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2006

Briefing

Polished Concrete Floors

An unlimited range of polished finishes can be provided by a variety of techniques such as steel trowelling, burnishing or honing the surface of the concrete. Colours and patterns can be introduced during construction thus adding to the spectrum of decorative options available. This publication provides an overview of a wide range of polished finishes from basic to elaborate outlining the major considerations in achieving the required finish.

INTRODUCTION

Polished concrete is a generic term covering a variety of decorative concrete flooring options which leave a concrete surface exposed as the final floor finish.

Polished concrete floors provide a wide range of colours and finishes. They are affordable, energy efficient, low-maintenance and dust-free.

The concept of a polished finish dates back some 20 to 30 years and was originally used to describe the process whereby a typical grey or coloured concrete floor was coated with a wax product and then highly polished. The wax used was generally powdered beeswax which was melted and mixed with turpentine, and a mineral pigment, if required. It was applied while still warm (and liquid), with powdered french chalk sprinkled over the surface some 12 hours later. The surface was then polished by rubbing vigorously with a soft cloth. Hence the term 'polished concrete floors'. While the name remains, polished finishes are now provided by a variety of techniques such as steel trowelling, burnishing or honing the surface of the concrete. Not only can different colours be provided, but patterns are also possible. Colours can be introduced by colouring the concrete and/or by using special aggregates,

while patterns are achieved with inlaid timber strips, joints, tiles or abrasive blasted and scabbled finishes forming borders around individual areas.

While polished concrete finishes have been generally associated with slab-on-ground type construction, they are equally applicable to suspended slabs. Also, on wall panels cast horizontally (tilt-up or precast) all the decorative options normally associated with floors can be utilised.

To enable an initial choice to be made, the full range of finishes – from basic to elaborate – is outlined in this Briefing.

POLISHED FINISHES

There are three basic methods of producing a polished finish on a concrete floor. Each of the methods can be used to polish either the slab itself or a topping provided subsequently. These are outlined below with detailed information on each provided in subsequent sections, followed by general information relevant to all finishes – including the introduction of colour by a variety of methods.

Steel Trowelled

Steel trowelling of the concrete surface is usually specified when a basic flat, smooth finish is required. Some trowel marks may be present **Figure 1** unless a finish free of trowel marks is specified **Figure 2**.

Typically, normal grey concrete is used, but concrete incorporating off-white cement can also be used to achieve a lighter and more consistent colour.

Burnished

Burnishing provides a hard-wearing, durable finish with a surface lustre. It is usually produced by steel trowelling the surface until the concrete surface takes on a polished or glossy appearance of its own **Figure 3**. Alternatively, products such as floor waxes, liquid polishes and resin-based coatings can be applied to the surface and burnished using polishing equipment **Figure 4**.

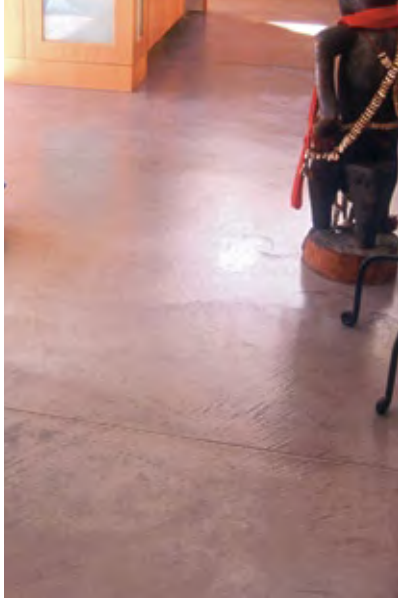


Figure 1 Steel trowelled finishes can add character and contribute to passive solar design. Note that some minor trowelling marks are present.

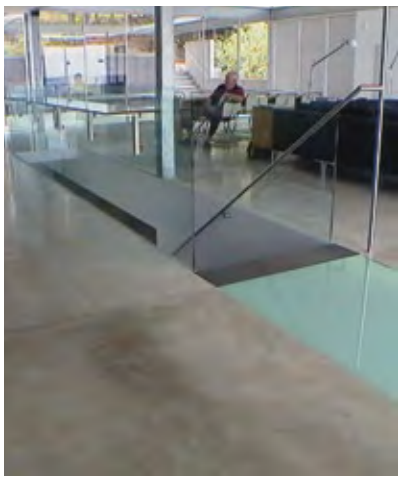


Figure 2 Steel trowelled finish to off-white concrete topping free of trowelling marks. Beeswax sealer applied to surface. *Architect: Craig Rosevear*

Honed

Honing typically provides a smooth, low-maintenance and durable finish. It is usually produced by grinding the concrete surface with abrasives. The term 'honed' is used to cover a level of grinding that produces a smooth but matt surface. Further grinding with progressively finer abrasives produces a 'polished' finish. The process of grinding exposes the aggregates which therefore have a significant influence on the final appearance. A uniform honed finish is shown in **Figure 5**, while patterned terrazzo (concrete incorporating marble aggregate) is illustrated in **Figure 6**.

Figure 3 Burnished finish with clear sealer applied to surface. Note that the reflective surface will highlight any trowelling marks and undulations

Figure 4 Burnished finishes can provide elegant up-market floors with low maintenance. Steel trowelling combined with surface sealer.

Figure 5 Driveway with ground finish incorporating decorative white quartz aggregate and 1% green pigment

Figure 6 Coloured terrazzo finish incorporating coloured marble chips as aggregate and inorganic mineral (metal) oxide pigments. The lighter coloured areas are unpigmented. Epping Plaza Shopping Centre, Victoria *(reproduced with permission from Ability Chemicals)*

STEEL TROWELLED FINISH

Although the most basic polished finish, a good quality steel trowelled finish with a surface sealer applied will often provide the required 'polished' look.

