COLD WEATHER IMPACT ON TILE SYSTEMS

Block B Ceramic Tile and Construction

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Abstract

Cold weather, and its impact on tile related systems is something that is often overlooked and misunderstood. There are instances when this issue has impacted on tile and waterproofing systems, resulting in failure and poor performance on some projects. The problems which often become apparent, such as aesthetic defects, bond failure, and waterproofing fillet failures are commonly attributed to poor installations or products. Reasons for failure are often given when analysis takes place long after installation. However, breakdowns in the system can be an effect of cold weather at the time of installation rather than later mistakenly attributed to an alternative problem/cause. Often blame is apportioned incorrectly with subsequent costly rectification orders, even though problems/causes have not fully considered the impact of cold weather.

Some examples of problems arising from the cold weather impacting on tile and waterproofing systems can include:

- Leaking / Failure of waterproofing to internal and external areas;
- Some subfloor(screed) failure/ degradation;
- Tile delamination, either partially or completely;
- Leeching of various types of residue from grout joints, perimeter and surrounding area of tile work;
- Discolouration/ appearance issues in some types of stone;
- Grout failure/ degradation;
- Discoloured grout;
- Efflorescence; and
- A combination of the above occurring either with internal or external situations

Regional Effects

Many regions that don't receive snow or multiple days of freezing, are considered generally to have climates ranging from temperate to hot. It is difficult to always make accurate tiling and waterproofing assessments for many areas where climate and temperature variations are unpredictable. The areas that experience cold weather that can impact tiling and waterproofing systems are greatly underestimated. Without delving into the science of Global weather patterns, simple research on regional patterns of weather will show large areas which are subject to cold weather (below 10 Degrees C[50f]). Areas such as North America, Canada and Northern Europe would be regarded as naturally cold regions and where steps would be necessary to accommodate cold weather [2]. However, this is not an adequate indicator for areas that would experience varying degrees of cold weather that would significantly affect tiling systems as previously mentioned. Some areas affected by this type of weather, reach from Australia, Southern Europe, Southern America and even into higher regions of Africa. Temperatures in many areas can consistently be below 0 degrees Celsius at night. Daytime temperatures also can consistently be from 15 degrees Celsius (59 degrees Fahrenheit) down to 5 degrees Celsius (41degrees Fahrenheit)[2]. These are not collated into scientific format as the area affected is too large, and temperature variation too great. The effect on a given product/systems for each region is too complex and extensive to determine and outside the scope of this document. Many large cities such as Sydney, Rome and Shanghai where temperatures can often drop below 5 degrees Celsius (41 degrees Fahrenheit) in winter and would not be considered as cold areas [3].

Product Guidelines

Most products used in tiling and waterproofing applications have indicated setting and curing times in their data sheets [8]. Commonly this will be a time to set at 20 or 23 degrees Celsius (68-73.4 degrees Fahrenheit) for the full time of setting which is usually 24 hours or more. A level of humidity is also often referred to in relation to the expected time to set/cure. Even a basic generic mortar or Screed mix containing cement, sand and perhaps lime has an expected curing time of approximately 1 week per 10mm (.4 inch) thickness of material.

This applies to normal Ordinary Portland Cement (OPC). However, there is a difference between a set mortar/screed and a dry one. OPC hardens under water, so can be hard and still water logged. This can cause multiple failures when covered by tile. A rule of thumb for OPC cure could be, speed decreases about six times, dropping from 20 to 5 degrees Celsius (68-41 degrees Fahrenheit), and virtually stops below 5 degrees Celsius (41 degrees Fahrenheit). Cement hardening is a crystallization process which requires liquid water in the initial stages. If the water is frozen, then no setting takes place. Therefore, from 5 degrees Celsius (41degrees Fahrenheit) to 0 Celsius, setting time increases exponentially. There are special admixtures used in cold climate to enable this

process to take place below 0 Celsius (32 Fahrenheit). These products work by dropping the freezing point of water. These products are seldom found and not usually specified for use in moderate climate areas.

The specified temperatures on a product data sheet are intended as a guideline, not a guaranteed performance outcome in all situations. A variation in setting times can be expected once the temperature and humidity vary from these recommendations. In many instances these setting times are referred to and relied upon by contractors, without considering the impact of temperature/ humidity figures of the actual jobsite especially overnight. Cold weather will nearly always result in dramatically extended setting and curing times. Projects are often subsequently scheduled around unrealistic setting and curing expectations. Even in instances where a tiling contractor may attempt to consider extra time needed for setting, other contractors on busy sites will often identify a vacant area which has been left to cure and commence other activities upon the work without consideration of the tile system requirements.

