A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates

Preface:

Moisture Testing procedures described in the A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates (A11 Best Practice or A11) are intended for use on all types of *Concrete Substrates* including old and new (regardless of age) concrete slabs-on-grade, suspended concrete slabs, concrete on steel decking, and floors covered with cementitious/gypsum (*Dew Point* only) underlayment and topping materials.

Moisture Testing procedures for wood substrates are similar and are specifically addressed within technical guidelines published by the National Wood Flooring Association (NWFA) at https://nwfa.org/technical-guidelines/ and are not re-described in this document.

Executive Summary:

The National Floor Covering Association (NFCA) struck a committee of subject matter experts drawn from the construction industry including floor covering installers; flooring inspectors; moisture testing agencies; manufacturers and distributors; concrete specialists; and *Design Professional*s and construction documentation specialists. They were tasked to identify and resolve moisture related failures of flooring installations that are occurring despite the well-intentioned efforts of the construction community. The result being the A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates.

- All concrete emits or contains moisture in some form that has potential to affect installation of *Flooring Products* if not managed during the construction process.
    - Moisture within the mass of concrete is essential and necessary for curing and strength gain of the *Concrete Substrate*.
    - Moisture within the top 19 mm to 25 mm (3/4-inch to 1-inch) and on the surface of concrete needs to be controlled and governs the recommendations described in the A11 Best Practice.
    - Moisture within *Concrete Substrates* is affected by thermodynamic forces (temperature differentials) and chemical modifiers (alkaline salts) that must be accounted for within the formal testing regimen.
- All installations of *Flooring Products* are susceptible to failure from wetting conditions, moisture vapour emissions or relative humidity when they exceed *Flooring Manufacturers* stated allowable tolerances.
- Establishing a well-defined moisture control plan and measurement system; in addition to a comprehensive concrete curing plan, is crucial for effectively managing concrete-related conditions during construction for all projects.
- *Permanent HVAC Systems* can be activated during construction; however, health care facilities are governed by CSA Z317.13 that limits use to supply air only using a separate system for exhaust air and must be accounted for when activating the HVAC system during construction. Other specialized projects such as laboratories and cleanrooms, or schools and extended care centres may have similar requirements that must be assessed and accounted for within the project specifications.

The A11 Best Practice addresses contributions to moisture related failures and promotes the use of well-established testing procedures using innovative approaches that can track concrete and environmental *Moisture Conditions* throughout the course of construction by introducing:

- Updates to the *Constructors*' quality management program to enhance control over concrete-related conditions such as placement, curing, weather protection, temperature control, and organization of trades impacting the quality of concrete to meet required installation conditions.
- Early testing protocols scheduled at regular intervals throughout the construction period that are budget conscious and can identify potential moisture related issues before they become a costly issue affecting scheduling and completion of the project.
- Coordinating moisture assessments and measurements using a standardized list of tests along with a schedule to optimize testing efficiency, enabling early identification of moisture issues for prompt remediation planning.
- Necessary temperature and humidity control requirements that must be met before, during, and after flooring installation until project completion.
- Identifying that the ASTM F2170 RH Test does not identify the potential for surface *Dew Point* relating to *Moisture Condition* concerns; determining *Dew Point* is affected by a variety of site conditions and is fully described in the A11 Best Practice, condensation could be present when atmospheric and surface condensation conditions are not tested for while recognizing how alkaline salts affect the *Dew Point*.
- Responsibility of construction activities associated with each party's ability to manage and control risks within their specific contribution to the overall project.

A11 gives a brief history about contributions to the rise in moisture-related flooring failures, standardizes definitions to enhance communication during construction, suggests best testing practices for consistent outcomes, and offers strategies for moisture mitigation that may occur during construction, and is contained within the Appendices.

A11 draws from other guides to successful moisture management strategies for concrete; such as the American Concrete Institute (ACI) ACI/PRC Concrete Slabs that Receive Moisture-Sensitive Flooring Materials and Cement Concrete and Aggregates, Australia (CCA) Moisture in Concrete and Moisture-Sensitive Finishes and Coatings, addressing approaches to successful moisture testing and management based on experiences from *Flooring Manufacturers*, *Testing Agencies*, *Flooring Distributors*, and *Floor Covering Installers* and members of the concrete manufacturing industry.

- The A11 Best Practice recommends that *Flooring Manufacturers* should use both the ASTM F1869 water vapour emission rate test and the ASTM F2170 RH test to confirm acceptable *Moisture Conditions* of *Concrete Substrates* in their written installation instructions in the same way as described in this Best Practice.
- The A11 Best Practice recommends that *Flooring Manufacturers* should include the ASTM F2659 moisture meter test in their installation instructions to map and assess *Moisture Conditions* throughout construction and during installation of *Flooring Products* to determine acceptable concrete surface *Moisture Conditions* in the same way as described in this Best Practice.

A11-1 Introduction:

Testing Innovation not Invention

The A11 Best Practice focusses on *Moisture Conditions* that affect installation of *Flooring Products* and addresses concerns for appropriate testing and interpretation of observed conditions that have potential to contribute to moisture related Flooring Product failures.

- A11 describes a variety of testing designed to lower the risk of floor failures arising from inconsistent *Moisture Conditions*; notwithstanding the fact that required *Flooring Manufacturer* tests were performed and were acceptable at the time of testing, but subsequent moisture related failures occurred.
- A11 promotes the use of a combination of controlled testing and indicative testing that are standard to *Floor Covering Installers*, *Flooring Manufacturers*, *Flooring Distributors* and *Constructors* that are used in an innovative way to provide a consistent approach to testing across all projects.
- A11 promotes early identification and correction of potential moisture issues, developing approaches to communication and coordination between all *Project Participants* required to improve installation outcomes.
- A11 recognizes the difference between commercial and residential installations that may have different performance expectations based on project complexity.

A11 advocates using a combination of Indicative Testing and Controlled Testing to assess *Moisture Conditions* that can be applied to larger portions of floor areas and that can be scheduled earlier than conventional approaches to testing that have been traditionally performed immediately prior to installation of *Flooring Products*.

The innovative and more inclusive approach to testing described in the A11 Best Practice allows for early identification of potentially problematic *Moisture Conditions* and can assist in developing drying strategies to mitigate moisture concerns so that they meet *Flooring Manufacturers'* required installation conditions and performance requirements.

Testing Types

The following test descriptions for controlled and indicative testing provide a balance between the traditional approach to measuring *Moisture Conditions* and the innovative approach promoted by the A11 Best Practice:

1. **Indicative Testing (Informal/Qualitative/Non-Destructive):** Testing required by *Flooring Manufacturers*; and required by the National Floor Covering Association (NFCA), that provides data about the condition and quality of the substrate and are usually inexpensive and economical to perform.
    a. Testing is considered informal; quality based and provides an indication of acceptable material properties without the need to provide precise numerical data.
        i. Many of the equipment tests described in A11 provide precise numerical measurements but are considered indicative because they represent a pass/fail or acceptable/unacceptable benchmark.
        ii. Measuring equipment manufacturers list precise pass/fail benchmarks that are specific to their brand and cannot be used comparatively with another manufacturer's equipment; meaning, the same equipment should be used for all indicative testing for current testing.

iii. Different manufacturers equipment can be used for subsequent testing, provided the dry condition readout is not compared to the other manufacturer's results; dry is dry based on the readout from all manufacturers.

b. Results are typically descriptive and require an experienced observer to provide interpretation of the tests, and who will typically be performing indicative testing.
c. Indicative testing will often be performed in conjunction with controlled testing to provide assurance that descriptive results are consistent with project performance requirements and meet requirements stated in the *Flooring Manufacturers'* literature.
d. Testing should be performed as construction progresses so that any changes to *Moisture Conditions* can be plotted to help identify any trends before issues arise that may cause problems for installation of *Flooring Products*.
e. Numbers of tests are not limited and can easily be performed across an entire floor area to assess overall *Moisture Condition*, can be repeated at previous locations and may indicate the need for additional controlled testing when results indicate conditions outside of stated minimum or maximum thresholds.

2. **Controlled Testing (Formal/Quantitative/Destructive):** Testing required by *Flooring Manufacturers* before installation of *Flooring Products* that provides precise numerical information relating to characteristics and performance of the *Concrete Substrate*:

   a. Testing is considered formal, quantifiable and specific to determine concentrations or quantities of substances found on or within concrete that have an effect on installation of *Flooring Products*, and that forms a part of the permanent project record.
   b. Controlled testing is performed by an experienced *Moisture Inspector*, who is responsible for documenting observed results and making recommendations based on known performance attributes and historical installation records.
   c. Testing should be performed as construction progresses so that any changes to *Moisture Conditions* can be plotted to identify any trends before issues arise that may cause problems for installation of *Flooring Products*.
   d. Tests may not be repeatable at the same locations and should be offset from previous tests to avoid false-results, because tests modify the existing condition of the measurement area.
   e. Tests are limited by the numbers stated within the referenced standards and can be labour-intensive, equipment dependent, and may be more costly and time consuming than indicative tests described above.

3. **Limitations with Moisture Testing Methods:** Concrete moisture testing methods have relied on measurements of relative humidity or moisture emission rates in the past. The tests typically only measure the gaseous (vapour) form of moisture and assumes that moisture distribution within concrete will equalize through the mass of the concrete slab-on-grade or suspended concrete slab during construction. *Moisture Inspectors* are expressing concerns that these methods of *Moisture Testing* using single point results are not providing an accurate assessment of unacceptable/acceptable *Moisture Conditions*.

   a. Many *Flooring Manufacturers* require RH testing before installation of *Flooring Products* using the ASTM F2170 Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-Situ Probes. The test was developed to provide quantifiable results using Controlled Testing methods to determine excessive internal *Relative Humidity* having potential to cause failure of installed finish flooring and coatings such as debonding, peaking and deterioration, and that contribute to microbial growth between *Flooring Products* and *Concrete Substrates*.

      i. Many RH probes used in the past may be unreliable when humidity levels within the mass of the concrete are below 10% and above 90% within the limits of the probe depth measurements.

> NFCA recognizes that In-Situ Probes have improved in recent years, and that many manufacturers of moisture measuring devices have specific methods to address these concerns. Many manufacturers have RH probes that can be left in-place and left on site to continuously monitor RH connected to multiple devices and allow for additional readings throughout the construction period.

ii. One limitation of the ASTM F2170 test is that it only measures *Relative Humidity* of a concrete slab at the fixed depth of the probe, and that it does not measure liquid water contained within the mass of the concrete.

1. RH can be higher or lower at different depths within the concrete slab and may not provide an accurate assessment of *Relative Humidity* near the surface (see A11.6 Drying Conditions for Concrete).
2. Liquid water within the mass of the concrete or arising from changes to *Hydrostatic Pressure*, is a latent condition that can cause high RH conditions after *Flooring Products* are installed.

iii. The frequency of ASTM F2170 tests required to provide confidence for installation of *Flooring Products* is expensive and may be impractical for large or complex floor areas.
iv. There is potential for increased costs for testing and delays (risk to the Constructor) when additional ASTM F2170 testing becomes necessary as a consequence of unacceptable results.
v. Single point testing associated with the ASTM F2170 can provide ambiguous results arising from other conditions associated with the concrete slab (alkaline salts, condensation, liquid water) as further described in the A11 Best Practice:

1. Reliance on single point tests may not be providing the results that people think. The test is useful, but identifies issues associated with concrete that are only valid on the date on which the tests were performed, and site conditions that were apparent on that date.

> NFCA recognizes that most tests are only valid on the date and site conditions under which the tests were performed. This is a common limitation published by the testing organizations and is not limited to the tests described in this A11 Best Practice. Test procedures should be reviewed for additional limitations and is the reason why NFCA recommends engaging with *Moisture Testing Agencies* that can provide evidence through certification or proof-of-training for the personnel performing the tests.

2. Measured conditions can change daily, monthly or seasonally due to (1) liquid water contained within the mass of the concrete, (2) *Hydrostatic Pressure*, and (3) changes in *Vapour Pressure Differential* between the *Concrete Substrate* and the construction environment.

b. Other *Flooring Manufacturers* require moisture vapour emission testing before installation of *Flooring Products* using the ASTM F1869 Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete using Anhydrous Calcium Chloride. The test was developed to provide quantifiable results using Controlled Testing methods to evaluate the rate of moisture vapour emitted by concrete (not gypsum cement or lightweight aggregate toppings) having potential to contribute to moisture related failures of *Flooring Products*.

i. A limitation of the ASTM F1869 test is that it only measures moisture vapour emissions from concrete when *Dynamic Moisture Transfer Conditions* exist at the time of measurement.
ii. The frequency of ASTM F1869 tests required to provide confidence for installation of *Flooring Products* is expensive and may be impractical for large or complex floor areas.
iii. There is potential for increased costs for testing and delays (risk to the *Constructor*) when additional ASTM F1869 testing becomes necessary as a consequence of unacceptable results.
iv. Single point testing associated with ASTM F1869 can provide ambiguous results when *Dynamic Moisture Transfer Conditions* are not favourable for determining accurate moisture vapour emission rates.

1. Similarly to comments for ASTM F2170, reliance on single point tests may not provide the results people think, and that results are only valid on the date and site conditions on which the tests were performed.
2. Measured conditions can change daily, monthly or seasonally due to changes associated with *Dynamic Moisture Transfer Conditions*.

c. *Flooring Manufacturers* are starting to recognize that ASTM F1869 and ASTM F2170 have merit when they are both performed to account for the diverse sources and reasons for moisture that impact floor covering installations, which adds complexity and cost associated with testing.

   i. This is leading some *Flooring Manufacturers* to include ASTM F2659 Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete, Gypsum Cement and Other Floor Slabs and Screeds Using a Non-Destructive Electronic Moisture Meter.
   ii. This test helps to reduce the number of retests when ASTM F1869 or ASTM F2170 indicate *Moisture Conditions* that do not meet their stated tolerances.

4. **Reliance on Flooring Manufacturers' Specified Testing:** *Flooring Manufacturers* have relied upon concrete testing as an attempt to accurately assess concrete properties associated with curing and strength gain in the absence of any specific testing designed to measure *Moisture Conditions* associated with installation conditions relating to *Flooring Products*.

   a. The two test methods typically referenced by *Flooring Manufacturers* include the following, neither test method is a predicter for the presence of moisture (condensation) arising from dew point when warm moist air contacts cold surfaces or the changes in dew point when alkaline salts are present:

      i. ASTM F1869, *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*, test for moisture vapour emissions from concrete that typically arise from mix water; or from below grade water intrusion for slabs-on-grade, and may not provide an accurate reading of surface condensation arising from the presence of alkaline salts which absorb water similar to the calcium chloride used in the test and may provide a lower moisture result than what is actually present.
      ii. ASTM F2170, Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes: Test for relative humidity arising from mix water in concrete which pertains to assessing hydration of concrete and the rate of cure and may not provide the full extent of moisture contamination affecting installation of *Flooring Products*, because of the depth of the probe.
      iii. The A11 Best Practice promotes using ASTM F2659 before conducting ASTM F1869 or ASTM F2170 to determine whether *Concrete Substrates* are dry enough to perform the more expensive and time-consuming Controlled Testing.
      iv. A11 also promotes using ASTM F2659 Indicative Testing before and during installation of *Flooring Products* to confirm that there are no changes to the accepted *Moisture Conditions* using ASTM F1869 or ASTM F2170.

   b. A common frustration heard from *Floor Covering Installers*; who are held responsible for replacing *Flooring Products* that fail because of moisture related damage, is "if *Moisture Testing* is so accurate, why do moisture problems continue to occur?"

      i. *Moisture Conditions* are responsible for billions of dollars annually relating to repairs and replacement of *Flooring Products*, and the consequential costs associated with loss of use to the homes, businesses and institutions that are affected by this type of failure.
      ii. The costs associated with moisture related failures in North America is trending upwards over the past 2 decades, resulting in substantial loss of businesses and personnel that are no longer able to shoulder the burden of costs for conditions that they have no control over and are not responsible for.
      iii. Some estimates for moisture related failures in North America indicate that the problem is much larger than anybody can anticipate as *Flooring Manufacturers* cover replacement *Flooring Products* under different failure categories, adding significant costs to the prices charged by *Flooring Manufacturers*.

5. **Innovative use of ASTM F2659 as Primary Test:** The two controlled tests used by *Flooring Manufacturers*; ASTM F1869 and ASTM F2170, can be costly to perform when performed without the aid of a moisture map created using the ASTM F2659 electronic moisture meter test. This is evidenced on large or complex projects, as well as smaller commercial and residential projects when the controlled tests have to be repeated when "wetter" conditions are identified and require retesting. The ASTM 2659 test provides similar results as ASTM F1869 and ASTM F2170 and provides greater accuracy on where to place the two controlled tests that are required to meet *Flooring Manufacturer's* installation *Moisture Condition* tolerances.

    a. Most *Flooring Manufacturers* currently rely exclusively on the results of ASTM F1869 or ASTM F2170 to determine acceptable *Moisture Conditions* for installation of their *Flooring Products*.

        i. There are a growing number of *Flooring Manufacturers* accepting use of the ASTM F2659 electronic moisture meter as a part of their testing routine.
        ii. The ASTM F2659 in those cases is used as a follow-up test used during installation of *Flooring Products* to identify areas of concern not otherwise identified by the ASTM F1869 or ASTM F2170 tests.

    b. NFCA's panel of subject matter experts; charged with creating content for the A11 Best Practice, have stated concerns for the accuracy of the standard controlled tests when moisture related floor failures occur despite acceptable test results.
    c. The recommendation from the NFCA subject matter experts is to run a defined minimum number of ASTM F1869 and ASTM F2170 tests concurrently with the ASTM F2659 test to show similar results between the *Moisture Condition* test results followed by a modified testing procedure starting with preliminary testing during construction as follows:

        i. The *Constructor* should start testing using ASTM F2659 beginning after completion and acceptance of all required concrete tests, which usually starts after the 28 to 56-days required to achieve the specified structural properties associated with the mix design.
        ii. The *Constructor* will create an initial moisture map of the entire *Concrete Substrate* using the ASTM F2659 to establish locations "wetter" and "dryer" areas and identify areas requiring modifications to the drying and protection plan to address "wetter" areas well in advance of performing the ASTM F1869 and ASTM F2170 tests.
        iii. The *Constructor* can revisit "wetter" areas periodically during the course of *The Work* to determine whether additional remediation measures described in the A11 Best Practice may become necessary to address areas of concern and maintain the construction schedule.

    d. The *Flooring Manufacturer* must be approached and agree to a mutually acceptable number and location of concurrent tests performed by the *Constructor* (ASTM F1869, ASTM F2170 and ASTM F2659) which could represent about 10% of the total floor area; or they could agree to testing only where "wetter" areas are located, regardless of which approach is used there is potential for significant cost savings associated with making controlled tests on larger or more complex projects.

        i. Perform the concurrent tests (ASTM F1869, ASTM F2170 and ASTM F2659) to verify that *Concrete Substrates* are ready for installation of *Flooring Products*.
        ii. Once an acceptable set of readings is established, the *Floor Covering Installer* will continue ASTM F2659 electronic moisture meter readings during the installation of *Flooring Products*.
        iii. *Moisture Conditions* can fluctuate hourly, daily or weekly particularly in areas that are exposed to direct sunlight that can temporarily show low areas of moisture concern and then "bounce" to a "wetter" condition once the heat from the sun is removed.
        iv. The *Floor Covering Installer* can request the *Constructor* to perform additional ASTM F1869 and ASTM F2170 if they find areas of concern; the *Constructor* can perform those tests or perform surface remediation based on the budget and schedule risks, and then schedule the *Floor Covering Installer* to complete installation of *Flooring Products* once the problem areas are addressed.

    e. Smaller projects such as light commercial and residential projects, may benefit from the early-stage moisture mapping strategy; and with the consent of the *Flooring Manufacturer*, may proceed with installation of *Flooring Products* using only the results of the ASTM F2659 electronic moisture meter test when there are no "wetter" areas identified during the course of *The Work* or during installation by *Floor Covering Installer*.

The minimum number of tests required by each of the testing methods described above account for increased number of tests to for thicker *Concrete Substrates*.

- ASTM F1869 confirms acceptable Moisture Vapour Emissions Rate and requires a minimum of 3 tests for the first 100 m^2 (1000 ft^2) followed by 1 test for each subsequent 100 m^2 (1000 ft^2).
- ASTM F2170 confirms acceptable Relative Humidity and requires a minimum of 3 tests for the first 100 m^2 (1000 ft^2) followed by 1 test for each subsequent 100 m^2 (1000 ft^2), offset from the ASTM F1869 testing apparatus.
- ASTM F2659 confirms acceptable Moisture Content and requires 3 to 5 tests at each location with the highest result governing if there are variations in the readings and is repeated in a minimum of 8 locations for the first 100 m^2 (1000 ft^2) followed by 5 locations for each subsequent 100 m^2 (1000 ft^2).

The number of tests is based on a statistical approach; that when installing the first series of tests, there is a likelihood of encountering areas of the concrete that have more aggregate, or that had water added during delivery, or were subjected to water from weather conditions.

- Requiring more tests initially and fewer tests once statistical reliance is established means that at least one truck load of concrete will be included in each subsequent test.
- More tests in the first tested area also considers the possibility of hitting a spot in the slab that's mostly aggregate, which will likely give too low a moisture reading.
- Putting multiple sensors in the first 100 m^2 (1000 ft^2) increases the likelihood that if one test result provides a low moisture result, that one of the other locations will find a "wetter" location within the concrete.

Test areas must be cleaned and prepared as stated for each individual ASTM test method, and typically requires an area that is free from flooring, coatings, patching cements, adhesive residue with the concrete surface exposed and cleaned. A dustless grinder may be used to clean the surface to speed up the process, without using any acid etching, water, strippers or clean sweeping agents which can create a semi-permeable or non-permeable surface film that will contribute to inaccurate reading of *Moisture Conditions*.

- Test locations must be protected from damage and disturbance; the ASTM F1869 test is required to be undisturbed for a period of 60 to 72 hours as an example; the core holes relating to ASTM F2170 must be capped and left undisturbed between each test so that the core is not artificially dried by leaving it open to the construction environment.
- The ASTM F2659 is the least affected by site protection requirements and requires only a clean dust free surface and can be performed in about 15 minutes for a complete test progression.

A11-2 Scope of the Best Practice:

The A11 Best Practice: *Moisture Testing* for *Flooring Products* contains a compilation of information and experiential knowledge provided by the Subject Matter Expert sitting on the NFCA Moisture Testing Technical Committee. It focusses on the need to improve the construction and design community's knowledge of how moisture in both its liquid (condensation) and gaseous (vapour) states affects compatibility between *Concrete Substrates* and *Flooring Products*. The A11 Best Practice proposes *Moisture Testing* methods and procedures that may help in confirming that *Concrete Substrates* are drying properly throughout construction and will be ready for installation of *Flooring Products* when they are required by the *Constructor's* project schedule.

- The A11 Best Practice offers guidance aiming to significantly reduce moisture-related issues leading to failures in *Flooring Products*, but they do not guaranty the prevention of such problems.
- The A11 Best Practice offers advice to help avoid construction practices that may contribute to moisture-related failures of *Flooring Products*, and the subsequent significant costs and losses arising from repair and replacement because of such problems.

RESPONSIBILITY CHART

The A11 Best Practice identifies existing construction procedures and standards that are already commonly used for project delivery. It describes rearrangement of some of the procedures for use at earlier stages of the project delivery schedule and introduces budget management strategies that can lower or eliminate costs associated with moisture mitigation during later stages of the project schedule. The A11 Best Practice is intended to be viewed as introducing innovation to managing concrete *Moisture Content* and should not be interpreted as inventing something that did not previously exist and can be summarized as illustrated in the following responsibility (next page).

RESPONSIBILITY	SCHEDULE	ACTIVITIES	PARTICIPANTS	TOPICS
Constructor: Preconstruction Meeting	Concrete Start-Up Meeting	Discuss moisture control requirements for *Flooring Products*	Concrete Trades Testing Agency Flooring Manufacturers or Flooring Distributors Floor Covering Installers Design Professionals	Concrete mix design Concrete finishing requirements Concrete curing plan Concrete protection plan Concrete testing schedule Concrete drying, surface mitigation and repair plan Activation plan for Permanent HVAC System
Constructor: Coordination of Construction Activities	Concrete Floor Construction	Concrete Placing, Finishing, Curing and Protection	Concrete Trades	Coordinate concrete flatness requirements described in NFCA A21 Best Practice: Measuring Substrate Flatness for Floor Covering Installations
	Testing and Reporting	Validation and Control of Concrete Substrate Conditions	Constructor Testing Agency Design Professionals (preparation of documents describing requirements)	Continuous early monitoring of Moisture Content: ASTM F2659 Verify acceptable Moisture Vapour Emission Rate: ASTM F1869 Verify acceptable Relative Humidity: ASTM F2170 Verify acceptable Alkalinity: ASTM F3441 Verify acceptable Concrete Porosity: ASTM F3191
	Concrete Substrate Correction	Mitigation and Repairs	Constructor Concrete Trades	Provide acceptable Floor Flatness using NFCA A21 Best Practice. Provide acceptable substrate *Moisture Condition* using NFCA A11 Best Practice.
	Flooring Products	Observation of Surface Conditions, Surface Preparation and Installation	Floor Covering Installer	Review Testing Agency reports and test results and verify conditions meet Flooring Manufacturer's written tolerances. Monitor *Moisture Content* before *Flooring Product* installation: ASTM F2659 Monitor potential for capillary moisture: ASTM D4263 Monitor surface bonding conditions: ASTM F3311 Continuous monitoring of *Moisture Content* during floor preparation activities and installation of *Flooring Products*: ASTM F2659
Constructor: **Go/No Go** Decision	Does Concrete Substrate meet Flooring Manufacturers' Requirements?	**No**	Floor Covering Installer	Notify Constructor and do not install *Flooring Products* until *Moisture Conditions* are corrected and meet required tolerances. OR Switch to a more moisture tolerant or moisture resistant adhesive consistent with *Adhesive Manufacturer's* written tolerances at additional cost (unforeseen conditions). OR Install moisture mitigation materials (ASTM F3010 and others) consistent with *Flooring Manufacturer's* written instructions at additional cost (unforeseen conditions).
		Yes	Floor Covering Installer	Install *Flooring Products* in accordance with *Flooring Manufacturer's* written instructions.