Steel trowelled finishes may be achieved by hand or power trowelling machine (often referred to as a helicopter). Hand trowelling might be considered for confined or small areas or where adjacent finishes must be protected from possible damage caused by the use of trowelling machines. Because it is difficult to produce a finish free of trowelling marks by hand **Figure 7**, the usual method to achieve a good-quality finish is by machine trowelling. Note that some minor trowelling marks may still be present, depending on the duration of trowelling or finish required **Figure 1**. The extra work required to ensure no trowelling marks remain will necessitate a near burnished finish.

Figure 7 High quality topping free of trowelling marks finished by hand steel-trowelling. Note the lower gloss levels compared to **Figure 8**

BURNISHED FINISH

A 'burnished' concrete finish will usually be specified where a surface free of trowelling marks is required. It is produced by steel trowelling until a very smooth finish and glossy appearance is obtained **Figure 8**. The additional trowelling required to produce this finish will ensure that no trowelling marks remain. However, the extent of trowelling may also 'burn' the surface as the trowel must be passed over the surface while the concrete is quite 'dry'. This may result in some areas having a darker colour.

The extent of trowelling required to produce a burnished finish necessitates the use of a power trowelling machine. For toppings placed after the walls are completed, the inability to machine finish up against edges and in corners may mean that a burnished finish is not possible over the entire floor area. This is because any areas that are finished by hand will generally have a lower gloss **Figure 7**.

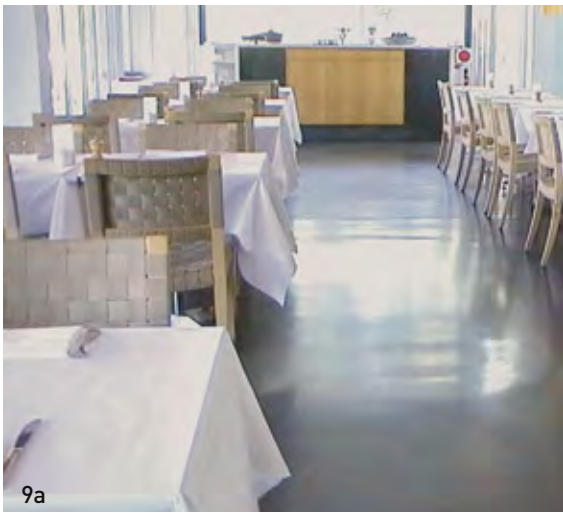
An alternative to burnishing the concrete surface is to simply specify a steel trowelled finish free of any trowelling marks and achieve the burnished appearance by applying a floor wax, liquid polish or resin-based coating and burnishing using polishing equipment.

Specifying a steel trowelled finish free of trowelling marks indicates to the concreter exactly what is required and does not leave the level of trowelling that constitutes a burnished finish open to interpretation. More information on burnished finishes can be found in *The Specification of Burnished Concrete Finish*[1].

However, a few trowelling marks can create texture and add interest to the finish. If these are required to be left in the finish, then the concreter needs to know how rough or fine a texture is required, as the appearance can vary considerably **Figure 9**. Usually a sample (from another floor) can be agreed on, or the finish approved during the course of the actual work.

Trowelling is best carried out prior to the walls being constructed as the entire floor area is accessible for power trowelling. Note that this will necessitate the protection of the finish during subsequent construction. See section *Construction Issues*.

Figure 8 Burnishing the concrete by extended trowelling (areas with gloss appearance completed)



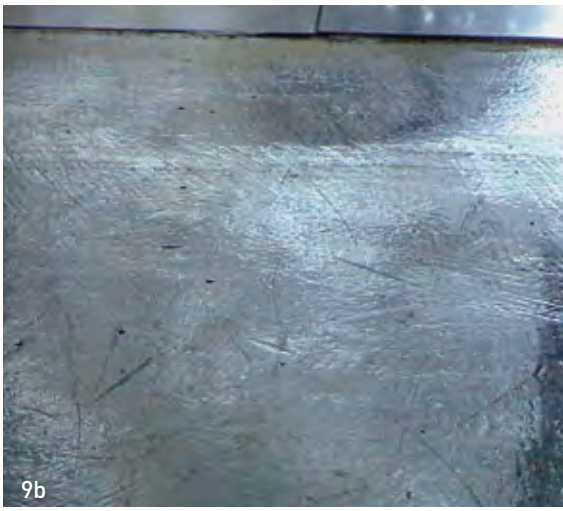


Figure 9 Cafe with burnished concrete floor (plus sealer)
9a → Steel trowelled burnished finish over majority of floor
9b → With some areas displaying trowelling marks

HONED FINISH

Honing provides the most-durable and most-versatile polished finish. It involves grinding the concrete surface (with progressively finer abrasives) until the desired glossiness/lustre are achieved. Grinding (depending on the depth) may expose the aggregates used in the concrete.

While normal concrete mixes can be used, special aggregates are usually chosen to give a polished stone appearance **Figure 5**. Hard aggregates such as quartz and igneous rocks (eg granite) are preferred as they polish well and provide a surface with excellent wear characteristics **Figure 10**. Aggregate colours, types (round or crushed), sizes, mineral-content, etc can all be selected and blended to produce a variety of finishes including polished granite-type (reconstituted stone) finishes.

The cost of special aggregates for large areas can be reduced by using them only in a topping or by seeding them into the surface. Because the latter process is difficult to control for smaller areas, it may be more economical and/or better to simply use the selected aggregate throughout the mix.

'Terrazzo' is the name traditionally used for honed concrete incorporating marble aggregate **Figure 11**; it is now often used to cover honed concrete containing other aggregates. Glass has sometimes been added to give a translucent appearance, but this is not generally recommended since undesirable reactions can occur between the silica in the glass and the alkalies in the concrete. Further details about honed concrete finish can be found in *The Specification of Honed Concrete Finish*[2].

