TECHNICAL BULLETIN – TB040

SUBFLOOR PREPARATION – SOURCES OF MOISTURE AND DAMP SLAB PROBLEMS

Date, Monday, 15 September 2014

INTRODUCTION & SCOPE

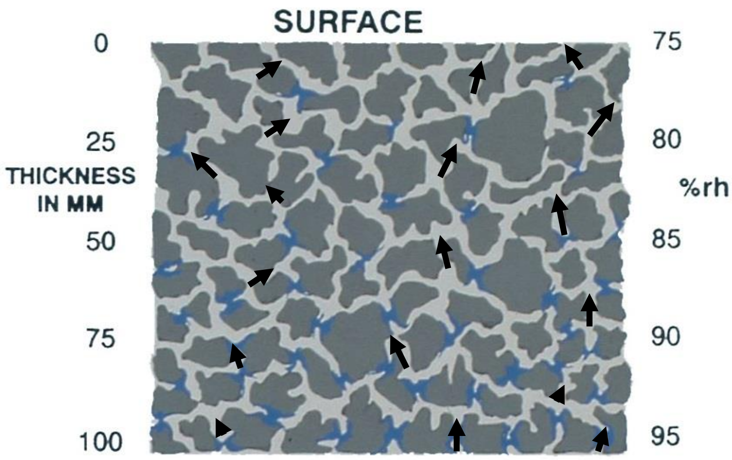
Problems with excessive moisture in both new and old concrete substrates have been around for many years, causing concerns to the contractor, layer, and client. They often result in costly blow-ups and failures – which seem to be more prevalent in recent times.
There are many reasons for excessive moisture in concrete substrates, remembering that moisture can travel hundreds of metres sideways through the concrete by capillary action, and not just appear over the exact cause or source.

OLD CONCRETE

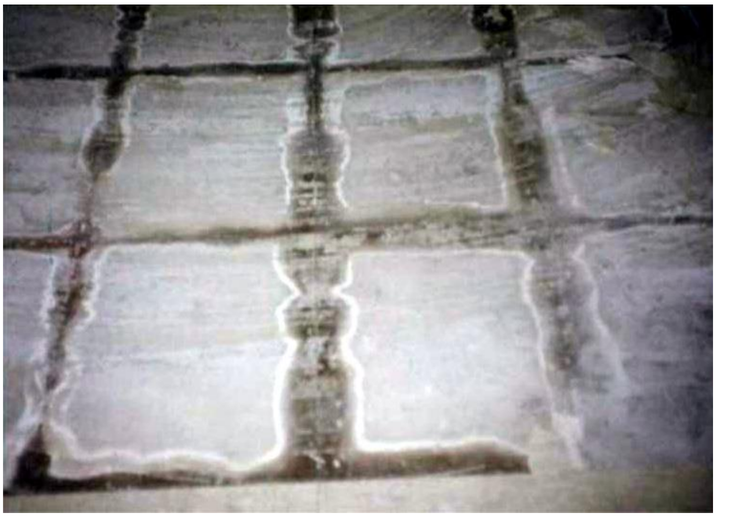
In the case of very old concrete, chances are there was never a moisture membrane used under the slab in the first place. If a membrane was used, it may have broken down over the years or possibly it was punctured during the installation of reinforcement and placing of concrete, rendering it useless.
A typical example of a problem faced by layers dealing with old slabs is when an existing floor covering, for example vinyl floor tiles bonded with old bitumen adhesive ("black jack") is removed. It is replaced with a welded sheet vinyl. The old vinyl tile installation has shown no apparent signs of moisture problems; however, the sheet vinyl soon starts to show signs of bubbles and lifting. In fact there may always have been a slight moisture problem. Although the tiles may have been laid when the ground and concrete were dry, subsequent changes in the moisture content of the ground beneath have penetrated the porous concrete. While no hydrostatic pressure was present, the concrete was like a sponge and the adhesive and tiles just held on, retaining most of the moisture. As well, the gaps between the tiles have allowed water vapour transmission (WVT) to occur. When an impervious membrane like welded sheet vinyl is installed, totally locking in the moisture vapour, the new flooring has to give.
The problem will be exaggerated if air conditioning has been installed since the tiles were originally laid. The warm ambient temperature above the floor will entice the moisture upwards from the slab. When you remove the old tiles and "black jack" adhesive, you get a "taking the plug out of the bath" effect. These types of problems are exacerbated in areas of high water table, high humidity, or high rainfall wet seasons, for example tropical Australia, Tasmania or New Zealand.