Many people involved in the tile/ waterproofing process are unaware or at least underestimate the effect of slower setting times. The combination of some, or all of the following can contribute to problems developing:

- Tile/ waterproofing contactors not familiar with and understanding the full meaning of setting times on data sheets;
- Building contactors being used to "always doing it that way";
- Product sales representatives, failing to grasp the full impact and the extent of cold weather on their product;
- Product Sales Representatives, Retailers, Architects and Head Building Contractors not fully explaining the extent of how cold weather will affect setting capabilities and the likely impact on the end user;
- Product representatives not being fully aware of temperature variations in a given region because site visits to such regions occur on limited basis;
- Incorrect product selection for application to a potential cold weather climate environment; and
- Inadequate product range being available to suit application as the location for use is not regarded as a cold weather climate environment.

Possible Problems

The combination of problems that can arise through slowed curing and setting at different stages are extensive and almost limitless. However, major issues are those arising from uncured underlays/screeds, waterproofing, tile adhesive, grout and lippage control devices (clip systems).

Uncured underlays/screeds:

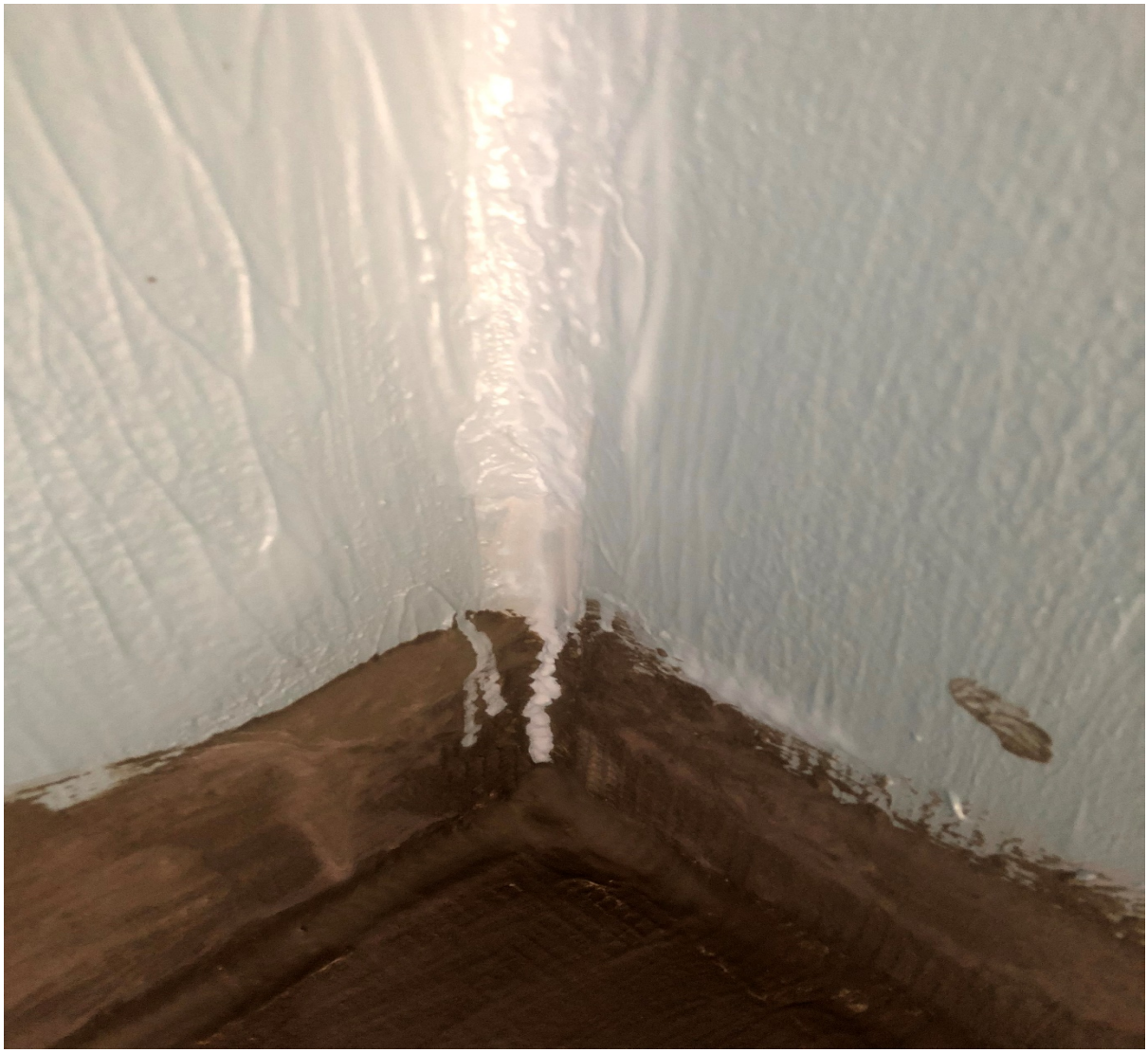
Underlays and Screeds which are not cured properly and are impacted by foot traffic or commencement of the tiling process can degrade quickly, especially on the surface.