Figure 10 Hard aggregates can provide a decorative finish having a durable and wear-resistant surface.

Figure 11 Colour and shape combined in terrazzo finishes The River Centre Rotunda, Minnesota. *Architect: Hammel, Green & Abramson, Artist: Phillip Larson*

COLOUR

General

There are a number of ways of providing a coloured surface to the concrete slab, ranging from the addition of a pigment into the concrete mix or topping (typically used when a uniform overall colour is required **Figure 12**) to the application of chemical stains and dyes/tints to the surface (typically used when patterns are to be provided **Figure 13**).

Of the methods listed below, integral colour is probably the most common method, although chemical staining is also increasing in popularity with various products becoming available.

Integral Colour

The use of pigments is the most common method of colouring the full thickness of the concrete or topping layer. The amount of pigment required is expressed as a percentage of the cementitious material within the concrete and is typically in the range of 5 to 8% of the mass of cement in the concrete mix. When used in conjunction with a honed finish that exposes the aggregates, a dosage of only 1 to 2% is usually adequate since the colour of the exposed aggregates dominates the final appearance.

Pigments are available as either powders, granules which dissolve, or liquids. The ultra-fine particles of the pigments disperse as fine solids throughout the concrete matrix and are bound into the concrete in the same manner as the other aggregates.

As the colour is affected by the pigment concentration and tinting strength of the pigment, it is generally preferable to specify the colour by either selecting a particular colour from a manufacturer's range, or if a non-standard colour is required, in consultation with the manufacturer. The correct dosage of pigment can then be determined between the supplier of the pigment and the premixed concrete.

Figure 12 Integrally coloured steel trowelled finish. *Architect: Ric Butt of Strine Design*

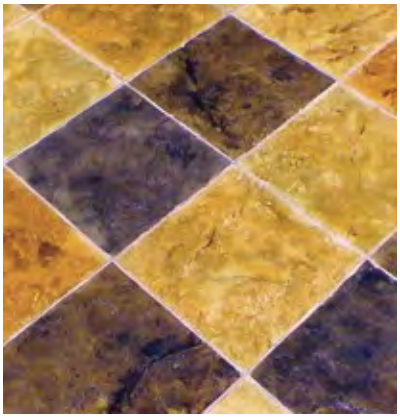


Figure 13 Slate texture in thin topping. Coloured using chemical stains

Dry-shake

Dry-shake is a mixture of pigment, cement and sand which is hand cast onto the pre-hardened concrete surface to colour it by forming a monolithic topping. Caution needs to be exercised in using the dry-shake method for polished concrete finishes as the colour intensity can be reduced by machine trowelling. Also, access over the concrete surface to allow trowelling may affect the consistency of the colour in the thin top layer.

Chemical Stains

Chemical stains are increasingly being used to provide a variety of colours to the surface of concrete slabs and toppings **Figure 14**. They consist of metallic salts in a slightly acidic, water-based solution. The acid opens up the dense steel trowelled surface of the concrete allowing the metallic salts to penetrate into the slab and react with the hydrated lime (calcium hydroxide) in the concrete to form insoluble coloured compounds that become a permanent part of the concrete.

Some points to consider when using chemical stains include:

- The time of application will influence the colour intensity achieved. More intense colours will be achieved if stains are applied earlier than the manufacturer's recommendation. This is due to the concrete being more permeable at early ages.
- Cements that produce larger amounts of calcium hydroxide (portland cements rather than blended cements) will give greater colour intensity.
- Higher cement (and hence calcium hydroxide) contents will produce more-intense colours. Specifying a higher strength concrete will therefore give better colour.
- Calcium-based aggregates (such as limestone) take stain readily and, if the aggregate is near the surface, produce a deeper colour to the cement paste above the stones. Note that limestone aggregates are seldom used in concrete due to limited availability. Siliceous aggregates such as gravels do not react with the stains.

Figure 14 Chemically stained concrete floor providing three-dimensional appearance

- Open or more-porous finishes (that usually involve minimal trowelling) allow more stain to penetrate, than do dense highly steel trowelled surfaces.
- Chemical stains do not produce a consistent colour over the entire surface but rather produce a mottled finish. This is due to the variability of the concrete itself and the different rates at which the stains are able to penetrate into it. The variable mottled finish achieved with chemical stains is a characteristic which provides a unique finish to each floor coloured by this method.
- Placing, finishing and curing techniques need to be kept consistent. Variations in the density and permeability of the surface resulting from differences in placing, finishing and curing will affect the penetration of the stain.
- To prevent the spread of the liquid stain and hence separate colours within patterns, pattern lines or shallow saw cuts are generally used. Angles, rails or some other method of guiding the cutting machine should be used to ensure that cuts are straight and curves are uniform **Figures 15 to 17**.
- Application by brush should be limited to small areas or those where brush marks and colour variations are acceptable **Figure 17**. Large areas should be stained using spray equipment, overlapping successive sprays and working away from completed areas to avoid marks from footprints.
- Chemical stains can be combined with pigments to increase the range of colour options available.

Figure 15 Pattern lines should be cut using guides to ensure accuracy

Figure 16 Intricate patterns can be saw cut. A die grinder with a 40-mm-diameter diamond blade was used for this design. Colour from black and turquoise chemical stains.

Figure 17 Application of stain by brush is generally suitable only for small areas.