A11-3 Measuring Moisture of Concrete Substrates:

REFERENCE STANDARDS

Construction requires standardized procedures to confirm compliance with the Contract Documents to avoid conflicts or disagreements that can arise when the quality of *The Work* is questioned. Reference Standards include documents published by recognized consensus organizations (such as ACI, ASTM, ANSI, CSA, IICRC, ULC) and that are directly related to *The Work*.

- Version dates are not included in the following listing to avoid potential conflicts that may arise when a different date is encountered in the specifications relating to a specific project.
- Most specifications include the publication date appropriate to the jurisdiction, manufacturers may include dates of the standards relating to the date that their products were last tested, and building codes may only recognize the version dates applicable at the time codes were published.
- Reference Standards are routinely updated, and information associated with testing or materials choices can change based on the version date used for the project.
- *Design Professionals* should confirm the versions applicable to their provincial jurisdictions or local practice.

1. **Reference Standards Applicable to Related Work:**

    a. ACI/PRC 302.2, Concrete Slabs that Receive Moisture-Sensitive Flooring Materials:

        i. Stated Usage: Contains recommendations for materials, design, and construction associated with concrete slabs-on-ground and suspended slabs that will receive moisture-sensitive flooring materials described within the A11 Best Practice.

        ii. Benefits: This guide describes design and construction coordination requirements that are beneficial to achieving conditions that require minimal subsequent preparation needed before the *Concrete Substrate* is turned over to the *Floor Covering Installer* and specifically addresses most of the issues described in the A11 Best Practice from the perspective of the concrete trades, including the following:

            1. Flooring Moisture Issues: Including moisture movement, concrete drying, effects of moisture movement, *Equilibrium Moisture Content*, protection from drying and wetting of concrete and controlling moisture loss during drying stages.
            2. Concrete Moisture Testing: Including standard guides and test methods, qualitative testing and quantitative testing (Controlled Testing and Indicative Testing), test parameters, testing of underlayments and comments on moisture vapour emission rate tests.
            3. Concrete pH Testing: Including effects of carbonation and adhesive water associated with alkaline conditions and presence of alkaline salts.
            4. Flooring Manufacturer Recommendations: Including coordination between different flooring and adhesive manufacturers and dealing with multiple different *Flooring Products* requirements.
            5. Drying of Concrete: Including different exposure conditions affecting drying of concrete, concrete thickness, requirements for controlled curing, drying and protection of concrete during construction and the drying environment.
            6. Vapour Barriers: Describes the need for vapour retarders/barriers/membranes as a part of an effective *Capillary Break* and includes considerations for vapour transmission through the vapour barrier materials.
            7. Floor Covering Materials: Describes the need for effective communication between the *Design Professionals* (architect, interior designer, structural engineer, mechanical engineer), available technical resources, relationship between flooring adhesives and *Flooring Products*, and the effect of concrete moisture on adhesive performance.
            8. Design and Construction Recommendations: Describes the relationship between moisture testing, vapour barriers, concrete materials and properties, surface finishes of concrete, concrete curing and surface preparation, repairs and moisture mitigation, and protection from environmental conditions affecting concrete and floor covering materials.

9. Limitations: The guide is specific to the structural *Design Professional* and the concrete trades, resulting in the content not being read or incorporated into the project documents or coordinate at the project start-up meeting.

b. ASTM C33, Standard Specification for Concrete Aggregates:

    i. Stated Usage: Defines requirements for grading and quality of fine and coarse aggregates for use in concrete, typically used by a contractor, concrete supplier or other purchaser obtaining materials described in the standard.
    ii. Benefits: This standard allows the specifier to select appropriately sized aggregates relating to the proportions of fine and coarse aggregate and blending of aggregates as required for concrete mix design.
    iii. Limitations: This standard is specific to concrete and contains defined gradations (sizes) of aggregates that are specific to concrete production; products are expensive and are frequently substituted for less expensive (pit-run, road-crush) aggregates containing higher percentage of fine aggregates diminishing the resistance to capillary uptake of below grade moisture with potential to increase moisture problems for slabs-on-grade.

c. ASTM D448, Standard Classification for Sizes of Aggregate for Road and Bridge Construction:

    i. Stated Usage: Defines requirements for aggregate size based on standard ranges of mechanical screens (sieve analysis) of coarse aggregate and screenings for use in construction of bridges and highways.
    ii. Benefits: This standard allows the specifier to select aggregate sizes based on specific uses and provides the ability to modify sizing choices based on the needs of end-product usage, including limits on variability of aggregate grading based on local materials.
    iii. Limitations: This standard is more flexible and allows for selection of a greater variety of outcomes including void-spacing (openness factor); but similar to ASTM C33, this standard is specific to concrete production relating to highway and bridge construction making the aggregates expensive and subject to substitution for higher capillary aggregates that have potential to cause moisture related issues for *Flooring Products*.

d. ASTM E1643, Standard Practice for Selection, Design, Installation, and Inspection of Water Vapor Retarders used in Contact with Soil or Granular Fill under Concrete Slabs:

    i. Stated Usage: This standard describes procedures for selecting, designing, installing, and inspecting flexible, prefabricated sheet membranes that are in contact with soils or granular fill used as vapour retarders under concrete slabs.
    ii. Benefits: Allows the specifier to describe materials that limit water vapour transmission and capillary transport of water upward through concrete slabs-on-grade to protect floor finishes from adverse moisture related issues and to protect interior humidity levels to prevent microbial growth on susceptible materials in contact with concrete slabs-on-grade.
    iii. Limitations: Building codes in Canada do not list this standard as a part of the protection systems for reduction of soil gas (radon), vapour migration and water penetration. Despite this standard being described in CSA A23.1/A23.2 for acceptable vapour barrier installation procedures, it is not well understood or specified leading to moisture related problems through exclusion.

e. ASTM E1745, Standard Specification for Water Vapor Retarders used in Contact with Soil or Granular Fill under Concrete Slabs:

    i. Stated Usage: Defines requirements for performance of flexible, preformed sheet membrane materials used as vapour retarders in contact with soil or granular fill under concrete slabs-on-grade.
    ii. Benefits: Materials are tested and manufactured for *Permeance* of many subgrade gases including water vapour, radon, and hydrocarbons, and to resist high and low temperatures without becoming brittle, be resistant to degradation from soil organisms, and have high tensile strength to resist construction loads and damage arising from exposure to installation of concrete slabs-on-grade.

iii. Limitations: Building codes in Canada list acceptable design solutions such as polyethylene sheets as a part of the protection systems for reduction of soil gas (radon), vapour migration and water penetration. Despite this standard being described in CSA A23.1/A23.2 for acceptable vapour barrier materials, it is not well understood or specified leading to moisture related problems resulting from breakdown of polyethylene sheets due to subgrade exposure conditions and that are less durable than the plastic materials described in the standard.

f. CSA A23.1/A23.2, Concrete Materials and Methods of Construction:

   i. Stated Usage: The standard describes requirements for concrete placement planning, material testing and sample collection, describes the roles and responsibilities of *Project Participants* for quality outcomes, including concrete procurement, concrete curing and protection during construction and coordination with trades affected by concrete work.
   ii. Benefits: Using the standard ensures a standardized approach to concrete construction and improving quality assurance of installed materials, promotes consistency and leads to more predictable concrete outcomes, and provides troubleshooting guidelines when issues affecting the quality of construction are encountered.
   iii. Limitations: The level of detail and complexity requires a thorough understanding of the standard to implement its requirements effectively and does not offer flexibility in its interpretation to identify potential issues that could reduce usability of concrete used as a substrate by other trades.

2. Reference Standards associated with *Flooring Manufacturers* performance requirements for *Moisture Condition* of *Concrete Substrates*:

i. ASTM F710, Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring:

   1. Stated Usage: The standard practice describes the processes for determination of acceptability of *Concrete Substrates* by describing preparation and construction necessary for the installation of resilient flooring finishes.

      a. The standard practice also recognizes that other moisture sensitive flooring finishes such as carpet tiles, carpet, wood flooring, coatings, films, and paints benefit from the same surface condition mitigations, preparation, and construction as resilient *Flooring Products*.
      b. The standard practice recognizes that concrete floors may appear dry from a visual examination but actually have a deleterious level of water vapour in, emitting from, or passing through a slab and recommends a series of moisture tests described in the A11 Best Practice (ASTM D4263, E1745, F1869, F2659, F2170, F3191, F3311).

   2. Benefits: The standard practice introduces concerns for residual moisture within concrete slabs and moisture that passes through concrete slabs from underlying soils that cause adverse effects due to the presence of water or water vapour emissions, or the build-up of alkaline salts (through evaporation) that result in adhesive failures or contributes to fungal growth and odours, with water sources being identified from the following:

      a. Failure to control temperature and *Moisture Conditions* during construction within *Flooring Manufacturer's* stated installation requirements will affect installation of *Flooring Products* and potentially cause rehabilitation or repair of the *Associated Work*.
      b. Water arising from construction such as precipitation (protection from weather), condensation (controlling temperature and humidity), or purposeful wetting (leaks or wet construction processes) must be managed or eliminated.
      c. Water arising from ground conditions must be controlled by installing an effective *Capillary Break* or waterproof barrier to reduce potential of natural ground water or irrigation water wick to underside of floor finishes.
      d. Water arising from building operation such as flooding floors with water to clean must be addressed through a formal operating and maintenance procedure.

3. Limitations: The standard practice is nonmandatory and is often not referenced or enforced meaning that the recommendations are not implemented, potentially causing the issues this Best Practice is addressing. The standard practice also does not address protection of concrete slabs during construction to reduce the potential for *Moisture Conditions* that may be deleterious to installation of flooring finishes, nor does it recommend procedures having potential to mitigate some potentially harmful *Moisture Conditions* when they occur.

ii. ASTM D4263, Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method:

1. Stated Usage: This standard test method describes indicative assessment for the presence of moisture in concrete resulting from capillary action that may be detrimental to the performance of *Flooring Products* that cannot tolerate moisture on or within the surface boundary between the concrete slab and the *Flooring Products*.
2. Benefits: This test is relatively simple and inexpensive to perform, involving placing a plastic sheet on the concrete surface and observing any condensation that forms with the presence of condensation indicating excess moisture in the concrete slab and highlighting potential issues for installation of *Flooring Products*.
3. Limitations: Interpretation of this test is subjective and relies on visual observation of condensation occurring on the underside of the plastic sheet:

    a. This test method becomes less accurate when applied to rough or uneven concrete slab surfaces potentially affecting the accuracy of Moisture Condition assessments.
    b. Results can be influenced by environmental conditions such as temperature, humidity, and airflow, or accidental or intentional manipulation of the plastic sheet that can lead to inconsistent observations.
    c. This test method primarily assesses surface moisture and may not detect moisture deeper within the concrete slab, potentially overlooking underlying issues that could affect *Moisture Conditions* that lead to Floor Covering installation failures after installation is complete.
    d. This test method may not account for capillary moisture migration within the concrete slab that can occur over a period of time limiting its ability to indicate Dynamic Moisture changes accurately.
    e. The results obtained reflect the condition of the concrete floor surface at the time of testing and may not indicate future conditions, which is the reason for conducting tests as close to operating conditions as possible.

iii. ASTM F1869, Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride:

1. Stated Usage: This standard test method describes a measurement determination of the moisture vapour (gaseous) emission rate (MVER) from below-grade, on-grade, and above-grade (suspended) bare concrete floors, measured as a weight per unit of area during a 24-hour period:

    a. Many *Flooring Manufacturers* state a maximum MVER limit, which when exceeded has increasing potential to cause installation failure of their *Flooring Products*.
    b. The standard test recognizes that all concrete slabs emit some amount of moisture in vapour form and that *Concrete Moisture* emissions are a natural process driven by environmental conditions.
    c. The standard test recognizes that all *Flooring Products* are susceptible to failure from excessive moisture and provides a standardize measurement process.

2. Benefits: The "calcium chloride moisture test" has been the industry standard for making this determination and is a practical, well-established, and accepted test of *Dynamic Moisture Transfer Conditions*, and quantifies results that are directly applicable to *Flooring Manufacturer's* stated installation conditions.

3. Limitations: The standard test method cannot be used to evaluate moisture vapour emitted from gypsum concrete or concrete containing lightweight aggregates and is limited to when moisture pressure differential favours (*Dynamic Moisture Transfer Conditions*) emissions from the slab surface into the in-service space, and the floor surface is free from alkaline salts.

    a. Alkaline salts adsorb water that could artificially lower the MVER reading, potentially resulting in a false acceptable moisture vapour emissions measurement.
    b. Polyethylene hats can be dislodged (intentionally or accidentally) causing an unsealed test condition and leakage of moisture vapour away from the testing medium resulting in unreliable acceptable moisture vapour emissions measurements.
    c. This test cannot be performed on concrete floor surfaces that are not properly cleaned and prepared, or performed at a location of a previous test which can result in unreliable MVER measurements.
    d. The distribution of tests may not be sufficient to show natural variations in MVER across the extent of the entire floor area.
    e. Damaged, displaced, or missing membrane forming a part of the *Capillary Break* can significantly increase the *Moisture Condition* of a concrete slab and potentially affect floor covering and adhesive performance.
    f. *Dynamic Moisture Transfer Conditions* must be present when the interior building environment is conditioned to those expected during occupancy, preferably using the permanent heating, ventilation, and air conditioning system.
    g. The results obtained reflect the condition of the concrete floor surface at the time of testing and may not indicate future conditions, which is the reason for conducting tests as close to operating conditions as possible.
    h. Tests are not performed over control joints (saw cuts or relief cuts), where moisture issues may occur as a consequence of capillary action or moisture migration from adjoining slab sections of the control joints.

iv. ASTM F2170, Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-Situ Probes:

1. Stated Usage: This standard test method describes measurements of the percent *Relative Humidity* in concrete slabs using a moisture probe inserted into a sleeved hole (drilled-in insert for hardened concrete or cast-in insert for fresh concrete). The sleeve permits an RH measurement at defined depths within the concrete slab.
2. Benefits: *Flooring Manufacturers* require this test to reduce the possibility of *Flooring Products* being installed on *Concrete Substrates* that have excessive moisture, which helps to decrease floor covering system failures such as adhesive re-emulsification, debonding of adhesives, peaking and deterioration of finish flooring and coatings and microbial growth resulting from moisture related issues.
3. Limitations: The test must be performed when *Concrete Substrates* are at temperature and humidity conditions similar to those when building is in-service, and that these conditions are maintained for a minimum of 48 hours before taking measurements (see definition for *Permanent HVAC System)*.

    a. Acclimation of *Concrete Substrates* may require additional time where concrete slabs were not protected from wetting conditions or were not kept consistently warm during construction, it can take about 1 month for each 25 mm (approximately 1 mm per day) of slab thickness before concrete is dry enough to take meaningful RH measurements.
    b. This test is typically performed within the top 20% to 40% of slab thickness depending on whether the slab is drying from a single surface or both surfaces and does not account for the top 25 mm (1-inch), which has the greatest influence on whether *Moisture Conditions* will be acceptable.
    c. This test requires a minimum of 3 inserts for the first 100 m^2 and 1 insert for each additional 100 m^2.

        i. The tests can become prohibitively expensive for large floor areas.
        ii. The distribution of tests may not be sufficient to show natural variations in RH across the large floor areas.

d. The results obtained reflect the interior condition of the concrete slab at the time of testing and may not indicate future conditions, which is the reason for conducting tests as close to operating conditions as possible.
e. Tests are typically not performed over control joints (saw cuts or relief cuts), where moisture issues can occur as a consequence of capillary action or migration from adjoining slab sections of the control joints.
f. Drilling into concrete slab for insertion of the RH probe sleeves can raise the potential risk for repair costs associated when electrical conduit, water pipes or hydronic heating pipes are damaged.

v. ASTM F2659, Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete, Gypsum Cement and Other Floor Slabs and Screeds Using a Non-Destructive Electronic Moisture Meter:

1. Stated Usage: This standard test method describes procedures for determining the comparative *Moisture Condition* within the upper 25 mm (1-inch) of concrete, gypsum, anhydrite floor slabs and screeds before installing *Flooring Products*.

    a. The measured depth may vary based on the manufacturer of the electronic moisture meter, with some meters measuring within the upper 19 mm (3/4-inch) of the surface.
    b. Electronic moisture meters from different manufacturers should not be used on the same project, results from different manufacturers may not be compatible with each other.
    c. This test method should be used in conjunction with ASTM F1869 or ASTM F2170 or both when required by the *Flooring Manufacturer* to establish a baseline of measurements used to determine the comparative *Moisture Condition*.
    d. This test method must be used in conjunction with the electronic moisture meter manufacturer's operation instructions and interpretive data.

2. Benefits: This test is used to determine if there are moisture-related conditions existing on; or in, *Concrete Substrates* that could adversely impact successful application and performance of *Flooring Products* and can also be used in the diagnosis of failures of installed *Flooring Products*.

    a. Some moisture meter manufacturers title their testing protocol as a "gravimetric test"; which is a destructive test method that provides very accurate assessment of moisture content in concrete, the "gravimetric test" is not performed on the actual concrete on site unless specific arrangements are made in advance with the meter manufacturer.
    b. Gravimetric testing is a highly accurate method for determining percentage of *Moisture Content* in concrete; involving weighing a concrete sample before and after a prescribed oven drying time, the difference in weight is used to calculate the percentage of *Moisture Content* in the concrete sample.

        i. The "gravimetric test" is performed by the meter manufacturer to calibrate the electronic moisture meter and confirm the accuracy of their devices, so that readings correspond to the actual *Moisture Content* of the concrete.
        ii. Electronic moisture meter manufacturers require a calibration check that must be used before making any measurements of *Moisture Content* with guidance indicating that the electronic device is returned to the manufacturer when the calibration check exceeds performance tolerances.
        iii. Electronic moisture meters returned to the manufacturer are then recalibrated to the laboratory sample using the gravimetric analysis procedure described above.
        iv. Electronic moisture meters must have proof of calibration within the manufacturer's usage limitations before executing this test on site.

3. Limitations: Comparative moisture content tests indicate the moisture in the slab, which is usually referenced to the percentage of dry weight, which is often incorrectly correlated with percentage measurements associated with RH within the concrete.

    a. May not be recognized by some *Flooring Manufacturers*.
    b. Individual meter manufacturers provide their own comparative number analysis, meaning that comparisons made between different electronic moisture meter manufacturers may not be possible.
    c. May have limitations of accuracy based on the wide variation of material mixtures and additives used in various *Concrete Substrate*s and hydraulic cement underlayments and screeds, and when contamination is present on the surface.

vi. ASTM F3010, Standard Practice for Two-Component Resin Based Membrane-Forming Moisture Mitigation Systems for Use Under Resilient Floor Coverings:

1. Stated Usage: This standard practice describes installation of resin-based, membrane-forming coating systems applied to the surface of *Concrete Substrates* that can significantly lower the moisture vapour emission rate and diminish effects of high RH of concrete slabs that have potential to contribute to *Moisture Conditions* that damage installation of *Flooring Products*.
2. Benefits: Products described by this standard practice can be used when there is insufficient time to permit drying of *Concrete Substrates* to meet *Flooring Manufacturers'* tolerances, or where site conditions contribute to persistently out-of-tolerance *Moisture Conditions*.
3. Limitations: Surface preparation and installation of products described by this standard practice can be expensive when a cash allowance was not included for potential mitigation of out-of-tolerance *Moisture Conditions*.

    a. Other types of moisture mitigation systems could also be acceptable to the *Flooring Manufacturer* and may include chemically reactive compounds that form a gel or crystalline substance within the concrete; penetrating water or solvent based compounds that do not form a continuous membrane on the concrete surface; or water-based, membrane-forming mitigation systems.
    b. *Design Professionals* may not include moisture mitigation products as a part of the project specifications when the *Owner* is reluctant to include contingencies to account for control of *Moisture Conditions* that fall under a *Constructor's* area of control and responsibility.
    c. *Constructors* must anticipate the need for concrete protection and concrete *Drying Time* as a part of their construction schedule, the *Owner* will not accept a lack of appropriate planning as justification for additional costs associate with unforeseen conditions.
    d. Unforeseen conditions may only be considered where the *Constructor* can demonstrate their diligence to controlling and mitigating conditions that contribute to out-of-tolerance *Moisture Conditions*.

vii. ASTM F3191, Standard Practice for Field Determination of Substrate Water Absorption (Porosity) for Substrates to Receive Resilient Flooring

1. Stated Usage: This standard practice describes methods to determine whether a substrate surface is porous or non-porous, and is performed before installation of resilient *Flooring Products*, and can also be used for other materials such as carpet tiles, carpet, wood flooring, coatings, films, paints, self-leveling and trowel-applied underlayments, primers, and other associated product.
2. Benefits: Most Flooring Manufacturers establish surface porosity as a critical indicator that affects application of adhesives and primers, and that directly affects the types of materials used during installation of *Flooring Products*, the volume of adhesives or primers used (spread rate) and the open time (limited window of installation).

3. Limitations: Non-porous (low or no absorption of water droplet) will typically require additional surface preparation or a change to the types of adhesives and primers used for the project, typically requiring additional time and cost to modify the *Flooring Manufacturers'* standard written instructions.

    a. Higher absorption of the water droplet can indicate poor surface conditions and potential for the surface of the *Concrete Substrate* to breakdown leading to dusting conditions and separation of the surface layer from the underlaying concrete slab; requiring additional surface preparation to consolidate the surface, changes to the types of adhesives and primers used for the project, typically requiring additional time and cost to modify the Flooring Manufacturers' standard written installation instructions.
    b. Higher absorption also increases the suction applied to water-based adhesive, leading to premature setting or crystallization of solids out of the adhesive.
    c. Increased or decreased porosity also changes the types of materials used, the volume of materials, and the open time associated with adhesive materials that will affect the quality of installation of specified *Flooring Products*.
    d. *Concrete Substrates* can have a mix of porous and non-porous areas and will require adjustments to the types, volumes and approaches to applying adhesives and primers across the whole of the floor area.
    e. The standard practice is usually performed in conjunction with the surface bond test (ASTM F3311) to confirm whether the surface porosity is compatible with *Flooring Products* proposed for use on the project.
    f. The standard practice may differ from some *Flooring Manufacturers'* written instructions and is not meant to replace published manufacturer's literature regarding determination of substrate porosity and the impact on substrate preparation requirements and on the installation of individual *Flooring Manufacturers'* respective materials.

viii. ASTM F3311, Standard Practice for Mat Bond Evaluation of Performance and Compatibility for Resilient Flooring System Components Prior to Installation:

1. Stated Usage: This practice describes procedures for performing mat bond evaluation of previously agreed upon areas at several different locations across the floor area to fully prepared and tested *Moisture Conditions* and compliant *Concrete Substrates* in accordance with the *Flooring Manufacturers'* written instructions.
2. Benefits: This practice is designed to provide a short-term indicative evaluation of the effectiveness and compatibility of the composite layers for flexible and fully adhered resilient *Flooring Products*, and should include (NFCA recommended Best Practice) evaluation of concrete surface profile (CSP), surface preparation, topical moisture mitigation systems (if any), hydraulic cement underlayment products (if any), primers (if any), and application and installation of the specified flexible and fully adhered resilient *Flooring Products*.

    a. Aspects such as surface profile, surface cleanliness, surface *Porosity*, the application methods, and the open, curing, and drying times of each layer of the flooring system can be assessed using this practice prior to the actual full-scale installation taking place.
    b. This evaluation is usually performed by a qualified installer; but can also be performed by a third-party *Flooring Inspector* (or *Moisture Inspector* having experience with flooring installations) who are trained and have experience to evaluate the adhesive bond strength between the Floor Product and the concrete slab.

The A11 Best Practice recognizes that *Moisture Inspectors* are trained and certified by other associations that have contributed to this document. The term *Flooring Inspector* used in this paragraph recognizes the additional experience necessary to review and report on mat bond testing procedure described in the ASTM F3311.

> *Flooring Inspectors* have specific experience and knowledge about how flooring adhesives are affected by *Moisture Conditions* and can better interpret the results of the test described in the A11 Best Practice, particularly with respect to assessing the ASTM F3311 Mat Bond test.
>
> NFCA recognizes the requirements of both Flooring Inspectors and Moisture Inspectors, and the roles they perform when conducting third-party testing. Some Flooring Inspectors are also Moisture Inspectors; however, they would not be employed to perform the same duties on a single project because this would be deemed as a conflict of interest.

c. The ASTM F3311 test is primarily intended for use with resilient flooring, but it also provides procedures for bond testing of other flooring types such as engineered hardwood, laminate flooring and carpets that are also bonded to *Concrete Substrates*.

