

Introduction

There have been instances of floor failure due to tenting following the installation of overlay timber floors when direct adhesive fixed to concrete slabs during hot and very dry conditions. The dryness of the air is measured by the relative humidity (RH), so when the average relative humidity is very low (35% and below) the air is very dry. If timber flooring is also very low in moisture content (around 9% and below) then the width of the boards will change little under these conditions. However, although these periods of low humidity may persist for some time, at other times of the year there may be periods when the average relative humidity is significantly higher and around say 70%. Under these conditions the timber floor will take up significant amounts of moisture from the air and swell as boards try to achieve a moisture content of about 12.5%. It is this scenario that this information sheet covers and such conditions often occur in locations such as South Australia.

Purpose

The purpose of this information sheet is to:-

- alert installers to the potential for this often expensive floor failure condition to occur
- make installers aware of the climatic conditions that can induce failure
- provide an understanding of the factors that slow the curing of the moisture curing (MC) polyurethane adhesives during dry conditions and the effect that moisture vapour barriers have on this.
- outline the differing effects between the flexible and more rigid polyurethane adhesives
- provide recommendations for installing directly adhered flooring in hot, dry, low humidity weather.

Background to tenting failures

As indicated above direct adhesive fixed overlay flooring when laid in hot dry conditions of low relative humidity have been prone to 'tenting' floor failures from the subsequent expansion of the timber floor when it takes up moisture (refer Figure 1). This is more likely with the higher density hardwood floors.

Most of the tenting failures examined by ATFA inspectors have been from floors laid in extended hot, dry periods where timber moisture contents at installation are about 9% or below. During these times the Equilibrium Moisture Content (EMC), which is moisture content that timber will approach under specific conditions of humidity and temperature, is also very low and in the order of 6.5%. Due to this, high levels of expansion occur when seasonally moist conditions return and EMC's rise to say 12.5%. In such installations the normal provision for expansion in terms of cork joints or gaps beneath skirtings are unlikely to be sufficient.

Characteristic of these tenting failures is a shear rupture failure of the MC polyurethane adhesive (refer Figure 2) from the timber expanding beyond the adhesives elongation-at-break property.



Figure 1 - Tenting in an overlay floor

The tensile strength of the adhesive (strength when stretched) is also considered to play a role. Higher tensile strength adhesives with associated higher strengths at failure, provide higher restraining forces on the expanding timber floor. This provides for a degree of mechanical restraint to timber floor expansion as it takes up moisture.

Tenting failures occur less frequently when the overlay floor has been mechanically fixed, that is pinned to the underlying slab. Tenting is also less likely to occur when the floor has been laid on plywood, then glued and mechanically fixed with cleats or nails.



Figure 2 – Shear failure of MC adhesive from high timber movement.

Moisture cure polyurethane adhesives need moisture to cure!

The moisture from the air reacts with the adhesive's 'free NCO' Isocyanate and completes the conversion of the partly cured adhesive in the form it is used in, into a completed tough polymer.

Studies by TAMSA International Consulting have shown that there can be a significant difference between brands of MC adhesives regarding their rate of reaction and curing time to achieve full cure properties, such that timber movement is restrained. It has been demonstrated that in low EMC conditions, some polyurethane adhesives can take many months to cease being mobile and achieve a normal cure state. This is related to the chemistry and formulation of particular adhesives. On one installation that failed in South Australia from board movement, the adhesive was still tacky some 6 months after installation.

The tenting is aggravated by partially cured adhesives that do not have the restraining power that more fully cured adhesives would have. Analysis of many tenting failures in has shown that the proportion of failures substantially increases with slow curing rate adhesives.

It appears conclusive that floors that are laid in hot dry periods can take an extended period of time to cure and result in a higher degree of floor expansion from when the flooring does start to take up moisture. As such the bond strength is compromised by slow curing and any movement that occurs during this time.