Dyes and Tints

Dyes and tints contain coloured particles in either a water or solvent solution and can produce colours that are not available with chemical stains, eg red and yellow. Dyes have very fine coloured particles and will penetrate into the concrete while tints have larger particles, are opaque and remain on the surface of the concrete. Unlike chemical stains, dyes and tints do not react with the concrete. This makes the results more predictable and less dependent on the consistency of the concrete or the weather conditions. Dyes and tints produce strong vibrant colours and along with other colouring options, extend the palette of colours possible to provide a vast range of colouring solutions for both large and small projects **Figure 18**.

Dyes and tints are also used to correct the results from chemical staining by colouring areas where the stain did not provide the required colour, or areas where the stain created a colour that was darker than intended.

The UV resistance, and hence the ability to use the product externally needs to be established for each dye or tint.

Figure 18 Dyes/tints used where strong vibrant colours were required to highlight details. Chemical stain used for the mottled green background.

Figure 19 Paint system used to provide decorative finish to existing floor

Surface Coatings

This simple method involves coating the surface of the slab with a paint/sealer system. Imaginative mottled finishes resembling sandstone, for example, can be achieved using a variety of colours and shades. A surface sealer is then used to protect the coloured finish **Figure 19**.

Note that most of the sealers available for concrete surfaces are solvent based and may not be compatible with the paints/coatings used to provide the coloured finish. The manufacturer should be consulted to ensure that a compatible paint or coating plus sealer system is specified.

PATTERNS AND TEXTURES

Patterns can be created by either saw cutting 'pattern' lines into the surface **Figures 20 and 21**, providing brass or zinc strips, or by the use of joints **Figure 22**. Patterns can resemble tiled or paved finishes and incorporate curved lines. A variety of colours can be used to highlight the pattern. Items such as inlaid timber strips, tiles and pavers can also form patterns in the floor and divide large areas into more workable areas in terms of placing and finishing the concrete. Creating patterns within large areas allows different colours to be used and can give a sense of scale to the area.

In honed finishes, different aggregates can be used to create patterns in the surface **Figures 6 and 23**. Areas are usually defined by brass or zinc strips which form borders between the various coloured concrete mixes. Recesses can be formed in the surface of the concrete (by using, say, high density foam or plywood forms laid into the surface during placement of the concrete) and later filled with concrete of a different colour **Figure 24**.

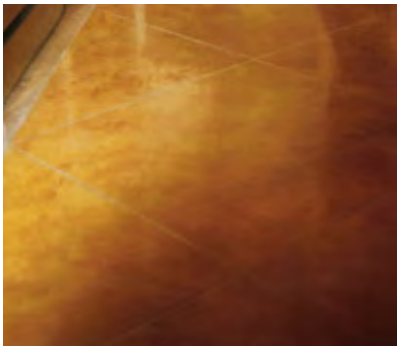


Figure 20 Textures including large tile finishes are easily included by using shallow saw cuts (pattern lines)

Figure 21[8] Patterns can be formed with shallow saw cuts and colours. Saw cuts are also used to create boundaries for application of chemical stains

Figure 22 Integrally coloured concrete separated by construction joints. Joints were saw cut and sealed with black silicone. Circular coloured features are integral part of slab and were applied at time of casting using 'spray-on' concrete topping product. *Architect: Ric Butt of Strine Design*

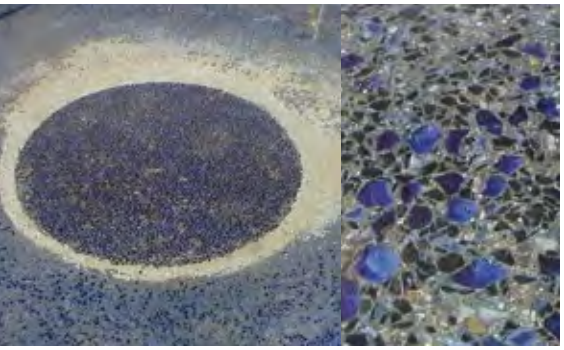


Figure 23 This pattern was created using four colours of crushed glass and a white colour hardener which were introduced through thin plastic stencils, and ground down and diamond polished to 3000 grit.

Figure 24 Colours, special aggregates and patterns can be added to enhance the finish. In this case the pattern was created by placing shaped pieces of high-density foam in the surface of the wet brown-coloured concrete. These were later removed, the recesses filled with coloured concrete and the surface ground to expose the aggregates.

In steel-trowelled and burnished finishes, patterns and textures can be applied to give the appearance of a range of natural stone finishes. However, to achieve a polished appearance, options are limited to the flatter textures such as slate that still allow a glossy appearance that results from the reflection of light **Figures 13 and 25**.

A light abrasive blast or acid etch can provide a fine texture and hence matt appearance to the surface. Tooled finishes such as abrasive blasted and scabbled can also be used to create decorative shapes and patterns on the surface, especially when used in conjunction with stencils. The surface can be coloured or textured prior to this additional process being used **Figures 26 and 27**.

Special features such as cut pipe sections **Figure 28**, natural stone, shells and tiles can also be used to create patterns. Artistic works **Figure 29** and text in various materials can be cast into the concrete, pictures can be applied to the surface, or decorative items can be recessed and grouted into the surface at a later stage **Figure 30**. Such features can be used in combination with any polished finish.

Figure 25 Shallow texture with palm frond pattern imprinted into the surface. Coloured using chemical stains

Figure 26[8] Patterns produced by colouring the concrete then abrasive blasting selected areas through stencils to remove some/all of the coloured surface material. This changes the texture and creates surface features.

Figure 27 Needle scabbling tool used to remove surface paste and produce fine detailed work

Figure 28 Cast-in stainless steel inserts used to add interest. Shapes formed by cutting pipe at various angles

Figure 29 Artistic terrazzo incorporating various materials and features. Materials include coloured glass, PVC pipe sections and pieces of coloured marble. *Artist: David Humphries of Public Art Squad*

Figure 30 Bronze artwork and ceramic tiles embedded into existing floor with colour added to surface. Tiles placed in shallow cored holes and surface coloured by applying slurry of pigment to existing slab.