Moisture can rise from the base of the slab and build up over time beneath the impermeable vinyl covering resulting in bubbling of the floor covering.

Where the subsurface is permanently damp the moisture then travels into the slab and upwards.



The adjacent floor was in a supermarket and had vinyl tiles laid over an existing slab. In this case the membrane has either failed, or none was installed and so moisture was penetrating to the base of the tiles. After the tiles were removed, the dampness pattern where moisture was rising through the tile joints was revealed.



BELOW GRADE SLABS

Slabs which are 'below grade', for example excavated or cut into the side of a hill can also suffer from severe problems, as there is generally a build-up of hydrostatic pressure forcing the moisture upwards. Even if the membrane were laid correctly under the slabs, the moisture can enter via the sides where the backfill has been done without drainage to take the moisture away, or where water physically runs onto the slab edges.

In new buildings, moisture problems can also be caused by water penetration through the sides of the slab, either as the result of heavy rain, or sprinklers on garden beds which have been formed without some sort of drainage, or the lack of a membrane coating up the sides and edges of the slabs or retaining walls below grade.

The site shown is a dwelling with a below grade slab. Water due to surface run off onto the surface, and also percolating ground water in through the base and edges have penetrated the slab and resulted in high moisture contents in the slab. A vinyl installation was put in place without a membrane and suffered de-bonding due to rising damp.

LEAKING PIPES AND BUILDING ELEMENTS

Leaking pipes or broken underground drainage are common problems in old commercial premises and are sometimes impossible to isolate. Other parts of the building can leak, and the moisture travel through out the construction, leading to difficult to identify sources. Examples include leaking gutters and downpipes, leaking building facades and curtain walls, leaking door and window frames and leaking roof membranes.

Usually the flooring has been installed during the summer of a dry spell. A week of heavy rain can result in an installation with moisture problems, which normally leads to the layer or contractor receiving the blame for something that is beyond their control.

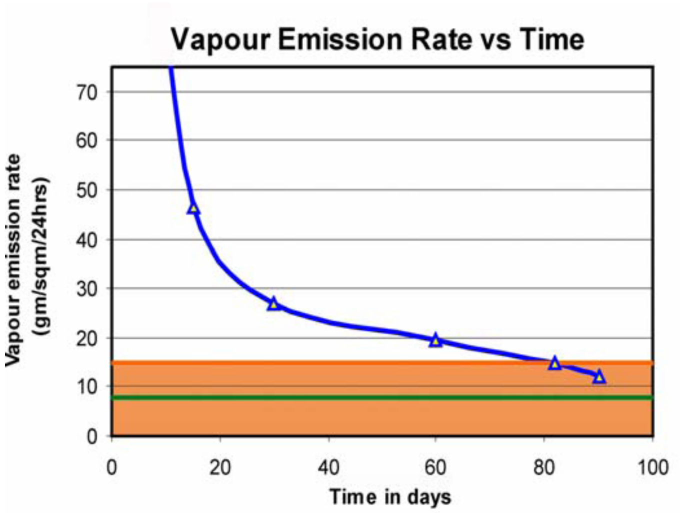
NEW CONCRETE

New concrete is a real problem for the layer today. No one has the time to let the concrete cure properly, bringing the moisture content down to the correct percentage. Pressure is always put on the contractor to go ahead prematurely, even though he knows he will be the one taking all the risks.

