisture barrier being utilized under the slab would make knowing the health of a building easier. Provided the data better decisions can be mad

References

Craig, P. , Donnelly, G. (2006) *Moisture Testing of Concrete Slabs*
https://www.proquest.com/docview/198737516?accountid=10362&parentSessionId=QfpWxp9kcZ6oqG9BuANuzvruAUyhkuHHG%2BfuwnruEBs%3D&pq-origsite=primo

Huntly, R. (2008) *Variables Affecting Calcium Chloride Testing For Moisture in Concrete*
https://www.proquest.com/docview/235969817?accountid=10362&parentSessionId=LxLhmQSsGLdUg5BVdsCAOYrPi0%2BP7cPUG1AluFmjKLE%3D&pq-origsite=primo

Palys, J. (2018) *The benefits of Rolled Moisture Barrier*
https://www.fcimag.com/articles/94566-the-benefits-of-rolled-moisture-barriers

Spangler, J.(2022) *40%: Why Testing at the Correct Concrete Depth Is Crucial*
https://www.wagnermeters.com/concrete-moisture-test/concrete-info/40-pct-testing-depth-crucial/

Spangler, J. (2016) New Wagner Meters Table Helps Estimate RH Readings
https://www.proquest.com/docview/1758651615?accountid=10362&parentSessionId=6NX1SC2T5Kbz%2Frz3CC9f8MDa%2BVwpQAL0vkAJRw6O%2BRc%3D&pq-origsite=primo

Spangler, J. ASTM F2170 Checklist
https://www.wagnermeters.com/pdf/F2170-Checklist.pdf

Spangler, J. (2017) *8 Reasons to Turn on Your HVAC* https://www.wagnermeters.com/concrete-moisture-test/concrete-info/8-reasons-to-turn-on-your-hvac/

Foundation Handbook (2013) https://foundationhandbook.ornl.gov/handbook/section4-1-water.shtml

TNEMEC *3 Ways to Test Concrete for Moisture* https://www.tnemec.com/remedy-index-page/3-ways-test-concrete-moisture/