SEALING THE SURFACE

The final stage in producing a polished concrete floor is the application of a surface sealer to prevent staining, to keep the concrete surface looking good for many years and to facilitate cleaning. Most sealers can be coloured to produce a variety of transparent or opaque coloured finishes.

The original waxing/polishing procedure (as described in the Introduction) can be used, but generally a simpler, more economical method is adopted. Again, there are a range of options, from wax- and petroleum-based products to various other chemical sealers which give a durable, long-wearing protective coating to the surface. Increasingly, a variety of petroleum-based waxes which give a much harder and more durable finish than beeswax are becoming available. The type of surface finish is a major consideration in selecting the appropriate sealer in terms of penetrating into the concrete surface; a burnished finish which provides a very hard compact concrete surface will vary considerably from that of a honed surface having a more open texture. Note that sealers are not curing compounds and the concrete should therefore still be cured by a suitable method. See *Curing* section.

More information can be found in *Sealers for Exposed Concrete Flatwork*[3].

MAINTENANCE

Polished concrete surfaces are easy to maintain, with regular cleaning generally being all that is required. Depending on the application and contribution of the concrete surface to the risk of slipping when wet or contaminated by other substances, the common maintenance issues are cleaning, application of floor polishes and replacement of the surface sealer. These areas are covered in detail in *Slip Resistance of Concrete Surfaces*[4], with the main points as follows:

Cleaning

Floors need to be regularly cleaned to ensure that the intended slip resistance does not diminish with contamination or over time **Figure 31**. As most level polished concrete floors will have adequate slip resistance if clean and dry, the simplest maintenance procedure is to avoid contamination. If contamination does occurs, its spread over the remainder of the floor should be limited by prompt cleaning.

Figure 31 Regular cleaning will maintain the finish even in high traffic areas or those subject to frequent contamination

Floor Polish

The regular application of floor polish tends to fill the surface roughness that provides friction or 'grip' required for slip resistance. For polished finishes with low surface roughness, only a few layers of polish can significantly reduce the slip resistance.

Where interior surfaces are maintained in a dry condition and free from other contamination, slip resistance is generally not an issue; regular polishing of the floor will assist in maintaining the lustre of the surface and possibly avoid the need to re-apply a sealer. For example, regular polishing of the floor shown in **Figure 32** has maintained this approximately 100-year-old floor in pristine condition.

For surfaces which may become contaminated (ie bathrooms and laundries having water on the floor) the best approach is to provide the initial penetrating sealer and maintain the original surface finish by regular cleaning.

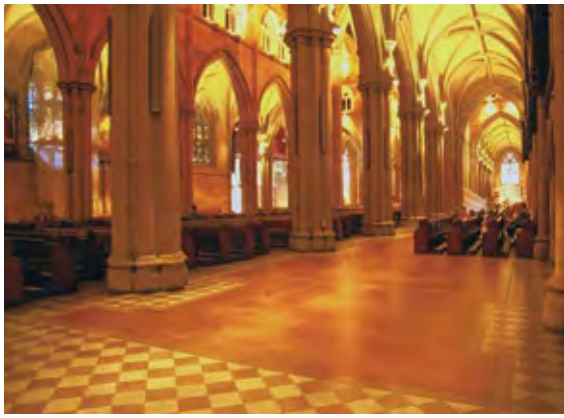


Figure 32 Coloured mortar topping (about 5 mm thick) applied as monolithic topping to structural suspended slab. *St. Mary's Cathedral, Sydney*

Figure 33 Surface sealer has worn and requires reapplication to restore surface lustre. **Figure 4** shows the floor when first sealed.

Sealing

The sealer prevents staining and should keep the finish looking good for many years. Most sealers will last about five years in a domestic application, with recoating being a simple and economical way to restore the original finish **Figure 33**.

In wet areas it should generally be removed and replaced to maintain the original surface roughness, rather than having another layer added to it. Note that recoating the surface without removing the original sealer may be an option depending on the initial surface roughness.

For areas that remain dry, adding another layer of sealer, similar to floor polish, will not affect the slip resistance of the surface. For solvent-based products, the solvent in the new sealer will allow some re-distribution of the old sealer and hence a more even coat to be applied.

An option to avoid re-coating and a build up in the sealer thickness over time may be to lightly wipe over the floor with solvent. This redissolves the sealer, evens out the coating and should restore the lustre to the floor. The sealer manufacturer should be consulted regarding the solvent required and compatible sealers.

Note that penetrating sealers are largely protected by the abrasion resistance of the concrete itself and therefore tend to have a good service life.

OTHER CONSIDERATIONS

Toppings

Applying a topping or thin layer of concrete/cementitious material on top of the main structural concrete slab is one of the most common methods of providing a decorative finish and/or colour to an existing concrete slab. There are a number of advantages in using decorative toppings:

- Cost saving by limiting the amount of material to be coloured.
- Reducing the risk of damage to the finish from construction activities. However, there will be some cost involved in coming back and providing a separate topping at a later stage. See section *Protection of finishes*.
- Special finishes can be achieved, particularly those that require various materials to be embedded or set into the surface of the concrete such as coloured stones and metallic/plastic objects. The ability to set these in position by fixing to the base slab and then placing a topping layer around them is critical to the final appearance of the finish or artwork created.
- Providing a decorative finish to an existing concrete slab, eg renovation and refurbishment projects.
- Correction of surface levels in the concrete which may result from differences in levels between new and existing work, or where finishes such as tiles have been removed.