There are many reasons for concrete taking longer to dry out sufficiently to meet the requirements of the Australian Standards. One of these is due to the speed that modern building techniques can erect buildings (often being to the lock up state with windows in place far earlier these day) not allowing sufficient ventilation and air movement over the concrete. Evidence of this can often be seen by condensation forming on the windows due to evaporation of water during the concrete drying stage giving high humidity readings. In many ways, the US market is more advanced in site based research and knowledge with regards to vapour emissions, if not in the use of relative humidity measures.

The accompanying graph gives an indication of the moisture vapour loss rate of fresh slabs. In this case the slab is 100mm thick and placed on Forticon membrane. The acceptable vapour transmission rate is 15gm/m^2/24hrs (3lbs/1000^{2}Ft/24hrs) shown by the upper limit of the shaded area. As can be seen it may take up the best part of 3 months to achieve a transmission rate that is satisfactory to lay resilient flooring.

The filled area defines is the maximum value allowable and the lower green line is the result achieved using Ardex Moisture Barrier. Adapted from Suprenant & Malisch (1998a). The method basis is ASTM F1869 and gives 'MVER' values.

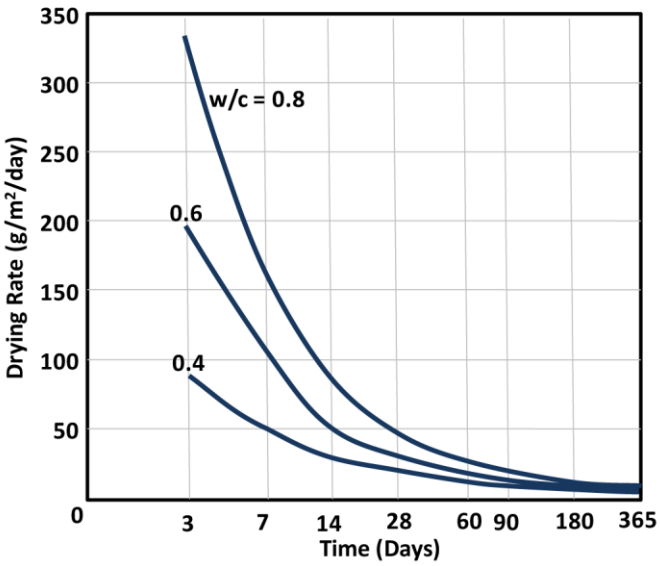


Whilst the flooring standard AS1884 has been revised in 2012, the old standard AS1884-1985 - Appendix A contains this interesting paragraph in *Determination of Dryness of Concrete Subfloors A3, Approximate Drying Times of Concrete:*

"As a general "rule of thumb" it has been found that under average conditions in Melbourne, and with good ventilation, a typical 100mm thick slab of normal concrete, drying from one face only, will take about four months to dry to a moisture content in equilibrium with the surrounding air. If ventilation is poor, the humidity high, or the temperature low, drying will naturally take longer; on the other hand, with good ventilation in hot weather, drying will speed up. It should also be noted that occasional wetting of the concrete surface will reverse the drying process, because dry concrete absorbs moisture rapidly. Consequently, drying time should be calculated from the time when the slab was last wetted by rain or dew. Even scrubbing of the surface before the floor layer commences work, should be voided as far as possible".

The basic measure here is that the required drying time approximates to 1 day per millimetre concrete thickness from each exposed face to reach equilibrium with the surrounding air. Whilst much of this useful information still holds *senso latto* true, more recent research has shown the numbers are not always *senso stricto* true and the 2007 Cement Concrete and Aggregates Australia publication 'Moisture in concrete' gives a more complex picture. The drying is not necessarily linear for thickness-time and going from 100mm to 150mm doubled the drying time, and tripled it going from 100 to 200mm. Other work suggests that 200mm slabs can take up to 12 months to dry adequately from one side, but this is halved for two sided drying.

When made, the concrete only requires 1/3 of the added water for the cement hydration reaction and the remainder is for workability so this water has to evaporate over time. It needs to be recognised that the cement-water ratio has a critical role in the drying rate. The usual recommended ratio is around 0.4 to 0.5, but can go over 0.7 when poorly controlled, and high ratios increase drying times not only because of more physical water, but also because the porosity of the concrete is changed as well due to the development and closure of capillaries. Recent types of high density concretes have been noted to dry more slowly than the figures quoted here due to closing of pores and trapping of moisture, so caution is urged on applicators to check moisture levels.