Crumbling and delamination can occur at the surface layer and separation can also occur at the point of bond to the substrate. Even once tiles are installed the adhesive setting time required can be impacted by excess moisture in the substrate. Subsequent access by others to the tiled surface can easily result in partially broken bond at the weakest point in the installation. Failing to account for the impact of cold weather can create several points where there could be issues arising in the future.

These underlays/screeds also need to be dry. This term is often misunderstood and confused with "cured". If a screed contains moisture, there is a large potential for leeching from efflorescence or adhesive polymers if tiles are installed over a wet substrate. Rain and low temperatures can combine to cause such problems as there is no way for the moisture to escape. It is also important to note the thickness of a screed/underlay. The drying rate follows Fick's Law of Diffusion which says that the time to dry increases by the square of the pathway length. This means a screed or underlay that is twice as thick needs four times longer to dry. This calculation assumes no further rain or moisture impact throughout the drying process.

Waterproofing

Depending on membrane selected there can be multiple issues for this step in the tile installation process. Single part acrylic/ SBR membranes require specific humidity and temperature to cure. Again, it is also important for the substrate to be dry as well as cured. There can be confusion when comparing with cement/concrete where cured and dry are intermixed. Membranes must dry and stay dry long enough for film form properly as per the data sheet. When these requirements are not met, this type of product will be impacted heavily if not allowed to cure adequately. Issues such as excessively damp substrate, impervious substrate including silicone/polyurethane bond breakers of various types, and rain/moisture impacts while curing, all will negatively affect this type of product. Most Liquid Polyurethane membranes for example, will not start to set until the temperature is well over 10 degrees Celsius (50 degrees Fahrenheit). They can actually take months to cure. (See photograph 1)



Photograph 1

This image shows a waterproofing membrane 2 days old, applied over a fillet bond breaker. The temperature is insufficient for curing of the membrane to take place. The membrane curing remains in a liquid state.

Tile Adhesive

Although there are many types of adhesives, popular products with an "E" classification (extended open time) are particularly vulnerable [5]. Any adhesive that hasn't set adequately is subject to delamination by having the adhesive bond broken by people accessing the installation before setting has taken place. This can be can be due to early setting which comes from the cement component. However, the polymer component does not film form well for at least a week under good conditions. This is more important as the tile size increases and if the application is subsequently applied onto a waterproofing membrane or non-porous surface. Most drying of tile adhesives comes from absorption by the substrate. Water cannot dry out through the tile and can only leave upwards through the grout line. If the tile is installed over a membrane,

particularly one which has been laid for some time and is well cured, then the water in the adhesive can only escape through the grout line. Both low temperatures and impact of moisture such as rain will slow the curing of the adhesive significantly. If there are installations that are exposed to rain or mist continually, any voids under the tiles, such as those from un-collapsed notched trowel application will further retain water. This in turn retards the setting of the adhesive dramatically. (see photograph 2)

Photograph 2

This image displays lack of adequate bond in the centre of the tile. The trowel technique has added to the ability to retain moisture. The tiles are 600mm x 600mm (24-inch x 24 inch) installation was done directly to waterproofing membrane during winter in Sydney, Australia. There was rain on the installation and the average temperatures in the installation period range from a high of 18 degrees Celsius (64 degrees F) and average low is 9 degrees Celsius (48.2F) [3].

Some documents such as ISO guidelines (ISO17870-2) [4], indicate that the time frame for drying could be measured in weeks for an application such as Thin Gauged porcelain panels. I have observed installations over waterproofing where the centre of the adhesive in the panel is still completely wet after 2 years. Efflorescence and/or polymer leeching from moisture contact with uncured adhesive is also a possibility. (see

photograph 3). This is particularly likely in the event of rain contacting externally installed work. In some cases, once the uncured adhesive has been impacted enough by moisture the degradation of the adhesive is permanent and its performance will be permanently adversely affected. Subsequent bond failure is very likely in this scenario. (see photograph 4)

Photograph 3

This image shows extensive polymer leeching which began to take place early after completion. There was rain on the installation and the average temperatures in the installation period range from a high of 18 degrees Celsius (64 degrees F) and average low is 9 degrees Celsius (48.2F) [3].