3. Limitations: The practice is limited to flexible, fully bonded resilient *Flooring Products* and cannot be used when liquid applied, loose laid, perimeter fixed, or rigid *Flooring Products* are required for the project.

a. The practice can only be performed on concrete floor surfaces that have been fully acclimated and meet *Flooring Manufacturers'* required temperature and *Moisture Conditions*, and that are within acceptable pH and *Porosity* limits.

i. This practice recommends testing for *Moisture Condition* in accordance with ASTM Test Methods F2170 or F1869, or ASTM Practice F2659, or combinations thereof.
ii. Moisture Condition measurements must meet all *Flooring Manufacturers'* specified requirements before installation of any samples.

b. The results obtained reflect the interior condition of the concrete slab at the time of testing and may not indicate future conditions, which is the reason for conducting tests as close to operating conditions as possible.

ix. ASTM F3441, Standard Guide for Measurement of pH Involving Resilient Flooring Installations:

1. Stated Usage: This guide discusses procedures that may be used for evaluating the comparative change in pH of reagent water placed on the surface of a properly prepared concrete slab surface and is intended to be used in conjunction with a flat surface pH meter or pH paper.
2. Benefits: This measurement is used to detect high concentrations of soluble alkali salts in the surface region of a concrete slab due to the initial bleeding process of a freshly placed concrete slab, having potential to form a high pH solution beneath installed *Flooring Products* that contribute to moisture related failures.
3. Limitations: The testing apparatus must be calibrated before use and must be operated or used in strict accordance with the test manufacturers' written instructions, interpretive data, and limitations of use.

a. Individual manufacturers provide their own interpretation data, meaning that comparisons made between different manufacturers may not be possible.
b. The results obtained reflect the surface condition of the concrete slab at the time of testing and may not indicate future conditions, which is the reason for conducting tests as close as possible to the time of installation.

3. Reference Standards associated with Concrete Drying:

a. ANSI/IICRC S500, Standard for Professional Mold Remediation:

1. Stated Usage: This standard is primarily written for use by those involved in the mold remediation work and others who investigate or assess mold complaints, prepare remediation specifications, protocols, or procedures, and manage remediation projects; mold is caused by favourable temperature, humidity, and airflow conditions similar to those when assessing acceptable *Moisture Conditions* for concrete slabs and the installation of *Flooring Products* and meeting *Flooring Manufacturers'* written installation instructions.

2. Benefits: This standard provides standardized definitions and methods for assessing *Moisture Conditions* that contribute to mold growth and suggests methods for remediation that are beneficial to correcting *Moisture Conditions* associated with concrete slabs and the installation of *Flooring Products*.
3. Limitations: Interpretation of the standard may vary among non-qualified individuals leading to potential inconsistencies in its application, arising from the intricate and detailed nature of this test which requires expertise and training to fully implement effectively.

    a. The standard may not always address site-specific or regional challenges and requires adaptation by the qualified Moisture Tester to address local conditions.
    b. Strict adherence to the standard may require significant resources in time, personnel, and equipment, which requires adaptation by the qualified Moisture Tester to address local conditions.

b. ANSI/IICRC S520, Standard and Reference Guide for Professional Water Damage Restoration:

1. Stated Usage: This Standard describes necessary procedures precautions required when performing water damage restoration similar to those required to remediate concrete slabs to acceptable *Moisture Conditions* ready for installation of *Flooring Products* meeting *Flooring Manufacturers'* written installation instructions.
2. Benefits: The standard provides standardized procedures for drying concrete slabs, provided that the underlying source or cause of non-conforming *Moisture Conditions* does not arise as a result of water intrusion or capillary action through the concrete slab.
3. Limitations: Interpretation of the standard may vary among non-qualified individuals leading to potential inconsistencies in its application, arising from intricate and detailed nature which requires expertise and training to fully implement effectively.

    a. The standard may not always address site-specific or regional challenges and requires adaptation by the qualified Moisture Tester to address local conditions.
    b. Strict adherence to the standard may require significant resources in time, personnel, and equipment, which requires adaptation by the qualified Moisture Tester to address local conditions.

Management of Humidity and Condensation during Construction

Moisture is generated by construction processes and materials causing condensation on cooler surfaces when the air becomes saturated within the enclosed building environment. Condensation was not considered as being problematic in the past and accepted for the following reasons:

- The construction and design community did not fully understand the extent of its impact on the failure of moisture-sensitive materials installed on *Concrete Substrates* that were "cured" for 30-days and longer.
- The presence of alkaline salts on the surface of concrete artificially showing lower moisture readings and increasing the likelihood of condensation.
- Temporary heating and ventilation systems were not designed for consistent temperature management and were not capable of decreasing atmospheric humidity, and often contributed to the problem.

Moisture has been identified as a critical management criterion by most interior finish manufacturers in recent years; and despite past recommendations for controlled interior heating and ventilation, they are now making installation of their products as a warranty requirement only after the building's heating, ventilating, and air-conditioning (HVAC) systems are fully active and providing "in-service" interior environmental conditions.

- Building must be operating under conditions similar to those expected when the building is in-service.
- This poses a challenge for *Constructors* and *Owners* who are reluctant to activate *Permanent HVAC Systems* prior to substantial performance of the Work leading up to ready-for-takeover, because starting of equipment instigates the beginning of the warranty period for products before the building is ready for occupancy:
    - The terms "substantial performance" and "ready-for-takeover" are used in standard forms of contract published by the Canadian Construction Documents Committee (CCDC) and are reflective of a defined stage of construction completion that should be familiar to *Constructors* and *Design Professionals*.

- The mechanical trade contractor must bring their work back to its original condition to reinstate the HVAC warranty when the building is ready-for-takeover, when *Permanent HVAC Systems* are used during construction.
- This involves installing additional filtration media on ductwork, replacing belts and bearings on operational components, employing skilled and experienced duct cleaning services, and performing other maintenance and restoration tasks specified by the equipment manufacturer.

> NFCA recommends that individual projects be assessed for use of *Permanent HVAC Systems* for specific limitations or restrictions to parts of the installed systems. Projects such as hospitals, laboratories or clean rooms have specific procedures for using *Permanent HVAC Systems* during construction to prevent contamination.
>
> As one example CSA Z317.13, Infection Control during Construction, Renovation, and Maintenance of Health Care Facilities limits use of *Permanent HVAC Systems* to supply air only. Exhaust air return cannot be used and must be vented directly to the exterior.
>
> Evaluate and incorporate the need for each project with the mechanical design professional and incorporate specific requirements for use of the *Permanent HVAC System* as a part of the *Constructor's* quality management program.

- Cost of the restoration is often cited as a reason for not specifying this requirement but does not consider any of the potential costs associated with replacement and remediation of materials affected by *Moisture Conditions* associated with the operation of temporary heating and ventilation systems, which can be substantial.

- A cash allowance, unit price or identified price can be used to account for restoration costs to return HVAC system to meet warranty requirements and include a scheduling requirement for protection of HVAC equipment from construction generated dust and contaminants, and activation of *Permanent HVAC System* and acclimation period in advance of interior finishing work.

Controlling humidity during construction can also be achieved by specifying more sophisticated temporary heating and ventilation systems that use indirect-fired equipment and ducted air supply systems. These systems can provide more efficient air distribution, consistent temperature range throughout building areas, and reduce atmospheric moisture by incorporating fresh make-up air. They also address concerns for improved air quality management needed to protect construction workers, and can help manage atmospheric conditions that contribute to moisture related problems described in this Best Practice:

- Specifications should guide the *Constructor* on "what-is-required" rather than "how-to-construct," and provide a consistent approach to describing conditions that affect quality and performance for product and execution.
- Specifications that include guidelines for optimal temperature and humidity control and that limit the use of traditional direct heating and ventilation methods meet the "what-is-required" approach to appropriate communications.
- The *Design Professional* who uses the "what-is-required" approach when writing specifications also respects the Contractor's contractual responsibility for managing the "how-to-construct" aspect of construction means and methods.

Management of Moisture Condition Testing during Construction

A clear division of testing responsibilities associated with tracking Moisture Condition of *Concrete Substrates* must be recognized based on the *Constructor's* ability to control *The Work*, and the *Floor Covering Installer's* limitations for accessing *The Work*. Informed risk management works best when the specifications can allocate *Work Results* associated with testing and reporting to the parties that are best able to control the outcomes.

The specification should include requirements for site quality control (refer to NFCA Guide Specification in Appendix 4) clearly indicating the *Constructor's* role in coordinating *The Work* and describing the types of tests and time periods that they are required to be performed. Responsibility for testing and reporting is split into *Related Work* (work performed by 'others') and *Associated Work* (work performed by the *Floor Covering Installer*).

- **Related Work:** The *Constructor* should include tests for work that they have control over as a part of their quality management program and retain a third-party *Moisture Testing Agency*.

> NFCA recommends that *Flooring Inspectors* provide proof of their experience in the form of verifiable credentials from the International Concrete Repair Institute (ICRI), Inspector Training Services (ITS) or a person that has successfully completed training recognized by NFCA. NFCA conducts certification training for members that perform ASTM F1869 and ASTM F2170 testing at regular intervals throughout the year.

Institute of Inspection, Cleaning and Restoration Certification (IICRC) conducts training for correction and mitigation of moisture conditions affecting concrete but does not run sessions specific to people that will be performing ASTM F1869 or ASTM F2170 testing. IICRC provided technical input into the A11 Best Practice and also recognize the need for specific training and certification for those that perform these tests.

ASTM F1869 and ASTM F2170 must be performed in strict compliance with the procedures and building conditions described in the test methods. Both of these tests will give inaccurate measurements when the in-service temperature and relative humidity conditions are not met during testing, when surfaces of concrete slabs are not properly prepared and controlled, or when the specified number of tests are not performed.

Design Professionals can request proof of experience and credentials within their specifications; but regardless of whether proof is requested or not, it is in the best interests of the *Constructor* to use certified *Flooring Inspectors* to offset potential construction risk and any costs associated with delays or remediation.

- **Control of The Work:** The *Constructor* controls conditions that affect Moisture Condition and starts from concrete procurement and mix design considerations, followed by concrete placing and finishing, establishing appropriate curing regimes, and protecting concrete from weather, wetting and temperature fluctuations during construction, and which the *Floor Covering Installer* has no ability to control or remediate.
    - Pre-Construction Activities: Develop a list of preconstruction activities associated with managing Moisture Condition of concrete including quality assurance and quality control observations and procedures, including coordination meetings that include all affected trades (concrete work and floor covering work), *Flooring Manufacturers*, and *Flooring Distributors*.
    - Construction Activities: Develop a schedule of testing and reporting activities required to confirm acceptable *Moisture Conditions* that are required before *Concrete Substrates* are considered acceptable for installation of *Flooring Products*, including activation of temporary or *Permanent HVAC Systems* required to establish optimal interior environmental conditions required by *Flooring Manufacturers* including the following tests performed by or coordinated by the *Constructor*:
        - Flatness assessments required by ASTM F710 (Refer to NFCA A21 Best Practice), performed by third-party measurement agency, may be the same as the *Moisture Testing Agency*.
        - Acclimation and conditioning required by ASTM F710 includes interior ambient air relative humidity, air temperature, and air dew point.
            - Many *Flooring Manufacturers* are modifying their written installation tolerances for *Dew Point* to account for site conditions that contribute to moisture related installation failures.
            - The A11 Best Practice adds a requirement for measuring the surface temperature of *Concrete Substrates* to determine whether the surface is cold enough to become a potential *Dew Point* concern.
            - The A11 Best Practice also identifies concerns with regards to the presence of alkaline salts that can also adversely affect the *Dew Point* condition by raising the temperature at which condensation forms to a point that could be higher than the ambient air *Dew Point*.
        - Performing *Moisture Condition* assessments throughout construction after acceptance of the 28-day or 56-day concrete strength gain acceptance (concrete is not technically dry at this stage of construction) to build a moisture map or moisture survey to using electronic moisture meter measurements in accordance with ASTM F2659.
            - Performing the *Moisture Condition* assessment throughout construction is relatively non-inversive and does not impact the *Constructors* construction schedule.
            - Performing ASTM F2659 testing throughout construction informs the *Constructor* of potential moisture concerns before they become a problem and can inform the *Constructor* to begin a drying regime or implement mitigation measures described in the A11 Best Practice to control their project risk.
            - Performing the ASTM F2659 testing and correcting any potential moisture concerns improves the likelihood of successful ASTM F1869 and ASTM F2170 testing described below.
            - It is not the *Floor Covering Installer's* role to conduct or prepare the moisture map or moisture condition assessments during construction prior to start of their trade work.

        - Calcium Chloride measurements of MVER using ASTM F1869 performed by third-party *Moisture Testing Agency* hired and paid for by the *Constructor* or *Owner*, with results shared to the *Consultant* and *Floor Covering Installers*.
        - RH measurements of Concrete Slabs using ASTM F2170 performed by third-party *Moisture Testing Agency* hired and paid for by the *Constructor* or *Owner*, with results shared to the *Consultant* and *Floor Covering Installers*.
        - Alkalinity measurements of concrete surfaces using ASTM F3441 performed by third-party *Moisture Testing Agency*.
        - Water droplet test to confirm *Porosity* of concrete surfaces using ASTM F3191 performed by third-party *Moisture Testing Agency*.

- **Associated Work:** The *Floor Covering Installer* should include tests for work they have control over as a part of their quality assurance activities and will self-perform these activities to verify that *Moisture Conditions* reported by the *Constructor* meet requirements of the *Flooring Manufacturers* before starting installation of *Flooring Products*.

    - Pre-Construction Activities: Meet with the *Constructor* and other trades that have influence over *The Work Results* relating to maintaining required *Moisture Conditions* and identify substrate and environmental tolerances that affect compatibility and installation of specified *Flooring Products*.
    - Construction Activities: Inform *Constructor* of installation requirements identified by *Flooring Manufacturers* and coordinate with the *Constructor's* construction schedule for activation of temperature and heating controls based on assessment of *Moisture Condition* third-party testing coordinated by the *Constructor*, with the following assessments performed by the *Floor Covering Installer*:

        - Electronic moisture meter spot checks using ASTM F2659 during installation of *Flooring Products* by the *Floor Covering Installer* following completion of ASTM F1869 and ASTM F2170 performed by *Constructor* to establish comparative Moisture Condition.

            - ASTM F2659 testing performed by the *Floor Covering Installer* does not replace the same testing required to build a moisture map or moisture condition analysis performed by the *Constructor* before *Work Results* associated with installation of *Flooring Products*.

                - Testing by the *Floor Covering Installer* is only performed to verify that concrete is dry in any part of the floor area of their choosing.
                - *Moisture Conditions* can vary after ASTM F1869 and ASTM F2170 are completed, which the ASTM F2659 can identify if problematic areas are present:

                    - ASTM F2659 should be performed by the *Constructor* throughout construction to map progress of slab *Drying Conditions.*
                    - The ASTM F2659 test helps provide better certainty for results when ASTM F1869 and ASTM F2170 are done by the *Constructor*.
                    - The *Floor Covering Installer's* risk for non-conforming *Moisture Conditions* can be greatly reduced.

                - Regular confirmation of moisture content by the *Floor Covering Installer* during installation of *Flooring Products* can help identify potential risks associated with *Moisture Conditions.*

        - Plastic sheet check using ASTM D4263 to verify whether capillary moisture is present and can show that MVER is present, and warrant follow up testing performed by the *Constructor* using ASTM F1869 to validate the condition of *Concrete Substrates* if the plastic sheet test indicates a potential concern.
        - Water droplet testing using ASTM F3191 to verify surface absorption rate (porosity) of the *Concrete Substrate* before applying any water-based adhesives.
        - Surface condition acceptability testing to confirm surface bond condition using ASTM F3311.

- These tests are only intended to verify that surface conditions are acceptable as reported by the *Moisture Testing Agency* and may identify concerns that need to be addressed through additional concrete *Drying Time* or that require additional testing by the *Moisture Testing Agency* to validate acceptable substrate conditions required by *Flooring Manufacturers*.

- **Flooring Manufacturers' Expectations:** Warranties associated with *Flooring Products* will only provide replacement material and installation when proper testing and recordkeeping are performed during construction, that *Moisture Condition* evaluations were performed at appropriate stages during construction, and that their installation instructions were implemented.

  - Pre-Construction Activities: Review manufacturers' warranty and installation instructions as a part of pre-construction and coordination activities forming a part of the *Constructor's* quality management program and identify concerns for protection of substrate and environmental conditions that the *Constructor* as a part of their responsibility for control of *The Work*.
  - Construction Activities: Use the *Flooring Manufacturers'* written installation instructions to schedule *Moisture Condition* testing and evaluations which are generally performed as follows and as described above for responsibilities associated with the *Constructor* and the *Floor Covering Installer*:

    - Engage third-party *Moisture Inspection Agency* retained by *Constructor* to perform ASTM F1869 MVER measurements or ASTM F2170 RH measurements or both ASTM F1869 and ASTM F2170; whichever combination is required by the *Flooring Manufacturer*, when *Concrete Substrate* is at in-service temperature and interior environment is operating at in-service temperature and relative humidity conditions using appropriate temporary heating facilities or *Permanent HVAC Systems*.

      - The A11 Best Practice encourages performing both ASTM F2170 and ASTM F1869 measurements when a *Flooring Manufacturer* only describes one of the two test methods.
      - There is support from some *Flooring Manufacturers* that perform both tests showing a significant reduction in moisture related *Flooring Product* failures when the ASTM F2170 standard test is performed in combination with the ASTM F1869 standard test compared to when only one ASTM F1869 or ASTM 2170 was performed.
      - All tests (ASTM F1869, ASTM F2170 and ASTM F2659) must be performed in strict accordance with the written process described in the reference standards; tests that do not adhere to the written process will provide incorrect information.
      - It is critical that once interior environmental operating conditions are established that they remain for the remainder of construction regardless of the test method used, because a return to a less conditioned interior environment can cause moisture related failures once operating conditions are restored after the building is returned to its in-service HVAC condition.

    - Perform ASTM F3191 *Water Absorption* testing throughout construction by the *Constructor* and the *Floor Covering Installer*; it is inexpensive and can provide early warning of potential moisture related issues, and immediately before installation of *Flooring Products* to verify that water-based adhesives will perform properly in accordance with *Flooring Manufacturer's* written adhesive application instructions, and only when the interior environment is operating at conditions required during occupancy using appropriate temporary or *Permanent HVAC Systems*.
    - Perform ASTM F3311 Mat Bond Testing performed by the *Floor Covering Installer* immediately before installation of *Flooring Products*, when interior environment is operating at conditions required during occupancy using appropriate temporary or *Permanent HVAC Systems*.

- Warranty Investigative Activities: The *Flooring Manufacturer* will investigate suspected moisture related failures and provide warranty repairs and replacements based on reasonable interpretation of testing performed during construction and immediately before installation of *Flooring Products*.

    - *Flooring Manufacturer* will confirm that interior environment was operating at in-service temperature and relative humidity prior to and during installation of *Flooring Products* using appropriate temporary heating facilities or *Permanent HVAC Systems*, and that they were sustained and monitored 24 hours per day/7-days per week for the remainder of construction (many *Constructors* use dataloggers to monitor temperature and relative humidity throughout construction).
    - *Flooring Manufacturer* also will rely on information such as observed site conditions at the time of concrete slab placement, concrete curing activities, protection of concrete during construction, time of building enclosure, and the time between building enclosure and when/if *Permanent HVAC System* was activated.

        - Observation of atmospheric/surface temperature and relative humidity conditions during construction and at the time of installation of *Flooring Products* will be used to determine whether *Dew Point* and condensation issues were a concern.

            - Atmospheric *Dew Point* is related to surface temperature sensitivity and the potential for condensation to form on *Concrete Substrates*.
            - Ionic *Dew Point* is related to surface alkalinity sensitivity and the potential to potential of condensation to form on *Concrete Substrates* at a temperature higher than the atmospheric *Dew Point*.
            - Ionic *Dew Point* and atmospheric *Dew Point*, and concerns for alkaline salts are described in Appendix 2: Contextual Concrete Information.

        - Observation of pH and presence of alkaline salt will be used to determine whether the *Concrete Substrate* was properly prepared and neutralized in accordance with the *Flooring Manufacturer's* written requirements.

    - *Flooring Manufacture* will account for overall performance and will typically honour their product warranty provided a reasonable number of tests was conducted.

        - Reasonable number of tests can include using the ASTM F2659 electronic moisture meter evaluations in addition to ASTM F2170 or ASTM F1869 tests to reduce the potential risk failures resulting from out-of-tolerance *Moisture Conditions*.

            - A single electronic meter reading indicating non-conformance may not indicate a concern, but 3 or 4 non-conforming readings may indicate out-of-tolerance *Moisture Conditions*.
            - An additional test using ASTM F2170 or ASTM F1869 must be performed when ASTM F2659 indicates an out-of-tolerance *Moisture Condition*, this will govern in the instance when *Moisture Conditions* are confirmed as within tolerance or when additional *Drying Time* is required when confirmed as out-of-tolerance.
            - The advantage of using ASTM F2659 evaluations is that they provide rapid feedback on apparent *Moisture Conditions* and can be performed more frequently than the traditional approach to testing.

                - Of the three tests identified in the A11 Best Practice; ASTM F2659 is the most efficient way to identify *Dew Point* and *Moisture Condition* concerns throughout construction.
                - ASTM F2170 RH testing does not identify *Dew Point* concerns.

        - The ASTM F2659 electronic moisture meter evaluations can also be used to reduce the number of tests required by ASTM F1869 or ASTM F2170, when agreed upon by the *Flooring Manufacturer*.

            - The *Flooring Manufacturer* must be informed when ASTM F2659 electronic moisture meter evaluations are being considered to reduce the number of ASTM F2170 or ASTM F1869 tests.

    - Not all *Flooring Manufacturers* recognize alternative methods to assessing *Moisture Conditions* and will require only the use of their approved testing methods.

- *Flooring Manufacturer* will investigate other potential causes of non-moisture related failures investigating sources of contaminants on the Concrete Substrate including potential contamination by curing or sealing compounds, organic and inorganic contaminants using petrographic analyses.

A11-4 Conclusion:

The A11 Best Practice describes risks and responsibilities associated with successful application of moisture-sensitive *Flooring Products*. The Constructor's testing responsibilities are tied to their quality control of *Concrete Substrates* during the course of construction and improves the likelihood for the *Floor Covering Installer* that the surface will meet the *Flooring Manufacturers'* written *Moisture Condition* tolerances with the need to incorporate remedial drying procedures or installation of moisture remediation products immediately before installation of the scheduled *Flooring Products*.

Project Participant Responsibilities Clearly Defined

The most significant innovation identified within the A11 Best Practice requires the *Constructor* to perform testing using an electronic moisture meter in accordance with ASTM F2659 as construction progresses because it provides rapid and accurate assessments of moisture content at the surface and within 25 mm (1") of the surface layer of the *Concrete Substrate*. This testing is non-destructive can be repeated at any time during construction to assess the progress of concrete drying; allowing the *Constructor* to manage mitigation and construction delay risks arising from *Moisture Conditions*, and potentially reducing costs associated with remediation of *Concrete Substrates* or replacement of damaged *Flooring Products*.

- Many *Flooring Manufacturers* require the use of the ASTM F2659 electronic moisture meter testing after tests for moisture vapour emission rate (ASTM F1869) or relative humidity (ASTM F2170) have been completed and show acceptable *Moisture Conditions*.
- Some *Flooring Manufacturers* will accept ASTM F2659 electronic moisture observations tests as a preliminary observation to establish that *Concrete Substrates* are ready for the ASTM F1869 or ASTM F2170 destructive testing required by manufacturers before installation of their *Flooring Products*.
- Some *Flooring Manufacturers* require both ASTM F1869 and ASTM F2170 tests before installation of their *Flooring Products*.
- The NFCA A11 Best Practice establishes an enhanced testing procedure as follows:

  a. *Constructor* performs the ASTM F2659 electronic moisture meter tests conducted at regular intervals during construction, after the structural requirements for concrete have been met.

     i. *Constructor* can record and maintain a trend log of drying and wetting conditions as a part of their daily construction logs and has the ability to implement supplementary drying procedures or concrete mitigation measures (applied coatings) identified within the A11 Best Practice well in advance of scheduling start of work by the *Floor Covering Installers* when the logs show *Moisture Conditions* that may not meet *Flooring Manufacturers'* installation tolerances.
     ii. *Constructor* has control and coordination of construction activities associated with the *Concrete Substrate* and is required to provide an acceptable concrete slab to the *Floor Covering Installer*, and performs tests associated with validating performance of the *Concrete Substrate*.
     iii. *Constructor* is responsible for correcting out-of-tolerance *Concrete Substrates*, which may require: (1) using specialist concrete drying personnel and equipment, or (2) using remediation procedures such as covering *Concrete Substrates* with a surface applied moisture resistive coating or material recommended in writing by the *Flooring Manufacturer*, or (3) using a more moisture tolerant adhesive recommended in writing by the *Flooring Manufacturer*.

  b. *Constructor* performs both ASTM F1869 and ASTM F2170 tests; as well as the tests for alkalinity (ASTM F3441) and absorbency (ASTM F3191) to validate acceptable *Concrete Substrate* conditions immediately before the *Floor Covering Installer* is scheduled to start installation of *Flooring Products* specified for *The Work*.

     i. *Constructor* can use this as their Go/No Go critical project milestone, knowing that specified *Flooring Manufacturer's* will not permit their products to be installed onto out-of-tolerance *Concrete Substrates*.
     ii. *Floor Covering Installers* have improved confidence and knowledge of the condition of the *Concrete Substrate* before they start their work, and that they will not be required to perform work that does not form a part of their trade responsibility.

c. *Floor Covering Installers* will perform a number of non-destructive quality assurance tests throughout the installation area to help identify any potential *Condition* issues that the *Constructor's* testing may not have discovered, including but not limited to the following:

   i. Continue ASTM F2659 electronic moisture meter testing for the duration of the time scheduled for installation of *Flooring Products*.

