Delamination of concrete floor surfaces

*Advisory engineer **John Plimmer** discusses the phenomenon of delamination*

Delamination of concrete floor surfaces – which is where a thin layer of the surface mortar separates from the main body of the slab – appears to be on the increase in the UK. The same seems to be true in the USA where three articles[1] have been published by the Aberdeen Group. These set out to explain and quantify the parameters involved when various forms of delamination occur and explain why it is not always the floorlayer's fault. By arrangement with the Aberdeen Group, photocopies of the three articles can be obtained by application to The Concrete Society.

The layer can vary from being paper-thin up to about 8mm, depending upon the mechanism involved and the area can vary from a centimetre or two across up to several square metres, again depending on the mechanism involved. However, it is important to stress that in the UK – although the number of delamination problems brought to the attention of the Concrete Advisory Service appears to be on the increase – many thousands of square metres of high-quality concrete floors displaying no such problems are constructed every day.

What is probably beyond doubt is that most delamination occurs in power-finished floors, now the accepted and only practical way of finishing large modern industrial floors. The author is not aware of any such problems with hand-finished floors in the past.

Floating and trowelling

For the finishing process to be successful, the concrete surface must behave uniformly in terms of its stiffening characteristics. It must therefore be thoroughly mixed, with close control over the workability of successive loads. Warm conditions, particularly drying winds, can affect the stiffening rate adversely and significantly reduce the 'window' available for finishing. Conversely, cold and damp extend the setting time and reduce evaporation extending the period until finishing can take place. Both these extremes can cause difficulties for the floorlayer.

Power trowelling requires considerable skill – not just in working the equipment to produce a dense uniform finish but in 'reading' the concrete to know when to carry out the various operations.

Overlayering

With delamination, there is a tendency to look for complex reasons for the problem when it is simply the result of smears or overlayering caused by transporting mortar from one area to another. This can happen in a number of ways:

1. The bad practices of adding water to the surface to liven up a concrete which has stiffened to the extent of making finishing difficult or impossible is fairly well known. Also most sites are similarly alert to the practice of applying water and scattering cement powder over the surface and then using the float to work up a slurry coating. The finished result in both cases is fairly characteristic and the failure is easy to identify.
2. Overlayers can also be created when the concrete surface has not been sufficiently well flatted before floating. The action of the float, and perhaps the trowel later, will tend to remove mortar from the high spots to fill the hollows. Because the concrete has stiffened to some degree, the lower undisturbed surface can be effectively sealed and not very conducive to bonding with the applied mortar skin: in effect a cold joint is formed.
3. Overlayers can also be created around the perimeter of concrete areas that have stiffened at different rates. This can happen when the concrete delivery has been delayed or the workability has varied significantly. However, it has also been found that variations in stiffening can occur with admixtures or with slag and pfa cement systems. But these materials can all offer considerable advantages in the right circumstances.[2]

Overlayering occurs because part of an area reaches a condition where it is ready for floating while the adjacent area is not. It is therefore necessary to start work on the ready area and return later to work on the adjacent area. Sometimes it may be possible to marry the boundary between the two areas without blemish but if the delay is too great the harder area becomes scored and too damaged for the trowel to subsequently heal. The temptation therefore is to work on the softer area as soon as possible and it is then that smears of material can be transported over the harder surface.

There are a number of variants of the overlayering theme, some quite subtle and difficult to ascribe to a precise cause unless the finishing processes are being very closely watched. Sometimes the finisher will not even realise that thin skins of mortar are being transported by the equipment. Considerable detective work can often be necessary.

With all overlayering, the surface of the delaminated area of mortar in contact with the underlying concrete is characteristically 'moulded'. The contact surface of the delaminated layer is usually slightly open in texture but is smooth and reproduces the features of the surface of the concrete below. This surface usually has a grey mortar finish with markings and characteristics present at the time it was overlayered. There may be a slight lime bloom. There will generally be no torn surfaces or exposed aggregate surfaces and no signs of the fine particle separation that occurs if water were present.