Photograph 4

This image shows degraded adhesive which is weakened and crumbling through lack adequate curing and moisture impact.

Grout

All grouts are affected by low temperatures. Setting is slowed in cementitious, polymer modified, acrylic and epoxy products. This could result in discolouration, efflorescence, or poor resilience once put into service. If the grout process is undertaken too soon, then efflorescence will occur. It is often assumed that the only requirement for grouting to be undertaken, is when the tiled floor is trafficable. Grouting work can trap moisture beneath tiles which can accelerate adhesive degradation.

Lippage control devices (clip systems)

Premature removal of the lippage control devices even under normal temperature conditions can have serious consequences. This issue has been raised previously *'Issues with tile installation levelling devices' by Colin Cass at Qualicer '16* [7]. Cold temperatures which have slowed/ halted the setting process of an adhesive would impact the bond of a tile when removed before adequate setting has taken place. In instances were tiles have been forced or "bent" flat against their natural shape, this is even more critical. The pressure of the tile to revert to its original profile would cause

increased pressure on uncured adhesive. This could lead also to bond failure after a time.

Longevity of Performance

The impact of the above possible problems (not an exhaustive list) plus other factors may not become obvious for some time. It could be a few months or a few years until any combination of the problems listed become apparent. Less drying shrinkage at an early age means more drying shrinkage at later age. If the shrinkage occurs when the adhesive is still soft, there is little built in stress. If the adhesive stays wet for a long time, it will set and harden, but the polymer will not film form properly.(see photograph 4) When it then begins to dry, the drying shrinkage causes a harder mortar to form and the stress build up on the tiling system is greater. Combined with poor results for the polymer, which is added to manage shrinkage stress, the tile is more likely to pop. *ISO 13007 (Grouts and Adhesives)* [6] has the heat stress test as part of its scope to determine the characteristics in this type of circumstance. It should be noted that some adhesive manufacturers only show the dry bond and wet bond strengths and not the 70 degrees Celsius (158 degrees Fahrenheit) Heat Stress test.

Photograph 5

The image above shows adhesive on tiles in various states of final curing. The tile bonded around the edges strongly, then less well towards the centre where prolonged moisture content and slow setting has retarded the outcome. Poor trowel method has exacerbated this problem.

Experts or adhesive manufacturers may be consulted to assess the cause of a tiling system failure in the case of warranty claims. At this point it is likely that unrelated or additional influences are blamed for the problems at hand. Issues such as notch trowel sizes, trowel method and back buttering and movement joints are factors which could be identified to indicate incorrect installation but may not be the major factor of influence. Expansion joints, slab construction, membrane thickness, type of adhesive product, environmental impacts such as sea air exposure and even mixing procedure of the product used can (sometimes incorrectly) be found as the cause of many of these problems. Of course, it isn't always easy to prove the impact or occurrence of some of these factors without expensive lab testing. Often the adhesive manufacturers or consultants don't know how to go about testing, and facilities to carry out such work are not readily available. If other causes are cited as cause of failure, it is quite possible the same products, methods and weather constraints are used and will impact the rectification work. Cold weather is usually never considered as its impact at the time of failure and is extremely difficult to prove.

Calculating the Impact of Cold Weather on Products

For the user of tiling products, it would be sensible to attempt to calculate the setting time as adjusted for the temperatures that are impacting the installation. There are usually no guidelines on packaging to calculate adjustment, only limitations of use. As a result, the contractor is obliged to estimate setting time based on the conditions which are going to impact on the project. Many products have 20 degrees Celsius (68 degrees Fahrenheit) as a quoted temperature to achieve setting time. Using this information, one scenario could be where an installer attempts to calculate a reasonable solution by themselves. It may be thought prudent by the installer to double the allowed setting time for an apparent halving of the temperature on site. For example, a reduction of temperature from 20 degrees Celsius (68 degrees Fahrenheit), to 10 degrees Celsius (50 degrees Fahrenheit). This also would mean a further reduction in temperature to 5 degrees Celsius (41 degrees Fahrenheit) on site would logically indicate a need to double the setting time again and perhaps double again for a temperature of 0 degrees. This is clearly unscientific and better described as a guess. Unfortunately, the effect on setting times is actually worse than this example as the response is nonlinear. It would be more accurate to triple these calculations. Unfortunately, once again, this type of calculated guess is neither accurate or reliable.