      1. The *Moisture Condition* of *Concrete Substrates* can change from when the testing was initially performed to when *Flooring Products* are physically installed.
      2. The change in *Moisture Condition* may not comply with moisture tolerances required by the *Flooring Manufacturer*.

   ii. *Floor Covering Installer* will monitor potential for capillary moisture using the ASTM D4263 plastic sheet test.
   iii. *Floor Covering Installer* will perform ASTM F3311 bond testing to provide short-term evaluation of the effectiveness and compatibility of the *Flooring* Products to adhere to *Concrete* Substrates.
   iv. *Floor Covering Installer* will provide a detailed log of ambient relative humidity, temperature and dew point, and regularly measure surface temperature to help identify whether there is a potential for dew point issues before and during installation of *Flooring Products* as required by ASTM F710.

The recommendation for continuous and frequent monitoring of *Moisture Conditions* using ASTM F2659 in combination with ASTM F1869 and ASTM F2170 is to reduce the risk of moisture related *Floor Covering* failures and to distribute responsibility for controlling the risk to the appropriate parties associated with *The Work*.

- Moisture testing using ASTM F1869 and ASTM F2170 must be performed using environmental conditions reflective of the in-service building condition, ideally using the *Permanent HVAC System*.
- In-service building heat and humidity should be established well in advance of any Controlled Testing activities so that *Concrete Substrates* can attain *Equilibrium Moisture Content* and reduce any possibility of reverting to unacceptable/nonconforming *Moisture Conditions*.

NFCA recognizes the **critical importance** of the need to establish in-service building heat and humidity for performance of these tests, and to reduce the risk of installation failures of *Flooring Products*. The *Design Professional* should identify this **key milestone** in their project specifications and in the *Constructor's* project quality management program.

NFCA also recognizes that being aware of manufacturer's written instructions is critical when the *Design Professional* is preparing their project specification, and that the manufacturer should be consulted when any of the information recommended in this best practice conflict with the written instructions.

NFCA **strongly recommends** that *Permanent HVAC* Systems are scheduled for activation based on results identified using Indicative Testing to determine how much *Drying Time* is required to obtain *Equilibrium Moisture Content*. Coordination with mechanical *Design Professional* and mechanical subtrades will be required to preserve warranties for *Permanent HVAC Systems*.

Costs associated with early activation and maintenance to return system warranties to ready-for-takeover status can be identified as a cash allowance during the bidding period by the *Design Professional* and included with bids for *The Work*. Alternatively, the *Constructor* can include a coordination risk allowance within their price.

Any costs associated with restoration of *Permanent HVAC Systems* will typically be less than replacement of *Flooring Products* when installed on *Concrete Substrates* that have not attained *Equilibrium Moisture Content*.

NFCA **cautions** against the use of any direct-fired temporary heating to obtain *Equilibrium Moisture Content*. Fossil fuel burning heaters can cause other issues that require more extensive preparation of *Concrete Substrates*.

NFCA also recognizes the increased availability of indirect-fired temporary heating systems that have potential to reproduce permanent heating conditions, but they must be used with caution to maintain consistent air movement and temperature range across the entire floor area and avoid any problems associated with "cold spots" or "rapid drying conditions".

Regardless of the heating system used to attain in-service conditions, there can be no interruption of the stable interior environmental conditions once *Flooring Products* are installed.

Other Considerations when Installing Moisture-Sensitive *Flooring Products*

The *Constructor* and *Floor Covering Installer* can take additional steps to reduce the risk of moisture related failures associated with installation of moisture-sensitive *Flooring Products* and that can be applied as a "rule-of-thumb" when coordinating and scheduling *The Work* using the principles described in the A11 Best Practice:

- Use concrete with low water-cement ratio and bleed characteristics.
- Allow adequate time for the concrete to dry.
- Adopt measures that contribute to establishing acceptable moisture vapour emission rate and relative humidity within the *Concrete Substrate*.
- Install adequate *Capillary Break* under concrete slabs-on-grade and protect membranes from damage during installation of concrete from puncture or other damage.
- Avoid temporary heating equipment such as air conditioners, heaters and fans that rapidly dry the surface in the misguided belief that these enable quicker installation of *Flooring Products*, and that ultimately contribute to false-positive (misleading acceptable) *Moisture Condition* reports.
- Protect *Concrete Substates* from direct exposure to sun (if possible) to prevent warming of the concrete that may increase the moisture vapour emission rate.
- For hydronic/radiant heated floor systems, strictly adhere to the *Flooring Manufacturer's* written surface temperature requirements and document the surface temperature of *Concrete Substrate* surface temperatures before, during and after installation.

    a. Activate the hydronic/radiant heating system well in advance of installation of *Flooring Products* to drive out (expel) potential built-up of excess moisture from concrete substrates.
    b. Reduce the temperature of the hydronic/radiant heating system during installation of *Flooring Products* (hydronic/radiant heating systems maintain a temperature of the concrete slab that is higher than the ambient temperature required for installation).

        i. Temperature of the *Concrete Substrate* must be within the adhesive manufacturer's stated maximum and minimum installation temperature range.
        ii. The adhesive will lose open/working time, will be subject to premature drying and skinning over when the temperature is too high.
        iii. The adhesive may not cure properly when temperature is too low and could cause failures to installed *Flooring Products* that appear similar to failures associated with *Moisture Conditions*.

    c. Use temporary or supplemental heating in cold climates while the surface temperature from the permanent hydronic/radiant heating system is lowered to maintain acceptable ambient air temperature conditions during installation.

- Use fast-setting primers that promote good bonding characteristics before moisture within the concrete redistributes sufficiently to affect the bond.
- Mix and proportion water soluble products that will provide proper setting and hardening, as different concentrations of soluble material in the concrete and surface preparation layer/adhesive may also cause diffusion of water and subsequent blistering problems under resilient *Flooring Products*.
- Surface preparation – repeat – surface preparation is essential and means that all laitance, efflorescence, chemical and organic contaminants and dirt should be removed from the surface to achieve good bond strength.
- Mechanically remove surface contamination such as any residual curing compounds, release agents and form/cutting oils.
- Do not wash or damp wipe concrete before installation of *Flooring Products* unless sufficient time is scheduled for surfaces to dry to an acceptable *Equilibrium Moisture Content*.

NFCA prefers abrasive blasting or other dry-cleaning processes to prepare the surface because water can dissolve salts and create a highly alkaline environment that may subsequently contribute to moisture related *Flooring Product* installation failures.

A11-5 WAIVER OF LIABILITY:

The National Flooring Covering Association assumes no responsibility and accepts no liability for any disputes, errors, corrective work, or repairs arising from the use of the document published by NFCA, entitled **A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates**. These guidelines and methods were developed by the NFCA Moisture Testing Committee and describe execution of *Moisture Testing* to address shortcomings of current procedures employed by the construction industry. The A11 Best Practice incorporates knowledge from leading industry authorities and subject matter experts, review of longstanding installation principles and practices, along with research and data regarding the provision of acceptable *Moisture Conditions* for *Concrete Substrates* based on experience and *Flooring Manufacturers'* claim history.

These guidelines and methods address a variety of methods for determining acceptable *Moisture Conditions* related to the installation of *Flooring Products* but are not intended to address issues arising to or from these guidelines. Individual construction contracts may and can affect the application of these guidelines. They are not enforceable standards in any other way than by individual project specifications. This document is offered at no charge, the user assumes all responsibility for any disputes resulting from following the provided information.

The principles and practices described in this publication are not universal requirements and may change. The recommendations in these guidelines and methods are directed at the North American market in general, and therefore may not reflect the most-accepted industry practices in other geographic areas. Some test methods and materials may not be suitable in some geographic areas because of local trade practices, or construction methods. All subfloor and substrate surfaces must remain in compliance with local building codes, ordinances, and trade practices when applying these guidelines.

In addition, *Flooring Manufacturers'* recommendations for *Moisture Conditions* affect installation of their specific products and should always supersede the recommendations contained in these guidelines when differences occur.

APPENDIX 1: DEFINITIONS

Definitions described below represent terms that are common to the construction and design community without introducing industry jargon or colloquial interpretations and are shown in *Capitalized Italic Text* for clarity throughout the A11 Best Practice.

Capillary Break: Materials or systems installed to reduce the potential for movement of moisture into a building by capillary action from the underside of the *Concrete Substrate* when it is in contact with ground water, and typically consists of one or a combination of the following general methods:

- **Membrane Layer:** A sheet material that is impermeable to water vapour manufactured in accordance with ASTM E1745, Standard Specification for Water Vapor Retarders used in Contact with Soil or Granular Fill under Concrete Slabs, installed in accordance with ASTM E1643, Standard Practice for Selection, Design, Installation, and Inspection of Water Vapor Retarders used in Contact with Soil or Granular Fill under Concrete Slabs.
    - These membranes are manufactured to resist inground conditions including microbiological action, construction loads that cause punctures and have a proven durability equal to the design life of the building.
    - These membranes also resist soil gases in addition to water vapour (radon, methane, hydrocarbons) that affect the health of building occupants, and are recommended by CSA A23.1/A23.2, Concrete Materials and Methods of Construction.

> NFCA recognizes that there are also a variety of post-installed vapour suppression membrane products that can be applied to the surface of *Concrete Substrates* including resin-based coatings, chemically reactive compounds that form a gel or crystalline substance within the concrete; penetrating water or solvent based compounds that do not form a continuous membrane on the concrete surface; or water-based, membrane-forming mitigation systems.
>
> *Flooring Manufacturer's* written recommendations should be used when acceptable *Moisture Conditions* cannot be guarantied through conventional *Capillary Break* installations, or when project schedule does not allow for sufficient time to attain *Flooring Manufacturers'* required *Moisture Conditions*.

- **Granular Layer:** Crushed granular aggregates, free from fines that contain void size that water cannot flow through by capillary action, keeping water from wicking from soils to the underside of the concrete slab.
    - Granular materials typically need to meet a standard such as ASTM C33 Standard Specification for Concrete Aggregates or ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
    - Granular layer should contain a variety of different sizes of clean aggregate to allow optimal compaction and allow for construction traffic and personnel to continue their work without displacing the granular layer, uniform sized aggregate size tends to reduce or even prevent compaction.
    - Size of the crushed aggregate should pass Sieve #6 (19 mm to 9.5 mm) and have a void content of about 40% or other equivalent performance based on local sources of supply. Aggregate containing materials less than 9.5 mm tend to fill in the void content and increase the capillarity of the granular layer.

- **Weeping System:** A system of drains in sheet or tubular form placed around the perimeter of the building and that may also be placed under the lowest concrete floor of the building to reduce *Hydrostatic Pressure* when the water table is higher than the lowest point in the building.
    - Weeping systems are designed by the *Design Professional* when geotechnical studies identify the risk of a water table having potential to affect *Moisture Conditions* within a building and will not typically be installed for at-grade or above-grade concrete floors.
    - *Hydrostatic Pressure* can be seasonal and contribute to problems associated with capillary action during "wet seasons" or "flooding events" when a weeping system is not installed and fluctuations in the water table have potential to occur.
    - *Hydrostatic Pressure* can also be constant when the water table is consistently high throughout the year requiring a more extensive drainage network within the weeping system to reduce the problems associated with capillary action.

Moisture Conditions: Moisture is the word commonly used to describe and measure the two main states (gaseous and liquid) of water in the air and within construction materials, and that critically impacts the performance of installed *Flooring Products*. As a result, the word "moisture" has become generic with many of the people involved with assessing the acceptable *Moisture Conditions* for installation of *Flooring Products* and led to confusion between testing requirements and reported results, and which test is appropriate for what outcomes. The following defined terms are used during construction and are referenced in this Best Practice when describing recommended *Moisture Testing* procedures.

- **Concrete Moisture:** The words "water content", "moisture content" and "relative humidity" are frequently used interchangeably when measuring moisture present in concrete, but each has a different measurement practice and the results being described are not interchangeable.
  - **Water Content:** Water content is only applicable at the time concrete is manufactured and can form between 30% and 40% of the wet concrete mix; and which reacts and binds with cement forming a permanent part of the mass of the concrete, any excess water content needs to evaporate through a controlled drying process to avoid problems arising from moisture content.
  - **Moisture Content:** Moisture content is any moisture in liquid or vapour form that is adsorbed or absorbed and is contained within the mass of the concrete. There is very little difference in moisture volume and relative humidity due to the extremely low volume of water vapour within the mass of the concrete, measurements for *Moisture Content* are typically 5% and less with 4% to 3.5% as "sufficiently dry" depending on the manufacturers of electronic moisture meters defined range.
  - **Relative Humidity:** Relative humidity (RH) is a specific measurement of the gaseous form of water in any open space within the mass of the concrete; RH measures water vapour where the concrete isn't, that being in rock pockets, pores, cracks and other void spaces within the mass of the concrete; *Flooring Manufacturer's* recommended tolerances for *Relative Humidity* typically require an RH of 75%, although some *Flooring Products* can tolerate higher RH ranges and there are products that can be applied to the surface to reduce the risk of moisture related problems (always confirm with the *Flooring Manufacturer*).

- **Relative Humidity (RH):** A measurement of the amount of water vapour contained within air or a material, expressed as a percentage of the total amount needed for saturation at the same temperature and atmospheric pressure.
  - If air has an RH of 50% at 20°C (68°F), it will approach saturation (*Dew Point*) when concrete surfaces are at a temperature of 9°C (48°F).
  - The saturation point is affected by the presence of alkaline salts, meaning that condensation could occur when concrete surfaces are at a temperature of 14°C (57°F) or higher, even when ambient conditions have a 50% RH and temperature of 20°C (68°F).
    - As an example, sodium hydroxide (a type of alkaline salt commonly found in concrete) has a *Critical Humidity Threshold* of about 12% to 13% RH which is made worse when sodium hydroxide becomes concentrated, and any contained water can have a much higher freezing point (See the Alkaline Salt Effect below).
      - The concrete industry identifies 20% concentration for sodium hydroxide as a standard which provides a freezing point of water at about -29°C (-20°F), the concern for acceptable *Moisture Conditions* is that site concentrations are typically higher.
      - This means that water will freeze when sodium hydroxide is present in concentrations of 40% when temperatures approach 15°C (60°F) and freezing at 51°C (128°F) when concentrations reach 65%.
      - The *Critical Humidity Threshold* becomes increasingly challenging to measure and predict as alkaline salt concentrations increase meaning condensation can exist at room temperature, making results from devices or other approaches to interpretation less reliable and moisture related failures more common.

- *Relative Humidity* (RH) measurements indicate how much moisture is already present relative to what is absorbable in the air or materials being tested.

  - **Drying Time:** *Drying Time* in the context related to installation of *Flooring Products* is based on the time it takes to achieve acceptable dry surface condition of *Concrete Substrates* within the top 19 mm to 25 mm (3/4-inch to 1-inch) meeting *Flooring Manufacturer's* written installation tolerances.

    - *Drying Time* is variable and is dependent on-site conditions during construction, whether the *Concrete Substrate* was protected from wetting, whether there were prolonged periods of time where temperatures were below the ideal temperature range and the amount of time that the building is acclimated to the in-service HVAC conditions required for *Flooring Manufacturer's* required testing and installation of *Flooring Products*.
    - Maintaining a temperature range between 18°C to 26°C (65°F to 80°F) helps with drying control and the curing process after confirmation of the 28-day or 56-day strength gain testing required to determine acceptability of concrete performance.

      - Concrete is not technically dry after the 28-day or 56-day period associated with strength gain and will require a prolonged period of additional drying or may require application of moisture resisting cementitious or resinous coatings when *Flooring Products* are schedule for installation within 4 to 6-months after placement of the concrete.

        - As stated later in the A11 Best Practice, concrete will dry at a rate of about 1 mm per day (approximately 1-inch per month) when temperatures can be maintained within the ideal range.
        - Concrete will dry slower at temperatures less than 18°C (65°F) and will not dry at all when temperatures are below 10°C (50°F).
        - Concrete surfaces will dry faster at temperatures higher than 26°C (80°F) but may still be wet within the mass of the concrete raising concerns for "the bounce effect" described later in the A11 Best Practice.

    - Moisture mapping or moisture condition analysis using an ASTM F2659 electronic moisture meter can be performed by the *Constructor* during construction to determine whether additional *Drying Time* is required, and to manage cost risk of moisture related remediation when *Moisture Conditions* do not meet the *Flooring Manufacturer's* written tolerances.

  - **Dew Point:** *Dew Point* is the temperature air needs to be cooled to (at constant pressure) to achieve a saturation point having a *Relative Humidity* (RH) of 100%, at which point gaseous water (vapour) can no longer be contained in the air and forms liquid water (condensation) on the first surface it encounters (refer to ANSI/IICRC S520).

    - The saturation point refers to the temperature at which air of materials cannot absorb any more moisture and drying stops, see *Equilibrium Moisture Content* (EMC) below (refer to ANSI/IICRC S500).
    - Condensation may not occur when EMC is present, and moisture measurements could indicate acceptable surface conditions for installation of *Flooring Products*.
    - *Dew Point* can occur after installation of *Flooring Products* when a temperature differential occurs with condensation occurring at the interface between the concrete slab and *Flooring Products*.

  - **The Air Effect:** Concrete will pull moisture from the air and will also release moisture back into it depending on whether the air is holding more or less moisture than the slab and is the reason why *Relative Humidity* (RH) in the air and within the slab is a critical measurement.

    - Air that has reached its *Dew Point* will cause vapour to condensate on the surface of the concrete slab, which in extreme cases will cause visible moisture on the concrete surface, otherwise colloquially called "sweating slab syndrome".

        - Concrete slab temperatures that are below the *Dew Point* of the air will cause condensation on or within, and in extreme cases on and within the surface of the concrete slab.
        - Knowing the *Dew Point* of the environment around the concrete is vital to assessing *Drying Time* and the *Moisture Condition* of the slab.

    - **The Alkaline Salt Effect:** Alkaline salts on concrete slabs have potential to lower the humidity necessary to create the *Dew Point* of surfaces meaning that condensation is more likely to occur when concrete surfaces are well above the *Dew Point* differential of the air, by as much as 5C° to 7C° or higher when alkaline salts are completely saturated as when water absorbs into the surface of alkaline salts (see following definition for *Critical Humidity Threshold*).

        - Alkaline salts form on or within the surface of concrete slabs through the natural process of liquid water containing dissolved salts being left behind or within to the surface through evaporation.
        - Alkaline salts and other soluble mineral form a powdery or crystalline residue on the surface when they are exposed to the air.
        - Deposition of visible alkaline salts and other minerals is called efflorescence; all of which can affect surface bond conditions for adhering *Flooring Products*, with alkaline salts having a significant impact on measurements used to determine acceptable *Moisture Conditions*.
        - Deposition of non-visible alkaline salts within the concrete surface is more common and is called sub-efflorescence and will contribute to out-of-tolerance measurements used to determine acceptable *Moisture Conditions*.

            - Alkaline salt accumulations tend to have very light concentrations and accumulate within small sections within the concrete surface but can become more problematic when Post Termination Protection of the *Concrete Substrate*; following Termination of Active Curing, is not included as a part of the *Constructor's* quality management program.
            - *Constructors* should include a progressive approach to cleaning alkaline salts from concrete surfaces starting with cleaning before moving on to more intensive procedures:

                - Light accumulations of alkaline salts can be removed or neutralized by surface buffing and cleaning using phosphoric acid or other *Flooring Manufacturer* recommend cleaning agents, followed by rinsing and allowing the *Concrete Substrate* to dry.
                - Moderate to heavy accumulations of alkaline salts can be resolved using a combination of *Flooring Manufacturer* recommended semi-permeable skim coat (allows for diffusion of salts within the troweled area) and epoxy.
                - Problematic areas need to have surfaces ground to a depth of up to 6 mm (1/4") and removed in its entirety.
                - Persistent accumulations may require a combination of all of the above procedures and may need to be repeated if not rectified after the first attempt at removal.

            - Alkaline salts also need to be removed or neutralized to prevent breakdown of adhesives; alkaline salts may crystallize the adhesives rendering them ineffective, or they can diminish the thickness and reduce the effectiveness of the adhesive layer.

- **Dynamic Moisture Transfer Conditions:** *Dynamic Moisture Transfer Conditions* exist when there is a differential between two components such as when a difference between RH exists between the air and the Concrete Substrate.

    - If the RH of the slab is higher than the air, moisture will tend to move from the concrete into the air and is measured as the Moisture Vapour Emission Rate (MVER) as described in ASTM F1869.
    - *Dynamic Moisture Transfer Conditions* must exist for the ASTM F1869 standard test procedure to provide accurate results, preferably at optimal building operating conditions.

- If the RH of the slab is lower than the air, moisture will move from the air into the concrete and will contribute to an acceptable MVER required by *Flooring Manufacturers* because the *Dynamic Moisture Transfer Conditions* are reversed during the time measurements are taken.
- Condensation will occur on the surface of concrete subject to *Dynamic Moisture Transfer Conditions* when the surface of concrete is at or below the *Dew Point* described above (see following definition for *Critical Humidity Threshold*).

    - *Moisture Conditions* are most significantly affected within the top 25 mm (1-inch) of the *Concrete Substrate* and is where the most significant gradient and differences in both alkalinity and RH occur from the remainder of the concrete.
    - The condition of the 25 mm (1-inch) layer has the highest impact on *Moisture Conditions* affecting installation of *Flooring Products* and is the least measured part of the *Concrete Substrate*.
    - Due to the higher concentration of alkaline salts within this 25 mm depth, the RH can be significantly lower than the RH measured within the 40% depth-of-slab required by ASTM F2170, which can be 40 mm (1.6-inch) for a 100 mm (4-inch) slab ranging up to about 120 mm (4.8-inch) for a 300 mm (12-inch) thick slab.
    - This creates *Dynamic Moisture Transfer Conditions* within the *Concrete Substrate* where a lower gradient RH and higher internal RH co-exist with little to no change of either.

        - This is caused by a combination of a cooler, more saturated interior concrete section at the bottom of the concrete slab and a drier, warmer and more alkaline gradient closer to the concrete surface.
        - Moisture "wants" to migrate from warm to cool (based on principles of thermodynamics and chemistry), but this migration competes with the tendency of alkaline salts to attract and absorb water and results in an internal dynamic equilibrium where a 90% RH cooler interior remains constant immediately adjacent to a warmer, higher alkaline area.
        - This is frequently observed on the construction site when drying efforts do not remove any additional moisture from concrete; contributing to the "*Moisture Bounce Effect*" described below, where moisture levels increase in the surface layer even as the moisture within the depth of the slab remains unchanged.

- **Equilibrium Moisture Content (EMC):** *Relative Humidity* (RH) measurements of the concrete slab and the air are in a stable condition with neither component gaining nor losing moisture, as when the moisture content of the concrete has stabilized to the RH and temperature of the surrounding air, refer to ANSI/IICRC S520. Many of the tests used to determine RH and other *Moisture Conditions* require a differential RH and can be subject to site conditions (Example: Diffusion in stagnant air may provide an equilibrium condition versus a dynamic condition when measured in moving air).

- **Critical Relative Humidity (CRH) or Critical Humidity Threshold (CHT):** The presence of alkaline salts changes the *Dew Point* because these materials adsorb moisture from the atmosphere, providing an artificially low RH or moisture reading when using traditional *Moisture Testing* methods.

    - The *Critical Relative Humidity* (CRH) of a salt is defined as the *Relative Humidity* of the surrounding atmosphere (at a certain temperature) at which the material begins to adsorb moisture from the atmosphere and below which it will not adsorb atmospheric moisture.
    - The *Critical Humidity Threshold* (CHT) occurs when the humidity of the atmosphere is equal to or greater than the CRH of the alkaline salt, where the sample will take up water until all the alkaline salt is dissolved resulting in a saturated solution.

        - *Critical Humidity Threshold* represents the ionic dew point of alkaline salts; as one example, the ionic dew point for sodium chloride (NaCl = table salt) is 75% RH, which chemists refer to as "*Critical Humidity Threshold*".
        - Each different alkaline salt has its own characteristic *Critical Humidity Threshold*, for concrete this is primarily calcium hydroxide ($Ca(OH)_2$) which has a pH between 11 and 12.5, and typically reaches *Critical Humidity Threshold* between 30% to 40% RH, CHT of several common alkaline salts are as follows:

            - Sodium hydroxide is slightly lower than 9% RH.
            - Sodium carbonate is 12% RH.

- Calcium hydroxide is 12.5% RH; and
- Calcium chloride is 18% RH, meaning there is moisture that calcium chloride cannot remove from concrete.

- These unique material properties make testing using traditional measurement methods challenging where capacity for moisture storage based on CRH decreasing as temperature increases; this effect is much more pronounced with *Relative Humidity* measurements.
- The CRH for moisture storage for alkaline salts differs from atmospheric RH; where the capacity for moisture storage increases as temperature increases, the opposite is true for alkaline salts.

Permanent HVAC System: *Permanent HVAC Systems* refer to the permanent heating, ventilation, and air conditioning plant that operates at the service temperature and relative humidity to maintain interior environmental conditions similar to those required during occupancy of the building after completion of construction and is a requirement for performing both the ASTM F1869 MVER testing, and the ASTM F2170 RH testing described within the A11 Best Practice.

Drying Conditions: *Drying Conditions* for concrete are as important to establishing acceptable installation criteria for *Flooring Products* as *Moisture Conditions*. The approach to curing, drying and conditioning of concrete surfaces is often not given the attention it needs, and will usually result in a rushed process if (or when) these issues are not addressed. The following defined terms form a part of this A11 Best Practice when describing recommended concrete drying procedures.

- **Water Absorption:** Absorption involves the mass transfer of liquid moisture into another material, such as a sponge soaking up spilled juice. The liquid can be wrung from the sponge or can be left to dry out through evaporation (refer to ANSI/IICRC S500).
    - Evaporation from the surface can cause warping and deformation of the surface unless the drying is controlled by slowing the rate of evaporation.
    - Concrete is also an absorbent material and will take-up or draw-in water in the same way as a sponge, and when released through evaporation will warp and deform (commonly referred to as slab curling) the surface unless this process is controlled using a formal curing and protection plan (refer to CSA A23.1/A23.2).
    - Concrete is tested using ASTM F3191 to determine a rate of *Water Absorption* based on a fixed water sample size over a period of time to completely absorb into the surface (refer to ASTM F3191).