In the case of (1), the mortar forming the delamination layer is invariably fine-grained and may be weak. With (2) and (3), the mortar layer, unless very thick, generally tends to be finer grained than the underlying concrete. If it is thick, it may be stratified with an upper region densified by trowelling and a less well compacted region beneath. The layer is usually quite hard and brittle.

Delamination

True delamination as opposed to overlayering is a debonding process caused by bleeding. Bleeding is the process by which water in the plastic concrete rises towards the surface as part of a sedimentation process. All concretes bleed to some degree.

In certain conditions, the top surface of the concrete can stiffen such that it is ready for the finishing operations while the underlying concrete is still relatively plastic and capable of bleeding. There is then a danger that the densification of the surface due to floating and trowelling can seal the top and trap the bleed water still trying to rise to the surface. A plane of weakness is then formed: see Figure 1a. If further trowelling takes place at a critical time, this plane of weakness can be extended as shown in Figure 1b. There is no way the floor finisher can realise this is happening unless blistering occurs, as illustrated in Figure 1c. Here a feature which looks exactly like a blister forms under the action of trowel blades. The pressure exerted by the blade tends to spread the bleed water, completely separating the mortar layer from the concrete. The dragging effect of the blade and the pressure relief behind produce a lifting action and the mortar layer is squeezed thinner allowing it to dome upwards to form a blister. Air from within the concrete and water partly fill the void but additional air must be drawn down through the mortar layer immediately behind the blade. Playing a significant role in this blister formation is the dragging action of the blade due to the contact surface of the mortar being too dry and hence lacking lubrication. At the same stage the mortar skin probably splits, slightly letting out water to provide lubrication, so limiting the size of the blister while allowing air to fill out the void.

The conditions leading to this family of defects require a concrete that has a tendency to bleed slowly over a long period and is subjected to climatic conditions causing rapid surface evaporation and consequent stiffening. Low humidity and particularly breezy conditions will cause rapid evaporation, resulting in stiffening if the bleed water rate is low. A low bleed water rate over a prolonged period may be associated with high ggbs cement contents and the use of some admixtures[2]. A cool subbase is also likely to make matters worse. A fine-grained cohesive mortar is also necessary. High cement mixes or those with pfa are likely to produce the right characteristics but a fine sand is also necessary. A coarse-graded sand will probably tend to make the concrete bleed faster but if the water is trapped the disturbance of the coarser grains in the surface layer of the mortar during finishing almost certainly provides an escape mechanism for accumulating bleed water.

With such a defect, the surface characteristics of the underside of the delaminated layer varies depending upon the severity of the problem as illustrated in Figure 1. The surface will be granular and, in marginal cases as in Figure 1a, the particles will be well covered with cement paste There will be some clean surfaces of aggregate due to the presence of water and there may be evidence of lime bloom and silty material on the exposed concrete surface. In severe cases, the surface will still have a granular texture but washout will be more evident, with more clean washed surfaces and clean silt and fine sand present.

Air-entrained concrete

Much of reference 1 concerns the delamination problems with air-entrained concrete, which is not usually a problem in the UK as air-entrained concrete is generally only used for the floors of some coldstores and blast freezers. However, the Concrete Advisory Service has been involved in significant number of cases where the concrete has ended up air-entrained – in some cases heavily so – when admixtures apparently not designed to entrain air have been used. The reasons for this are being investigated.

Entrained air has a marked effect on bleeding. The tiny air bubbles, deliberately introduced into the mortar by an admixture, form in the spaces between solid particles and in effect form an almost perfect grading. The mix requires less water and sedimentation is much reduced. Bleeding for all practical purposes is negligible. Unfortunately, this means that the concrete can be very prone to premature drying and stiffening effects which can turn cause finishing problems.

Because bleeding is markedly reduced, the top surface of the slab is vulnerable to rapid stiffening due to evaporation. The body of the concrete below behaves normally and remains plastic, stiffening gradually through the chemical reaction of the cement. Nevertheless, the surface condition of the slab governs when finishing can begin, as otherwise finishing will become impossible. A possible explanation is that the surface can become very dry during the trowelling process(es) – causing considerable drag within the surface mortar layer – whereas the lower part of the layer 2-3mm down is still plastic and cohesive. The series of shearing actions due to the passage of the trowel blades cause the air bubbles to coalesce to create a layer of flattened elongated voids with weak mortar walls.