The three sources of moisture that are available for the MC adhesive to cure are:-

- from contact with the air
- extracted from the concrete below
- extracted from the timber

It follows that in very low humidity, the availability of atmospheric moisture is also very low, especially during the brief open time on the floor. The use of moisture vapour barriers (MVB's) is now common with ground floor direct fix installations. The use of a MVB severely restricts moisture availability from the concrete slab to assist in the curing reaction. Note that tenting failures in previous years of directly adhered floors where no MVB had been used was extremely rare for similar climatic hot and dry periods. It is therefore considered that one of the main sources of moisture to facilitate cure, i.e. from the concrete slab, has been closed off through the use of MVB's.

Timbers that are very dry, at or below 9% moisture content, also have little available moisture to facilitate curing of the MC adhesive. Generally flooring is manufactured in the range from 9% to 14% to meet the manufacturing standard AS 2796, however it is not uncommon for overlay flooring to be manufactured toward the lower end of this range. The reason for this is that thin material will be more reactive to climatic conditions and when manufactured at lower moisture contents it is less susceptible to gapping after installation. Similarly, some pre-finished flooring products are also known to be of low moisture contents. Once the timber is coated, or if pre-coated this further slows the availability of the moisture diffusing through to the underlying adhesive. A property called moisture vapour transmissibility (MVT) of the coating type impacts the rate of moisture uptake into the timber as does the number of coats.

Recommendations for overlay flooring in low EMC conditions

Swelling with moisture uptake from EMC changes

Humidity and temperature impact on the EMC and resultant expansion of timber. Typical unrestrained expansion for hardwood in an 80 mm wide board is about 0.25 mm for each 1% change in moisture content. The fixing and particularly with a full bed of adhesive will reduce this movement significantly and may only be a third of the unrestrained movement. The conditions outline in the table below are more likely to occur in summer, in southern and inland regions of South Australia and the table illustrates the degree of swelling that could be expected if timber flooring was loose laid in a typical room width of 5 m. Floors do not expand by this amount due to the fixings but this translates to pressure in the floor which must be withheld by the fixings.

Installation Conditions			After installation	
Temperature (°C)	Relative Humidity (%)	EMC (%)	EMC (%)	Unrestrained expansion over 5 meters (mm)
20	45	8.3	12.5	66 mm
25	40	7.3	12.5	79 mm
30	35	6.4	12.5	96 mm

Board restraint and tenting

Adhesives provide significant restraint to natural board expansion and if the adhesive bond is compromised due to initial slow curing the subsequent pressure in the floor during times of moisture uptake and expansion can result in tenting.

So the tendency to tent can be reduced in a low EMC environment, direct fix installation by:-

1. Use of mechanical fixing of the overlay timber to the concrete slab. The more the fixing the greater the fixing strength. However, this can also contribute to peaking (a cupped appearance due to pressure effects at board edges).
2. Using MC adhesives that cure faster in situations of lower moisture availability.
3. Using MC adhesives that have greater tensile rupture strength.

Some have suggested that in situations of very low EMC, to lightly mist spray water onto either the adhesive or the base of the timber prior to fixing. This or any other remedial measure would need to be endorsed with appropriate written procedures by the adhesive manufacturer to be recognised by the ATFA.

Consider alternative installation methods

These might include laying onto plywood, where the plywood is mechanically fixed to the slab and the overlay timber is both mechanically and adhesive fixed to the plywood.

Conclusions and summarised recommendations

In periods when the EMC is low (below 9%), **be aware** that once the floor takes up moisture, large degrees of floor expansion pressure can occur, with the worst-case situation being a tenting failure.

Review the intended installation with the adhesives manufacturer concerning the environmental conditions and specific advice regarding their adhesive and MVB use. Any advice should be in writing and the advice if complied with should result in the warranty applying.

Check the moisture content of the flooring prior to laying and do not acclimatise the flooring to the dry conditions.

Consider MC polyurethane adhesives that show improved cure rate in low moisture availability situations.

Consider MC polyurethane adhesives that cure to a higher strength so as to provide improved fixing strength.

Consider installing over plywood.

Delay installation to a moister period with higher EMC (over 9% recommended).

Be aware that if the floor gaps after installation it may be more prone to edge bonding with some finish systems.