> Several of the NFCA subject matter experts added concerns about absorption and desorption characteristics the longer concrete is in place. Concrete undergoes a process called hysteresis as it ages; where the absorption rates can continue to increase, even as the desorption rates decrease.
>
> Hysteresis happens when there is a lag between input and output (absorption and desorption). This effect disappears as the input changes more slowly. This effect when applied to concrete is often referred to as rate-dependent hysteresis to distinguish it from hysteresis with a more durable memory effect, such as within magnetic metals.
>
> Diffusion models that rely on balanced input and output are effective only during the initial curing and drying stages of the concrete. Hysteresis renders all diffusion models occurring after the initial curing and drying stages have finished as unreliable despite many standards relying on diffusion for their analysis and that many researchers ignore.

- **Water Adsorption**: Adsorption involves the attachment of moisture vapour onto the surface of another material or substance, such as the silica gel often found in moisture sensitive packaging used as a dehumidification aid. The adsorbent material does not get wet until it reaches equilibrium at which point the water will condense and liquid water will be present. (refer to ANSI/IICRC S500).

Comparing Adsorption and Absorption Both processes are similar in that there is a transfer of liquid or gaseous water onto or into another solid substance, they differ in several ways that help to address the concerns identified in this Best Practice:	
Adsorption	**Absorption**
Accumulates moisture onto the surface of another substance	Accumulates moisture throughout the body of another substance
Surface Phenomenon	Bulk Phenomenon
Lowering temperature favours this process; similarly, substances that raise the *Dew Point* temperature favours this process	Unaffected by temperature
Rate of adsorption steadily increases until equilibrium is achieved	Occurs at a uniform rate until equilibrium is achieved
Surface concentration differs from internal concentration within the substance	Concentration eventually becomes equal throughout the substance

- **Porosity:** *Porosity* describes the amount of air space (voids) within a substance and is measured as a fraction between 0 and 1, or as a percentage between 0 and 100%. *Porosity* determines a substance's permeability or its ability to allow liquids or gasses to pass through (refer to ANSI/IICRC S520).

> NFCA recommends the use of *Capillary Breaks* (membrane plus aggregates) below concrete slabs-on-grade because *Porosity* is associated with capillary concerns described above. The smaller the size of interconnected voids within substances, the greater the potential absorption rate drawing liquid water through the mass of concrete to the floor surface and causing replacement and retrofit of installed *Flooring Products* when a *Capillary Break* is not installed.

- **Permeance:** *Permeance* describes the ease that fluids or gases move through a substance, generally the lower the *Porosity* the lower the *Permeance* (refer to ANSI/IICRC S500).

> Several of the NFCA subject matter experts added concerns about the general definition for *Permeance*. As with many generalizations there are exceptions to the definition.
>
> One exception is that *Permeance* can allow moisture to travel due to capillarity as well as concrete compositions exhibiting various levels of hygroscopic and hydrophilic properties.
>
> *Permeance* can and will change with the age of the concrete and environmental exposures, with recent research noting that the cement itself can alter the permeance and transport of moisture.

- **Desiccant:** A hygroscopic substance that draws moisture into itself from the surrounding air or from surfaces by absorption or adsorption processes described above (refer to ANSI/IICRC S500).

- **Hydrostatic Pressure:** *Hydrostatic Pressure* (sometimes called hydrodynamic pressure) is the force exerted by water on below grade walls and floors in contact with soils when the water table is higher than the lowest floor level, the force increases proportionally to the depth measured from the surface as the weight of water increases (refer to ANSI/IICRC S500).
    - The effects of low force *Hydrostatic Pressure* and subsequent *Water Absorption* through concrete slabs-on-grade can be reduced and managed by installation of appropriate *Capillary Breaks* unless the force exerted is greater than the ability of the Capillary Break to resist water intrusion.
    - The effects of low force *Hydrostatic Pressure* can also contribute to higher MVER measurements associated with concrete slabs-on-grade by contributing to *Dynamic Moisture Transfer Conditions* that the ASTM F1869 is intended to test.

- **Vapour Pressure Differential:** *Vapour Pressure Differential* is the variance in vapour pressure between two different environments or materials; in context with this Best Practice, it describes the difference in moisture vapour pressure between different material layers within a building assembly.
    - This pressure difference influences the movement of moisture vapour that affects performance, durability, and overall integrity of the installation of *Flooring Products*.

- Understanding and managing the *Vapour Pressure Differentials* is crucial in controlling Moisture Condition issues during construction.

The Work: *The Work* applies to the total construction and related services required to complete construction, is described by the contract between the *Constructor* and the Trades, and is consistent with the specifications and drawings prepared by the *Design Professional*:

- **Associated Work:** In the case of this Best Practice, *Associated Work* includes generic descriptions of the finishes, *Work Results* and specified requirements associated with performance of the *Floor Covering Installer*.
- **Related Work:** In the case of this Best Practice, *Related Work* includes descriptions related to, or that are dependent on the finishes, *Work Results* and specified requirements associated with the performance of the concrete trades or the *Constructor*.
- **Work Results:** In the case of this Best Practice, *Work Results* are the permanent or temporary aspects of construction that are achieved by the application of skills associated with the trades performing *The Work* as described in the specifications.

Flooring Products: *Flooring Products* is defined in the A11 Best Practice to describe various flooring/floor covering/floorcovering materials in tile or sheet form, and including materials such as adhesives, preparation products, and components that form a part of a complete installation, and apply generically to any material applied over a *Concrete Substrate* that provides a finished walking surface.

Floor covering types influenced by this Best Practice include resilient and static control flooring, broadloom carpet, carpet tile flooring, hardwood flooring, laminate flooring, bamboo flooring and cork flooring described in the NFCA Floor Covering Reference Manual, Part A16-2 Specification Guides.

Additional floor covering types that are also influenced by this Best Practice includes resinous coatings, liquid applied flooring, tile and stone flooring, and other applied floor finishes such as mechanically polished concrete or terrazzo flooring, which are governed by their own trade associations.

Project Participants: The people who contribute to *The Work Results* associated with achieving acceptable concrete Substrate Flatness, and that can include the following:

The NFCA Floor Covering Reference Manual includes recommendations for construction sequencing and coordination of *Project Participants* in Part A Appendices, AA5 Construction Sequence and Trade Coordination.

- **Owner:** The *Owner* is the entity defined by the contract, who establishes the performance of *The Work* and engages with a *Design Professional* for preparation of the project documents that define *The Work* and forms an agreement with a *Constructor* for delivery of *The Work*.
- **Design Professional:** The Registered Architect, Professional Engineer or Licensed Interior Designer who is responsible for describing the *Owner's* project performance requirements in the project documents (the specifications, schedules, and drawings) associated with *The Work*.
- **Constructor:** The General Contractor, Design-Builder or Construction Manager described within the various forms of contract selected by the *Owner*, and who has general control over the means and methods of construction associated with delivery of *The Work*.

Floor Covering Installers: The *Floor Covering Installer* is responsible for minor surface preparation as described in Part A12 of the NFCA Floor covering Manual to an acceptable Concrete Substrate, is commonly certified in the installation of a variety of *Flooring Products* described above and is recognized as Trade Qualified or Product Qualified when they have successfully completed any NFCA recognized installation training program.

Qualifications and certifications for *Floor Covering Installers* are described in the NFCA Floor Covering Reference Manual, Part A05-1 Qualification of Installers, which also recognizes specialty product qualified programs provided by *Flooring Manufacturers*.

The NFCA Floor Covering Reference Manual describes the *Floor Covering Installer's* responsibilities for preparation of *Concrete Substrates* Part A12, which describe Substrate Preparation.

- **Flooring Distributor:** *Flooring Distributors* manage distribution and local representation of *Flooring Products* and can stock/warehouse material from one or several *Flooring Manufacturers* and are often responsible reviewing site conditions and confirming that *Moisture Testing* is acceptable to the *Flooring Manufacturer's* written requirements.

- **Flooring Manufacturer:** *Flooring Manufacturers* produce *Flooring Products* that include the diverse types of *Flooring Products* and accessories described in the NFCA Floor Covering Reference Manual, and includes manufacturers of floor preparation materials, hydraulic cement underlayment products, adhesives, tools, and maintenance materials.
  - *Flooring Manufacturers* provide installation instructions that establish flatness tolerances (Refer to NFCA A21 Best Practice), installation environmental conditions, surface preparation and moisture limitations.
  - *Flooring Manufacturers* also provide information about compatibility with adjacent materials that are essential to the successful installation and longevity of *Flooring Products* and have potential to affect manufacturer warranties.
- **Moisture Testing Agency**: A third-party inspection and testing company engaged by the *Owner*, or the *Constructor* (using a cash allowance provided by the *Owner*) to perform testing specifically related to determining the *Moisture Condition* of *Concrete Substrates* and verify that *Concrete Substrates* meet *Flooring Manufacturer's* required installation criteria.
  - **Moisture Inspector:** Someone with expertise in conducting specific tests and using testing equipment to assess the Moisture Condition of *Concrete Substrates*, and who is capable of generating reports with recommendations for addressing unacceptable moisture levels.

> NFCA recommends retaining third-party *Moisture Testing Agencies* that employ experienced *Moisture Inspectors* familiar with the specified test methods and equipment. Moisture Inspections do not form a part of NFCA activities and should be form a component of the *Constructor's* quality management program.
>
> NFCA recommends engaging an experienced and certified International Concrete Repair Institute (ICRI), or Institute of Inspection, Cleaning and Restoration Certification (IICRC) Moisture Technician or Restoration Specialist, or a person that has successfully completed the NFCA moisture testing training who can provide proof of their credentials.
>
> *Design Professionals* can request proof of experience and credentials within their specifications; but regardless of whether proof is requested or not, it is in the best interests of the *Constructor* to use certified *Moisture Inspectors* to offset potential construction risk and any costs associated with delays or remediation.

  - **Moisture Testing:** Specific testing required to track progression of concrete curing and *Moisture Conditions* during construction, with completion performed before scheduling the *Floor Covering Installer* starting their *Associated Work*.

APPENDIX 2: CONTEXTUAL CONCRETE INFORMATION

HISTORICAL CONTEXT

The number of moisture related installation failures of *Flooring Products* is increasing. Costs associated with repairing or replacing those installations are frequently burdened with secondary expenses related to delays or loss of use of the spaces affected by moisture related failures.

Moisture testing procedures traditionally required by *Flooring Manufacturers* to determine acceptable conditions for concrete substrates for installation of *Flooring Products* are not providing as consistent outcomes based on the numbers of moisture related flooring failures as they once did.

- A large part of the issue with measuring moisture tolerances for *Flooring Products* is predicated on a historical misunderstanding of contributions to moisture related failures, and that many design and construction professionals lack accurate knowledge about appropriate methods and consistent approaches relating to testing of concrete for moisture.
- Different *Flooring Manufacturers* will often favour use of one Controlled Test instead of another, other *Flooring Manufacturers* will use a combination of Controlled Tests, and more recently some *Flooring Manufacturers* are introducing Indicative Tests as a part of their installation requirements.
- Consistency of testing protocols is critical but is not the complete answer, this A11 Best Practice has identified several areas of testing and appropriate coordination between the contributors to *The Work* that can help improve control and identification of moisture related issues to reduce the incidence of installation failures of *Flooring Products*.

Concrete chemistry has also undergone significant changes over the past many decades, rendering previous testing practices developed for historic mix designs as mostly irrelevant for present day assessment of moisture in concrete for suitability with modern *Flooring Products*.

The following appendix content provides context to changes that have occurred to cement production and chemistry, misconceptions about approaches to testing and language associated with concrete, and that are needed to address misunderstandings and help to address the increasing numbers of moisture related failures as a Best Practice specific to the floor covering community.

CONCRETE IS DIFFERENT TODAY

Concrete has undergone significant changes since the 1920s, including improvements in cement manufacturing, grinding processes, and standardized methods for placement and curing. During the 1980s, changes in cement production resulted in the introduction of Supplementary Cementitious Material (SCM) allowing for reductions in the amount of cement in concrete mixes to achieve similar strengths as those produced in the 1950s.

- Improved grinding methods meant that cement powder became finer and enabled concrete mix designs to meet higher compressive strengths using less cement.
- Finer cement grinds result in higher hydration process temperatures, making water/cement ratios and detailed curing programs more crucial to achieving desired concrete strength and quality.
- In the past 20 years, advancements in the production of modern cements with a focus on sustainability have made water/cement ratios and curing programs even more important, particularly with the introduction of Cement Kiln Dust (CKD) into concrete mix design.

> NFCA recognizes that the incidence of moisture related failures has increased since the introduction of CKD and relies on input from subject matter experts contributing to this Best Practice identifying this as an area of concern. The effect of other Supplementary Cementitious Materials (SCMs); such as fly ash, slag or silica fume, may not have a similar influence on *Critical Dew Point* as cement kiln dust.
>
> *Design Professionals* should make themselves aware of Supplementary Cementitious Materials proposed for use as a part of performance enhancement or sustainable design practice and modify their specifications to account for any potential compatibility issues that may arise on site. Cement manufacturers have concrete mix specific approaches to curing and site management, particularly for sustainable and high-performance concrete mixes that rely heavily on SCMs.

- The Environmental Protection Agency (EPA) required reductions in flue gas emissions in cement production which resulted in the deposition of a fine powdery residue (CKD) that was initially a waste product, until it was discovered that it could be added to concrete without significantly impacting performance properties when added to the mix design, solving a critical air pollution issue, and creating a safe disposal solution.
    - The inclusion of CKD as a sustainable concrete solution heightens concerns with compatibility in the floor covering community regarding changes to moisture behaviour and surface compatibility due to the presence of alkaline by-products when appropriate concrete curing protocols, maintaining drying conditions and weather protection measures are not implemented by the Constructor.
    - Alkaline by-products in CKD are water soluble and are deposited on the surface of concrete slabs as excess water evaporates from within the mass of the concrete slab; the alkaline by-products change the Dew Point when measuring Relative Humidity (RH).
    - See definition for *Critical Relative Humidity* definition in this Best Practice.

- The evolution of concrete mix design in the 2020's resulted in cement with higher alkaline salt deposits on the surface that leach from CKD and that lead to challenges in workability due to lower water content in the concrete; requiring a more controlled curing regime that was not required for older mix designs prior to the 1990s; and consequently, increased the numbers of claims associated with moisture related failures of *Flooring Products*.
- Modern concrete is essentially a new product, requiring a re-evaluation of traditional Moisture Testing methods that previously provided satisfactory results for *Flooring Products* using older mix designs.

MOISTURE SOURCES

A long-held belief is that most of the moisture migration occurs from the underside of concrete slabs-on-grade and installing vapour barriers under the slab eliminated this problem; however, moisture related Flooring Product failures still occur with this design solution and does not fully explain moisture related failures for suspended concrete slabs.

- The laws of thermodynamics (science moment) explains that heat moves from a higher temperature object to a lower temperature object until they reach equilibrium. The laws of thermodynamics address energy transfer, temperature and heat and govern the mechanisms by which *Moisture Conditions* are affect by differences between two materials (air and concrete) or within a material (surface of concrete to underside of concrete).
  - Air at a higher temperature will move towards surfaces having a lower temperature.
  - Air contains water vapour; warmer air can hold a greater volume of water vapour than cooler air; condensation will form once air is sufficiently cooled to the point of saturation.
  - See definition for *Dew Point* in this Best Practice.
- Moisture vapour in concrete slabs-on-grade should move from the relatively warm upper surface towards the cooler underside, moisture vapour should not be moving from the subgrade towards the slab surface, which would violate the second law of thermodynamics. Moisture movement of this type can only happen when the upper surface is cooler than the ground temperature.
  - Moisture in this case refers to gaseous water (vapour) and liquid water (condensation) when it encounters a low enough temperature and is subject to the second law of thermodynamics.
  - Below grade moisture in its liquid form (water) can cause moisture related problems through capillary action and hydrodynamic/hydraulic pressure that can be controlled through the installation of appropriately sized clean granular aggregates, membrane materials or a combination of aggregates and membranes depending on the water table on the building site.

> NFCA recommends the use of *Capillary Breaks* (membrane plus aggregates) below concrete slabs-on-grade because water levels can fluctuate seasonally and annually, and as a result of changed site conditions from around the building or adjacent buildings that change drainage and may increase the likelihood of water beneath the slab leading to capillary water related failures. Failures resulting from below grade water intrusion is one of the most frequent causes for replacement and retrofit of installed *Flooring Products* when a *Capillary Break* is not installed.

  - See definitions for *Capillary Break*, *Hydrostatic Pressure* and *Porosity* in this Best Practice.
- Concrete in contact with the ground is generally cooler than ambient air temperature; condensation from warmer air forms on the concrete surface and is absorbed by the cooler concrete, moving downwards due to the temperature differential. This process follows the laws of thermodynamics; except when alkaline salts are present on the concrete surface which introduce a chemical modification, which can have different effects potentially worsened by their presence.

> NFCA recognizes that suspended concrete slabs can also be cooler than ambient air temperature and that similar conditions will exist that can contribute to artificially lower moisture readings as described below.

  - Alkaline salts absorb moisture which leads to measurably lower moisture readings using traditional measurement procedures and devices, even when the same amount or higher moisture volumes exist.
  - Alkaline salts are by-products products are normal to Portland cement-based concrete, as well as the inclusion of CKD into concrete and must be managed (elimination is a challenge for the concrete industry) by a more involved curing process and better protection of concrete surfaces (controlled temperature, ambient humidity, protection from exposure to wetting).
  - Alkaline salts become supersaturated as temperature increases and become liquid at normal in-service building temperatures (see *Critical Relative Humidity*) when the *Permanent HVAC System* is activated, and result in moisture related *Flooring Product* failures.

CONDENSATION

Measuring *Dew Point* and determining when condensation will occur is challenging based on the construction community's lack of understanding about how various influences such as appropriate controlled curing and protection affects concrete outcomes; the effects of high alkalinity on surface conditions and *Moisture Testing*; or the importance of temporary heat, ventilation, and humidity controls during construction.

- The lack of understanding of site conditions that surround determination of *Dew Point* on concrete surfaces with the resultant formation of condensation at temperatures considerably higher than atmospheric *Dew Point* (See *Critical Dew Point* below, ionic dew point).

> NFCA recognizes that site conditions during construction are significantly different than in-service conditions once the *Permanent HVAC System* is fully operational. Testing for condensation also needs to consider what the *Equilibrium Moisture Content* will be once the *Permanent HVAC System* has established the in-service conditions typical during building occupancy.

  - Reliance on testing methods that were designed for accurately determining the proper curing of concrete means that many testing agencies can inadvertently provide a determination that *Moisture Conditions* of the *Concrete Substrate* are acceptable for installation of *Flooring Products* even when they may not be.
  - The presence of alkaline salts means that liquid water (condensation) can be present on or immediately within concrete surfaces when a *Moisture Testing Agency* is only testing for atmospheric related RH and indicating "safe moisture levels", even when considering surface temperatures that could be cooler than air temperatures.
  - Internal RH measurements measured by ASTM F2170 can be different than RH measurements on the surface of the concrete, because internal measurements are not affected by the presence of alkaline salts.

CONCRETE CURING versus CONCRETE DRYING

Construction practices commonly rely on the completion of concrete curing to denote acceptance of that part of *The Work* and transferring that acceptance as indicating that concrete is acceptable for other components of *The Work*. The terms concrete curing and concrete drying are often used interchangeably leading to incorrect assumptions about acceptable substrate conditions for successful installation of *Flooring Products* based on the end of the active curing stage described below.

- Concrete curing is defined by the American Concrete Institute (ACI) as "the process of maintaining satisfactory temperature and moisture conditions in concrete long enough for hydration to develop the desired concrete properties. The potential strength and durability of concrete will be fully developed only if concrete is properly cured."

  - The desired concrete properties relate to structural performance criteria specified by the Design Professional that includes strength gain and durability appropriate to exposure conditions and locations within *The Work* and does not account for *Drying Time*.

    - The desired concrete properties do not reference the rate of drying, concrete requires a defined amount of mix water to react with cement particles (hydration) to achieve the specified performance criteria for strength and durability.
    - The mix water amount is expressed as a percentage of the total concrete mix delivered to the site, usually ranging from 30% to 50%, the proportion can vary based on the specific mix of cement, aggregates, admixtures, and supplementary cementitious materials required to achieve the desired concrete properties.
    - Mix water also maintains Relative Humidity and prevents rapid drying within the mass of the concrete during the curing period, concrete requires moisture to cure properly.
    - Extra water (often call water-of-convenience) may be added during concrete delivery to aid in material flow without the awareness of the Design Professional or Constructor. It is important to restrict or avoid this practice when the additional water does not form part of the specified percentage needed in the concrete mix.
    - The additional water can become problematic; contributing to *Moisture Condition* concerns, which may prolong the drying period to acceptable tolerances for installation of *Flooring Products*.

- Curing and concrete placement strategies are also described in CSA A23.1/A23.2 Concrete Materials and Methods of Construction and requires the Constructor to prepare a formal curing plan forming a part of their quality management program and consists of the following stages:

  - Initial Curing Stage: Active curing procedures performed after placing of concrete and before final finishing to reduce water loss from the surface concrete resulting from low environmental humidity, direct exposure to solar heating and wind exposure.
  - Final Curing Stage: Active curing procedures performed immediately after final finishing of concrete until termination of curing to reduce water loss from surface of concrete and to control temperature of concrete:

    - The final curing stage can take between 3 to 7-days, until reached 70% of its desired performance properties have been achieved.
    - Adjustment to the number of days may be necessary when properties are not being achieved as a result of site conditions.
    - Adjustment may also become necessary when sustainable concrete or concrete containing high percentage of supplementary cementitious materials are specified.

  - Curing Protection: Protection of concrete surfaces during the initial and final curing stages from mechanical damage by construction equipment, materials and methods, application of curing procedures, exposure to running water and precipitation (rain, snow, sleet or hail), and temperature conditions detrimental to strength gain.

    - Curing protection should be in place until specified strength gain has been achieved, which can take between 28 to 56-days depending on the concrete mix design, sustainable requirements and percentage of supplementary cementitious materials.
    - Curing protection may require a longer period of time when temperature conditions are cooler than needed to attain strength gain.

  - Termination of Active Curing: Removal of active curing procedures once concrete has achieved specified compressive strength and durability as confirmed by testing described in the Design Professional's specifications.
  - Post Termination Protection: Protection of finished concrete surfaces after removal of active curing procedures from mechanical damage by construction equipment and trade activities, formation of condensation on and within concrete scheduled for applied finishes, and freeze/thaw conditions when standing water or high humidity conditions are present on non-air entrained concrete.

    - Post termination protection is essential for good quality concrete.
    - Not including a formalize approach to post termination protection often contributes to slab deformation (warping and curling), and slow drying times (see below) that contribute to harmful *Moisture Conditions* described in this Best Practice.

- Concrete drying is defined by the Portland Cement Institute (PCI) as "providing the proper conditions to allow the concrete to achieve a moisture condition appropriate for its intended use". Controlled drying is essential to the curing process described above; but once the <u>desired concrete properties</u> are attained, controlling drying conditions often no longer form a part of the *Constructor's* quality management program.

  - Post termination protection is necessary once active curing has been terminated, particularly in climate regions that are subjected to a wide range of temperatures and continued wetting potential from precipitation.

    - Hot weather conditions can delay the formation of crystalline minerals (ettringite) when temperatures rise above 26°C (80°F) contributing to shrinkage and cracking, slow strength gain and decrease the overall durability of the concrete, additional water may be added to offset the effects of hot weather drying which can also contribute to shrinkage and warping.
    - Cold weather conditions can affect desired performance properties when temperatures fall below 4.5°C (40°F) by preventing strength gain and will freeze when fresh concrete temperature is below -3.5°C (25°F).

        - As with curing, drying temperature ranges are affected by the desired concrete properties used for the project, and requirements for sustainability, supplementary cementitious materials content and high-performance requirements that also require more drying control for longer periods of time.

    - Maintaining a temperature range between 18°C to 26°C (65°F to 80°F) helps with drying control and the curing process during the post termination period and contributes to better concrete quality after completion of the 28-day or 56-day curing period leading to improved strength gain throughout the remainder of construction.
    - Drying time is not tied to curing time associated with strength gain; *Moisture Conditions* must be assessed differently than concrete curing, concrete slabs are often too wet after the completion of the 28-day or 56-day curing period and will require application of expensive coatings to offset the risk of moisture related installation failures of *Flooring Products* when the project schedule requires rapid completion.

        - Concrete will dry at a rate of about 1 mm per day (approximately 1-inch per month) within the ideal temperature range.

            - A 100 mm thick concrete slab open to one face can dry in 100-days when exposed to ideal drying conditions, this time is approximately halved when the concrete slab can dry from two faces.
            - Concrete must be protected from wetting by weather conditions or from capillary action from below grade.
            - Concrete that is allowed to cool below the ideal temperature range or that is not protected from wetting will require more days to dry, with at least as many days as the concrete was exposed to cool temperatures or wetting conditions added to the projected *Drying Time*.

        - Concrete exposed to warm or hot conditions may dry too quickly and provide misleading test results for acceptable *Moisture Conditions* (see "Moisture Bounce Effect" below).
        - Concrete exposed to cool or cold conditions, or prolonged wetting periods will affect Drying Conditions and may require remedial drying measures to remove excess moisture from concrete (see Basic Guidelines for Removal of Excess Moisture from Concrete below) when the construction schedule does not allow for additional time.
        - Concrete exposed to rapid air movement may dry too quickly, similar to concrete exposed to warm or hot conditions.