Many products are restricted for use below 5 degrees Celsius (41 degrees Fahrenheit). It is important to note that ambient temperature and surface temperature often differ.

Surface temperature of the substrate is commonly lower than ambient temperature, which further exacerbates error in judgement in suitability for product application.

Two important matters need serious consideration in the context of ambient and surface temperatures. What is the measurable impact of these realities and how is it applied to any given situation? What are the calculations and steps necessary to be taken at any given temperature for the contractor? This information is not on product packaging or data sheets. To compound these issues, the additional heat sink effect of a cold slab is almost impossible to estimate, but it is safe to say it is usually grossly underestimated. Many product labels only reference that they aren't to be allowed to freeze. This is probably an obvious and reasonable requirement. However, this doesn't give an indication of how much longer it will be before the products have set/cured enough in order to commence the next step of installation.

In reality an accurate calculation is not possible. The setting is slowed and increased at different rates for different products as the temperature fluctuates. Temperature and humidity are also regionally and locally variables that add even more combinations of influences. Indeed, products such as some polyurethanes used in the waterproofing process become static below 5 degrees Celsius (41 Degrees Fahrenheit) [8] and can cease setting at all. It can also be safely assumed that 10 degrees Celsius is the temperature required to start the setting action of many adhesives. If 10 degrees Celsius (50 Degrees Fahrenheit) is the desirable minimum temperature for many chemical processes in adhesives to take place, what can be expected if an installation experiences fluctuating temperature both above and below this figure? So, if for example, temperature fluctuations are unknown overnight, it isn't realistic to expect a tile contractor to accurately calculate the length of time a series of products will take to dry/cure in such a fluctuating environment.

By way of practical example, I will refer to research and subsequent calculations I made for the application of a popular waterproofing product in a particular region in Australia. The region of the Australian Capital Territory could be regarded as of moderate climate in a global context. Maximum temperature ranges of 8-40 degrees Celsius (46-104F) for winter -summer periods, and 0 to 20 degrees Celsius (41-68F) minimums for winter-summer periods [1]. I found when cross referencing weather records for a 12-month period for the area of application, that there were only 9 days in that year likely to provide the conditions required by the manufacturer to achieve setting as stated on the data sheet. By making further reference the Australian Bureau of Meteorology data and matching it to a popular C2S1(as defined in ISO 13007) [5] adhesive, I found there were only 6 days of the year in which the weather was in congruence with setting times. In alternative lower altitude more temperate areas [1], it was apparent that between 20 and 30 days per year would have optimal weather conditions to suit setting requirements. To calculate these results, I made an allowance for an additional 1 degree Celsius (33.8F) to give a best-case scenario for what appears on the data sheet of the adhesive to meet manufacturer's conditions. This is not to say these products won't set, but that setting is likely to be different from the data sheet. The additional time required for setting to take place in order to satisfy manufacturer's conditions is difficult to know without further practice and research. It is safe to conclude that areas all over the world

having similar weather variations to Australia, would also face the same risk with product not drying/curing as per manufacturer's product guidelines. It is arguable that weather variations are not fully considered by Industry when using and specifying waterproofing or similar products.

Possible Solutions

There are some possible solutions to the cold weather influences. They are of varying practicality depending on individual sites.

Heating the jobsite

It may be possible to heat the jobsite for internal works to a level that can facilitate more realistic setting times. In reality many new build construction sites are not practical to heat due to issues such as expanse of site, ability to seal off the area due to uninstalled windows or doors and the size of the heating unit to achieve the temperatures required. Indeed, even the type of heating can be detrimental, for example, gas heating which can cause chalking carbonation which weakens mortars and grouts. This solution is obviously not possible for external applications.

Hot water/heating of products

Hot water can be used in adhesives to speed up or initiate the setting process. This has a variable effect as it depends on the magnitude of the cold weather present and the appropriate timing as to when to commence/halt/slow/cease the process. This method is only useful if there is access to hot water at the jobsite. Keeping liquid and powders components warm prior to use can also help to initiate setting the process.