Toppings can be divided broadly into two categories: those placed during construction of the slab (monolithic toppings) and those placed over an existing concrete slab (bonded or unbonded).

For toppings placed during construction, some form of protection must be provided to avoid damage from the construction activities that normally follow the placement of the slab, ie walls, roof, fitout. The main advantage for installation during construction is the ability to finish the surface from edge to edge. This eliminates the need for hand finishing (and perhaps hand grinding) of the surface along edges and in corners — and the possible variation in finish which may result.

Monolithic toppings Monolithic toppings are surface layers applied after the base or structural concrete slab has been placed, and while the concrete is still in its 'plastic' or workable state. This allows bonding of the two layers as they set and harden together, effectively producing a single or monolithic element.

Dry shake toppings are the most common type of monolithic topping used to provide a coloured surface and involve casting dry powder by hand over the surface of the fresh concrete and working it into the surface by trowelling. The dry powder is usually a mixture of cement, sand and pigment. A hardener may also be incorporated to increase the strength of the surface layer and hence the products are often referred to as 'coloured surface hardeners'. They typically provide a surface layer about 3 to 5 mm thick. Precautions need to be taken to protect surrounding areas and finishes from the fine airborne particles, and breathing masks should be worn.

An alternative to casting dry powder over the surface is to apply a thin layer of mortar to the surface **Figure 32**. This can either be trowelled on or more recently, sprayed onto the surface.

A surface layer of coloured concrete can also be placed as a monolithic topping. Because concrete surface layers/toppings have similar properties to the concrete layer below, there is no limit to the thickness of a concrete surface layer. Practically, the thickness is kept to a minimum to reduce pigment costs, with the minimum thickness usually governed by the maximum aggregate size used.

Bonded toppings Bonded toppings are relatively thin layers of material that are bonded to the existing slab. They can be classified according to their thickness. Ultra-thin toppings up to a few millimetres in thickness and thin toppings up to about 10 mm in thickness consist of speciality mortar type mixes, incorporating polymers

and bonding agents[6]. Pigments can also be added, or the surface chemically stained after hardening similar to any other cementitious material **Figures 34 and 35**. Thicker toppings in the range of 20 to 40 mm consist of concrete mixes containing coarse aggregates to better control drying shrinkage; the thickness is a function of the aggregate size used. The usual maximum thickness for unreinforced bonded toppings is about 50 mm. Beyond this, the topping will behave more like a thin slab and achieving an adequate bond to the existing slab becomes even more important to prevent delamination from factors such as shrinkage and curling.

The use of thin toppings (about 10 mm thick) which are trowelled onto the surface of existing slabs have seen considerable growth overseas, as they allow a durable, low-maintenance and decorative concrete floor to be laid like other floor finishes (eg carpet and tiles) at the end of the project. This avoids construction damage, does not interfere with levels, requires no set downs in the surface of the concrete slab and products provide excellent bond with the substrate.

Figure 34 10-mm-thick topping with textured/patterned surface in shopping centre

Figure 35 Thin cementitious polymer topping about 10-mm-thick with darker areas consisting of a blue-coloured cement-based micro-topping about 1 mm in thickness. Surface was finished using a solvent-based blue dye. Pattern formed using self-adhesive stencils.

Unbonded toppings Unbonded toppings are separated from the existing slab, contain reinforcement and act as individual thin slabs. If toppings greater than 50 mm in thickness are required, then a separate unbonded reinforced topping should be considered. A plastic membrane is typically used to separate the old or existing concrete from the new. To allow cover to the reinforcement and minimise curling problems a thickness of about 70 to 75 mm is recommended. Because unbonded toppings do no rely on the substrate to control shrinkage and hence cracking, a layer of reinforcing mesh needs to be provided for crack control. Note that the durability requirements may govern the concrete strength and minimum topping thickness.

While these toppings are typically used for waterproofing applications by allowing the installation of a polythene sheet or other waterproof membrane, they also provide a useful means of topping existing timber or concrete floors. The greater thickness allows the use of a minimum 14-mm aggregate.

Toppings that exceed 75 mm in thickness should be regarded as new concrete slabs and designed accordingly.

Slip Resistance

Slip resistance is a measure of the ability of a surface to substantially reduce or prevent the risk of a pedestrian slipping in both dry and wet conditions. With the increasing popularity of polished concrete finishes, providing adequate slip resistance has become an important consideration. The aspects of a concrete floor or pavement surface that may impact on the risk of slipping include the surface finish, texture and applied sealer (if present). These three combine to produce a final surface roughness. All polished concrete surfaces will provide adequate slip resistance when dry or not contaminated by other substances. The surface roughness of floors should be maintained by regular cleaning to remove any contaminants that may increase the risk of slipping. See *Maintenance* section.

Slip resistance (measuring, specifying, achieving, improving) is dealt with in detail in *Slip Resistance of Polished Concrete Surfaces*[4].

Figure 36 External polished pavements can have adequate slip resistance. *Sydney International Airport*

Figure 37 Polished concrete finishes are suitable for 'wet' areas if the appropriate slip resistance is provided

Construction Issues

CONCRETE

The typical concrete used for most residential slabs has a compressive strength of 20 MPa, and is designated as **N**ormal-Class N20 concrete. However, for polished work, the use of a higher strength concrete is recommended: N32 for steel trowelled and honed finishes; N40 for burnished finishes.

The specification of the concrete is only the first step in achieving the desired polished finish; as in all concrete work, the adoption of good site practices is of equal importance if expectations are to be met. All aspects of concrete and concreting are covered in detail in *Guide to Concrete Construction*[5]. Salient points for polished concrete floors are:

Concrete supply The concrete for any given area should be kept as consistent as possible as minor variations between batches can affect the colour **Figure 38**. The incorporation of appropriate joints is a common way of masking any minor colour variations that may occur when concrete from different batches is used in a particular area.