The graph at left shows the effect of increasing the water-cement ratio on the moisture emission rates.

From Building & Construction Research & Consultancy. TN024 Concrete and Moisture Sensitive Coverings.

So many times when the client is asked when the slab was poured, the answer is “months ago”. One would think this would normally be sufficient time for curing, however maybe the roof did not go on then, or the windows were not installed, therefore in theory the drying time should be adjusted from the last time the slab was wetted by rain.

An interesting contrast is typical sand-cement or granolithic screeds used under tile finishes; which dry at a rate of around 1.0mm thickness per day.

AIR-CONDITIONING

Air conditioning appears to be playing a major part in moisture related blow-ups, especially in new construction work. Clients will notice that most problems occur a short time after the air conditioning is commissioned, which is sometimes up to three months or more after the flooring has been installed.

Most installation procedures are done in a fairly stable ambient temperature, which does not initially lead to any problems. However, a combination of little things can accumulate to cause problems: the slab moisture content was fractionally outside the recommended tolerance, the levelling compound was mixed with more water than recommended, the adhesive was applied before correct cure of the levelling compound and wasn’t allowed to tack off correctly, this leaves us with excess moisture. Another situation that can occur is high ground moisture levels which may not have enough pore pressure to cause rising damp, but provide a latent source of moisture which can penetrate the slab.

This may be okay at the ambient temperature during construction, but when the air conditioning is commissioned, the dehumidifiers in the plant remove the moisture from the air. This can result in an unbalanced situation with relatively dry air above a source of moisture and so any excess moisture is drawn upwards causing problems.

A similar effect can result from slow combustion stoves which tend to dry out the air and also encourage water vapour formation, which when the environment cools down, forms liquid water which can accumulate under impervious surfaces.

What do the standards say on this matter? The revision of the resilient flooring standard makes the following suggestions;

***AS1884-2012 Floor coverings—Resilient sheet and tiles—Installation practices*:**
“4.1.2 Air-conditioned areas

Where air conditioning is installed, no underlay or floor covering shall be laid on the subfloor until the conditioning units have been in operation at the expected operating temperature & humidity levels for at least 7 days. During this period the temperature and humidity shall not be allowed to fall outside the recommended limits of the manufacturer of the floor covering. These conditions shall be maintained during laying and for 48 hours thereafter.

NOTE: Without such temperature control at this stage, subsequent failure of the subfloor, underlay or underlayment and floor covering may occur"

and

AS/NZS 2455.1-2007 Textile floor coverings – Installation practice. Part 1: General
"2.4.2 a) Air-conditioned area*, Wherever possible no underlay or textile floor covering shall be laid on the subfloor until the air-conditioning units have been in operation at normal operating temperature for at least 7 days".*

THE AUSTRALIAN STANDARDS

Flooring contractors are strongly advised to obtain copies of the Australian Standards for floor covering installation. However, there are those who do have copies but never seem to read them and they see them as a handicap rather than a benefit.

The standards are an excellent guide and a selling tool, which can be used to qualify prices and procedures relating to quality installations. They are also an excellent form of protection and assistance in getting a signed release of liability when the contractor is instructed to proceed with work practices, which contravene those Standards.

Ardex strongly recommends that contractors familiarise themselves with the provisions of the Australian Standards.

The following excerpts are taken from AS1884-2012 and AS/NZS2455.1-2007 (together with the two excerpts already discussed above) and define two **'golden rules'** for installers in relation to moisture.

AS1884
3.1.1.2 Dryness
Before subfloor preparation is performed and a floor covering is laid on a concrete subfloor, the dryness of the concrete shall be determined as described in Appendix A.