    - Post termination protection can help prevent many of the sources of moisture that affect installation of *Flooring Products* when these measures form a part of the *Constructor's* quality management program, offsetting a number of risks associated with maintaining the construction schedule and unanticipated costs associated with concrete remediation.

- Other terms that are frequently used interchangeably with concrete curing and concrete drying, are concrete setting and concrete hardening. Although these terms do not affect outcomes arising from *Moisture Conditions* it is essential that these terms are not used outside of the context of concrete finishing to avoid any confusion.

    - Setting describes the stiffening of the fresh cement paste when the onset of rigidity occurs and signals the start of concrete finishing while the surface is still in a plastic state.
    - Hardening starts once setting has allowed sufficient stiffness for a person to walk on the surface without leaving tracks, finishing continues during the hardening phase and affects the surface texture, flatness profile and surface porosity from continuation of trowelling operations.
    - Setting and hardening result from the continuing reaction between the cementitious material and water.

        - Setting and hardening occur during the Initial Curing Stage described above and forms a part of the finishing operations.
        - Finishing is complete once the concrete is hardened and defines the start of the Final Curing Stage described above.

HIGH pH versus HIGH ALKALINITY

A common misconception is that the terms High pH and High Alkalinity are interchangeable, they are separate issues that have different context when measuring concrete properties. High alkalinity associated with the presence of alkaline salts chemically affects the predicted thermodynamic heat and moisture conditions and can result in a *Dew Point* temperature that is significantly higher than when alkaline salts are not present.

- As described above, alkaline salts are a natural by-product of cement production and have increased in concentration with the introduction of CKD. This doesn't aim to criticize modern cement production, but it emphasizes how changes in vital structural components can have unforeseen effects on construction relying on concrete conditions, often necessitating different testing approaches than before these changes occurred.
  - pH measures how acidic or alkaline (basic) water is using a range of 0 to 14, with 7 being neutral and a pH of less than 7 indicating acid and a pH greater than 7 indicating alkaline.
    - Alkaline salts commonly found in concrete such as calcium hydroxide at full concentration has a pH of 12.5; sodium carbonate at full concentration has a pH of 12; and sodium hydroxide at full concentration has a pH of 14.
    - pH can vary for each material based on the dilution, meaning that sodium hydroxide has a potential for pH 13 at low dilute concentrations and moving towards pH 14 at higher dilute concentrations.
  - It is the concentration of the specific salts that contributes to conditions that can cause moisture related damage. As described above alkaline salts absorb moisture; and when wetted to measure the pH, provide an artificially low RH result.
    - Freshly placed concrete has a pH of 12 to 13; as the calcium hydroxide ($Ca(OH)_2$) reacts with moisture and carbon dioxide in the air forming calcium carbonate ($CaCO_3$), the pH of concrete surfaces typically reduces to between pH 9 to 10 over a period of time.
    - This process is called carbonation and is a naturally occurring process where acidic environmental influences (like CO_2 combined with moisture) neutralize the surface alkalinity and can gradually continue this neutralization process within the concrete over the course of several years.
    - It is also one of the reasons why open-flame heaters damage concrete by injecting excess CO_2 into the environment at a time when the concrete is vulnerable to carbonation occurring deeper within the matrix, which decreases the strength of the surface causing non-moisture related conditions (such as dusting) that can also affect adhesive bond strength and the installation of *Flooring Products*.
    - Making concrete less alkaline is also not a solution by itself; concrete needs to maintain an optimal pH 10 or more to maintain its structural properties and the cohesive bonds between the cementitious materials and the aggregates.
    - Concrete is not generally adversely affected by alkaline salts and there is evidence showing that the presence of these salts in certain conditions provides a buffering effect to the natural carbonation process that protects concrete from atmospheric degradation in critical infrastructure construction types.
    - The high pH creates a "passivating" effect on and around the steel reinforcement, and prevents the corrosion of the steel, absent of chlorides or other contaminants.
  - It is the presence of alkaline salts (high alkalinity not high pH) that attain *Critical Relative Humidity* under building operating/in-service conditions and subsequently become liquid that have high pH and that the effect of full concentration becomes a problem.
  - Alkaline salts may not react as readily with CO_2 and are more sensitive to influences of atmospheric *Moisture Conditions* (ambient *Relative Humidity*) the lead to high alkaline conditions and problems for installation of *Flooring Products*.

CONCRETE LAITANCE

Laitance is a milky or powdery layer of cement dust, lime and sand fines that are loosely bonded to the surface of *Concrete Substrates*, and forms when concrete is over-watered during delivery and placement or allowed to dry prematurely when an effective curing plan and concrete protection facilities were not in-place.

- Laitance is a *Permeance* barrier and can delay drying of the *Concrete Substrate* and will require mechanical removal to reduce the *Drying Time* and allow moisture to evaporate from the mass of the concrete.
- Laitance is also a barrier to many of the other surface testing procedures described in the A11 Best Practice and must be removed to expose the surface of *Concrete Substrates* to improve the accuracy and reliability of those tests.
- Many reference standards and most *Flooring Manufacturer's* written installation instructions require removal of laitance using mechanical abrasion methods before starting any installation of moisture sensitive *Flooring Products*.

CONCRETE FINISHING

Concrete finishing specifications typically call for a "hard trowel" finish, which provides a hard and smooth surface to the Concrete Substrate that is minimally permeable and closes pores and capillaries at the surface.

- This is done to retain moisture within the mass of the concrete and provide a more durable surface that is less prone to dusting and separation of the surface layer, often the consequence of overworking the "hard trowel" finish that can contribute to the problems that this finish is supposed to solve.
- The "hard trowel" finish slows the drying process of concrete similar to application of concrete treatments, densifiers and cleaning compounds described below.
- Additionally, "hard trowel" will require some reworking to "roughen" or "profile" *Concrete Substrate* surfaces to provide a suitably absorptive surface to establish a bond with water-based adhesives associated with installation of *Flooring Products*.

    - *Flooring Manufacturers* written instructions usually have specific requirements for floor preparation of "hard trowel" finished floors and may include primers and trowel applied skim coats to achieve an optimal surface condition.
    - "Hard trowel" finishing may not be necessary when the intent is to cover *Concrete Substrates* with *Flooring Products* to avoid many of the costs associated with floor preparation, provided the *Constructor* accounts for moisture management and *Drying Time* as a part of their curing plan.

RELIANCE ON CONCRETE TREATMENTS, DENSIFIERS AND CLEANING COMPOUNDS

Constructors have become reliant on many forms of concrete treatments, densifiers and cleaning compounds to improve the quality of concrete and reduce the time it takes to deliver a finished project to the *Owner*. The overwhelming benefits of these products to concrete is undeniable; however as new products are introduced or old products were not fully understood, they may have an adverse effect on *Moisture Conditions* and acceptable *Concrete Substrates* when they are used incorrectly, or when manufacturers' instructions are not fully implemented.

- Concrete Treatments: Concrete treatments are typically used to shorten the active curing stage and expedite construction schedules to provide early usable floor spaces to other trades.

    - Treatments are intended to be a temporary application and are advertised as breaking down over time when exposed to ultraviolet light, wind and wetting conditions and are often described as typical construction environmental conditions.
    - Commonly used concrete treatments such as curing agents, curing/sealing agents, or curing/hardening agents are designed to slow evaporation and improve the concrete curing and hardening processes associate with attaining specified concrete strength and durability.
    - They are designed to retain moisture within the *Concrete Substrate* which slows the *Drying Time* from the mass of the concrete and will continue to prolong *Drying Time* when removal of the treatment is not complete.
    - The reliance on environmental conditions to remove concrete treatments is often not sufficient as a consequence of buildings being enclosed or materials placed on the *Concrete Substrate* obscures or protects the treatment from the natural weathering process and will require abrasive removal to expose the surface to optimal drying conditions.

- Concrete Densifiers: Densifiers are liquid applied compounds that improve surface durability and reduce dusting and abrasive erosion of the surface of *Concrete Substrates* and are frequently mis-named "liquid-hardeners".
    - Densifiers such as sodium silicate, lithium silicate and potassium silicate are commonly used to improve surface resistance to abrasive wear and are typically applied during the Curing Protection Stage or later once sufficient calcium hydroxide has formed to react with the silicate solutions to form calcium silicate hydrate.
        - Densifiers do not harden concrete in the same way as dry-shake aggregate basalt, carborundum or quartz hardeners do, which are worked into the surface during finishing of the *Concrete Substrate* towards the end of the Initial Curing Stage.
        - Dry-shake hardeners significantly increase the Mohs Scale of Hardness and do not provide a surface compatible with any *Flooring Products*; concrete has a hardness of between 6 to 7 Mohs, application of dry-shake hardeners can improve hardness to about 8 to 9 Mohs.
        - Densifiers retain moisture within the *Concrete Substrate*; reducing the moisture vapour emission rate (ASTM F1869) and raising the internal relative humidity (ASTM F2170); which may provide false or negative results for acceptable *Moisture Conditions*, while improving the structural properties and durability of the concrete.
        - Densifiers react to a depth of 4 mm to 6 mm (or more depending on the silicate formulation), forming calcium silicate hydrate crystals within the voids of the *Concrete Substrate*; providing a favourable environment for any remaining cement to react with moisture to reduce the potential for dusting and toughening the surface layers of concrete.
        - Densifiers improve the surface density; raising the natural hardness of concrete by about 0.5 Mohs to about 7 to 7.5 Mohs, the improved density often makes it difficult for water-based adhesives to form a bond to the *Concrete Substrate* and many *Flooring Manufacturers* have specific instructions and product recommendations when encountering this floor treatment.
- Sweeping Compounds: Most concrete slabs are cleaned using sweeping compounds that can contain oils or chemicals that adhere to dust and other surface contaminants.
    - Sweeping compounds make it easier to keep *Concrete Substrates* clean and greatly improves indoor air quality during construction by removing dust and fine particulates that have potential to harm worker safety.
    - Many sweeping compounds leave behind an oily residue that reduces the permeance of the *Concrete Substrate* unless it is washed off with soapy water and rinsed with clean water; potentially reducing surface evaporation and prolonging the *Drying Time*.
    - The oily residue also creates a barrier to obtaining accurate electronic moisture meter measurements (ASTM F2659) if it is not removed, meaning that only measure surface moisture in the form of condensation will register providing an incorrect RH reading.

Appendix 3: Managing Drying Conditions for Concrete

Controlling and monitoring moisture levels; both within the concrete mass and on its surface, are crucial during construction. The responsibility lies with the *Constructor* to manage proper *Drying Conditions* because they have control over site conditions that can affect the development of issues related to moisture and alkalinity. Preventative measures should form a part of the *Constructor's* curing plan as required by CSA A23.1/A23.2, Concrete Materials and Methods of Construction, and include a mitigation strategy when intermittent testing shows that *Moisture Conditions* are not aligning with *Flooring Manufacturers'* stated requirements.

Floor Covering Installers are not responsible for addressing moisture or alkalinity issues, as they do not have control over site conditions. *Floor Covering Installers* will perform indicative spot checks prior to starting installation of *Flooring Products* and will report to the *Constructor* when those checks identify conditions that may be problematic. The *Constructor* should conduct additional tests and begin drying procedures to correct any identified moisture issues before requesting the *Floor Covering Installer* to begin their portion of *The Work*.

The *Design Professional* can specify a cash allowance where the extent of remedial solutions needed to correct concrete dryness because inclusion as a bid component is not practical because the extent or necessity of this process cannot be accurately determined.

> The NFCA Floor Covering Reference Manual describes the *Constructor's* responsibilities for providing acceptable floor surfaces in the General Requirements described in Part A10 and Part A12, which describe Acceptable Conditions and Substrate Preparation.

Most concrete specifications rely on performance-based requirements to assess its suitability for use on the project. The *Design Professional* should make themselves aware of the importance of test methods that better describe *Moisture Conditions* required for successful Floor Product installation and direct the *Constructor* to make appropriate *Drying Conditions* necessary to obtain ideal *Moisture Conditions* during the course of construction.

Basic Guidelines for Removal of Excess Moisture from Concrete: The concrete drying process requires heat, air movement, dehumidification, and time. The process for removing excess moisture from concrete must not start until after it has fully cured and has achieved its specified structural performance requirements. The most important aspect of concrete drying is time; schedules and project deliverables may not provide sufficient quantities of time, ultimately excess moisture within concrete will move only as fast as it wants and speaks to the challenges of obtaining appropriate *Moisture Conditions* necessary for installation of *Flooring Products*.

> NFCA recommends engaging an experienced and certified ICRI or IICRC Moisture Technician or Restoration Specialist who is familiar with conditions affecting drying potential of concrete, and that can provide specific concrete drying recommendations based on observed site conditions and constructed assemblies.

- **Confirm Moisture Content:** Determine moisture content of concrete using testing methods described in this Best Practice and identify the source of where moisture is coming from (environmental, ground, internal, site activities), and establish protective measures so that concrete remains dry once acceptable moisture levels are attained.
    - *Moisture Testing* should be performed throughout the construction phase to confirm that moisture levels are diminishing, and related formation of alkaline salts are controlled.
    - Delaying testing until immediately before installation of *Flooring Products* may cause a delay to the project schedule where moisture levels need to be addressed, and alkaline salts are neutralized or removed.
- **Confirm Effective Capillary Break:** Use appropriate *Capillary Break* materials, NFCA recommends the use of *Membrane Layer* to control the ingress of water from sub-slab granular materials, which can be enhanced by using a high void content, clean, crushed aggregate layer.
    - Granular materials form a typical part of sub-slab depressurization systems, but there are other types of high void geo-composite materials that can form a part of the sub-slab depressurization system; confirm with project specification for material composition.
    - Depressurization systems may also be present and are used to control deleterious subsoil gases such as radon, methane and other hydrocarbons and are required by the National Building Code as adopted and modified by provincial jurisdictions.

> NFCA recommends installing a *Flooring Manufacturer* recommended surface applied moisture mitigation coating or change the *Floor Product* to a proven moisture tolerant material if moisture intrusion sources cannot be definitively determined and there is potential that excess moisture from *Concrete Substrates* will continue to be problematic.

Guidelines for Excess Moisture Removal: Establish a timetable, testing methodology and a target *Moisture Condition* required for a successful outcome with the understanding that concrete naturally dries slowly. Allowing sufficient time is critical for successful moisture removal and adjusting the construction schedule to account for contributing site conditions must factor into the planning required to improve drying potential between the concrete and the air.

- **Moisture Desorption**: The primary goal for mitigating excess moisture is to slowly remove excess moisture from the concrete by introducing desorption (the opposite of *Absorption* or *Adsorption*) conditions to the surface and creating improved potential for evaporation of the resulting surface moisture into warm dry air using low-speed airflow while maintaining the following variables:

    - **Surface Condition:** Remove any laitance or other low *Permeance* materials that may be present that has potential to slow *Drying Time* or that has potential to hinder the drying process.
    - **Airflow:** Airflow must be maintained at a low velocity/slow speed, typically less than 0.5 m/s (100 FPM) which will allow capillary action to remain active during the drying process, breaking the capillary action by increasing airflow will hinder the drying action and may significantly slow moisture movement to the surface (the desorption effect).
    - **Humidity Control:** Reducing atmospheric moisture in the air reduces the air's vapour pressure and results in a greater *Vapour Pressure Differential* between the dry air and the comparatively wet concrete, rapid reduction of atmospheric moisture has potential to over-dry the surface of the *Concrete Substrate* and cause the *Moisture Bounce Effect* described below.
    - **Temperature:** Concrete should ideally be at a temperature above 18°C (65°F) and needs to be limited to temperatures less than 26°C (80°F), higher temperatures will speed drying but may not be beneficial.

        - Temperatures above 18°C are beneficial to facilitating moisture movement.
        - Temperatures lower than 18°C correlates to lower vapour pressure in concrete; cold concrete competes with dry air and reduces the *Vapour Pressure Differential*.

            - Low vapour pressure in air combined with low vapour pressure in concrete creates a smaller *Vapour Pressure Differential* resulting in slower desorption.
            - Low vapour pressure in air combined with high vapour pressure in the concrete creates a larger *Vapour Pressure Differential* resulting in faster desorption.

    - **Permeance:** *Permeance* of concrete is low and is the final determining factor relating to speed of moisture movement and is key to estimating the amount of energy required to influence the *Vapour Pressure Differential*.

        - Concrete Substrate thickness changes the speed at which moisture will move through concrete by capillary action, the further water needs to travel through the concrete to the surface the longer the concrete will need to dry.
        - *Permeance* of concrete is also influenced by its construction of the assembly; for instance, suspended slabs that are exposed to air on both sides will dry faster than slabs-on-grade or composite metal deck/concrete suspended slabs that can only dry from one surface.

- **Final Testing and During Drying Process:** Moisture Condition of concrete slabs must be monitored at regular intervals during the drying process and after the concrete has reached its optimal Moisture Condition before removal of temporary containment barriers and equipment used to aid concrete *Drying Conditions*.

Limitations to Excess Moisture Removal Process: The guidelines presented above require involvement of experienced and certified ICRI or IICRC *Moisture Inspector* or Restoration Specialist who are familiar with conditions affecting drying potential of concrete, and understand the effort required to obtain *Flooring Manufacturers'* recommended *Moisture Conditions* for their *Flooring Products*.

- **"Moisture Bounce Effect":** The "*Moisture Bounce Effect*" describes the tendency for moisture movement in a concrete slab that is on cool or cold ground and the top surface of the concrete is heated meaning that the bottom surface remains cool against the soil. Mid-level moisture can travel downwards to the cooler, lower vapour pressure region, and then return or "bounce" back towards the surface after drying and cooling of the concrete slab.
    - Applying heat in this situation may not solve the issues contributing to *Moisture Condition* concerns, because once heat is removed the moisture that was driven into the lower and cooler portion of the slab will return to the surface once heat is removed:
        - The drier top surface of the concrete slab will draw moisture back to the surface after the slab cools within days or weeks and can lead to the return of *Moisture Conditions* that damage installation of *Flooring Products*.
        - Application of heat, airflow and humidity controls must be balanced and adjusted to the specific site conditions and requires advance planning and notification.
    - Time is an aid and a hinderance in this situation, removing sufficient excess moisture to create an *Equilibrium Moisture Content* can take months rather than days:
        - Managing and mitigating excess moisture should form a part of the *Constructor's* quality management program and be deployed well in advance of calling the *Floor Covering Installer* to the site.
        - Moisture mitigation processes should not be considered as a "quick-fix" solution in the absence of an established concrete protection plan.
        - Older or more permeable concrete is more prone to the "moisture bounce effect" than newer or less permeable concrete, newer or less permeable concrete does not transport moisture as efficiently meaning that a return of harmful *Moisture Conditions* is more likely on older, more permeable concrete.
        - ASTM F1869 MVER (Calcium Chloride) testing will show elevated evaporation rates (false-negative) than they should, which may incorrectly confirm that the drying process is working.
        - ASTM F2170 RH (Probe) testing may result in artificially low RH (false-positive) readings, and which can also occur when testing is performed too soon after removal of heat.
    - Concrete that is maintained at a temperature lower than 15°C (60°F) does not dry effectively because there is not enough heat energy to initiate the *Vapour Pressure Differential*.
        - Concrete needs moisture to cure effectively, but also needs heat to hydrate and gain strength as it cures.
            - Optimal temperature for obtaining specified concrete strength is at temperatures above 10°C (50°F) and 32°C (90°F); temperatures outside of this range can hinder strength gain during curing.
            - Optimal temperatures for promoting drying potential are between 16°C (62°F) and 17°C (65°F); adding small amounts of heat during construction after concrete has cured may improve the drying rate (shorten the *Drying Time*), contribute to improved concrete strength performance, and result in less warpage and deformation (flatter surfaces).
            - Maintaining optimal temperatures during construction may also reduce the risk of enacting a concrete drying program and reduce the impact of manoeuvring trades around temporary facilities associated with a concrete drying program.
    - Construction created moisture can be four to five times greater than what the building will experience during normal occupancy and can take about 2 years for a building to reach *Equilibrium Moisture Content* when temperature and humidity are not accounted for as a part of the construction process, which may account for moisture related Floor Covering failures that occur after building occupancy.

- **Containment/Compartmentalization:** Separating, containing, or compartmentalizing areas of the building to reduce the volume of air used to establish controlled atmospheric conditions that are more favourable managing *Vapour Pressure Differential* conditions and improve the efficiency of the drying process, and provide protection of the controlled atmospheric conditions from the surrounding external environment

APPENDIX 4: GUIDE SPECIFICATION

Project Name: [Guide Specification]
Project Number: [Insert Project Number]
Date: [2024-08-01]

01 84 21.11
Moisture Testing: Concrete Floor Slabs
Page #

DISCLAIMER: This Guide Specification contains information and recommendations for coordinating moisture content tolerances, management of moisture conditions during construction, and moisture testing performed during the progress of The Work and differentiates work results that occur between the Constructor (Contractor, Construction Manager, Design builder) and the Floor Covering Installer (Subcontractor).

Information in this Guide Specification represents a potential solution developed with input and review from many industry experts and floor covering installers, and from the referenced standards in this .Usage of the information is at the editor's own risk based on their own expertise and experience, exercising reasonable diligence in determining appropriate of this specification into their project documents, and does not represent advice for any specific project situation. The author of the document and the National Floor Covering Association of Canada are not liable in any event for any claims or damages arising from or in connection with the use of this information.

SPEC NOTE: content of this section and subsequent coordination with related requirements is based on information provided by the National Floor Covering Association of Canada (NFCA), and supporting technical guidance associated with Consultant coordination and responsibilities provided by the author.

SPEC NOTE: This section makes specific reference to the NFCA FLOOR COVERING REFERENCE MANUAL, which is available as a hardcopy or digital online version for a nominal cost for non-NFCA members.

1 General

1.1 INTENT

1.1.1 The intent of this Section is to establish guidance for the [Constructor]'s role in developing a quality management program that promotes cooperative and collaborative approaches to achieving concrete moisture tolerances required by the Flooring Manufacturer and that are appropriate for *Flooring Products* specified for the Project; it is not intended to establish policies for policing-the-work and punitive-measures to enforce the Contract.

1.1.2 The intent of this Section is to establish quality management procedures associated with managing moisture conditions during construction and testing moisture conditions in concrete slabs that will receive moisture-sensitive *Flooring Products* that is consistent with the NFCA A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates.

1.2 SUMMARY

1.2.1 Work of this Section includes requirements for developing content relating to construction of concrete [slabs-on-grade] [and] [suspended slabs] (concrete flatwork) for the [Constructor]'s Quality Management Program (QMP) specified in Section 01 45 00 – Quality Control that documents the [Constructor]'s policies and organizational structure to achieve Flooring Manufacturers required concrete moisture tolerances associated with the following:

SPEC NOTE: Concrete mix design is a critical requirement having potential to affect moisture content that has potential to compromise installation moisture-sensitive *Flooring Products*. Discuss the following with the structural engineer and include appropriate language in RELATED REQUIREMENTS to offset construction risk associated with Flooring Manufacturers' moisture tolerances.

1.2.1.1 Concrete Mix Design: Prepare concrete mix design that accounts for appropriate workability (slump and flow) based on performance requirements for the Project, [sustainability,] and that accounts for concrete trades' requirements to achieve specified structural concrete tolerances including adjustment for slump and consolidation on site [and] [,] water-to-cement ratio and water added during concrete delivery and placement.

1.2.1.2 Concrete Delivery: Control delivery of concrete to maintain concrete mix design properties accepted by the Consultant at time of discharge, without use of unscheduled water by the transit mix operator and onsite personnel.

1.2.1.3 Concrete Curing: Describe methods for managing application and removal of Products used to aid the concrete curing process, with the goal to minimize the use of surface applied curing compounds, sealer/hardeners and moisture retarders that may be detrimental to achieving required moisture tolerances and installation of *Flooring Products*.

1.2.1.4 Concrete Protection: Describe methods to protect newly placed and finished concrete from rain and snow, freezing conditions, wind, heat and differential shading until concrete is sufficiently dry to accept installation of *Flooring Products*.

1.2.1.5 Concrete Surface Preparation: Describe methods for managing removal of incompatible curing compounds and mitigate of out-of-tolerance moisture conditions required to provide concrete surface acceptable for installation of *Flooring Products*.

1.3 RELATED REQUIREMENTS

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Chapter AA3 – Specification Guide 02 42 10 – Existing Flooring Removal to describe selective demolition associated with removing existing flooring, salvaging existing materials and preparing substrates ready for installation of new or reclaimed applied finishes and floor coverings. Content of this section can be included with your flooring materials specifications when the scope is limited to only floor covering removal and reinstallation.

1.3.1 Section 02 41 19 – Selective Interior Demolition: Removal [and salvage] of existing flooring materials ready for installation of new [and reclaimed] *Flooring Products*.

SPEC NOTE: Concrete testing and inspection procedures can be identified as a common work result or be included as a part of Section 03 31 00 site quality control requirements.

1.3.2 [Section 03 08 30 – Concrete Observation, Review and Testing Procedures: Source and site quality control requirements associated with testing concrete moisture conditions and reporting of site observations.]

1.3.3 Section 03 31 00 – Structural Concrete: Establish requirements for maximum surface density of placed concrete when using supplementary cementing materials to achieve Flooring Manufacturer's requirements for effective adhesive bond and minimize concrete surface preparation.

SPEC NOTE: Indicate limitations of densified concrete floor finishes on Drawings, and limit to only those areas that require this treatment.