Figure 38 Penetration of chemical stains and resultant colour intensity may vary due to variations in the concrete mix or placing, compaction and curing techniques.

Placing For concrete placed by pump, the priming material used to coat the pump line should be excluded from the finished work as it may cause colour variations in steel trowelled finishes. Concrete should be placed as close as possible to its final location and vibrators should not be used to move concrete. This may result in uneven aggregate distribution in honed finishes.

Compaction Adequate compaction of the concrete significantly increases its strength, abrasion resistance and general durability by providing a dense concrete with little entrapped air (from the batching, mixing and placing processes) and lower permeability. These characteristics also contribute to the reduction of drying shrinkage, thereby minimising the risk of drying shrinkage cracking in the polished concrete finish.

While any deeper sections of the floor/pavement such as edge thickenings and downturns should be compacted using an immersion vibrator, for slabs on ground that are 100 mm or less in thickness, adequate compaction can usually be achieved through the placing, screeding and finishing processes. Sometimes, surface vibration will be used in the form of a small hand-held vibrating screed. Immersion vibrators are not recommended for 100-mm-thick slab-on-ground construction, as the slab depth does not allow proper immersion of the vibrator head, and the plastic membrane (if provided) may be damaged.

For honed finishes, care must also be taken when compacting concrete. The use of immersion vibrators may cause sand streaks in the finish **Figure 39** and also uneven distribution of the exposed aggregate in the polished surface resulting in a patchy appearance **Figures 40**. Rectification usually involves grinding the surface to a slightly greater depth to obtain an even exposure of the aggregate.

Figure 39 Sand streaks caused by dragging an immersion vibrator through a concrete topping

Figure 40 Uneven aggregate distribution caused by use of immersion vibrator

Figure 41 Tamping the surface during screeding has caused slight settlement of the aggregate resulting in sand streaks in the honed finish

Figure 42 Sand streaks in the finish may be subtle and add to the character of the floor

Finishing Care must be taken when finishing concrete that is to be honed. Once concrete is placed it is usually screeded with a straightedge to provide a surface having the specified level and flatness properties. If the surface is worked too much with the screed to settle the aggregate and fill depressions, the aggregate exposure in the surface may, after grinding, be uneven and there may be lines or sand streaks in the finish **Figures 41 and 42**. As mentioned earlier, grinding to a greater depth can provide a uniform finish.

Curing Lack of curing is one of the main causes of weak and powdery concrete surfaces. The implications for polished concrete finishes where a hard and durable surface is required are obvious. The minimum curing period for polished concrete surfaces should be 7 days.

Curing with water may cause staining or colour variation if impurities are present in the water. Curing with plastic sheeting should be used with caution for polished concrete work as uneven contact with the surface may cause colour variations. For the example shown in **Figure 43**, slight colour variations are not considered critical as the surface is to be honed and the predominant colour will be that of the aggregates **Figure 5**. Either plastic sheeting suspended just above the concrete surface or liquid membrane-forming curing compounds are recommended. If curing compounds are used they should be removed before sealing the surface.

Figure 43 Clear plastic sheeting used for external applications

Control of shrinkage An important aspect of exposed concrete work is the control of the long-term drying shrinkage of concrete. This occurs mainly as a result of the water in the concrete mix drying out over time. All concrete will 'shrink', but measures can be taken to limit or control it. Good compaction and curing will help, but most importantly, no water (in excess of the designed mixing water) should be added to the concrete on site.

REINFORCEMENT

In addition to carrying the tensile loads in the concrete, reinforcement is placed in slabs-on-ground to hold tightly closed any cracks that may form.

For polished concrete floors, increasing the amount of reinforcement in the slab is recommended to provide better control of any cracks that may occur **Figure 44.**

Similarly, for unbonded topping slabs, providing more than the minimum amount of reinforcing mesh (SL/RF 52) will provide better control of any cracks that may form.

Figure 44 SL81 mesh used to control shrinkage cracking in polished section of residential floor slab.

JOINTS

Joints are used to allow for movement, control cracking from long-term drying-shrinkage and to break up large or restricted access areas into smaller, more manageable ones that are easier to place and finish. Depending on the detailing of the joints, they may also be used to mask minor colour variations between adjacent panels/areas placed from different batches of concrete, or areas having different surface finishes.

Joints can be formed in a number of ways, ranging from the traditional methods of sawcutting and use of pressed-metal joints, to brass or zinc strips and inlaid tiles or timber strips. These not only conceal joints, but can become a striking feature of the floor **Figure 45**.

Joints are often provided where cracking is likely, eg along column lines **Figures 46 and 47**. They may also be used to create patterns **Figures 48 and 49**.

In a topping to an existing slab, joints can be used to conceal random cracking in the substrate **Figure 50**.