Appendix A - A3.1 Concrete subfloors

A3.1.1 Test methods
Wherever possible the relative humidity in-situ probe test in accordance with ASTM F2170 shall be carried out on the subfloor as, even though the surface may record an acceptable moisture content reading, this may not be the case beneath the surface. The only exception to using this test is where there is in-slab heating, a security system, an anti-static wiring installation or where slabs have been treated with a penetrative moisture suppressant. In these cases the surface mounted insulated hood test in accordance with ASTM F2420 shall be performed.

A3.1.2 Relative humidity in-situ probe test
Concrete subfloors shall be considered sufficiently dry when measurements taken in accordance with ASTM F2170 do not exceed 75% relative humidity. Three tests shall be performed for the first 100 m^2 and at least one additional test for each additional 100 m^2 and other recommended positions in accordance with ASTM F2170. Refer to the adhesive manufacturer's recommendation for acceptable relative humidity levels for their product.

A3.1.3 Relative humidity surface mounted insulated hood test
Concrete subfloors shall be considered sufficiently dry when measurements taken in accordance with ASTM F2420 do not exceed 70% relative humidity. Three tests shall be performed for the first 100 m^2 and at least one additional test for each additional 100 m^2 and other recommended positions in accordance with ASTM F2420. Refer to the adhesive manufacturer's recommendations for acceptable relative humidity levels for their product.

NOTE: The surface of the test area should be mechanically prepared to ensure it is clean, open and porous

It is important to recognise that the figures are very different to the older AS1884 with removal of the 5.5% moisture content measured with an electrical probe, and relegation of the surface relative humidity test and 70% RH to a lesser option. Research showed that when the surface was covered over with impervious flooring, moisture rose from below to restore equilibrium rendering surface measurements less reliable. It was found that 5.5% moisture content equalled 85%+ RH, and 70% RH at the surface was equivalent to around 3% moisture content. The newer requirement of 75% RH at 0.4x slab depth is a tighter specification and is approximately equal to 2% moisture content (similar to the DIN standard requirements) and 60% RH at the surface. The textile floor covering figures are less stringent.

AS/NZS2455
2.4.2 c) Subfloor preparation
(i) *All subfloor surfaces shall be dry, smooth, plane sound and clean (see Appendix A). Dryness shall be considered satisfactory when relative humidity by the hygrometer test does not exceed 70% in Australia or 75% in New Zealand.*

NOTE: For the determination of subfloor dryness, methods detailed in Appendix B are recognised procedures.

The procedures described in the appendices are the in-slab and surface hygrometer methods.

The in-slab hygrometer method is intrusive and requires the use of probes which are placed into holes drilled in the slab to a depth of 0.4x the slab thickness. The method measures residual moisture and depth and avoids problems where surface drying could lead to the low moisture figure being measured.

The surface method is the older style method, is non-intrusive and the equipment is relatively cheap and at its most basic requiring only a fairly simple temperature and humidity sensor and a plastic container to seal the device in. There a number of issues with this method and it has been placed as the secondary method for user where holes in the slab are not possible.

Remember that once a contractor has accepted the contract he is deemed to have tested (amongst other things) the substrate for moisture.

Surprisingly, many contractors do not have testing equipment, although it is relatively low priced. If you haven't this facility to buy or hire this equipment then there are reputable people who offer a field-testing service which includes a written report.

If you conduct your own reading and the results are border-line, Ardex highly recommends that you have another test done with calibrated equipment from a professional company to save any demarcation problems down the track.

There are many other reasons for damp slab problems, such as cutting penetrations and trenches through the slab, breaking the membrane, bad drainage and ventilation under above-ground slabs – the list can go on and on. However, by using correct procedures, there is usually a way to prevent these problems before they arise.

PROCEDURES TO OVERCOME MOISTURE PROBLEMS

Concrete slabs laid on ground need to have a below slab barrier applied over the subsoil, sand or gravel base. Typically these barriers are made from heavy duty plastic sheets 0.2mm thick (c.f. 'Forticon' sheeting). The requirement for these sheets is described in AS2870, whilst the equivalent American Standard ASTM E1745-2009 has a permeability specification for these sheets of 0.1 Perm when measured by ASTM E96 (this value is a very low level of permeability). Examination of the effects of a sub-slab barrier by Suprenant & Malisch (1998b) showed that where a plastic sheet was in place, the rate of moisture transmission was reduced by between 44 and 54 gms/m^2/24hrs (9-11lbs/1000^2Ft/24hrs) compared to concrete without a barrier (note that when this testing was done, an older version of ASTM E 1745 then in force allowed a higher permeability of 0.3 Perm). This shows how essential a correctly installed plastic barrier is in reducing hydrostatic and ground water infiltration.