Where the air content is high – say 8% – large sheets of surface mortar can slide free of the underlying concrete during trowelling. With fine sands, blistering, as described earlier, may occur[3]. With lower air contents, the surface may apparently finish quite well with delamination occurring days or weeks later, when surface drying shrinkage causes the breakdown of the 'cell' walls.

The surfaces of the fracture plane are generally coarse and grey with flat bubble sites and broken walls just detectable.

Air-entrained concrete is undoubtedly difficult to power trowel successfully and so best avoided. And as the Aberdeen article[1] shows, it is not reasonable to place the blame on the floor finisher. ■

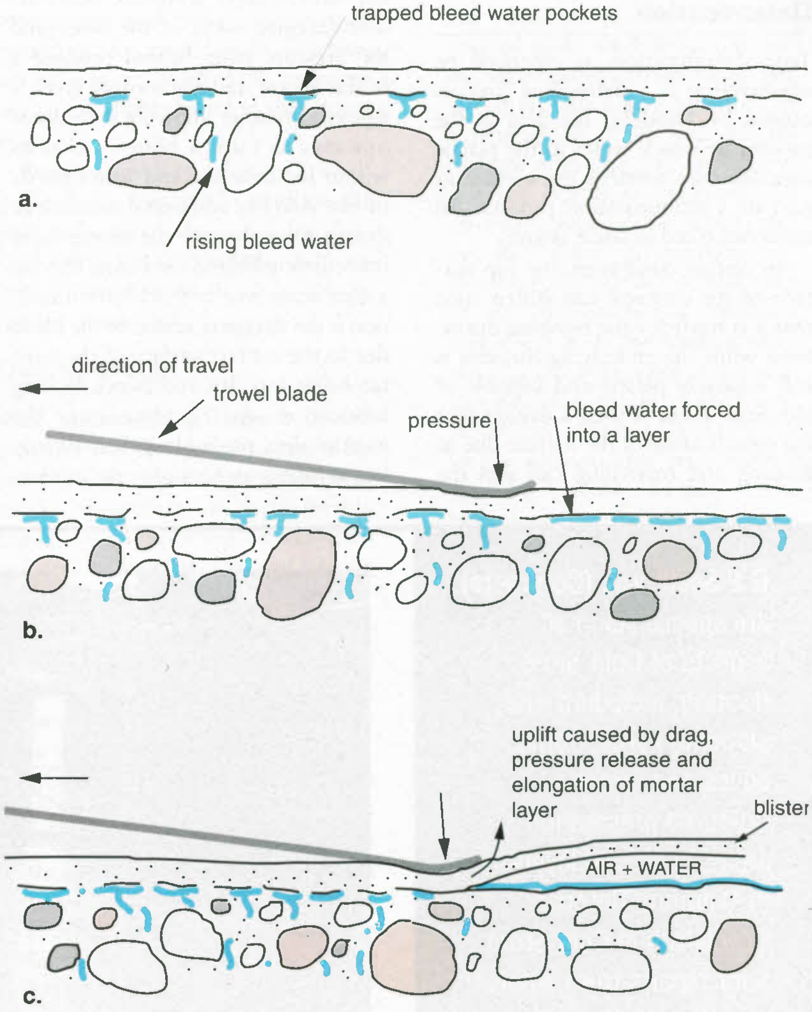

Figure 1: Delamination mechanisms

References

1. SUPRENANT, B. and MALISCH, W.R. Diagnosing slab delaminations (three parts). Concrete Construction. 1998. Photocopies available through The Concrete Society.
2. ASSOCIATION OF CONCRETE INDUSTRIAL FLOORING CONTRACTORS. Guidance on specification, mix design and production of concrete for industrial floors. Slough, The Concrete Society, 1998. (To published in June.)
3. NATIONAL READY MIXED CONCRETE ASSOCIATION. What, why and how? Concrete blisters. Silver Spring, Maryland 20910. CIP 13.