- **Densified concrete may affect the porosity of concrete substrates and impede bond of many water-based adhesives for many floor covering products.**
- **Additional floor preparation and grinding may be required when surface densifiers are applied to achieve a suitable profiled finish for adhesion or require an aggressive surface profiling and full cementitious underlayment or topping when light profiling does not solve adhesion concerns.**

1.3.4 [Section 03 35 41 – Densified [and Burnished] Concrete Floor Finishing: Concrete mix and substrate tolerances required for specified surface finish.]

SPEC NOTE: Include Section 03 35 45 to improve bond between adhesives concrete surfaces that have a smooth trowelled finish (that has a 'closed' surface profile), or to remove curing compounds from concrete slabs that have potential to affect bond of adhesive materials.

- **The concrete finisher can achieve a concrete surface profile in the range of CSP-2 to CSP-3 when required to achieve acceptable bond for adhered *Flooring Products*, or the Constructor can opt to prepare concrete surfaces using mechanical methods to achieve CSP-2 as describe by ICRI.**
- **Concrete surface profile in the range of CSP-3 to CSP-5 will require mechanical surface preparation for applied finishes such as liquid applied resinous flooring and high-performance coatings.**
- **Concrete toppings, gypsum cement underlayments and hydraulic cement underlayments also require CSP-3 to CSP-5 or greater based on manufacturer recommendations for surface preparation.**

- **Concrete surface profiles are described within the specifications listed in the RELATED REQUIREMENTS and are based on defined level of preparation by the International Concrete Repair Institute (IRCI).**

1.3.5 Section 03 35 45 – Interior Concrete Floor Dry Finishing: Mechanical preparation of Concrete Surface Profile (CSP) to substrates receiving moisture-sensitive *Flooring Products*.

SPEC NOTE: The specifier should make themselves aware of different materials used to cure concrete, wet curing through misting or retaining a water layer using coverings provides the most reliable curing conditions that have minimal effect on subsequent installation of *Flooring Products*.

- **Curing compounds tend to be film forming, residual films from curing compounds can decrease bond strength of mortars and adhesives used to install *Flooring Products*.**
- **Additional floor preparation and grinding may be required when curing compounds are applied to achieve a suitable profiled finish for adhesion or require an aggressive surface profiling and full cementitious underlayment or topping when light profiling does not solve adhesion concerns.**
- **Curing compounds are described as hardeners, sealers, cure/seals and similar names that denote a specific type of curing outcomes.**
    - **Hardeners break surface-tension of mix water, breaking up balls of cement so that more cement particles can react with available water and provide a denser surface finish and slightly improves the surface hardness of concrete.**
    - **Sealers cover and seal capillary channels and pores in the concrete surface; retaining mix water to complete curing of concrete, can be combined with surfactant to improve surface hardness.**
    - **Internal curing compounds reduce the formation of capillary channels and pores as an integral component of the concrete mix and retain mix water more effectively to reduce contraction cracking and curling and produce a dense surface.**
    - **Densifiers described above are reactive and introduce silicates that react with free-lime to seal capillary channels and pores and provide hard and dense surfaces that resist wear and significantly improve hardness of concrete.**
- **Curing compound removal is described in this section as a part of a unit price cash allowance, where the Constructor has indicated that wet curing is not practical because of temperature concerns or construction schedule limitations.**

1.3.6 Section 03 39 00 – Concrete Curing: Curing of horizontal concrete surfaces receiving moisture-sensitive *Flooring Products*.

SPEC NOTE: Include the following requirement when improved surface tolerances are required for building operations and maintenance such as hospitals, clinical and diagnostic facilities, athletic facilities, Class A office occupancies and similar occupancies.

- **Confirm compatibility of gypsum cement underlayments with requirements of Flooring Manufacturers for conditions affecting bonding of adhesives to substrate.**
- **Confirm compatibility of gypsum cement underlayments with floor loading requirements, where compressive strength is critical to support point loads or rolling loads.**
- **Gypsum cement underlayments must meet manufacturer minimum compressive testing, typically in the range of 20 kPa (3000 PSI) or greater.**
- **Gypsum cement underlayment materials will require a mechanically prepared surface profile of between CSP-3 and CSP-5 specified in Section 03 35 45.**
- **Gypsum cement underlayment materials can also be specified Section 03 01 30 based on the type of repairs required for the project at the choice of the Specifier.**

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Chapter AA1 – Specification Guide 03 54 12 – Gypsum Underlayment when a self-levelling cementitious underlayment is required over substrate surfaces to provide an acceptable surface for installation of applied finishes and floor coverings.

1.3.7 [Section 03 54 13 – Gypsum Cement Underlayment: Gypsum-based, lightweight self-levelling underlayments required to achieve surface tolerance required for specified surface finish.]

SPEC NOTE: Include the following requirement when improved final concrete finishing tolerances is required for building operations and maintenance such as hospitals, clinical and diagnostic facilities, athletic facilities, Class A office occupancies and similar occupancies.

- **Confirm compatibility of hydraulic cement underlayments with requirements of Flooring Manufacturers for conditions affecting bonding of adhesives to substrate.**
- **Hydraulic cement underlayment materials will require a mechanically prepared surface profile of between CSP-3 and CSP-5 specified in Section 03 35 45.**
- **Hydraulic cement underlayment materials can also be specified Section 03 01 30 based on the type of repairs required for the project at the choice of the Specifier.**

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Chapter AA1 – Specification Guide 03 54 15 – Hydraulic Cement Underlayment when a self-levelling cementitious underlayment is required over substrate surfaces to provide an acceptable surface for installation of applied finishes and floor coverings.

1.3.8 [Section 03 54 16 – Hydraulic Cement Underlayment: Cement-based, self-levelling underlayments required to achieve surface tolerance required for specified surface finish.]

SPEC NOTE: Section 09 05 61 includes for skim coating compounds that are used to smooth concrete substrates and correct minor surface inconsistencies that affect long-term maintenance and corrects visual appearance of thin *Flooring Products*, and to achieve final concrete finishing tolerances without the need for additional patching and repairing materials.

- **Skim coating compounds consist of trowellable substrate filler materials formulated to smooth and fill minor depressions, voids and holes, and prepare in-tolerance concrete slab surfaces ready for installation of floor covering materials.**
- **Skim coating compounds are not used to repair out-of-tolerance concrete substrates associated with work specified in Section 03 31 00.**
- **Specifier can describe overlayment and underlayment compounds specified Section 03 54 13 or Section 03 54 16 to improve the final concrete finishing tolerances to a more planar finish.**

SPEC NOTE: Section 09 05 61 includes for moisture mitigation compounds, that are typically surface applied materials formulated to reduce moisture vapour emission rate (MEVR) of new and existing concrete slabs prior to installation of *Flooring Products* to meet Flooring Manufacturers' recommended RH.

SPEC NOTE: Components of common work results are described in the NFCA Floor Covering Reference Manual: Chapter A10 – Acceptable Conditions, and can be used as a guide when coordinating the work for Division 09 – Finishes and the extent of flooring preparation common to all specified floor finishes.

- **This section is intended for use where extensive materiality and repetitious work is required to describe project work and can be incorporated into individual technical specification sections when there are fewer *Flooring Products*, or the project is less complex.**

1.3.9 [Section 09 05 61 – Applied Floor Finishes Surface Preparation: Preparation of concrete slab surfaces using cementitious skim coatings and filling materials [, and] [moisture mitigation compounds] required to achieve Flooring Manufacturers written surface conditions ready for installation of *Flooring Products*.]

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part E – Laminate Flooring, Chapter E06 – Specification Guide 09 62 19 – Laminate Flooring when specifying solid or engineered strip, plank or parquet hardwood flooring.

1.3.10 [Section 09 62 19 – Laminate Flooring: Moisture condition tolerances required for installation of laminate flooring products.]

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part D – Hardwood Flooring, Chapter D06 – Specification Guide 09 64 29 – Hardwood Flooring when specifying solid or engineered strip, plank or parquet hardwood flooring.

1.3.11 [Section 09 64 00 – Wood Flooring: Moisture condition tolerances required for installation of resilient wood floor covering assemblies.]

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part B – Resilient Flooring, Chapter B06A – Specification Guide 09 65 00 – Resilient Flooring when specifying resilient sheet and tile finishes, sports floors, stair coverings, bases and trims.

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part B – Resilient Flooring, Chapter B06B – Specification Guide 09 65 30 – Static Control Flooring when specifying static control resilient sheet and tile and accessories.

1.3.12 Section 09 65 00 – Resilient Floor Coverings and Accessories: Moisture condition tolerances required for installation of resilient *Flooring Products*.

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part C – Carpet, Chapter C06A – Specification Guide 09 68 16 – Carpet Flooring when specifying sheet carpeting and accessories.

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part C – Carpet, Chapter C06B – Specification Guide 09 68 13 – Carpet Tile Flooring when specifying modular or carpet tile flooring and accessories.

1.3.13 Section 09 68 00 – Carpeting: Moisture condition tolerances required for installation of [sheet] [and] [tile] carpeting.

SPEC NOTE: Discuss requirements for activation of Permanent HVAC System with project mechanical engineer. Moisture testing described in this section requires the Permanent HVAC System to be operating before conducting the tests.

- **Acclimation of concrete slabs using the Permanent HVAC System may cause moisture conditions showing an acceptable "dry condition" before activation to become out-of-tolerance after activation, it is essential that Permanent HVAC Systems are running well in advance of scheduling installation of Floor Products.**
- **Manufacturers of HVAC equipment will typically require reconditioning of the Permanent HVAC System before issuing their warranty, which must be accounted for in the specification as an identified price or cash allowance within the specifications.**

1.3.14 Division 23 – Heating, Ventilation and Air Conditioning: Requirements for activation of Permanent HVAC System and restoration of Permanent HVAC System to warranty conditions prior to Ready-for-Takeover.

SPEC NOTE: Athletic surfaces require the similar moisture condition tolerances described in this Section for interior floor finishing. Modify requirements of this section when moisture-sensitive athletic paving or surfaces are required for the Project.

SPEC NOTE: This Section does not address specific requirements for the various types of sports surfacing available to the specifier. Additional information is available for the specifier from the manufacturers of these materials and from the ISO recognized organizations listed below; additional research is required when specifying performance for these types of *Flooring Products*.

- **BSI 7044, Sports Surfaces**
- **CEN-EN 15330 Series, Surfaces for Sports Areas**
- **DIN 18035 Series, Synthetic Sports Surfaces**
- **World Athletics (IAAF) Performance Specifications for Synthetic Surfaced Athletic Tracks**

1.3.15 [[Section 32 12 16 – Athletic Asphalt Paving] [32 18 23 – Athletic Surfacing]: Moisture condition tolerances required for installation of [athletic asphaltic paving] [,] [sheet-type athletic surfacing] [and] [liquid applied athletic surfacing].]

SPEC NOTE: This Section identifies a fixed price component for managing moisture conditions that can be accounted for based on the establishing a concrete protection and drying plan, and that can be expected of horizontal concrete that is placed when using appropriate quality management controls, curing methodologies and experienced trades associated with the concrete work result.

SPEC NOTE: Price and Payment Procedures must be coordinated to each of the floor covering specification sections forming a part of the project manual and that are listed in the RELATED REQUIREMENTS. Close coordination is essential to complete communication of the General Requirements with each of the trades affected by the work described in this Section.

SPEC NOTE: Inclusion of Price and Payment Procedures must be discussed with the Owner; they must be informed of the concerns that lead to use of additional floor preparation or moisture mitigation procedures.

- **The only certainty involved with the Unit Price Allowance is that concrete will be different between the first measurements and the measurements taken at the time *Flooring Products* are installed.**
- **Price and payment procedures includes for known, unforeseen conditions and must be dealt with in the same way that other known, unforeseen conditions are handled (such as extent of hazardous materials abatement, subgrade conditions in brownfield sites that may also be managed using cash allowances).**
- **Price and payment procedures are not intended to be used to account for a lack of adequate planning and preparation on the part of the Constructor.**

SPEC NOTE: Delete Price and Payment Procedures only when the Owner expectation states that prices for this work is included as a component of the submitted Bids. Modify this specification to indicate that Unit Price Allowances are mandatory floor preparation requirements. This will affect the Bid Price, with the trade-off being price certainty for the Owner.

1.4 [PRICE AND PAYMENT PROCEDURES]

1.4.1 Unit Price Allowances: Materials described in this Section form a part of unit pricing for a supply and installation cash allowance specified in Section 01 21 00 – Allowances, as follows:

SPEC NOTE: Discuss methods and products associated with curing of concrete with the structural engineer and include appropriate content or editing to Section 03 39 00 – Concrete Curing. Some structural engineers may include curing requirements in Section 03 31 00 – Structural Concrete and will also require coordination and description of improved concrete curing plan required by CSA A23.1/CSA A23.2.

- **Preference from an applied *Flooring Products* perspective is for moist cure and impermeable coverings, but that approach is not always practical from a construction scheduling or protection procedures for freezing weather conditions.**

Membrane forming curing compounds can be used to address scheduling and weather condition concerns, and there are two applicable standards associated with membrane forming curing compounds that must be considered when specifying curing materials in Section 03 39 00:

- **ASTM C309 product manufacturers often state that their products are self-removing through the action of wind, rain and UV exposure, and do not require additional surface preparation for installation of adhered *Flooring Products*, and that differs from Flooring Manufacturers written requirements requiring surface preparation:**
    - **Construction process and temporary enclosure of concrete slabs do not allow sufficient exposure to natural weathering to permit removal of curing membrane remnants and will require surface grinding to allow bonding between slab and underlayments, toppings and floor covering adhesives.**
    - **Delete requirement for unit price allowance associated with slab grinding and specify grinding and surface preparation as a project requirement in Section 03 35 45 – Interior Concrete Floor Dry Finishing when specifications include ASTM C309 curing and sealing products.**

- **ASTM C1315 product manufacturers test their products for compatibility with many adhesives commonly used with *Flooring Products* and state that their products do not require surface grinding and preparation for installation of adhered *Flooring Products*:**
    - **Many underlayment, topping and adhesive manufacturers have not tested adhesion with this type of curing membrane and will require confirmation of adhesive bond to concrete substrate using test methods described in Section 09 05 61 – Common Work Results for Flooring Preparation.**
    - **Include requirement for unit price allowance associated with slab grinding to cover additional work when testing shows adhesion does not meet underlayment, topping and adhesive manufacturers stated adhesive bond strength.**
    - **Include Section 03 35 45 – Interior Concrete Floor Dry Finishing, stating that work of that Section forms a part of a unit price allowance for removal of curing compounds when testing shows insufficient adhesion between concrete slab and underlayments, toppings and adhesives used for the project.**

1.4.1.1 [Abrasive Floor Preparation: Include unit price allowance based on area ($/m²) for abrasive floor preparation that will be used if concrete surface profile does not develop required bond with adhesive materials used for installation of *Flooring Products* as specified in Section 03 35 45.]

SPEC NOTE: Moisture mitigation treatments are typically only required for concrete slabs-on-grade but may be required when suspended concrete is installed during high-humidity temporary heat settings.

- **Moisture content of slabs-on-grade can remain high as a consequence of poorly installed or incorrect moisture mitigation layers below the slab and can only be corrected by application of topical treatments.**
- **Moisture content is not tied to the 28-day or 56-day curing time required for strength gain; drying can take 4 to 6 months (or longer) to release excess moisture acceptable to floor covering installation.**
    - **Typical rate of moisture release is 1-day for each millimetre of concrete thickness, meaning that a 150 mm thick slab will require a minimum of 150-days to achieve an acceptable RH when environmental conditions are suitable for release of moisture.**
    - **Slabs that are exposed during cold weather, or that are subjected to temporary heating will delay the drying potential to achieve an acceptable RH required by Flooring Manufacturers.**
    - **The drying potential will require 1-day for each-day that the slab is not subjected to permanent HVAC system, meaning that a 4-month exposure to unconditioned heating conditions could add an additional 120-days to the time period required to achieve optimal moisture condition tolerances.**

- **Surface applied (topical) treatments are available to balance Moisture Vapour Emission Rate (MVER) and high RH conditions into a range that does not affect adhesion of *Flooring Products*. Confirm the types of surface applied treatments that are compatible with specified *Flooring Products* with Flooring Manufacturer.**

1.4.1.2 [Moisture Mitigation Compounds: Include unit price allowance based on area ($/m²) for supply and installation of moisture mitigation compounds required to lower excessive concrete slab moisture emission to a rate required by [floor covering] [and] [applied finish] manufacturers as specified in Section 09 05 61.]

1.4.2 Unit Price Submission with Bid: Identify unit price allowances in [Section 00 43 22 – Unit Prices Form] and submit with Bids; unit price allowances submitted by the [Constructor] [[Subcontractor] responsible for the described work] must account for the following:

1.4.2.1 Unit price allowances are determined by the [Subcontractor] responsible for the described work.

1.4.2.2 Unit price allowances account for variation between calculated deformation of concrete slabs described in this Section and observed deformation at time of installation of *Flooring Products* and other applied flooring products.

1.4.2.3 Unit price allowances for the components of work described above are firm until date of Substantial Performance of the Work.

1.4.2.4 Unit price allowances are limited to adjusting Contract Price where adjustments are required for Work arising from differential deformation only and will not be used to correct deficiencies in the Work that are the responsibility of the [Subcontractor]s responsible for the deficient component of work.

1.4.2.5 Unit price allowances include required labour, material, equipment, supervision, transportation, financing, overhead and fees to complete the work associated.

1.4.2.6 Do not include amounts for value added taxes; [GST [and PST]] [HST] will be administered as a component of the Contract Price adjustment.

1.4.3 Adjustment Price Format: Submit Unit Price Allowances for additional work, and for reduction of work as follows:

1.4.3.1 Addition Prices include for [Subcontractor]s' additional overhead and profit associated with unit price work and that was not originally contained in the Stipulated Price Bid.

1.4.3.2 Deletion Prices do not include overhead and profit; [Subcontractor]s are entitled to retain overhead and profit originally contained in the Stipulated Price Bid.

1.5 DEFINTIONS

SPEC NOTE: Specifier should confirm that their source documents contain references to Quality Management (QMP) documentation as a part of the quality management text. Identifying some form of formal quality control process is essential to achieving flooring tolerances specified in this Section.

Most Constructors use some form of written QMP to manage quality expectations and deliverables to the Owner, and will often make the QMP available to Subcontractors, Consultants and Owners when specified.

This specification uses the following guidance for quality management processes:

- **Quality Assurance: These are Validation Procedures performed by the Constructor and include activities, actions, and procedures performed before and during execution of the Work by the Constructor to protect against defects and deficiencies and validate that construction is consistent with regulatory requirements, performance requirements, qualification statements and certification requirements listed within the Contact Documents.**
- **Quality Control: These are Verification Procedures performed by the Constructor and include tests, inspections, procedures, and related actions performed by the Constructor during and after execution of the Work using an independent inspection and testing agency acceptable to Owner and Consultant to verify that completed construction complies with specified standards and technical requirements within the Specifications.**
- **Quality Audit: These are Validation Procedures performed by the Owner and can include tests, inspections, procedures and related actions performed by the Owner's third-party Quality Auditor (inspection agency) during and after execution of the Work to establish that work complies with Specifications and are typically additional to quality control and quality assurance activities performed by the Constructor.**

1.5.1 Quality Management Program (Documentation by [Constructor]): As described in Section 01 45 00 – Quality Management; QMP requirements described in this Section can form a part of the overall QMP required for the Project, and that address the following:

1.5.1.1 Quality Assurance (Validation Procedures by [Constructor]): As described in Section 01 45 00; [Subcontractor]s are required to contribute to [Constructor]'s concrete floor finishing validation procedures described in this Section.

1.5.1.2 Quality Control (Verification Procedures by [Constructor]): As described in Section 01 45 00.

1.5.1.3 Quality Audit (Validation Procedures by [Owner]): As described in Section 01 45 00.

SPEC NOTE: Definitions described in this Section do not create new words or different interpretations to existing accepted terminologies, the definitions listed in this Section use existing standards and terms to differentiate between the disconnect caused by differential tolerance standards that exists between measurements used by Division 03, Division 07 and Division 09 requirements.

1.5.2 *Flooring Products*: Moisture-sensitive surface finishes that are directly adhered to concrete substrates such as resilient flooring, carpeting, wood flooring, laminate flooring, and other similar flexible premanufactured finishes.

1.5.2.1 *Flooring Products* also includes adhesives and floor preparation products required to install the types of products described above.
1.5.2.2 Other moisture-sensitive *Flooring Products* that may require moisture testing include supported wood flooring, fluid applied and resinous flooring, and other flooring treatments that are not otherwise defined as *Flooring Products*.

1.5.3 Flooring Manufacturer: Flooring Manufacturer manufacturers *Flooring Products* and accessories including floor preparation materials, underlayments, adhesives, tools and maintenance materials and establish concrete substrate moisture tolerances, installation environmental conditions, surface preparation and moisture limitations that apply to their *Flooring Products*.

1.5.4 Concrete Surface Profile (CSP): Topographical contour, surface texture of exposed concrete surfaces or substrates as defined by the International Concrete Repair Institute (ICRI) and are required to establish acceptable mechanical bond between *Flooring Products*, applied finishes, mortar setting materials, fluid applied flooring, or cementitious coatings with individual material CSP requirements specified in RELATED REQUIREMENTS.

1.5.5 Permanent HVAC Systems: Permanent HVAC Systems refer to the permanent heating, ventilation, and air conditioning plant that operates at the service temperature and relative humidity to maintain interior environmental conditions similar to those required during occupancy of the building after completion of construction and is a requirement for performing both the ASTM F1869 MVER testing, and the ASTM F2170 RH testing described in this Section.

1.6 REFERENCE STANDARDS

1.6.1 American Concrete Institute (ACI):

1.6.1.1 ACI/PRC Concrete Slabs that Receive Moisture-Sensitive Flooring Materials
1.6.1.2 ACI 117.1R-[14], Guide for Tolerance Compatibility in Concrete Construction

1.6.2 ASTM International (ASTM):

1.6.2.1 ASTM D4263-[24], Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method
1.6.2.2 ASTM F710-[22], Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring
1.6.2.3 ASTM F1869-[23], Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride
1.6.2.4 ASTM F2170-[19a], Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-Situ Probes
1.6.2.5 ASTM F2659-[23], Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete, Gypsum Cement and Other Floor Slabs and Screeds Using a Non-Destructive Electronic Moisture Meter
1.6.2.6 ASTM F3191-[23], Standard Practice for Field Determination of Substrate Water Absorption (Porosity) for Substrates to Receive Resilient Flooring
1.6.2.7 ASTM F3311-[24], Standard Practice for Mat Bond Evaluation of Performance and Compatibility for Resilient Flooring System Components Prior to Installation
1.6.2.8 ASTM F3441-[24a], Standard Guide for Measurement of pH Involving Resilient Flooring Installations

1.6.3 Canadian Standards Association (CSA):

1.6.3.1 CSA A23.1:[19]/A23.2:[19], Concrete Materials and Methods of Concrete Construction/Test Methods and Standard Practices for Concrete = comprehensive curing and protection plan

1.6.4 National Floor Covering Association of Canada (NFCA):

1.6.4.1 NFCA Floor Covering Reference Manual
1.6.4.2 NFCA A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates
1.6.4.3 [NFCA Quality Assurance Program (QAP)]

1.7 ADMINISTRATIVE REQUIREMENTS

SPEC NOTE: ACI 117.1R describes the Consultant's responsibility for coordinating concrete work tolerances with tolerance requirements of other trades whose work adjoins the concrete work and identifying conditions that require coordination between those different trades.

- **ACI also states that finish and architectural details should be compatible with concrete tolerances.**
- **Inclusion of this statement makes a balanced risk statement and indicates to the Constructor and trades associated with the work that there are no 'hidden' design requirements that may be identified during the construction phase.**
- **It is the Consultant's responsibility to identify and detail components that are affected by coordination with concrete installation tolerances, several examples of this coordination and potential detailing are included in ACI 117.1R.**

1.7.1 Consultant's Specified Requirements: Consultant researched and incorporated appropriate measurement tolerances for materials, components, accessories and assemblies affecting performance outcomes associated with interior floor finishing during the design and documentation phases of the Project; and included descriptions within the Drawings and Specifications issued by the Consultant where appropriate.

SPEC NOTE: ACI 117.1R describes Constructors responsibility for coordinating the work of the trades contributing to the work associated with interior floor finishing that includes establishing a preconstruction tolerance coordination meeting and assigning responsibilities for achieving construction tolerances to the trades contributing to the work, and assigning responsibility to trades for correction of deficiencies when they are encountered.

- **The following item includes content based on the assumption that Constructors have a Quality Management Plan.**
- **The specification content includes guidance for coordinating the trades that contribute to floor finishing performance requirements that have direct impact on outcomes on the overall success of achieving the tolerances specified for the project.**
- **It is critical to maintain the separation between the Consultant and the Constructor's role when modifying the following content, and that content should not state specific means and methods.**
- **The specifications identify what work is required; the Constructor determines how that work is performed.**

1.7.2 [Constructor]'s Quality Management Program (QMP): Submit QMP indicating standardized approach to managing quality of materials and workmanship during execution of the work associated with achieving concrete finishing tolerances identified in the Specifications including the following:

1.7.2.1 Preconstruction Quality Planning: Develop preconstruction activities forming a part of the QMP in accordance with CSA A23.1, Article 7.1 and requirements of this Section.

1.7.2.2 Quality Assurance: Activities, actions, corrective remedies and procedures performed before and during execution of the Work by the [Constructor] to protect against defects and deficiencies and confirming that construction is consistent with specified performance requirements listed within the Specification.

1.7.2.3 Quality Control: Observations, procedures, and related actions performed by the [Constructor] during and after execution of the Work to verify that completed construction complies with specified performance requirements, standards and technical requirements listed within the Specifications

1.7.2.4 Limitations: Quality management activities performed by the [Constructor] do not include contract administration and reporting performed by the [Consultant] [or Quality Auditing activities performed by the [Owner]].