Then we need to look at the concrete itself for example when it is fresh ('green'), the sub-slab barrier has aged, or the situation where the slab is not on grade but above it. The Australian and New Zealand standards do not specify the ASTM F1869 "MVER" test for measurement of slab moisture, but use relative humidity; the countries differ slightly with regards to the allowable relative humidity when measured by surface tests (NZ at the time of writing has not adopted AS1884-2012 and hence ASTM F2170). Where time allows, the simplest method of dealing with new concrete is to let it dry naturally to an acceptable moisture content level as defined above.

Alternatively where time does not allow waiting, and it is known that construction water is the source of the moisture, Ardex offers a solution to seal the concrete surface in the form of a single coat of Ardex WPM300 Hydrepoxy. However, the recommended moisture content should be less than 90% relative humidity (at 0.4x depth) or 85% (surface measurement) and reducing since a single coat does not provide a full barrier protection.

Alternatively an application of Ardex WPM368 will provide a moisture barrier that is single part and does not require sand blinding or use of a primer.

In all other situations including new slabs and old damp slabs, the most effective and proven system uses Ardex WPM300 Hydrepoxy. The system is based on a special two pack water based epoxy system which is simply rolled on in two separate coats, allowed to cure, then primed and a levelling compound is applied as a normal floor preparation. Once cured, this membrane will give a moisture barrier equivalent to that of a sheet of polyethylene at 1.2mm thick and will withstand 25 metres of head of hydrostatic pressure. The water vapour transmission is 7.9gms/24 hours /m² @32°C@100% vapour pressure which is close to half the maximum value nominally recommended by the American Floor Covering Institute for resilient flooring to be laid.

Ardex Moisture Barrier/WPM300 can be used internally or externally and can be installed over damp surfaces and fresh concrete only 24 hours old.

More recently in the US market, a new standard ASTM F3010-13 has been introduced, which for 100% solids two part moisture barriers (i.e. epoxy such as Ardex MC) requires a permeability of 0.1 Perms (the same as plastic sheeting for sub-slab barriers). This standard does not apply to WPM300 or WPM368 which are water borne systems, and WPM300 has been measured to have a permeability of 0.6 Perms, which has been perfectly suitable in Australia-New Zealand contexts. What this means however, is that for critical applications with highly non-permeable resilient flooring, a higher level of performance can be achieved with non-water or solvent borne epoxy barriers.

Refer to Ardex Technical Bulletins TB006 or TB192 for the full barrier system or TB172 for a moisture suppression system for green slabs.

References

Suprenant B.A & Malisch W.R. (1998a) Are your slabs dry enough for floor coverings? Publication #C980671, The Aberdeen Group.

- (1998b) Don't puncture the vapor retarder; Even small holes increase water-vapor emissions. Publication #C981071, The Aberdeen Group.

AS1884-1985. Australian Standard. R. Floor coverings—Resilient sheet and tiles—Laying and maintenance practices.

AS1884-2012. Floor coverings - Resilient sheet and tiles - Installation practices.

ASTM E96/E96M. Standard Test Methods for Water Vapor Transmission of Materials.

ASTM E1745-2009 Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs.

ASTM F1869-2011. Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride.

ASTM F2170-2011. Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes.

ASTM F2420-05 (2011). Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood.

ASTM F3010-2013. Standard Practice for Two-Component Resin Based Membrane-Forming Moisture Mitigation Systems for Use Under Resilient Floor Coverings.

REASON FOR REVISION

Revision of references including ASTM F3010. Changes of text including sheet underslab barriers. Addition of WPM36, and mention of Ardex MC.

REVIEW REQUIRED

24 months from issued.

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