Use of fast set products

There are many options available for fast setting components to the tile/waterproofing system, Screed additives, fast cure membranes, fast setting adhesives and grouts are available. These are often an overlooked solution and should be utilized far more regularly. Not all fast setting products will be a total solution as many still need optimal temperatures to be effective. Cost is also something to consider when utilising this type of product. Using a system of these products will certainly cut down on the moisture retained and slow setting of the whole process. This approach should be considered as a recommended method during colder periods.

Installation Practices

Installation which minimises voids for moisture to gather is also critical. Any voids created by poor installation practices should be eliminated. Failing to properly collapsed notch trowel ridges for example will allow moisture to gather and possibly be retained and thus retard the curing of adhesive. If grouting is installed over moisture such as this, then it can prevent adhesive from curing properly at all

Covering Work

In external situations covering methods such as tenting should be utilized as common practice. As already mentioned, rain on exposed work will introduce moisture which will be difficult to remove. (see photograph 5 and 6) For installations such as pools, it is critical to allow the entire construction to be protected from unwanted moisture ingress. The Curing of the shell and any subsequent installation of tile systems is essential for long term performance.

Photograph 5

This image shows external work exposed to rain during winter. Some joints aren’t filled allowing ingress of water.

Utilising Moisture meters

It would be beneficial if moisture meters were used to determine the suitability of substrates for an indication of dryness. This would be of particular value for external applications as it would give a more realistic indication of when it is suitable to proceed with each step of an installation.

Longer setting allowances

Allowing longer times for each process to set and cure is of course optimal. This is increasingly less practical as time frames on most construction projects tighten. This remains as an unlikely option but may be a cost-effective option in some instances. Adhesive that appears to be set in a tile joint is not an indication of the progress of a curing process in the centre of a large tile. External applications subject to freezing would simply have to be delayed to an optimal time of year.

Improved Guidelines

Adhesive manufacturers could introduce further guidelines which help installers decide on correct process and product selection based on temperatures experienced. Further testing of adhesives could be carried out by manufacturers to determine the parameters of adequate curing and setting. The ISO (13007) [6] guidelines such as the 'pull up test', which establishes a 'C' classification, could be utilised to determine this information in a universally beneficial measurement.

Conducting various pull off tests at various temperatures (for example 10 degrees Celsius or 50 degrees Fahrenheit) for various time frames. One, two or 3 plus days at a reduced temperature would provide information about how a particular adhesive will perform. This is important as contactors only have classifications such as C2S1[5] for adhesives, to use as performance guides. These classifications do not provide enough information to gauge the impact of cold weather on a tile installation. Some products could be described on packaging as 'Summer' or 'Winter' products for an easier choice by contractors.

Other Considerations

- Cold weather characteristics are influences many contractors should consider more seriously. Each contractor should be aware of their own regional weather impacts on installations and should design them accordingly. Extra time for setting and curing should be insisted upon when required.

- Product suppliers should consider broadening their range of fast setting products to customers in colder areas. This would have the effect of improving the range of products available across the market and by encouraging other manufacturers to develop quality fast cure products.

- Adhesive manufacturers should stress the importance of cold weather and moisture issues when conducting training and trade days.

- Product manufacturers should clarify the extent of setting delay due to the impact of cold weather rather than just having an acknowledgement that it exists. It may be beneficial to have 'Summer and 'Winter' products.

- Training organisations such as trade schools should include in their relevant syllabus, the challenge cold weather and moisture presents and provide solutions to mitigate risks facing potential new trades people in the industry.

- Architects and building contractors should acknowledge cold weather and moisture as a possible risk issue and adjust actions, schedules and specifications on projects before and during construction to mitigate those risks. This is particularly important in relation to waterproofing as it is part of a critical aspect of the construction.

Photograph 6

This image shows preparation for silicone joint installation where work is clearly not ready for this process. This installation is in Sydney Australia during winter. The average high temperature is 18 degrees Celsius (64 degrees F) and average low is 9 degrees Celsius (48.2F) [1].

Conclusion

It is important to the resilience and longevity of tiling installations that cold weather is considered. The whole industry is negatively affected from failing installations of tile and waterproofing. There is also a massive environmental cost to rectifying failed work, particularly as tile is intended to be a long-lasting quality finish. Waterproofing has a function to protect aspects of a construction and when this fails the damage is usually significant. Undertaking the installation process multiple times contributes needlessly to waste of product and resources and has a significant reputational detriment to the tiling industry.

Although many of the effects and characteristics mentioned in this paper are quite possibly well understood on a scientific level by chemists and manufacturing experts, the impact of cold weather is an issue that needs addressing, and awareness of problems associated should be raised across the waterproofing and tiling related construction industry.

References;

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