1.7.3 [Subcontractor] Contribution: [Subcontractor]s will coordinate requirements described in this section with the [Constructor] to identify installation conditions affecting concrete placing and finishing, and that affect compatibility of *Flooring Products* discussed during the pre-construction meetings described below, [Constructor] will incorporate comments as a part of the QMP.

1.7.4 Pre-Construction Tolerance Coordination Meetings: Conduct pre-construction tolerance coordination meetings in accordance with Section 01 31 19 – Project Meetings, attended by Owner, Consultant, [Constructor] and [Subcontractor]s whose work is affected by work of this Section to discuss the following before starting any concrete related construction:

1.7.4.1 Methods for aligning moisture condition tolerances for individual trades and Flooring Manufacturers contributing to the work, to those required by other parts of the work.

1.7.4.2 Confirming concrete density, absorption and surface profile required for installation of *Flooring Products*.

1.7.4.3 Resolve issues and implement management controls associated with meeting specified moisture condition tolerances.

1.7.4.4 [Management of unit price allowances described by this Section associated with meeting specified tolerances.]

SPEC NOTE: Temporary heating sources can change throughout the construction period and is typically controlled by the Constructor. Part 3 of this Section includes guidance of the types of temporary heating that could be used to prevent floor covering installation failures and that improve ability to maintain specified concrete moisture condition tolerances.

1.7.4.5 Management of temporary heating to maintain optimal concrete drying conditions, and management of temperature and humidity required for installation of *Flooring Products*.

1.7.4.6 Scheduling of start-up of Permanent HVAC Systems in advance of testing specified in this Section and that are required by the Flooring Manufacturer.

1.7.4.7 Managing floor flatness tolerances described in Section 01 84 21 – Interior Floor Finishing Performance Requirements.

1.7.4.8 Other topics affecting the work described in this Section.

1.7.5 Pre-Construction Meetings: Conduct pre-construction meetings starting approximately [1 month] before starting concrete work, and throughout the construction phase as necessary to achieve specified performance requirements in accordance with Section 01 31 19 – Project Meetings, attended by Owner, Consultant, [Constructor] and [Subcontractor]s whose work is affected by work of this Section to discuss the following:

1.7.5.1 Best Practices Meetings: Confirm best practices in accordance with NFCA A11 relating to workmanship required to achieve specified floor finishing performance including the following:

1.7.5.1.1 Sequence of work and confirmation of compatibility of installed materials and substrates including concrete mix design and finishing requirements and concrete curing and protection plans.

1.7.5.1.2 Responsibility for completion of substrate preparation and ambient weather measurements performed by [Constructor] before start of [Subcontractor] work described in this Section.

1.7.5.1.3 Responsibility for measurements and testing performed by the [Constructor] and that affects [Subcontractor]'s work described in this Section including testing schedule, identification of concrete drying strategies (mitigation and repair) and activation plan for Permanent HVAC System.

1.7.5.1.4 Installation follow-up procedures to reduce or eliminate substrate and installation deficiencies.

1.7.5.1.5 Using experienced, trained or certified [Subcontractor]s for components critical to achieving specified performance requirements.

1.7.5.1.6 Other procedures identified during best practices meetings that affect work results described in this Section.

1.7.5.2 Condition of Substrates: Confirm that concrete substrate moisture conditions are acceptable to Flooring Manufacturers written requirements for relative humidity, mechanical bond and porosity, smoothness and other conditions affecting quality of *Flooring Products* installation.

1.7.5.3 Measurement and Testing Frequency: Determine frequency and timing of site testing and observation reporting of moisture conditions to confirm acceptability for Flooring Manufacturers' written installation requirements.

1.7.5.4 Other topics affecting work described in this Section.

1.7.6 Coordination: Coordinate contributions from Division 03 and requirements from Division 09 associated with interior concrete floor preparation as follows:

1.7.6.1 Coordinate concrete curing methods proposed for use on the Project as specified in Section 03 39 00 with RELATED REQUIREMENTS and confirm that curing methods and materials, and substrate remediation methods and drying conditions are compatible with installation of *Flooring Products*.

1.7.6.2 Coordinate requirements for measurements, testing and preparation of concrete substrates as specified in Section 09 05 61.

1.8 SUBMITTALS

1.8.1 Provide required information in accordance with Section 01 33 00 – Submittal Procedures.

1.8.2 Information Submittals: Provide the following submittals during the course of work of this Section:

1.8.2.1 Substrate Condition and Compatibility Report: Submit confirmation that substrate conditions and applied curing agents [,] [toppings] and [underlayments] are acceptable for specified *Flooring Products*.

1.8.2.2 Moisture Condition Data: Submit moisture condition testing reports, concrete drying activities and date of start-up of Permanent HVAC Systems to [Subcontractor] before starting installation of *Flooring Products*.

SPEC NOTE: Refer to NFCA Floor Covering Reference Manual: Part A – General Requirements, Chapter A04 – Quality Assurance Program for information governing administration of the QAP, which is only applicable in jurisdictions where the Provincial Floor Covering Association adopts and underwrites the program, and only applies to the flooring materials included in the NFCA Floor Covering Reference Manual.

SPEC NOTE: Confirm which entity is receiving QAP Report in the following two subparagraphs.

- **Owner can directly contract with NFCA and should receive documents when this is the case.**
- **Constructor can also receive documents when QAP forms a part of their project cost deliverables.**
- **Consultant should always receive a copy of the QAP Report and is the only entity that issues additional instructions to the Constructor and Subcontractor/Trade Contractor when QAP Report describes non-conforming work.**

SPEC NOTE: The NFCA *Flooring Products* Quality Assurance Program is an additional quality checkpoint for the project additional to the Constructor's overall Quality Management Program.

- **The Owner also has the option of engaging with a third-party inspection agency to ascertain quality of concrete work, and conduct site observations and reporting instead of the NFCA QAP.**
- **This specification uses the terms "Owner's Quality Auditor" and "NFCA Accredited Quality Assurance Provider" when choice is required for selection of appropriate terms.**

1.8.2.3 [*Flooring Products* Quality Assurance Program: Submit a copy of QAP Request for Review Form to NFCA before starting work associated with *Flooring Products*, with a copy of the completed Request for Review Form sent to Consultant [,] [Owner] and [Constructor].]

1.8.2.4 [[NFCA Floor Covering QAP Reports] [Third-Party Observation Reports (Owner's Quality Auditor)]: Submit site observations prepared by NFCA Accredited Quality Assurance Provider] [Owner's Quality Auditor] to the [Owner] [,] [Consultant] [and [Constructor]]; Consultant will distribute report and instructions (if any) to [[Constructor] and] [Subcontractor]s when recommendations are reviewed and accepted.]

1.9 QUALIFICATIONS

1.9.1 Moisture Testing Agency: Engage an independent third-party moisture testing agency that employs experienced Moisture Inspectors who are familiar with specified test methods and equipment and that are certified by the International Concrete Repair Institute (ICRI), Institute of Inspection, Cleaning and Restoration Certification (IICRC), or that have successfully completed the NFCA moisture testing training, and who can provide proof of their credentials.

SPEC NOTE: Confirm that NFCA QAP is available in the region where the project is located and confirm with the Owner that they are aware of the benefits of the QAP prior to including the following in the project manual.

SPEC NOTE: NFCA QAP Accredited Quality Assurance Provider is a different entity from the Owners third-party quality auditing service.

- **The Owner can elect to use the NFCA QAP, or a third-party quality auditing service to conduct site observations, and report of conformance and non-conformance issues, the primary difference between these entities is as follows:**
  - **The NFCA Accredited Quality Assurance Provider is engaged by the NFCA and provides a report on the quality of installation *that permits issuance* of the NFCA QAP Maintenance Bond.**
  - **The Owner's Quality Auditor provides an independent review of the quality of installation, that provides the Owner with validation that the work complies with the specification but *does not permit issuance* of the NFCA QAP Maintenance Bond.**
- **The Owner can also elect to include both NFCA QAP, and third-party quality auditing service based on the complexity and quality expectations for the project.**
- **QAP Accredited Quality Assurance Provider is <u>only required</u> when Warranty Maintenance Bond is required under Special Warranty described in this Section.**

SPEC NOTE: Red Seal designations are recognized across Canada as providing testing and designations for trades; some provinces and territories provide apprenticeship training, and most provinces have a defined number of hours for the apprenticeship term. Saskatchewan is the only province that has no requirement for Red Seal or apprenticeship training.

1.9.2 Floor Covering Installer Qualifications: Engage floor covering [Subcontractor]s that maintain membership in the National Floor Covering Association of Canada [and that participate in the NFCA Quality Assurance Program (QAP)] [,] [and] [that employs Red Seal Floor Covering Installers experienced with the materials specified for the Project] [, and as follows:] [.]

SPEC NOTE: Include the following two paragraphs when NFCA QAP forms a part of the project specification.

1.9.2.1 [Subcontractor]'s Responsibility: Perform work of this section in accordance with requirements of NFCA QAP and make application and submittals required by QAP Acreditted Quality Assurance Provider.

1.9.2.2 QAP Accredited Quality Assurance Provider: Use QAP Accredited Quality Assurance Provider recognized by NFCA inspection and reporting requirements.

1.10 [WARRANTY]

SPEC NOTE: Include Special Warranty for floor covering materials and installation only when NFCA QAP is included as a project requirement. Coordinate this requirement with manufacturer warranties (if specified) under RELATED REQUIREMENTS.

1.10.1 Special Warranty – Floor Covering Materials and Installation: Submit NFCA QAP [2 year] 100% Maintenance Bond before declaration for Substantial Performance of the Work.

2 Products

2.1 PERFORMANCE REQUIREMENTS

2.1.1 Moisture Conditions: Moisture content, relative humidity and moisture vapour emissions rate required by Flooring Manufacturer, and that are specific to the specified Flooring Product described in RELATED REQUIREMENTS.

2.1.2 Drying Conditions: Protection of concrete after curing procedures have been removed and provide conditions that promote drying of concrete substrates as describe in the NFCA A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates.

2.1.3 Floor Product Installation: Install floor preparation materials and *Flooring Products* in accordance with NFCA Floor Covering Reference Manual, manufacturer's written instructions and requirements described in RELATED REQUIREMENTS associated with specified *Flooring Products*.

3 Execution

SPEC NOTE: A more detailed description of Acceptable Substrate Conditions is contained in the NFCA Floor Covering Reference Manual: Chapter A10 – Acceptable Conditions, which has specific recommendations for concrete flatness, levelness, placing and curing, testing requirements and specific coordination for concrete slab conditions.

3.1 EXAMINATION

3.1.1 Concrete Testing: Refer to [Section 03 08 30] [Section 03 31 00] for testing associated with concrete quality.

SPEC NOTE: Refer to NFCA A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates for procedures and recommendations for managing humidity, drying conditions, temperature and other factors affecting installation of *Flooring Products*.

- **NFCA recognizes the need for temporary heating systems during construction and is aware of problems that affect installation of *Flooring Products* as a result of these systems.**
- **Recommendations in this Guide Specification provide alternatives to temporary heating systems that are typically found on construction sites and should be investigated by the specifier as they complete the editing of this Section ready for their project.**
- **NFCA also confirms the requirements Permanent HVAC Systems to be operational in advance of moisture testing (ASTM F1869 and ASTM F2170) and installation of *Flooring Products* in accordance with Flooring Manufacturers' written installation instructions.**

SPEC NOTE: Exhaust gasses expelled from unvented, forced air, open flame propane heaters commonly used for temporary heating contain large quantities of water vapour (H_2O) and carbon dioxide (CO_2), which can be problematic for *Flooring Products*:

- **Increased H_2O in the air delays desorption of water and reduction of moisture content in concrete, and also causes localized hot-spots near the heaters and generalized cool-spots throughout the heated area that may cause inconsistent reduction of moisture content in concrete.**
  - **Localized hot-spots can decrease water content prematurely, decreasing potential for cement hydration and causing weakness in concrete surfaces.**
  - **Inconsistent temperatures can also contribute to changes in concrete flatness tolerances arising from differential drying rates of concrete slabs.**
- **Increased CO_2 in the air contributes to increased surface density of concrete through carbonation, which contributes to reduced surface porosity and can affect bond strength between adhesives and concrete substrates.**
- **Exhaust gasses also contain carbon monoxide (CO), which decreases indoor air quality during the construction period and safe work practices for construction workers and can affect consideration for credit criteria associated with many Sustainable-Design rating systems.**
- **Exhaust gasses also delay set-up or curing of many water-based applied finishes and adhesives used for floor covering installation.**

Coordinate specification content for Temporary Facilities and include descriptions of outdoor indirect temporary heating units, which also provides more consistent temperatures with lower H_2O content, and greatly improves indoor air quality during construction by eliminating exhaust gasses in the working environment:

- **Gas fired, forced air, outdoor indirect heating units distribute heated air throughout interior areas using flexible using easily relocatable ductwork; may not be suitable for larger projects since length of uninsulated ductwork causes lower temperatures further away from the heating units, and temperature cannot be locally adjusted with building areas.**
- **Gas fired; hydronic; outdoor indirect heating units distribute heated air using fan coil heat exchangers distributed throughout interior areas, and allow for temperatures that can be locally adjusted, multiple heat exchangers also provide more consistent heating in all areas.**
- **Specifier should make themselves aware of advantages and disadvantages of indirect heating sources and include appropriate direction to the Constructor.**

High relative humidity will affect installation of water-based adhesives and finishes and is a concern for most interior construction. Protection references Section 01 50 00 – Temporary Facilities because temperature and humidity are controlled at a project level by the Constructor, not at the trade level.

- **Constructors have correctly assigned specific temporary facilities such as lighting and fans to the trades requiring additional ventilation or illumination than provided for the project, because these temporary facilities tend to be isolated and easily controlled by the trades involved with the specific work result.**
- **Temperature and humidity cannot be controlled by individual trades, additional heating units brought to site at the time of installation of products affected by moist installation conditions cannot compensate for a whole building condition and should remain under the control of the Constructor.**
- **Controlled temperature and relative humidity will contribute to reducing air moisture content contributions from wet construction processes; moisture comes from many sources including concrete, gypsum board joint materials, water-based paints and applied coatings, adhesives to name a few.**
- **High relative humidity is a normal part of construction and is not considered a deficient condition unless it affects installation of products; and only becomes a problem when humid air encounters a temperature condition that reaches dew point and causes condensation.**
- **Relative humidity on construction sites can reach 60% to 80% depending on ventilation rate and air temperature; surfaces that are colder than air temperature can create conditions where dew point is a concern when water-based materials are installed on those surfaces:**

    - **High mass materials (such as concrete) require time to heat to match air temperature; meaning that the moisture concern experienced with installation of water-based adhesives on concrete may not be associated with the concrete but may become an issue with the water released by the adhesive when it cures and increasing the RH at the installation interface.**
    - **Air temperature at 20°C and RH 70% will reach dew point when it meets a surface temperature of slightly more than 14°C; or with an air RH of 80% at 16.5°C surface temperature.**
    - **Moisture moves from warm to cool; warm air combined with cool concrete equates to potential moisture issues, warm air combined with warm concrete greatly reduces concerns associated with dew point and additional water contained in construction materials.**

- **Different temporary heating sources can be employed based on the conditions that need to be maintained during construction or based on the type of construction.**
    - **Healthcare projects constructed to comply with CSA Z317.13 governing infection control during construction requires negative air pressure within the construction zone, makes using a forced air, outside indirect heating sources impractical during the finishing phases of construction – they cannot generate sufficient heat to account for the exhaust requirements to meet negative air pressure requirements.**
    - **Forced air systems may be practical during earlier phases of construction, but will require a switch to hydronic, outdoor indirect heating units connected to multiple heat exchangers to conserve energy and maintain heating budgets.**
    - **Section 01 50 00 – Temporary Facilities can anticipate these issues and describe expectations to the Constructor, but the Constructor is ultimately responsible for the means and methods deployed to control temperature and humidity of the construction site.**

- **Non-healthcare projects are not governed by the negative air pressure requirements of the CSA Z317.13 standard but require similar control over temperature and humidity during the finishing construction phase, and should form a part of preconstruction meeting discussions, and confirm the Constructor's approach to maintaining appropriate environmental conditions during construction.**

3.2 PROTECTION

3.2.1 Temperature and Humidity Controls during Construction: [Constructor] will install indirect temporary heating sources for building interior spaces in accordance with Section 01 50 00 – Temporary Facilities capable of maintaining consistent and controllable thermostats capable of maintaining temperature of substrates between 4.5°C and 26°C during initial placement and curing, between 18°C and 26°C to promote drying conditions and at a minimum of 5°C above air dew point.

3.2.2 Protection of Concrete Substrates: [Constructor] will protect concrete substrate surfaces from rapid drying and exposure to wetting conditions during construction to minimize surface contamination and provide a surface that is compatible with Flooring Manufacturers' written moisture condition tolerances, free from alkaline salts, dust and dirt, adhesives, paints and coatings, solvents and oils, grease, wax, form release agents, film forming sealers and curing aids, and film forming hardening compounds that are incompatible with flooring adhesives.

3.3 ALIGNING DIFFERENTIAL TOLERANCES

3.3.1 Consultant's Contributions: Consultant is responsible for identifying tolerances used for construction and aligning compatibility of differing tolerances between components of the Work in accordance with ACI 117.1R and has been completed as follows:

3.3.1.1 Consultant has accounted for compatibility between differing tolerances in the Drawings and Specifications and developed content that identifies measurement standards used for concrete floor finishing, and measurements required for installation of *Flooring Products*.

3.3.1.2 Consultant will review moisture measurement data compiled by the [Constructor] and collaborate with Owner, [Constructor] and [Subcontractor]s affected by work of this Section to determine acceptability of moisture conditions [and determine expenditures from unit price allowances for adjustments to the moisture correction products and procedures].

3.3.1.3 Consultant will provide written direction to [Constructor] for interpretations arising from measurements and testing that do not meet moisture condition performance requirements for installation of *Flooring Products* described in this Section.

SPEC NOTE: Delete the following when NFCA QAP does not form a part of the project specification.

3.3.1.4 [Consultant will review reports submitted by Floor Covering Accredited Quality Assurance Provider to determine acceptability of floor covering installations, and will provide written direction to [Constructor] and [Subcontractor]s for interpretations arising from recommendations contained in the report.]

3.3.2 [Constructor]'s Contributions: [Constructor] is responsible for managing coordinated-source concrete placing, finishing and curing of concrete, and establishment of a concrete protection plan described in this Section in accordance with CSA A23.1, Part 7 and the following:

3.3.2.1 [Constructor] will include or add content to their QMP that describes their approach for identifying and correcting concrete drying procedures.

3.3.2.2 [Constructor] will establish moisture testing and drying condition protocols as a component of their QMP provisions required to control concrete moisture conditions required to achieve Flooring Manufacturers' required moisture and concrete substrate surface conditions.

3.3.2.3 [Constructor] will perform continuous monitoring of moisture content in concrete in accordance with ASTM F2659 to monitor drying conditions of concrete and implement mitigation procedures when necessary to obtain acceptable moisture content described by electronic moisture meter equipment manufacturer and will perform the following tests indicating acceptable conditions before notifying [Subcontractor] to proceed with installation of *Flooring Products*:

3.3.2.3.1 Verify acceptable Moisture Vapour Emission Rate: ASTM F1869.
3.3.2.3.2 Verify acceptable Relative Humidity: ASTM F2170.
3.3.2.3.3 Verify acceptable Alkalinity: ASTM F3441.
3.3.2.3.4 Verify acceptable Concrete Porosity: ASTM F3191.

3.3.2.4 [Constructor] will coordinate with Flooring Manufacturer's written moisture tolerances and prepare a report of active and passive procedures associated with controlling concrete moisture conditions.

3.3.2.5 [Constructor] will notify Owner and Consultant of any differential between anticipated rate of concrete drying to observed rate of concrete drying [; Consultant will provide written direction for adjustment to unit price allowance when adjustments or changes to materials associated with drying procedures are required].

3.3.3 [Subcontractor]'s Contributions: [Subcontractor]s are responsible for managing surface preparation and monitoring moisture conditions during installation of Floor Products described within RELATED REQUIREMENTS and as follows:

3.3.3.1 [Subcontractor] will confirm the [Constructor]'s QMP modifications following pre-construction meetings specified above that they require to achieve Flooring Manufacturers' required moisture tolerances.

3.3.3.2 [Subcontractor] will review [Constructor]'s moisture control measures and testing results before starting installation of *Flooring Products* and confirm that moisture conditions are meet Flooring Manufacturers' written moisture tolerances.

3.3.3.3 [Subcontractor] will perform measurement and testing specified in RELATED REQUIREMENTS associated with their work result as follows:

3.3.3.3.1 Monitor moisture content of Concrete before and during installation of Floor Products: ASTM F2659.
3.3.3.3.2 Monitor potential Capillary Moisture: ASTM D4263.
3.3.3.3.3 Monitor surface Porosity Conditions: ASTM F3191.
3.3.3.3.4 Monitor surface Bonding Conditions: ASTM F3311.

3.3.3.4 [Subcontractor] will notify the [Constructor] when test results do not meet Flooring Manufacturers' written moisture tolerances or when the [Subcontractor]'s monitoring procedures identifies out-of-tolerance moisture conditions:

3.3.3.4.1 [Subcontractor] will pause their work and wait for [Constructor]'s correction to concrete substrates through additional drying procedures or application of surface applied moisture mitigation systems.
3.3.3.4.2 [Subcontractor] will resume their work after [Constructor] has corrected surface moisture tolerances in a manner acceptable to the Flooring Manufacturer.

3.3.4 Manufacturers' Contributions: Manufacturers will provide written instructions to [Subcontractor]s identifying product installation requirements including modifications to standard procedures, measurements and testing necessary to achieve specified concrete floor moisture conditions.

3.4 SITE QUALITY CONTROL

SPEC NOTE: Refer to NFCA A11 Best Practice: Moisture Testing for Floor Covering Installations on Concrete Substrates for Innovative Testing based on the use of ASTM F2659 as the primary test method for determining acceptable moisture conditions. This approach will require coordination and acceptance from the *Flooring Products* Manufacturers (adhesives and moisture sensitive floor coverings). Adjust the following site quality control procedures when the innovative testing approach is confirmed.

3.4.1 Measurement and Testing: Site quality control requirements are described in this Section and includes measurement and testing responsibilities of Owner, [Constructor] and [Subcontractor]s.

3.4.2 [Constructor]'s Quality Management: QMP will list measurements and testing and identify [Subcontractor]s responsible for site quality control requirements required to achieve requirements identified in this Section.

SPEC NOTE: Include the following when NFCA Floor Covering Quality Assurance Program is being used for the project. Coordinate with nouns used under INFORMATION SUBMITALS and use the same naming conventions for the following edits.

3.4.3 [NFCA Accredited Quality Assurance Provider: NFCA Accredited Quality Assurance Provider will prepare observations of the work including non-compliant work in accordance with NFCA QAP requirements and as follows:]

3.4.3.1 NFCA Accredited Quality Assurance Provider will notify [Owner] [,] Consultant and [Constructor] of observed non-conforming work, irregularities or variations from NFCA QAP requirements.

3.4.3.2 [Owner] [,] Consultant and [Constructor] will discuss options for correction to non-conforming work with [Subcontractor] responsible for the work to determine appropriate recommendations for correction.

3.4.3.3 Consultant will prepare written communication describing acceptable correction for non-conforming work and issue to the Owner, [Constructor] and [Subcontractor]s responsible for the work.

3.4.3.4 The NFCA Accredited Quality Assurance Provider is not authorized to release, revoke, alter or enlarge requirements of the Contract Documents, make changes to manufacturer's written instructions, nor approve or accept any portion of the Work.

3.4.3.5 The NFCA Accredited Quality Assurance Provider will not be permitted to perform any duties of the Consultant or [Constructor].

SPEC NOTE: Include the following when Owner chooses the services of a third-party observation and testing agency. The Owner can also opt to use both the NFCA QAP and a Quality Auditor when complexity of the project requires additional observation.

3.4.4 [Owner's Quality Audit: Owner may engage services of a third-party observation and testing agency to perform quality auditing services necessary to validate [Constructor]'s quality assurance and quality control procedures described in the QMP; scope of service provided by the Owner's quality auditor will be limited to the following:]

3.4.4.1 Quality auditor will notify Owner, Consultant and [Constructor] of non-conforming work, irregularities or deficiencies observed during the performance of its services.

3.4.4.2 [Owner] [,] Consultant and [Constructor] will discuss options for correction to non-conforming work with [Subcontractor] responsible for the work to determine appropriate recommendations for correction.

3.4.4.3 Consultant will prepare written communication describing acceptable correction for non-conforming work and issue to the Owner, [Constructor] and [Subcontractor]s responsible for the work.

3.4.4.4 Quality auditor is not authorized to release, revoke, alter or enlarge requirements of the Contract Documents, make changes to manufacturer's written instructions, nor approve or accept any portion of the Work.

3.4.4.5 Owner's quality auditor will not be permitted to perform any duties of the Consultant or [Constructor].

3.5 CLOSEOUT ACTIVITIES

3.5.1 Cleaning: Keep installed work clean as installation progresses in accordance with Section 01 74 13 – Progress Cleaning and perform final cleaning as required by Section 01 74 23 – Final Cleaning, coordinated cleaning activities described in RELATED REQUIREMENTS.

3.5.2 Demonstration [and Training]: Provide demonstration and training for Owner's personnel associated with specified *Flooring Products* in accordance with Section 01 79 00 – Demonstration and Training, coordinated with maintenance activities described in RELATED REQUIREMENTS.

END OF SECTION