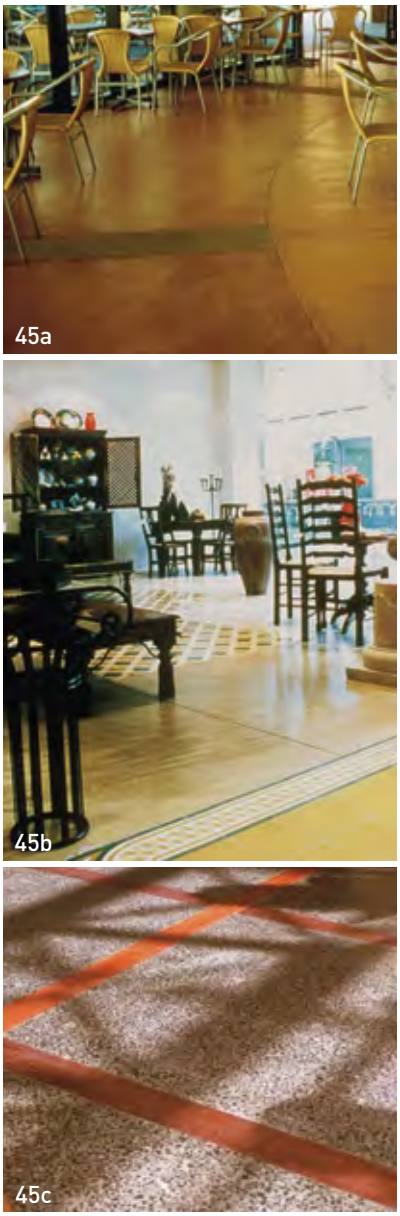


Figure 45 Concrete blended with other materials to provide features and joints
45a → Large areas given scale by colours, inserts (concrete pavers) and joints
45b → Ceramic tiles used to create joints and patterns
45c → Polished timber strips used to create pattern and to provide joints

Figure 46 Saw cut joints in line with columns

Figure 47 Joints (on column lines) formed with brass strips

Figure 48 Joints used to create pattern by dividing large area into workable panels and to disguise colour variations between panels placed at different times. Joints sealed with silicone sealant.

SURFACE TOLERANCE

A good quality surface finish is particularly important for polished concrete finishes as the generally highly polished and therefore reflective surface will highlight any trowelling marks and undulations(uneven or wavy surface).

The main tolerance criterion that may affect polished finishes is the flatness of the surface. In honed finishes, a flatter finish is generally easier to achieve with the use of larger grinding machines. Further information and guidance on the appropriate tolerance for concrete surfaces can be found in *Tolerances for Concrete Surfaces*[7].

Figure 49 Joints used to create patterns in the floor and to separate colours/finishes

Figure 50 Random stone patterns have been formed by cutting joints in the thin 10-mm-thick topping to existing slab. Pattern can be used to conceal any random cracking in the existing slab

EXISTING FLOORS

Many existing concrete floors can be polished to produce a low-maintenance durable floor surface. The normal approach of lightly grinding the surface to remove stains and minor defects, remnants of adhesive, trowelling marks and to provide a more uniform surface should generally improve the appearance and give satisfactory results.

Since such slabs have not been designed to receive a polished finish and the surface may have been repaired or had sections replaced to run new services, a variable finish should be expected. Cracks and poor joint details may also need attention. If cracks are exposed, these can either be filled or repaired to reduce their impact, or left as features in the floor. Depending on the application, they can often add character to the finish.

In most cases, people's attention will not be focussed on the floor, so the overall impression becomes more important than some of the minor details. An example of this is the art gallery floor shown in **Figure 51**. From a distance many of the issues with the existing floor are masked by the gloss sealer and the floor provides a good overall impression, while from a closer viewing distance people's attention is focussed on the surrounding artwork and not the concrete floor.

Figure 51 Existing floor ground to remove previous finish and expose the aggregates. Cracks, uneven aggregate exposure, repairs and different concrete colours rather than detracting, may add to the attractiveness of the finish. *Art Gallery of New South Wales*

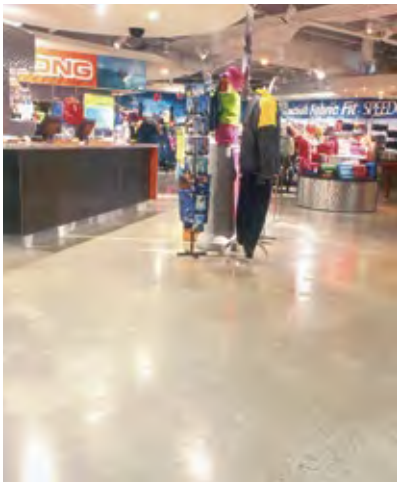


Figure 52 Existing post-tensioned slab lightly ground and left exposed. Surface sealed to provide high quality 'polished' appearance.

Figure 52 is an example of where an existing post-tensioned floor in a shopping centre has been polished. These types of slabs are generally not designed to allow a significant grinding of the surface and consequent reduction of thickness. In most cases a light grind to remove any high spots, old adhesive and stains and to improve the flatness is all that is required to achieve a good finish: the gloss sealer giving the impression of a high-quality finish. Again, the variable aggregate exposure is masked by the gloss appearance and people's attention is drawn to the displays rather than the floor. Post-tensioned concrete floors are generally crack free with widely-spaced joints, allowing extensive joint-free polished areas to be achieved.

In the worst case, any damaged floors can be topped to provide a new finish to the surface.

PROTECTION OF FINISHES

Decorative concrete finishes can either be applied directly to the structural slab during construction, or added later as a topping to the previously-completed concrete slab.

If applied to the structural slab prior to completion of the building, the surface must be protected from damage during construction.

The degree of protection will vary depending on the scale of subsequent building work and the likelihood of damage occurring. Methods include covering with a soft material such as felt carpet underlay or old carpet, or rigid materials such as plywood sheets. Any timber used should be softwood based as hardwoods typically cause staining of concrete when wet.

For decorative finishes the possibility that staining may occur from the materials used to protect the surface must be considered. Sometimes, the colour variations from curing and timber staining are preferred as they can create an almost 'antique' appearance on the grey concrete surface.

The large shift overseas towards the use of thin toppings applied at the end of construction is a result of a combination of the added expense of providing protection during construction, no guarantee of completely eliminating damage, and the possibility that the protection method used may interfere with the construction activities.

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FURTHER INFORMATION

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Briefing 05 November 2006 supersedes Briefing 05 August 2001

OTHER BRIEFINGS available online from www.concrete.net.au are:

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ISBN 978-1-877023-19-4

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